SEVEN SEASONS OF FOLIAR FUNGICIDE TRIALS IN LOUISIANA COTTON

P. Price
M. Purvis
D. Ezell
LSU AgCenter, Macon Ridge Research Station
Winnsboro, LA

Abstract

Target spot (TS), caused by *Corynespora cassiicola*, is an annual issue in Louisiana. In some cases, the disease may cause premature defoliation resulting in yield loss. The cotton leaf spot complex (CLSC), most commonly associated with potassium deficiency and caused by *Alternaria*, *Cercospora*, and *Stemphylium* spp., also is an annual concern in the state. The most common questions encountered regarding these maladies relate to fungicide efficacy. Nineteen and nine foliar fungicide efficacy trials conducted since 2015 with moderate to heavy TS and CLSC, respectively, were selected for summary. In 18 of 19 trials, significant reduction of TS severity compared to non-treated controls was observed following fungicide application, while 5 of 9 trials showed significant reductions of CLSC severity. In 3 of 19 TS trials, significant yield preservation was observed compared to non-treated controls. In 1 of 9 CLSC trials, significantly preserved yield was observed compared to the non-treated control. Across all TS trials, average disease severity reduction by fungicides ranged from 19 to 62 percent, and average seedcotton yield preservation ranged from 103 to 209 lbs./A. The highest potential return on fungicide investment (ROFI) was determined to be with one application of Headline or Priaxor during the first month of flowering in a susceptible variety under high disease pressure. Across all CLSC trials, average disease severity reduction ranged from 9 to 39 percent, and average seedcotton yield preservation ranged from -59 to 93 lbs./A. The odds of a ROFI when applications are targeting CLSC were determined to be very low.

Introduction

Target spot of cotton (*Gossypium hirsutum* L.) is caused by the fungus *Corynespora cassiicola*. Although it has been a sporadic problem since the 1960's when first reported in Mississippi (Jones 1961), target spot has been a significant cotton disease in the southeastern United States since 2005 (Fulmer et al. 2012). More recently, the disease has been reported in Alabama, Arkansas, Georgia, Louisiana, Mississippi, and Tennessee (Allen 2011, Conner et al. 2013, Faske 2013, Fulmer et al. 2012, Price et al. 2015, Butler et al. 2016). In severe cases target spot has been estimated to cause losses of approximately 60 to 350 lb. lint/A (Kemerait et al 2011, Fulmer et al 2012, Hagan et al 2013a, 2013b, Bowen et al. 2018, Hagan et al. 2018). Since 2014, target spot has been widespread throughout cotton producing areas in Louisiana with moderate to heavy disease severity in rainy years when disease initiates during the month of July (Price and Fromme, 2014). Prior to disease epidemics in cotton, target spot has been observed in maturing soybeans; however, it has been determined that the causal fungus is genetically distinct within each crop (Sumabat, et al. 2018). In cotton, symptoms first appear in the lower canopy as round lesions exhibiting a green to gray water-soaked appearance. As lesions develop, they become tan to brown and develop concentric rings occasionally surrounded with yellow halos. Microscopic examination can easily confirm the presence of *C. cassiicola* conidia. In some cases, the disease may progress upwards through the canopy and cause rapid premature defoliation. Rainfall, wind, and/or overhead irrigation may aid in spreading the pathogen resulting in new infections, and the pathogen overwinters in plant debris. Up to 75% defoliation has been observed in farmers' fields, and up to 90% defoliation has been observed occasionally in research plots in Louisiana. Differences in varietal susceptibility, presumably because of plant height and/or structure, have been noted throughout the southeastern United States (Kemerait et al 2011; Hagan et al 2013a, 2013b, Bowen et al., 2018, Hagan et al., 2018). There are no completely resistant varieties, and any cotton line that becomes rank may develop symptoms. Applications of fungicides from the first through eighth week of bloom have been shown to effectively reduce disease incidence and severity and in some cases preserve yield (Kemerait et al 2011, Hagan et al 2013b, Bowen et al. 2018, Hagan et al. 2018, Mehl et al. 2020).

