EXPIRATION OF SINGLE-GENE BOLLGARD® TECHNOLOGY: ANALYSIS OF ALTERNATIVES AVAILABLE TO GEORGIA COTTON PRODUCERS

W. Don Shurley[1], J. LaDon Day[2], Phillip R. Roberts[3], and A. Stanley Culpepper[4]
[1]Agriculture and Applied Economics, University of Georgia, Tifton Campus
[2]Department of Crop & Soil Science, University of Georgia, Griffin Campus
[3]Department of Entomology, University of Georgia, Tifton Campus
[4]Department of Crop & Soil Science, University of Georgia, Tifton Campus

Introduction

Over 90% of Georgia's cotton acreage is planted to BR (Bollgard® plus Roundup-Ready®) technology (USDA-AMS, 2008). Less than 1% of the state is non-transgenic (conventional) cotton. The state used to plant a greater amount of straight Roundup Ready (RR) cotton but yields were not good. Adoption of BR technology was aided by much improved yields in BR varieties.

To date, the state has not widely adopted Bollgard II® (B2), RF (Roundup-Ready Flex®), Widestrike® (W), and Liberty-Link® (LL) technologies (Table 1). Previous research at The University of Georgia has concluded that these technologies are of value and have utility for the producer, but yield potential remains the major determinant of profitability (Jost, et al., Shurley, et al.)

Not only is over 90% of Georgia cotton acreage planted to BR varieties, but of greater significance is the fact that approximately 86% of the state is planted to a single variety: Deltapine 555 BR. Prior to the 2008 growing season, cotton specialists with The University of Georgia Cooperative Extension recommended that Georgia farmers begin to plant relatively small acreage of other technologies and varieties due to the pending expiration of single-gene Bollgard technology. There were slight increases in two-gene technologies B2R, B2RF, WR, and WRF in 2008 compared to 2007 (USDA-AMS, 2008). Even so, varieties planted to these technologies still comprised less than 5% of the state in 2008.

Situation

Single-gene Bollgard technology and related variety types (B and BR) expires September 30, 2009. Because this technology dominates the Georgia cotton landscape and because one variety, DP555BR, accounts for the vast majority of these acres, Georgia producers are concerned about the loss of single-gene technology and more specifically, DP555BR. DP555BR and other single-gene varieties will not be available after the 2009 crop year (availability in 2010 will be limited to very few remaining stocks).

In Georgia, DP555BR has offered a strong and consistent yield advantage compared to other varieties. To-date, Georgia producers have not embraced available two-gene technologies Bollgard II (B2) and Widestrike (W). Georgia producers also face

increasing/spreading glyphosate resistance in Palmer Amaranth. Many two-gene varieties are "packaged" with RF but both R and RF have reduced value in Georgia due to the need to use residual chemistries to combat glyphosate resistance.

Table 1. Percent of Georgia cotton acres planted by technology and variety brand, 2008.[1]

	Variety Brand [2]					
Technology	**BCS-FM**	**BCS-ST**	**DP**	**PHY**	**Others**	**Total**
Conventional	.06		.56			.62
RR	.48		1.86			2.34
RF		.16				.16
B						
BR	.45	.28	89.60			90.33
B2R	.33		.05			.38
B2RF		.26				.26
LL						
B2LL	.12					.12
W						
WR				2.55		2.55
WRF				.40		.40
Not Specified		.04	1.20	.05	1.55	2.84
Total	**1.44**	**.74**	**93.27**	**3.00**	**1.55**	**100.00**

[1]/ Source: USDA-AMS, September 2008.
[2]/ BCS (Bayer CropScience), FM (Fibermax), ST (Stoneville), DP (Deltapine), PHY (Dow Phytogen)

The economic impact of the expiration and future unavailability of single-gene technology is uncertain. Questions remain concerning (1) the availability of variety and technology choices, (2) differences, if any, in lint yield and fiber quality, and (3) any differences in production practices and costs.

