BACTERIAL BLIGHT ON COTTON

Terry A. Wheeler
Texas A&M AgriLife Research
Lubbock, TX

Abstract

Symptoms caused by the organism *Xanthomonas citri* subsp. *malvacearum* (Xcm, bacterial blight) include dark brown lesions on leaves with water soaking on the underside of the leaf. Bacteria symptoms can occur on petioles and bolls as well. The bacteria are typically spread by rain/wind events. Symptoms can be initiated by infected seed, plant debris on the soil from previous years, blowing/splashing into a field, or possibly from epiphytic survival on nonhost weeds. Planting resistant varieties is the most effective method of controlling the disease. Resistance to race 18 (the current race in the U.S.) has been available since the mid 1970's. An application method has been utilized for the past 18 years to treat and rate field nurseries with bacterial blight. The bacteria is applied at 10^6 colony forming units/ml in a tank at 50 gal/acre, and includes the product Silwet L-77 at 0.2% v/v, to improve movement of the bacteria into plants. Since 2010 in Georgia and 2008 in Mississippi and 2014 in Texas, more than 50% of the cotton acres have been planted to blight susceptible varieties. Since the elimination of DP 555BG/RR, DP 444BG/RR, and ST 5599BR, the midsouth and southeastern U.S. has struggled to find blight resistant varieties that were popular with producers. Bacterial blight resistant varieties from Fibermax and NexGen helped keep bacterial blight from developing in Texas until 2015. DP 1646B2XF is a partially blight resistant variety that was planted on many acres in 2016 and may help reduce bacterial blight across the U.S.

Introduction

Bacterial blight in cotton is caused by the organism *Xanthomonas citri* subsp. *malvacearum* (Xcm). This organism has had different names historically including *X. axonopodis* pv. *malvacearum*, *X. campestris* pv. *malvacearum*, and *X. malvacearum*. Xcm can cause leaf spot symptoms that are dark-brown in color and somewhat blocky in appearance (Fig. 1). These lesions can have a water-soaked appearance on the underside.

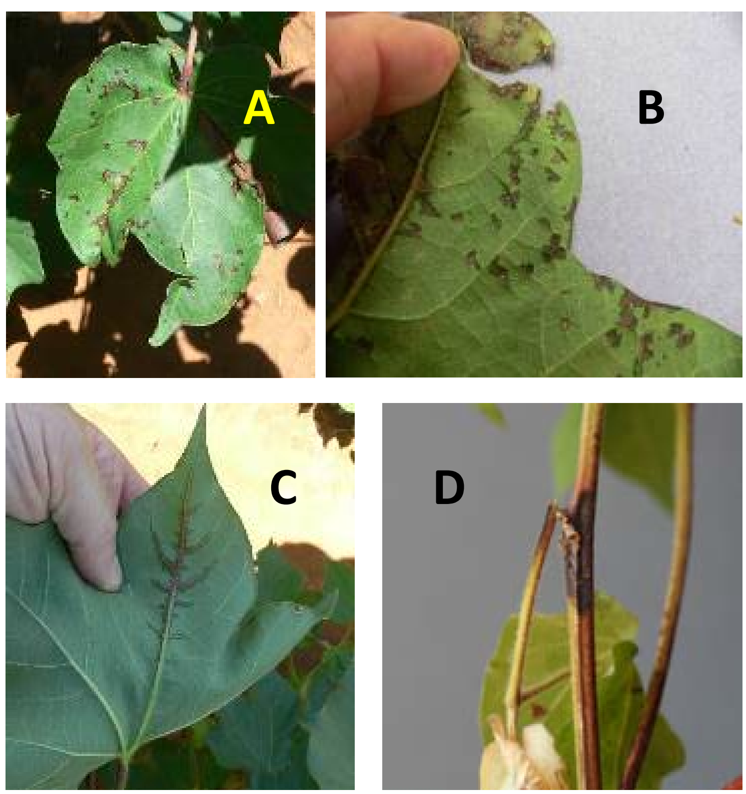

Figure 1. Symptoms of bacterial blight. A) Leaf spots; B) water soaked leaves; C) water soaked veins; D) Black arm

symptom. T. Wheeler photographed A, B, and C; Tom Isakeit (Texas A&M Extension Service) photographed D. The symptom termed black arm can occur on the petiole and branch (Fig. 1D). Xcm can also cause boll rots, stain the lint, and infect seed (Fig. 2).