A complex of leaf spot diseases comprised of *Alternaria*, *Cercospora*, and *Stemphylium* spp. have been observed throughout the southeast and have been prevalent in Louisiana (Bashi et al. 1983, Sinclair and Shatla, 1962, Chupp 1953). These leaf spots are usually observed in cotton fields where plants are deficient in potassium. Lesions are sometimes distinguishable from target spot by reddish-purple margins and absence of typical target spot lesions low in the canopy, but further identification requires microscopic examination. The pathogens are spread by rainfall and wind, and symptoms are usually evident throughout the canopy with new infections occurring on new leaves near the terminal. Other factors may exacerbate disease severity such as drought, low pH, hardpans, hail damage, or herbicide injury. Fungicide efficacy information on this disease complex is limited, and economic benefits of these applications are not well-defined. Results from studies in Georgia and Texas showed no decrease in disease incidence/severity when fungicides were applied to an Alternaria/Stemphylium complex (Kemerait et al. 2011). Conversely, fungicides were shown to be effective on CLSC, but economic benefit is not well-defined (Price and Purvis, 2018, Price et al. 2021).

Over the past 7 growing seasons, our program has conducted many foliar fungicide efficacy trials working with TS and CLSC. Our aim is to summarize those results herein.

Materials and Methods

During the 2015-2021 growing seasons, 28 foliar fungicide trials were conducted at the Dean Lee Research Station (DLRS) in Alexandria, LA, the Macon Ridge Research Station (MRRS) near Winnsboro, LA, and the Northeast Research Station in St. Joseph, LA. All trials were planted during the recommended window on 38-to-40-inch rows with target spot-susceptible varieties. Weeds, insects, and fertility were managed according to LSU AgCenter recommendations. Test areas were irrigated (furrow or overhead) as needed, and plots were allowed to achieve rank growth by limiting use of plant growth regulators. Depending on the individual test, fungicides were applied to the center two rows of four row plots once or twice during the first four weeks of flowering (typically during the month of July) with a CO_2- or compressed air-powered boom delivering 15 gpa at 32 psi using TeeJet XR11001 flat fan nozzles. All fungicides were applied within labeled rate ranges. Disease was assessed thereafter by visually estimating disease severity. Target spot severity was determined by estimating percent defoliation, and CLSC severity was estimated on a 0-9 scale where 0=no disease and 9=100% incidence and severity. Average disease severity reduction was determined as a percentage of the non-treated control, while disease preservation was calculated as the numerical difference between a given treatment and the non-treated control, which was reported as seedcotton (lb./A). Trials with moderate to heavy (10-90% defoliation for TS or 2.3 to 8 [0 to 9 scale] for CLSC) disease severity were selected for presentation. Fungicides were included in the summary if at least six observations in three tests were available. Rainfall frequencies and totals July and August varied among years (Table 1). Plots were harvested with specialized, small-plot pickers, and fiber quality was not determined in all tests.

All trials were arranged in randomized complete block designs with 4 to 6 replicates. Individual trial data were analyzed using analysis of variance, and treatment means were compared using Tukey's Honest Significant Difference (HSD) Test at the 90% confidence level (P=0.10). There was considerable variability in individual fungicide performance between trials which did not allow efficacy to be statistically compared among trials. It should be noted that there was no significant difference between one and two fungicide applications in trials where the comparison was possible.

Results

Total rainfall from first flower (~July 1st) to cutout (~August 31st) varied from year to year and ranged from 3.8 to 22.9 inches (Table 1). Rainfall frequency ranged from 11 to 58 events each year. Final defoliation due to target spot ranged from 10 to 90%. Significant fungicide efficacy was observed in 18 of 19 trials conducted during 2016-2021, while significant yield preservation was observed in 3 of 19 trials. Yield difference ranges (the span from lowest to highest) in trials varied widely from 48 lbs. seedcotton/A to 538 lbs. seedcotton/A.

Table 1. Details for fungicide efficacy trials conducted with target spot in Louisiana during 2016-2021.

Trial ID	Year	Variety	Rainfall Frequency (Total)[z]	Target spot (% defoliation)[y]	Significant Fungicide Efficacy?[x]	Yield Differences (low to high)[w]	Significant Yield Preservation?[v]
DL1602	2016	PHY499	32 (22.9)	3-75%	Y	-238-169	N
MR1607_499	2016	PHY499	18 (10.6)	3-77%	Y	126-509	N
MR1607_1137	2016	DPL1137	18 (10.6)	2-36%	*N*	-106-319	N
NE1603_499	2016	PHY499	58 (15.2)	6-72%	Y	3-708	N