Objectives

The objective of this study was to investigate the impacts on Georgia cotton producers and farmer income due to the expiration of single-gene Bollgard (B) technology and the resulting need to change to other technologies and varieties. Specifically, objectives were (1) to compare and determine possible differences in lint yield, (2) to compare fiber quality characteristics, (3) to compare technology-related production practices and input costs for single-gene technology (DP555BR, specifically) to two-gene B2 and W technology, and (4) to analyze alternatives available to Georgia producers.

Materials and Methods

Effective with the 2010 crop, the alternatives available to cotton producers are non-Bt cottons (R/RR, F/RF, and LL) and/or two-gene cottons (B2, B2R, B2RF, B2LL, W, WR,

and WRF). Table 2 illustrates the technology types and variety brands available based on 2008 acres (technology available by variety brand for those brands with acreage in Georgia) (USDA-AMS, 2008).

For this study, analysis was conducted comparing DP555BR to two-gene varieties included in The University of Georgia Later Maturity Official Variety Trials (OVT's). Data was analyzed for the 3-year period 2006-2007 (Day, et al., 2007, 2008, and 2009). Conventional (non-transgenic) and other non-Bt cotton's were not considered.

In 2008, DP555BR was the only BR variety in the tests (Table 3). There were 11 two-gene (B2 and W) varieties. In 2006 and 2007, there were 8 and 11 two-gene varieties respectively. OVT's included the same varieties in both irrigated and non-irrigated tests. Irrigated tests were conducted at 4 locations. Non-irrigated tests were also conducted at 4 locations but for this analysis, Athens was omitted from non-irrigated data because DP555BR is not adapted for that location.

Table 2. Alternatives available to single-gene Bollgard® technology by variety brand.

Technology		**Variety Brand**				
Non-Bt	Conventional	DP	ST		FM	Others
	RR or R	DP		PHY	FM	Others
	RF or F	DP	ST	PHY	FM	Others
	LL				FM	
Two-Gene	B2				FM	
	B2R	DP			FM	Others
	B2RF	DP	ST		FM	Others
	B2LL				FM	
	W			PHY		
	WR			PHY		
	WRF			PHY		

[1]/ FM (Fibermax), ST (Stoneville), DP (Deltapine), PHY (Dow Phytogen).

Table 3. Number of varieties in University of Georgia official variety trials[1], by technology type.

	Technology Type										
Year	**Conv**	**R**	**RF**	**BR**	**B2R**	**B2RF**	**B2LL**	**W**	**WR**	**WRF**	**Total[1]**
2006	1	1	3	9	1	4	2			1	22
2007	1		5	6		10				1	23
2008			2	1		6	1	1	1	2	14

[1]/ Includes company experimental not yet released. Excludes University of Georgia experimentals.
[2]/ Four locations, irrigated- Bainbridge, Tifton, Plains, and Midville. Three locations, non-irrigated- Tifton, Plains, and Midville.

University of Georgia OVT data for 2006-2008 was used to compare yield and fiber quality. The single highest yielding, top 3 yielding, top 5 yielding and average of all two-gene varieties were compared to DP555BR each year and averaged over 3-years; averaged across locations. Average yield across locations and time was used to allow technology and variety performance comparisons over a combination of environments.

Weed and insect management practices can vary by technology. Seed costs and technology fees also vary. Seed and technology-related costs were estimated for two-gene varieties and compared to DP555BR. These costs included insecticides, herbicides, cost of application (Shurley and Smith, 2008), seed and technology fees. Insecticide and herbicide programs were examples based on University of Georgia Cooperative Extension recommendations (University of Georgia, 2009) and were for illustration purposes only. Seed price and technology fees were for 2009 based on suggested prices from the manufacturer. All other inputs and practices were assumed the same regardless of technology and therefore irrelevant and need not be considered.