Figure 2. Boll rot, lint discoloration, and seed contamination with *Xanthomonas citri* subsp. *malvacearum*. Images by Jason Woodward, Texas A&M AgriLife Extension Service.

The occurrence of bacterial blight can be a result of infected cotton seed, though there are also other ways it can spread into new fields. In 2011, bacterial blight became a problem in Arkansas and Mississippi. Tom Allen, extension plant pathologist with Mississippi State University, began to map locations where the disease was reported. Bacterial blight continued to spread into new counties in Mississippi in 2012. In 2014, new fields were found with bacterial blight in Missouri, Tennessee, south Texas, and one county in Georgia. In 2015 and 2016, fields positive for bacterial blight were reported in many additional counties in Georgia, and also in Arkansas, Mississippi, Tennessee, Florida, Alabama, Louisiana, the High Plains of Texas, and Oklahoma. Inoculum of the bacteria was so widespread, that any cotton growing area was at risk of having a significant disease problem. The spread of the disease could be from a number of sources besides infected cotton seed, including plant debris from infected cotton, and nonhost weeds, where it may have survived epiphytically (Koczan et al., 2017). However, the driving source of the disease is the high percentage of cotton acres planted in susceptible varieties.

The bacteria are spread during rain events, particularly when wind or hail causes wounds on the plant. Humidity must be high for infection to be successful. It takes 24 to 48 hours for infection to occur, and then approximately two weeks before water soaked lesions appear on the leaves. It can be difficult to diagnosis the bacteria late in the season once leaves have spots from many different factors, or the plants have defoliated. Inspection for the disease should occur approximately 3 weeks after rain events that may cause bacterial blight. This is particularly important for fields that are growing seed for the next year's crop. Late season inspection to certify fields for seed, is a common practice, but is too late to detect infection by Xcm.

In 2005, the primary blight resistant varieties planted were DP 555BG/RR, DP 444BG/RR, ST 5599BR, and FM 958 (Fig. 3). The Bollgard® I gene was discontinued at/after 2010 as an EPA requirement for registration of the Bollgard® II gene. As a result, the acres planted to DP 555BG/RR and DP 444BG/RR were replaced by 2010 with mostly susceptible varieties, and overall the acreage planted to resistant Deltapine varieties was < 5% until 2016 when DP 1646B2XF was introduced. While there were a few Deltapine varieties introduced between 2009 and 2016 with bacterial blight resistance (DP 0920B2RF, DP 1032B2RF, DP 1133B2RF, DP 1359B2RF, DP 1410B2RF, and DP 1518B2XF), none had the sustained impact of the earlier successes. ST 5599BR was a widely planted, blight resistant variety that was partially resistant to root-knot nematode. Unfortunately, its replacement, ST 5458B2F was susceptible to bacterial blight, and in fact all varieties introduced with root-knot nematode resistance after ST 5599BR were susceptible to bacterial blight (ST 5458B2F, ST 4946GLB2, PHY 417WRF, PHY 427WRF, DP 1454NRB2RF, DP 1558NRB2RF, and DP 1747NRB2RF). The Fibermax varieties have historically been resistant to bacterial blight, with few exceptions. FM 958 was the most popular Fibermax variety in 2005 (Fig. 3). The Fibermax varieties have been widely planted in Texas (Fig. 4), and have been the most important source of blight resistant varieties there until 2016 when the change to dicamba resistant varieties caused producers to switch to other varieties. The impact of NexGen blight resistant varieties has been primarily in Texas, and increased acreage has coincided with decreases in Fibermax resistant variety acreage. The loss of Bollgard I varieties combined with the surge in glyphosate resistant pigweed, resulted in producers looking for varieties with tolerance to glufosinate. In some areas, PHY 375WRF became a popular replacement, and dominated most acres planted to Phytogen varieties. However, from 2010 until 2015, no single blight resistant variety obtained a substantial share of the market. DP 1646B2XF was introduced in 2016 and is primarily responsible for the increase in blight resistant varieties.

