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BREEDING AND GENETICS

A Comparison of Bollgard/Glyphosate Tolerant Cotton Cultivars to Their Conventional Parents for Open End Yarn Processing Performance

Philip J. Bauer*, David D. McAlister, III, James R. Frederick

ABSTRACT

Textile manufacturers have raised concerns that mill performance of cotton (*Gossypium hirsutum L.*) has been compromised by transgenic technology. The objective of this study was to compare two transgenic Bollgard (BG) and glyphosate tolerant (RR) cotton cultivars to their conventional parents for fiber properties, processing characteristics, and fabric quality. Field experiments were conducted with 'Deltapine 458 BG/RR' and 'Deltapine 655 BG/RR' and their recurrent parents, 'Deltapine 5415' and 'Deltapine 5690'. These cultivars were planted at three planting dates (mid-April, early May, and mid-May) in 2000 and 2001. Ginned cotton was tested for fiber properties, processing waste, spinning performance, yarn characteristics, and white specks in dyed fabric. The transgenic and recurrent parent cultivars were not different in lint yield at any planting date in either year, and only small differences in HVI fiber properties occurred. Similarly, differences between the transgenic and recurrent parent cultivars for processing waste, spinning performance, yarn quality, and white specks were small, even when statistically significant. Differences between the transgenic and recurrent parent cultivars tended to be of the same magnitude or smaller than differences among planting dates. Late-planted cotton tended to have better yarn quality than early-planted cotton. The results indicate little difference in processing quality or efficiency between these transgenic cultivars and their recurrent parents.

Transgenic cotton cultivars became commercially available in the mid-1990s, and their use was rapidly adopted by cotton growers. These cultivars now dominate the cotton seed market with over 82.6% of the upland cotton cultivars grown in the United States containing genes that provide the plants with tolerance to herbicides and/or lepidopterous insects (USDA-AMS, 2005). Textile manufacturers have raised concerns that mill performance of the harvested cotton fibers has been compromised by transgenic technology (Jordan et al., 2003).

Considerable research has been conducted comparing transgenic and conventional genotypes for cotton classing fiber properties. Wilson et al. (1994) reported that nine transgenic germplasm lines containing the toxin gene from *Bacillus thuringiensis* had similar or better fiber properties than their parent lines. Culpepper and York (1998) found micronaire, fiber strength, fiber length, and fiber length uniformity were not affected by the glyphosate-tolerant technology. Glyphosate-tolerant cultivars had similar yield and fiber properties to conventional check cultivars (York et al., 2004). Across several genetic backgrounds, transgenic traits [Bollgard (BG), Roundup Ready (RR), and BG/RR] had both positive and negative effects on fiber properties when compared with their recurrent parents (Verhalen et al., 2003). In addition, the large database of comparisons between transgenic to conventional cultivars based on official variety trials across the Cotton Belt indicate small differences between lines for fiber length, strength, and micronaire (Jordan et al., 2003).

Measurements of physical properties with high volume instrumentation (HVI) provide mills with an indication of the processing characteristics of cotton fibers. Little research has been reported directly comparing transgenic cultivars to conventional cultivars for mill performance. Ethridge and Hequet (2000) evaluated cotton fiber from two cotton families (Deltapine 5415 and Deltapine 5690) grown at three locations. There were few statistically significant differences between BG and RR cultivars and their parents for fiber properties or yarn and fabric quality,

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P. J. Bauer, USDA-ARS, 2611 West Lucas Street, Florence, SC 29501; D. D. McAlister, III, (formerly: USDA-ARS, Cotton Quality Research Station, P.O. Box 792, Clemson, SC 29633) Uster Technologies, Inc., 456 Troy Circle, Knoxville, TN 37919; J. R. Frederick, Clemson University, 2200 Pocket Road, Florence, SC 29501
*Corresponding author: bauer@florence.ars.usda.gov

and the differences that were statistically significant appeared to be of little practical importance in cotton fiber processing. These results suggested processing quality is not diminished in cultivars containing transgenic traits.

In addition to genetic background, weather influences cotton quality. Environmental conditions during boll set and maturation helps determine fiber properties and altering planting date affects whole crop fiber properties (Bilbro and Ray, 1973; Porter et al., 1996; Bauer et al., 1998; Pettigrew, 2002) and distribution of fiber properties within the canopy (Davidonis et al., 2004). Bradow and Bauer (1998) found that differences in environment due to planting date can influence yarn properties and dye uptake by the fabric.

The objective of this research was to compare cultivars with stacked transgenic traits (BG/RR) to their conventional recurrent parents at three planting dates for fiber properties, processing characteristics, and yarn and fabric quality.

MATERIALS AND METHODS

Field experiments were conducted in 2000 and 2001 at the Clemson University Pee Dee Research and Education Center near Florence, SC, on a Norfolk loamy sand soil (fine-loamy, kaolinitic, thermic Typic Kandiudult). Treatments included planting dates and cultivars. Planting dates were 17 April, 1 May, and 17 May in 2000 and 19 April, 3 May, and 16 May in 2001. Cultivars were Deltapine 458 BG/RR and Deltapine 655 BG/RR and their respective recurrent parents, Deltapine 5415 and Deltapine 5690 (DP; Delta Pine and Land Co.; Scott, MS). Experimental design was split-plot with planting dates as main plots and cultivars as subplots. Subplots consisted of 16, 1-m wide rows that were 30 m long in 2000 and 18 m long in 2001. There were four replications each year. Precipitation and temperature data were collected at a weather station located within 0.5 km of the plots. Cumulative heat units were calculated by summing daily heat units {[(maximum temperature + minimum temperature)/2] -15.6}. Solar irradiance data were collected from a weather station approximately 11 km from the plots.