Results and Discussion

Yield

Over 3 years at 4 irrigated locations, the highest yielding two-gene variety each year averaged approximately 9% less than DP555BR (Table 4). The top 3 varieties averaged 12.5% less and the top 5 varieties averaged 14.5% less. The average yield of all two-gene cottons was approximately 18% less than DP555BR. Yield difference between the highest yielding two-gene variety and DP555BR has declined over time. Whether this is a function of better varieties and/or weather and/or location has not been determined.

Table 4. Yield comparison of two-gene varieties to DP555BR, later maturity, irrigated.

	Yield Per Acre				Comparison to DP555BR	
	2006	**2007**	**2008**	**Average**	**Pounds**	**Percent**
DP555BR	2,106	1,825	1,813	1,915		
Highest Two-Gene Variety	1,678	1,775	1,787	1,747	-168	-8.8
Top 3 Two-Gene Varieties	1,619	1,642	1,764	1,675	-240	-12.5
Top 5 Two-Gene Varieties	1,585	1,586	1,739	1,636	-278	-14.5
All Two-Gene Average [1]	1,528	1,509	1,682	1,573	-341	-17.8

[1]/ Eight varieties in 2006, highest 10 yielding varieties in 2007 and 2008.

Over 3 years at 3 non-irrigated locations, the highest yielding two-gene variety each year averaged 7% less yield than DP555BR (Table 5). The top 3 varieties averaged about 11% less and the top 5 varieties averaged about 13% less. The average yield of all two-gene cottons was approximately 17% less than DP555BR. Again, the yield difference between the highest yielding two-gene variety and DP555BR has declined over time. In 2007, the highest yielding two-gene variety yielded higher than DP555BR.

Table 5. Yield comparison of two-gene varieties to DP555BR, later maturity, non-irrigated.

	Yield Per Acre				Comparison to DP555BR	
	2006	**2007**	**2008**	**Average**	**Pounds**	**Percent**
DP555BR	1,329	911	1,275	1,172		
Highest Two-Gene Variety	1,106	1,020	1,156	1,094	-78	-6.7
Top 3 Two-Gene Varieties	1,082	942	1,120	1,048	-124	-10.6
Top 5 Two-Gene Varieties	1,061	904	1,100	1,022	-150	-12.8
All Two-Gene Average [1]	1,035	836	1,050	974	-198	-16.9

[1]/ Eight varieties in 2006, highest 10 yielding varieties in 2007 and 2008.

Typical of small plot OVT's, yields appear high relative to on-farm. Despite this, relative differences are worthy of analysis. Over the 3 years at multiple locations, the highest and best yielding two-gene varieties averaged about 10% less than DP555BR.

Fiber Quality

In addition to yield, University of Georgia OVT data was also analyzed for differences in gin turn-out and fiber quality. Fiber quality for the same two-gene varieties based on yield from Tables 4 and 5 was compared to DP555BR.

It has generally been believed that DP555BR is not the very best quality fiber. This study does not attempt to confirm or deny that belief, but it is nonetheless worth considering how a shift to two-gene varieties may impact Georgia fiber quality.

Seedcotton samples for each variety at each location were ginned and HVI classed. Seedcotton was ginned using a table-top hand operated "gin" that separates the seed and trash material from the lint. Fiber quality parameters reported in the OVT's, therefore, were not subject to a commercial ginning process. For this reason, Staple and Uniformity in particular may appear high. Nevertheless, relative differences in fiber quality can be observed.

In both irrigated (Table 6) and non-irrigated tests (Table 7), two-gene varieties on average have been higher in Staple and fiber length Uniformity than DP555BR. Georgia producers may experience some improvement in Uniformity and Staple but the differences appear slight based on the OVT's when averaged across location and time.

Table 6. Fiber quality comparison of two-gene varieties to DP555BR, later maturity, irrigated. [1]

	Gin T/O	Uniformity	Staple	Strength	Micronaire
DP555BR	44.2	82.6	37.1	30.5	4.5
Highest Two-Gene Variety	42.6	82.8	38.1	30.0	4.5
Top 3 Two-Gene Varieties	41.8	83.0	37.6	30.2	4.4
Top 5 Two-Gene Varieties	41.6	83.2	37.6	30.6	4.4
All Two-Gene Average [2]	41.4	83.2	37.9	30.7	4.4

[1]/ Average of 4 locations over 3 years, 2006-08.