NE1603_1137	2016	DPL1137	58 (15.2)	5-47%	Y	-99-318	N
MR1711	2017	PHY499	26 (8.1)	5-39%	Y	-15-33	N
DL1703	2017	PHY499	22 (14.3)	7-49%	Y	6-462	N
MR1709	2017	PHY499	11 (3.8)	4-33%	Y	-196-173	*Y*
MR1707	2017	PHY499	11 (3.8)	9-21%	Y	-14-116	N
MR1806_490	2018	PHY490	15 (9.8)	10-90%	Y	-16-222	N
MR1806_1646	2018	DPL1646	15 (9.8)	4-52%	Y	-17-386	*Y*
DL1801	2018	PHY490	16 (5.8)	14-49%	Y	38-425	N
MR1807	2018	PHY490	15 (9.8)	2-18%	Y	-109-103	N
NE1803	2018	PHY490	22 (8.6)	11-70%	Y	170-708	*Y*
NE1804	2018	PHY490	22 (8.6)	6-12%	Y	-113-40	N
MR1809	2018	PHY490	15 (9.8)	4-10%	Y	42-252	N
MR1908	2019	PHY480	16 (6.4)	5-17%	Y	112-392	N
MR1907	2019	PHY480	16 (6.4)	2-23%	Y	-73-190	N
MR2111	2021	PHY480	29 (10.4)	3-11%	Y	81-288	N

[z]Total number of rainfall events and total rainfall (in) from July 1 to August 31 each year.
[y]Range of defoliation due to target spot observed in each study.
[x]Significantly lower disease severity in fungicide treated plots compared to the non-treated control according to Tukey's HSD (P=0.10).
[w]Range of seedcotton yield differences (lb./A) within the trial.
[v]Significantly higher seed cotton yield in fungicide treated plots compared to the non-treated control according to Tukey's HSD (P=0.10) in each study.

Mean disease severity reduction of target spot ranged from 16.0 to 62.2% (Table 2). Overall, Priaxor performed the best followed by Headline, Miravis Top, Topguard, and Quadris in descending order. Priaxor was, by far, tested the most with 44 observations, while Miravis Top had the fewest observations (n=10). Average yield difference between treated and non-treated ranged from 103 to 209 lb. seedcotton/A. Overall, Headline had an average yield preservation of 209 lb. seedcotton/A followed by Priaxor, Topguard, Miravis Top, and Quadris in descending order. Yield preservation ranges were widely variable for each fungicide.

Table 2. Performance of fungicides on target spot in Louisiana across 19 trials conducted during 2016-2021.

Trade Name (number of observations)[z]	Active Ingredient (%)	Severity Reduction (low-high)[y]	Yield Preservation (lb. seedcotton/A)[x]
Headline (n=12)	pyraclostrobin (23.6)	37.4 (12.2-76.7)	209 (-100-509)
Miravis Top (n=10)	pydiflumetofen (6.9) + difenoconazole (11.5)	37.3 (19.3-76.9)	104 (-59-392)
Priaxor (n=44)	fluxapyroxad (14.3) + pyraclostrobin (28.6)	62.2 (0-92.3)	191 (-196-708)
Quadris (n=13)	azoxystrobin (22.9)	19.1 (0-39.6)	103 (-106-391)
Topguard (n=14)	flutriafol (11.8)	26.4 (0-49.7)	108 (-99-318)

[z]Fungicide trade name and the number of times (n) it was compared to a non-treated control in a replicated field trial.
[y]Mean disease severity reduction calculated as a percentage of the non-treated control.
[x]Mean yield preservation calculated as the difference from the non-treated control.

Assuming the average seedcotton yield preservation, 40% turnout, and $20/A cost of a fungicide application, potential return on fungicide investment (ROFI) was highest with one application of Headline ($30.16 - $76.14) followed closely by Priaxor ($25.84 - $67.86/A) (Table 3). Miravis Top, Quadris, and Topguard ROFIs with one application were markedly lower averaging ~$5.00 - ~$29.00/A. All potential ROFIs were lower with two applications, but the distribution pattern obviously was similar.

Table 3. Average yield preservation, value added, and return on fungicide investment (ROFI) for target spot applications.