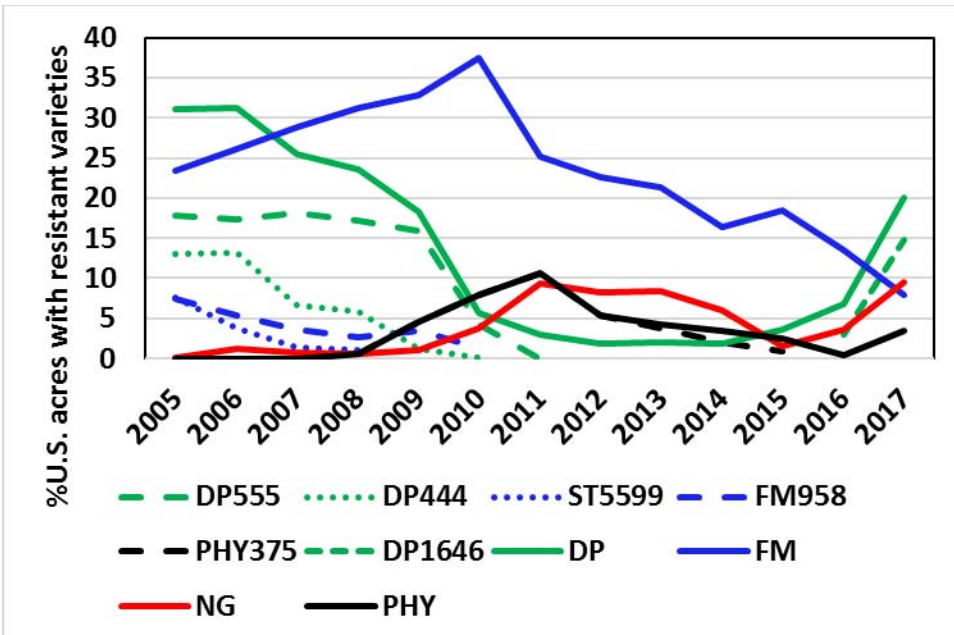

Figure 3. Percentage of U.S. cotton acres planted with bacterial blight resistant varieties or company brand names. DP = Deltapine, FM = Fibermax, NG = NexGen, and PHY = Phytogen. DP555 is DP 555 BG/RR; DP444 is DP 444 BG/RR, ST5599 is ST 5599BR, FM958 is FM 958, PHY375 is PHY 375WRF, and DP1646 is DP 1646B2XF. Estimates of planting acres for each variety/company were obtained from the USDA Agricultural Marketing Service annual survey conducted for the Cotton Program.

In Georgia, DP 555 BG/RR was planted on approximately 80% of the cotton acres from 2005 to 2009 (Fig. 4). Glyphosate resistant pigweed became a critical problem in Georgia around the time that Bollgard I was phased out, so the producers were looking for cotton varieties that could be sprayed with glufosinate, which included the Liberty-link® varieties with Bayer CropSciences and some Phytogen varieties. Varieties like PHY 375WRF were somewhat tolerant of glufosinate, if the rates were managed carefully. Varieties with these herbicide traits and blight resistance that began to dominate in Georgia included FM 1845LLB2, ST 6448GLB2, and PHY 375WRF. The initial varieties available with dicamba resistance in 2015 were almost all susceptible to bacterial blight. However, by 2016 the variety DP 1646B2XF was introduced and had expanded to 40% of the cotton acres in Georgia by 2017. This variety is partially resistant to bacterial blight.