[2]/ Eight varieties in 2006, highest 10 yielding varieties in 2007 and 2008.

Table 7. Fiber quality comparison of two-gene varieties to DP555BR, later maturity, non-irrigated[1].

	Gin T/O	Uniformity	Staple	Strength	Micronaire
DP555BR	43.7	82.4	36.1	30.6	4.5
Highest Two-Gene Variety	42.3	82.2	36.6	28.5	4.3
Top 3 Two-Gene Varieties	42.0	82.5	36.6	29.8	4.4
Top 5 Two-Gene Varieties	41.8	82.6	36.7	30.4	4.4
All Two-Gene Average [2]	41.1	82.6	36.9	30.7	4.4

[1]/ Average of 4 locations over 3 years, 2006-08.
[2]/ Eight varieties in 2006, highest 10 yielding varieties in 2007 and 2008.

Costs

Upon expiration of single-gene Bollgard technology and producers then having to switch to other technology(ies), in addition to any yield and fiber quality effects, cost of production could also change. Such cost changes could include seed and associated technology fees, insect control, and weed control.

Estimated seed and technology cost per acre is shown in Table 8. This is based on 36-inch rows and planting 2 to 3 seed per foot (or 36,300 seed per acre) which is typical or thought to be an average for Georgia.

For 2009, the combined seed and technology cost per acre for DP555BR is $65.40 per acre. B2R and B2RF varieties are approximately $79.50 per acre (about $14.00 per acre higher). The least expensive two-gene varieties without weed management traits (W and B2) are $30.00 per acre and $15.00 per acre cheaper than DP555BR, respectively. B2LL and WR are approximately the same cost as DP555BR. WRF is about $10.00 per acre more than DP555BR.

Table 8. Seed and Technology Cost Per Acre [1], By Technology and Variety Brand [2], 2009.

	DP555BR	B2	B2R	B2RF	B2LL	W	WR	WRF
DP	$65.40		$79.68	$78.37				
FM		$50.08	$80.77	$79.46	$66.58			
ST				$79.46				
PHY						$34.88	$65.57	$75.07

[1]/ Based on 36-inch row spacing, 2 to 3 seed per foot of row.
[2]/ DP (Deltapine), FM (Fibermax), ST (Stoneville), PHY (Phytogen)

Table 9 represents an example comparison of insect control programs and costs for single-gene technology (B) compared to two-gene technology (B2 and W). The programs and materials shown are for illustration purposes only and do not constitute a recommendation. Situations and materials used vary widely.

Based on Georgia experience, compared to single-gene Bollgard (B), B2 is expected to provide improved control of corn ear worm. Sprays are expected to be needed for stink bugs only. Widestrike (W) technology is expected to also provide better control and less spray applications than B but generally not as good of control as B2.

Compared to single-gene technology, both B2 and W technologies offer the possibility of fewer applications and less cost. With either B2 or W, insecticide spray costs are expected to be lower than B, but the difference between B2 and W is expected to be moderate to minor on average.

Upon expiration of single-gene Bollgard technology, producers switching to two-gene varieties containing B2 and W will find this technology “packaged” with R/RR (Roundup Ready), RF/F (Roundup Ready Flex), or LL (Liberty Link). Therefore, compared to DP555BR, a switch to B2 or W will likely also mean a change in weed control technology and management.

Table 9. Estimated Insecticide Cost Per Acre By Technology[1], 2009.