Trade Name	Average Seedcotton Yield Preservation[z]	Value Added Range/A ($)[y]	ROFI range/A 1 application[x]	ROFI range/A 2 applications[x]
Headline	209	$50.16 - $96.14	$30.16 - $76.14	$10.16 - $56.14
Miravis Top	104	$24.96 - $47.84	$4.96 - $27.84	-$15.04 - $7.84
Priaxor	191	$45.84 - $87.86	$25.84 - $67.86	$5.84 - $47.86
Quadris	103	$24.72 - $47.38	$4.72 - $27.38	-$15.28 - $7.38
Topguard	108	$25.92 - $49.68	$5.92 - $29.68	-$14.08 - $9.68

[z]Average seedcotton yield preservation across 19 foliar fungicide trials with target spot conducted from 2016-2021 in Louisiana.
[y]Value added based on 40% turnout and cotton price range of $0.60 to $1.15 from 2015-2021.
xReturn on fungicide investment based on value added minus the cost of application ($20/A).

Rainfall frequency in 2015 and 2020 was 8 and 18 events with a total of 4.4 and 7.6 inches, respectively (Table 4). Severity of the cotton leaf spot complex ranged from 2.3 to 8.0 on the 0 to 9 scale. Significant fungicide efficacy was observed in 5 of 9 trials, while significant yield preservation was observed in 1 of 9 trials. Yield difference ranges (the span from lowest to highest) varied widely from 134 to 419 lb. seedcotton/A.

Table 4. Details for fungicide efficacy trials conducted with the cotton leaf spot complex in Louisiana during 2015 and 2020.

Trial ID	Year	Variety	Rainfall Frequency (Total)[z]	CLSC severity (0-9)[y]	Significant Fungicide Efficacy?[x]	Yield Differences (low to high)[w]	Significant Yield Preservation?[v]
MR1504_499	2015	PHY499	8 (4.4)	4.7-6.3	N	-250-169	N
MR1504_1137	2015	DPL1137	8 (4.4)	3.7-5.2	Y	-109-66	N
MR1505	2015	PHY499	8 (4.4)	4.0-5.0	N	-6-128	N
MR1506	2015	PHY499	8 (4.4)	5.3-8.0	Y	123-265	Y
MR1507	2015	PHY499	8 (4.4)	7.3-8.3	N	-195-28	N
MR1508	2015	PHY499	8 (4.4)	5.0-7.0	N	-117-128	N
MR2005	2020	PHY480	18 (7.6)	3.2-6.0	Y	106-271	N
MR2006_basf	2020	PHY480	18 (7.6)	2.3-6.7	Y	-71-77	N
MR2006_bay	2020	PHY480	18 (7.6)	4.8-6.7	Y	-120-32	N

[z]Total number of rainfall events and total rainfall (in) from July 1 to August 31 each year.
[y]Range of defoliation due to target spot observed in each study.
[x]Significantly lower disease severity in fungicide treated plots compared to the non-treated control according to Tukey's HSD (P=0.10) in each trial.
[w]Range of seedcotton yields (lb./A) within the trial.
[v]Significantly higher seed cotton yield in fungicide treated plots compared to the non-treated control according to Tukey's HSD (P=0.10) in each trial.

Mean disease severity reduction of the cotton leaf spot complex ranged from 8.7 to 38.7% (Table 5). Overall, Miravis Top performed the best followed by Priaxor, Headline, Topguard, and Quadris in descending order. Priaxor was tested the most with 14 observations in the 9 trials, while Miravis Top and Topguard had the fewest observations (n=6). Average yield difference between treated and non-treated ranged from -59 to 93 lb. seedcotton/A. Overall, Miravis

Top and Priaxor had the only positive average yield preservations of 93 and 88 lb. seedcotton/A, respectively. Yield preservation ranges were widely variable for each fungicide type.

Table 5. Performance of fungicides on cotton leaf spot complex in Louisiana across nine trials conducted during 2015 and 2020.

Trade Name (number of observations)[z]	Active Ingredient (%)	Severity Reduction (low-high)[y]	Yield Preservation (lb. seedcotton/A)[x]
Headline (n=7)	pyraclostrobin (23.6)	19.7 (3.8-33.8)	-21 (-140-169)
Miravis Top (n=6)	pydiflumetofen (6.9) + difenoconazole (11.5)	38.7 (18.2-58.2)	93 (77-114)
Priaxor (n=14)	fluxapyroxad (14.3) + pyraclostrobin (28.6)	23.4 (5.5-50.7)	88 (-84-271)
Quadris (n=8)	azoxystrobin (22.9)	8.7 (0-21.7)	-59 (-250-96)
Topguard (n=6)	flutriafol (11.8)	12.4 (3.8-19.2)	-3 (-56-128)

[z]A=Fungicide trade name and the number of times it was compared to a non-treated control in a replicated field trial.
[y]Mean percent disease control calculated as a percentage of the non-treated control.
[x]Mean yield preservation calculated by the difference from the non-treated control.