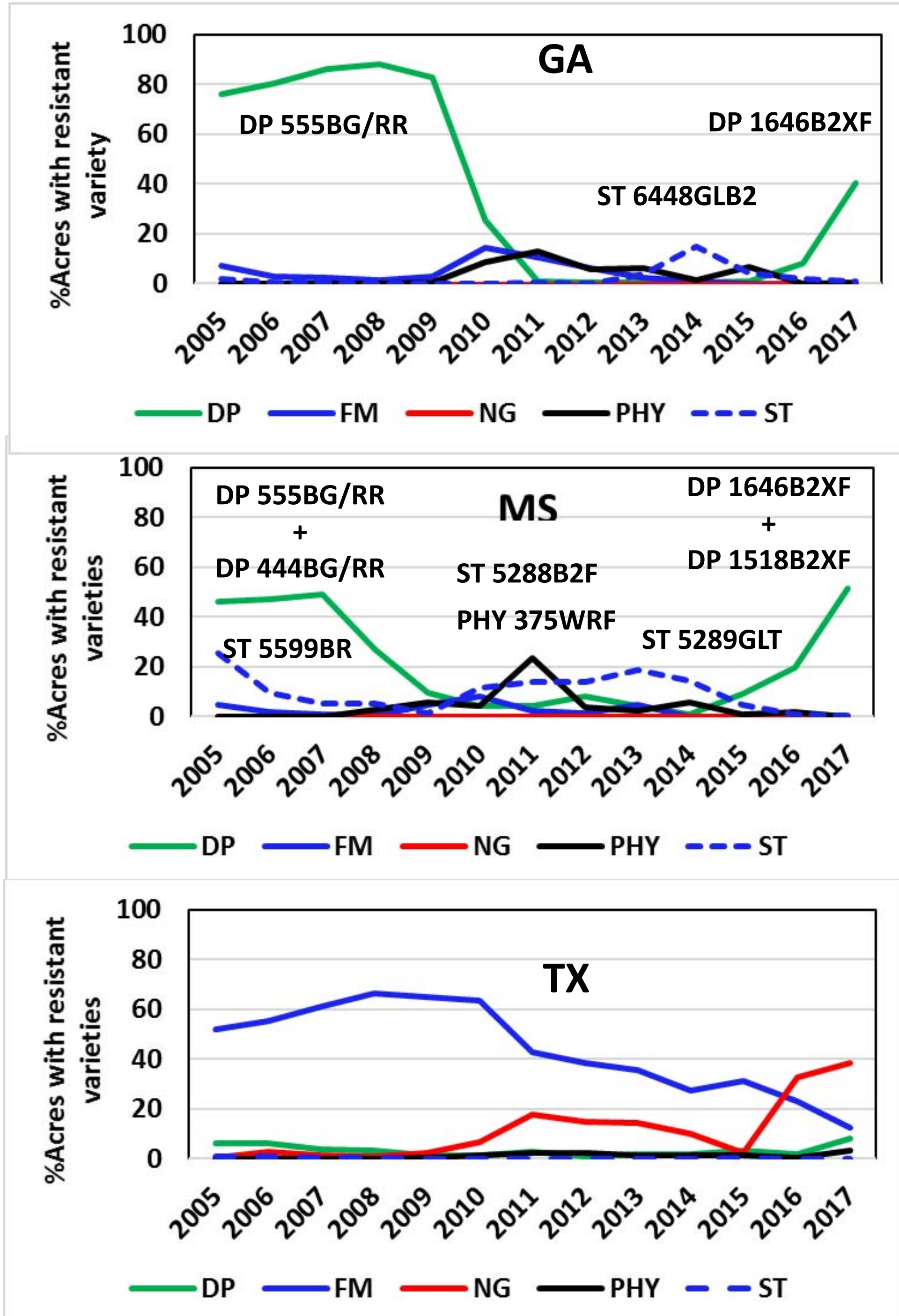

Figure 4. Percentage of acres in Georgia, Mississippi, and Texas planted to blight resistant varieties with brand names of Deltapine (DP), Fibermax (FM), NexGen (NG), Phytogen (PHY) and Stoneville (ST). Estimates of planting acres for each variety/company were obtained from the USDA Agricultural Marketing Service annual survey conducted for the Cotton Program.

In Mississippi, both DP 444 BG/RR and DP 555BG/RR were popular, and were planted on an average of 41% of the cotton acres in 2005 to 2008 (Fig. 4). ST 5599BR was also popular in Mississippi and was planted in 25% of the cotton acres in 2005. In Mississippi, by 2009 the producers began switching varieties each year, with no one variety dominating. Blight resistant varieties that were planted on the most acres included FM 1740B2F and PHY 375WRF. Several Stoneville varieties were also included over the next few years including ST 5288B2F and then replaced with ST 5289GLT. In 2016, there was a shift to the blight resistant varieties DP 1518B2XF (7.2%), DP 1639B2XF (2.4%), and DP 1646B2XF (10.2%). This trend continued in 2017 with DP 1518B2XF being planted on 16.8% and DP 1646B2XF on 34.6% of the cotton acres in Mississippi.