Technology	Product	Rate Per Acre	Time of Application	Cost Per Acre	Application	Total
B	bifenthrin	4 oz	early to mid Jul	$4.38	$2.90	$7.28
	bifenthrin + dicrotophos	4 oz + 4 oz	mid to late Jul	$7.29	$2.90	$10.19
	dicrotophos	6 oz	late Jul to mid Aug	$4.36	$2.90	$7.26
Total						**$24.73**
B2	dicrotophos	6 oz	mid to late Jul	$4.36	$2.90	$7.26
	dicrotophos	6 oz	late Jul to mid Aug	$4.36	$2.90	$7.26
Total						**$14.52**
W	bifenthrin + dicrotophos	4 oz + 4 oz	mid to late Jul	$7.29	$2.90	$10.19
	dicrotophos	6 oz	late Jul to mid Aug	$4.36	$2.90	$7.26
Total						**$17.45**

[1]/ Does not constitute a recommendation. For illustration purposes only. Programs and costs vary.

Weed control (materials used and cost) varies widely and depends on weather, location, typical/common problems, management, and choice of materials. Table 10 represents one of many possible such programs. The programs and materials shown are for illustration purposes only and do not constitute a recommendation. The weed control program illustrated assumes the producer does not currently have glyphosate resistance but is managing to control resistance by using residual chemistry as needed.

Based on the example program, weed control spray and application cost is expected to be similar for RR, RF, and LL cottons. In the example, the same weed control program is assumed for RF and RR. While Roundup Ready Flex does offer utility and flexibility for the producer (specifically, the ability to spray beyond the 4-leaf stage if needed) the technology has limited value when managing for resistance.

While weed control problems and costs can, and do, vary widely, it is possible based on the example of Table 10 that there could be little difference in materials and application costs between R/RR, RF, and LL systems.

Upon expiration of single-gene Bollgard technology and as Georgia cotton producers shift acres from DP555BR to other (non-transgenic or two-gene) varieties, the costs that

could be impacted include seed, technology fees, insecticides, and herbicides. In Table 11, B2RF, WRF, and B2LL varieties are compared to DP555BR.

The combined cost of seed and technology fee is estimated to range from about the same cost as DP555BR (for B2LL) to $10.00 to $14.00 per acre higher (for WRF and B2RF, respectively). Herbicide cost, due to the need to manage for glyphosate resistance, is similar regardless of technology. Insecticide cost is about $10.00 per acre cheaper for B2 and about $7.00 per acre cheaper for W.

For B2RF, the $10.00 per acre savings in spray materials and application is offset by the $14.00 increase in seed and technology cost. B2RF and WRF costs are approximately the same. B2LL is lower. Seed and technology-related costs vary but differences are relatively minor. Seed and technology-related cost was estimated to be $144.32 per acre for DP555BR compared to $147.82 for B2RF, $146.71 for WRF, and $134.37 per acre for B2LL.

Table 10. Estimated Herbicide Cost Per Acre By Technology[1], 2009.

Technology	Product	Rate Per Acre	Time of Application	Cost Per Acre	Application	Total
R or RF [2]	pendimethalin	2 pt	PPI or at planting	$6.00	$6.26	$12.26
	glyphosate + S-metolachlor	22 oz + 1.33 pt	POST OTT	$17.44	$2.90	$20.34
	glyophosate + flumioxazin	22 oz + 1.5 oz	POST Directed	$15.69	$5.91	$21.60
Total						**$54.20**
LL	pendimethalin	2 pt	PPI or at planting	$6.00	$6.26	$12.26
	glufosinate-ammonium + S-metolachlor	29 oz + 1.33 pt	POST OTT	$21.57	$2.90	$24.47
	diuron + MSMA	2 pt + 2.5 pt	POST Directed	$10.63	$5.91	**$16.54**
Total						**$53.27**

[1]/ Does not constitute a recommendation. For illustration purposes only. Programs and costs vary.
[2]/ Cost includes Monsanto rebates on use of residual chemistries if applicable.

Table 11. Comparison of Estimated Seed and Technology-Related Costs Per Acre.