Assuming the average seedcotton yield preservation, 40% turnout, and $20/A cost of fungicide application, potential return on fungicide investment (ROFI) was highest with one application of Miravis Top ($2.32 - $22.78) followed closely by Priaxor ($1.12 - $20.48/A) (Table 6). Miravis Top, Quadris, and Topguard ROFIs were not calculable due to net-negative yield effects. Potential ROFIs were obviously lower with two applications of Miravis Top and Priaxor.

Table 6. Average yield preservation, value added, and return on fungicide investment (ROFI) for cotton leaf spot complex applications.

Trade Name	Average Seedcotton Yield Preservation[z]	Value Added Range/A ($)[y]	ROFI range/A 1 application[x]	ROFI range/A 2 applications[x]
Headline	-21	--	--	--
Miravis Top	93	$22.32 - $42.78	$2.32 - $22.78	-$17.68 - $2.78
Priaxor	88	$21.12 - $40.78	$1.12 - $20.48	-$18.88 - $0.48
Quadris	-59	--	--	--
Topguard	-3	--	--	--

[z]Average seedcotton yield preservation across 19 foliar fungicide trials with the cotton leaf spot complex conducted from 2016-2021 in Louisiana.
[y]Value added based on 40% turnout and cotton price range of $0.60 to $1.15 from 2015-2021.
[x]Return on fungicide investment based on value added minus the cost of application ($20/A).

Discussion

Results from many field trials indicate that multiple fungicides are effective on target spot. Headline, Miravis Top, and Priaxor appear to be the most efficacious products. However, Headline and Priaxor appear to be the highest performing products regarding yield preservation. Statistically significant (P=0.10, Tukey's HSD) yield preservation was observed in only 3 of 19 target spot trials where minimum final defoliation was 33%. This indicates that moderate to high amounts of defoliation due to target spot may cause yield losses. On the contrary, moderate to severe defoliation (10-90%) was observed in other trials where significant yield differences were not observed. Variation within yield data and a relatively conservative statistical test *post hoc* may explain this discrepancy. Further, the ability of cotton plants to compensate for foliar damage must not be ignored. In most trials included in the summary, varieties considered susceptible (PHY) were used, although final defoliation in less susceptible (DPL) varieties ranged from 36 to 52%. Another complicating factor is disease initiation, and those time points were not fully available for these trials. The earlier target spot initiates during reproductive stages, the more likely one is to incur losses due to target spot, particularly if frequent rainfall events are encountered. Target spot epidemics are driven by free moisture and frequent rainfall events, and a minimum of 11 rainfall events occurred from July 1 to August 31 in trials where significant fungicide efficacy was observed.

Results from nine field trials indicate that multiple fungicides are effective on the cotton leaf spot complex. Miravis Top and Priaxor appear to the most efficacious products in this summary and are the only two products that averaged positive yield preservation across observations. Significantly preserved yield appears to be the exception rather than the rule in trials with moderate to severe CLSC. When CLSC occurs, drought and potassium deficiency are usually the underlying issue. Six of the 9 trials were conducted in 2015, which was a relatively dry year compared to those when target spot was prevalent. In 2020, rainfall was more frequent than 2015; however, the rainfall total was relatively low. Further, potassium deficiency is all to common in the location where the trials were conducted.

Based on our summary, the odds of having a positive ROFI when spraying for target spot appears to be highest with one application of Headline or Priaxor during the first month of blooming. ROFI is likely to be lower with two applications when spraying for target spot. Similarly, the highest odds of having a positive ROFI when spraying for the CLSC is with one application of Miravis Top or Priaxor during the first month of blooming; however, the top end of that ROFI barely covers the cost of application.

Cotton farmers should consider a number of factors when managing target spot including varietal susceptibility, correct disease identification, weather, canopy management, proper N fertilization, timely application of fungicides, and economics. If a grower has a susceptible variety, disease has initiated in the first month of blooming, the extended forecast calls for rain, and the crop is rank and/or over-N-fertilized, one application of Headline or Priaxor by ground with 15GPA total volume has the best chance of an economic return.

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