The most popular varieties in Texas from 2005 to 2016 were Fibermax varieties, of which almost all were resistant to bacterial blight. Varieties that were popular in the pre-Liberty-link era included FM 958, FM 960B2F, FM 9063B2F, FM 9058F, FM 1740B2F, FM 9170B2F, FM 2484B2F, and FM 2011GT. Liberty link varieties which achieved significant acres (> 4%) in Texas and were blight resistant included FM 9250GL and FM 1830GLT. NexGen varieties with blight resistance that were popular in Texas included NG 3348B2RF, NG 4111RF, and NG 4012B2RF. A popular NexGen dicamba resistant variety, with blight resistance is NG 4545B2XF.

Materials and Methods

A bacterial blight screening program was initiated in 2000 and has continued through 2017. The protocol was described in Wheeler et al. (2007), but briefly, the bacteria was grown to 10^8 colony forming units (cfu)/ml in trypticase soy broth for 1.5 days on a shaker. The field application involved spraying the bacteria at 10^6 cfu/ml, in 50 gallons of water/acre, plus the addition of Silwet L-77 at 0.2% v/v. Plots were either 1 or 2 rows wide, 30 to 40 feet in length, and entries were arranged in a randomized complete block design with four replications. The plots were rated for the incidence of plants with bacterial blight symptoms. A comparison of varieties that were treated in both 2016 and 2017 with regards to temperature after application is provided to demonstrate year to year variability.

The identification of resistant and susceptible varieties that was presented in Fig. 3 and 4 was primarily determined by this protocol. There were some varieties that are included in the annual planting estimates, that have not been tested. Table 1 provides the % of bacterial blight resistant, susceptible, and not tested for Georgia, Mississippi, and Texas. Table 2 provides a list of ratings for more recent varieties.

Results and Discussion

From 2005 to 2007, most varieties planted in GA, MS, and TX were resistant to bacterial blight (Table 1). By 2008 in MS, 2010 in GA, and 2014 in TX, the majority of acres were planted with blight susceptible varieties. Initially there were a number of Deltapine and Stoneville varieties with unknown ratings. Most of the Dynagro varieties have not been rated for blight, with the bulk of these planted in Texas.

Table 1. Percentage (%) of varieties in Georgia, Mississippi, and Texas that are resistant or susceptible to bacterial blight.

Year	Georgia			Mississippi			Texas		
	R[1]	S[1]	U[1]	R	S	U	R	S	U
2005	84.9	3.1	12.0	78.7	13.9	7.4	60.2	17.2	22.6
2006	83.6	8.6	7.8	59.1	32.5	8.4	66.8	14.3	18.9
2007	88.2	7.6	4.2	54.8	41.9	3.3	67.5	22.9	9.6
2008	89.3	6.9	3.8	35.7	64.3	0	70.7	23.9	5.4
2009	86.1	11.4	2.5	21.2	77.1	1.7	69.6	25.0	5.4
2010	47.7	51.6	0.7	30.9	65.9	3.2	73.3	23.0	3.7
2011	24.7	73.6	1.7	43.8	55.9	0.3	66.2	28.6	5.2
2012	12.5	86.7	0.8	26.8	70.3	2.9	57.5	39.8	2.7
2013	12.6	85.9	1.5	29.8	69.4	0.8	53.0	41.7	5.3
2014	20.8	78.8	0.4	20.8	74.2	5.0	41.0	51.7	7.3
2015	12.2	87.0	0.8	14.6	85.0	0.4	38.6	52.7	8.7
2016	10.1	91.8	0	22.4	76.7	0.9	32.9	59.5	7.6
2017	41.7	57.1	1.2	51.6	49.5	0	41.5	49.6	8.9

[1]R are varieties listed as bacterial blight resistant, S is susceptible, and U is unknown.

Table 2. Ratings of varieties to bacterial blight (*Xanthomonas citri* subsp. *malvaceraum*), race 18.