	DP555BR	**B2RF [1]**	**WRF**	**B2LL [2]**
Seed	$20.03	$20.76	$19.89	$37.62
Technology Fees	$45.37	$58.34	$55.18	$28.96
Herbicides [3]	$54.20	$54.20	$54.20	$53.27
Insecticides [3]	$24.72	$14.52	$17.44	$14.52
Total Per Acre	**$144.32**	**$147.82**	**$146.71**	**$134.37**

[1]/ Seed cost is average of DP (Deltapine), ST (Stoneville), and FM (Fibermax)
[2]/ Seed cost includes LL fee.
[3]/ Includes cost of application.

Summary and Conclusions

Based on University of Georgia Official Variety Trials (OVT's), yield per acre for two-gene (B2 and W) varieties has been less than DP555BR. Over 3 years and multiple locations for both irrigated and non-irrigated production, the best two-gene varieties have averaged about 10% less lint yield than DP555BR. These differences in yield may have narrowed and new varieties continue to be developed. At present, however, there is no equal substitute for DP555BR. This variety accounted for 86% of Georgia acreage planted in 2008 and will no longer be available after the 2009 crop year.

Fiber quality could improve with the shift from DP555BR. Improvements in fiber length Uniformity and Staple are possible. The OVT data on this, however, is not strong/consistent.

Production practices, inputs, and cost of production vary widely. Cost estimates conducted for this study conclude that total seed and technology-related production costs for two-gene varieties could be similar to DP555BR. Depending on choice of variety and technology, costs could be lower than DP555BR or slightly higher.

Yield will likely continue to be the major factor in choosing a variety after expiration of single-gene Bollgard technology. There are cost differences. Two-gene technology packaged with Roundup-Ready Flex offers added protection and management flexibility for the producer and thus has utility and value. In terms of cost, however, differences in cost per acre are relatively minor in contrast to differences in yield. A $10.00 per acre savings, for example, is equivalent to less than 20 pounds of lint yield per acre at a 55-cent per pound net price to the producer. Therefore, yield will likely be at least as important as any other factor, as Georgia cotton producers decide how to adjust to the loss of single-gene Bollgard technology.

Literature Cited

Day, J. LaDon, Anton E. Coy, Stevan S. LaHue, Larry G. Thompson, and Paul A. Rose. *2006 Peanut, Cotton, and Tobacco Performance Tests*, Research Report 709, College of Agricultural and Environmental Sciences, University of Georgia, January 2007.

Day, J. LaDon, Anton E. Coy, Stevan S. LaHue, Larry G. Thompson, and John D. Gassett. *2007 Peanut, Cotton, and Tobacco Performance Tests*, Research Report 714, College of Agricultural and Environmental Sciences, University of Georgia, January 2008.

Day, J. LaDon, Anton E. Coy, Stevan S. LaHue, Larry G. Thompson, and John D. Gassett. *2008 Peanut, Cotton, and Tobacco Performance Tests*, Research Report 719, College of Agricultural and Environmental Sciences, University of Georgia, January 2009.

Jost, P., D. Shurley, S. Culpepper, P. Roberts, R. Nichols, J. Reeves, and S. Anthony. "Economic Comparison of Transgenic and Nontransgenic Cotton Production Systems in Georgia", *Agronomy Journal*, Vol. 100, Issue 1, pages 42-51, January-February 2008.

Shurley, Don and Amanda Smith. *2009 Cotton Budgets*, Department of Agricultural and Applied Economics, University of Georgia, December 2008.

Shurley, W. Don, Philip H. Jost, A. Stanley Culpepper, Phillip Roberts, and Robert L. Nichols. "Economic Comparison of RF and BG2 Technologies to RR and BG", *Proceedings of the 2007 Beltwide Cotton Conference*, National Cotton Council, Memphis, TN.

University of Georgia, *2009 Georgia Cotton Production Guide*, ENT-09-01, Cooperative Extension Service, College of Agricultural and Environmental Sciences, January 2009, Phillip Roberts, ed.

USDA Agricultural Marketing Service (AMS), *Cotton Varieties Planted 2007 Crop*, mp_cn833, August 2007.

USDA Agricultural Marketing Service (AMS), *Cotton Varieties Planted 2008 Crop*, mp_cn833, September 2008.