Brand	Variety	Bacterial Blight[1]	Brand	Variety	Bacterial blight
All-Tex	AT AridB2RF	S	Fibermax	FM 1911GLT	R
All-Tex	AT Concho B2XF	R	Fibermax	FM 1944GLB2	S
All-Tex	AT DineroB2RF	S	Fibermax	FM 1953GLTP	R
All-Tex	AT EdgeB2RF	S	Fibermax	FM 2007GLT	R
All-Tex	AT Epic RF	S	Fibermax	FM 2011GT	R
All-Tex	AT Nitro-44B2RF	R	Fibermax	FM 2322GL	S
Croplan Genetics	CG 3226B2XF	S	Fibermax	FM 2334GLT	R
Croplan Genetics	CG 3475B2XF	MS	Fibermax	FM 2498GLT**	R
Croplan Genetics	CG 3527B2XF	S	Fibermax	FM 2574GLT**	R
Croplan Genetics	CG 3787B2RF	R	Fibermax	FM 2484B2F	R
Croplan Genetics	CG 3885B2XF	S	Fibermax	FM 9250GL	R
Deltapine	DP 104B2RF	S	NexGen	NG 1511B2RF	MS
Deltapine	DP 1044B2RF	MS	NexGen	NG 3306B2RF	S
Deltapine	DP 1050B2RF	S	NexGen	NG 3405B2XF	S
Deltapine	DP 1133B2RF	R	NexGen	NG 3406B2XF	S
Deltapine	DP 1137B2RF	S	NexGen	NG 3500XF	R
Deltapine	DP 1212B2RF	S	NexGen	NG 3517B2XF	MS
Deltapine	DP 1219B2RF	S	NexGen	NG 3522B2XF	S
Deltapine	DP 1252B2RF	S	NexGen	NG 3640XF	R
Deltapine	DP 1321B2RF	S	NexGen	NG 3699B2XF	R
Deltapine	DP1359B2RF	PR	NexGen	NG 3780B2XF	S
Deltapine	DP 1410B2RF	R	NexGen	NG 4012B2RF	R
Deltapine	DP 1441RF	S	NexGen	NG 4111RF	R
Deltapine	DP 1454NRB2RF	S	NexGen	NG 4545B2XF	R
Deltapine	DP 1518B2XF	R	NexGen	NG 4601B2XF	S
Deltapine	DP 1522B2XF	S	NexGen	NG 4689B2XF	R
Deltapine	DP 1538B2XF	S	NexGen	NG 4777B2XF	R
Deltapine	DP 1549B2XF	S	NexGen	NG 4792XF	S
Deltapine	DP 1553B2XF	S	NexGen	NG 5007B2XF	S
Deltapine	DP 1555B2RF	S	NexGen	NG 5711B3XF	R
Deltapine	DP 1558NRB2RF	S	Phytogen	PHY 220W3FE	PS
Deltapine	DP 1612B2XF	PS	Phytogen	PHY 222WRF	S
Deltapine	DP 1614B2XF	MS	Phytogen	PHY 223WRF	R
Deltapine	DP 1639B2XF	R	Phytogen	PHY 230W3FE	R
Deltapine	DP 1646B2XF	PR	Phytogen	PHY 243WRF	PR
Deltapine	DP 1725B2XF	S	Phytogen	PHY 250W3FE	R
Deltapine	DP 1747NRB2XF	S	Phytogen	PHY 300W3FE	R
Deltapine	DP 1820B3XF	R	Phytogen	PHY 308WRF	S
Deltapine	DP 1835B3XF	S	Phytogen	PHY 312WRF	MS
Deltapine	DP 1840B3XF	R	Phytogen	PHY 330W3FE	R
Deltapine	DP 1845 B3XF	R	Phytogen	PHY 333WRF	S
Deltapine	DP 1851B3XF	R	Phytogen	PHY 339WRF	R
DynaGro	DG 2615B2RF	PR	Phytogen	PHY 340W3FE	R
DynaGro	DG 3109B2XF	S	Phytogen	PHY 417WRF	S
DynaGro	DG 3445B2XF	R	Phytogen	PHY 427WRF	S
DynaGro	DG 3544B2XF	R	Phytogen	PHY 430W3FE	R
Fibermax	FM 1320GL	PS	Phytogen	PHY 440W3FE	R
Fibermax	FM 1740B2F	R	Phytogen	PHY 444WRF	MS
Fibermax	FM 1830GLT	R	Phytogen	PHY 450W3FE	R
Fibermax	FM 1888GL	R	Phytogen	PHY 480W3FE	R
Fibermax	FM 1900GLT	R	Phytogen	PHY 490W3FE	R

Phytogen	PHY 495W3RF	S	Stoneville	ST 5032GLT	S
Phytogen	PHY 499WRF	S	Stoneville	ST 5115GLT	R
Phytogen	PHY 575WRF	R	Stoneville	ST 5289GLT	R
Stoneville	ST 4747GLB2	S	Stoneville	ST 5471GLTP**	R
Stoneville	ST 4848GLT	S	Stoneville	ST 5517GLTP**	R
Stoneville	ST 4946GLB2	S	Stoneville	ST 6182GLT	S
Stoneville	ST 4949GLT	S	Stoneville	ST 6448GLB2	R
Stoneville	ST 5020GLT	R			

[1]S = highly susceptible; MS = mostly susceptible; PS = partially susceptible; PR = partially resistant; R = highly resistant

**Varieties were inoculated by Terry Wheeler, but ratings were conducted by Bayer CropScience personnel.

The maximum temperature for the first 7 days after application (DAA) averaged 99 and 96ºF, for 2016 and 2017, respectively. The maximum temperature 8-14 DAA averaged 97 and 85ºF, for 2016 and 2017, respectively. As a result, plots were rated at 14 DAA in 2016 and 24 DAA in 2017. Variety responses were relatively consistent between the two years (Table 3), but DP 1646B2XF had more disease in 2017 than is normal for a partially resistant variety. The resistance for that variety may not be as durable as with most partially or fully resistant varieties. Luther Bird (1986) described resistance from his sources as a complex of several major (B_2B_3) and minor (B_{sm}) genes. The source of B_2B_3 combined or B_{12} alone is considered necessary for resistance to race 18 (Girardot et al., 1986; Silva et al., 2014).

Table 3. Average incidence of blight in 2016 and 2017 for varieties[1].

Variety	2016	2017	Rating
	% Blight		
Phytogen PHY 499WRF	100	100	Susceptible
NexGen NG 4601B2XF	96	100	Susceptible
Phytogen PHY 312WRF	86	97	Moderately susceptible
Phytogen PHY 444WRF	91	90	Moderately susceptible
Deltapine DP 1612B2XF	47	65	Partially susceptible
Deltapine DP 1646B2XF	28	40	Partially resistant
Phytogen PHY 243WRF	27	18	Partially resistant
Deltapine DP 1518B2XF	5	0	Resistant
Deltapine DP 1639B2XF	1	2	Resistant
NexGen NG 4689B2XF	0	0	Resistant

[1]Varieties were divided into two separate tests each year, but select varieties from the two tests are combined in each column to show the range of results from different years.

Acknowledgements

I appreciate the funding from the Plains Cotton Improvement Program to determine the susceptibility or resistance of commercial varieties and work with cotton seed companies to develop blight resistant varieties. I also appreciate the assistance of Cotton Incorporated and NIFA on bacterial blight projects.

References

Bird, L. S. 1986. Half a century dynamics and control of cotton disease: bacterial blight. *In* Proceeding of the Beltwide Cotton Research Conference, Cotton Disease Council 46:24-33. National Cotton Council Am. Memphis, TN.

Girardot, B., E. Hequet, M. T. Yehouessi, and P. Guibordea. 1986. Finding a variety of *Gossypium hirsutum* L. resistant to strains of *Xanthomonas campestris* pv *malvacearum* (Smith) Dye virulent on associations of major genes (B_2B_3 or $B_{9L}B_{10L}$). Coton Fibres Trop. 41:67-69.

Koczan, J., D. W. Albers, and K. Gholston. 2017. Identification of an alternative source of inoculum causing bacterial blight in cotton. Pp. 248-249. *In* Proceedings of the Beltwide Cotton Conference, 4-6 Jan., Dallas, TX 2017.

Silva, R. A., P. A. Vianna Barroso, L. V. Hoffmann, M. Giband, and W. M. Coutinho. 2014. A SSR marker linked to the B12 gene that confers resistance to race 18 of *Xanthomonas axonopodis* pv. *malvacearum* in cotton is also associated with other bacterial blight resistance gene complexes. Austral. Plant Path. 43:89-91.

Wheeler, T. A., U. S. Sagaram, G. L. Schuster, and J. R. Gannaway. 2007. Identification of factors that influence screening for bacterial blight resistance. J. Cotton Sci. 11:91-97.