Experimental plots were placed in fields that had corn (*Zea mays* L.) as the previous crop each year. Nitrogen, P, K, Mg, S, and B were applied each year at rates based on soil test results and/or recommendations by Clemson University Extension. A burn-down herbicide application was made about 2 wk before the first planting date each year to control existing vegetation. All plots were sub-soiled to a depth of 30 cm before the first planting date each year.

On each planting date, cotton was planted at a seeding rate of approximately 13 seeds per meter of row with a four-row planter equipped with wavy coulters. Aldicarb (Temik 15G; Bayer CropScience; Research Triangle Park, NC) was applied in-furrow at planting at 0.5 kg a.i. ha^{-1}. Weeds were controlled by a combination of herbicides and hand weeding. All herbicides were applied at rates recommended on the label. Plots were routinely scouted and insecticides were applied as needed to control insect pests. Supplemental irrigation (approximately 2.5 cm) was applied when plants began to wilt, although soil water content was not measured to document the level of stress. It took 2 d to irrigate the entire experiment with two traveling gun irrigation systems. Applications were made on 5-6 July, 11-12 July, and 18-19 July in 2000 and on 6-7 August and 15-16 August in 2001.

Cotton was chemically defoliated with thidiazuron (Dropp 50WP; Bayer CropScience LP; Research Triangle Park, NC), tribuphos (DEF 6; Bayer CropScience LP), and ethephon (Prep 6L; Bayer CropScience LP) at recommended rates each year. Defoliation dates were 27 September for the first two planting dates and 18 October for the third planting date in 2000. In 2001, defoliants were applied on 18 September, 26 September, and 25 October. All rows from each sub-subplot were harvested with a spindle picker. Harvest dates in 2000 were 5 October for the first planting date, 20 October for the second planting date, and 1 November of the third planting date. In 2001, harvest dates were 9 October for the first planting date, 11 October for the second planting date, and 31 October for the third planting date.

Seed cotton was ginned on a 20-saw gin without lint cleaning. Ginned cotton was tested as described by McAlister and Rogers (2005). A sample was also evaluated for HVI fiber properties (Uster Technologies; Knoxville, TN) at the USDA-AMS Cotton Classing Office in Memphis, TN. Each lot of cotton was mixed thoroughly using three blending hoppers in a Fiber Controls Synchromatic Blending System and fed to a modern Truetzschler cleaning line consisting of an Axi-Flo cleaner, a GBRA blending hopper, a RN cleaner, a RST cleaner, and a DUSTEX fine dust remover (all Truetzschler; Monchengladbach, Germany). The cotton was then fed by chute into a DK 740 card operating at 36 kg h^{-1} to produce 5.67

g m^{-1} card sliver. Two processes of drawing, six and eight doublings, respectively, using Rieter RSB draw frames (Witerthur; Switzerland) produced a 3.90 g m^{-1} drawing sliver. Fiber was tested for maturity ratio, short fiber content, and neps using the Advanced Fiber Information System (AFIS; Uster Technologies) before (raw stock) and after (finish draw) carding and drawing. A Zinser model 660 roving frame (Ebersbach, Germany) was used to produce 590.5 Tex roving for spinning into 21.9 Tex yarn with a 3.75 twist multiplier on a Zinser model 321 spinning frame at a spindle speed of 14,500 rpm. Stops were monitored and recorded. Yarn was conditioned in a controlled environment and tested for mass evenness defects (Uster Tester 3), tensile properties (Statimat), and infrequent defects (Classimat). Jersey knit fabrics were produced from the resultant yarns and dyed. Dyed fabric was evaluated for white specks.

All data were subjected to analysis of variance using the MIXED procedure (Littell et al., 1996) of SAS (SAS Institute, Cary, NC). Data were analyzed as a split plot over years with planting date as main plots and genotypes as subplots. Years and replicates were considered random effects. Single degree of freedom contrasts were computed to determine if the transgenic cultivars were different from the conventional cultivars for the parameters measured and to determine if there were significant interactions between year and cultivar type. Means were separated by computing a least significant difference when sources of variation were significant at $P \leq 0.05$.

RESULTS AND DISCUSSION

Seasonal heat unit and precipitation totals and average daily solar irradiance for the three planting dates in both years are shown in Table 1. Within each year, heat unit accumulation for the entire growing season was similar for the three planting dates, which was expected since all three are considered full season plantings for this region. Similarly, there was not a substantial difference in total precipitation among the planting dates within each year. Average daily irradiance was lowest for the third planting date each year, primarily due to fewer daylight hours during late September and October.

The 2000 growing season tended to be warmer than 2001 with heat unit accumulations being slightly greater in 2000 than in 2001 for the first two planting dates. Seasonal accumulated precipitation was also higher in 2000 than it was in 2001, but the distribution in that year was rather poor. Nearly one-third (21.5 cm) of the 2000 precipitation occurred in a three-week period between 19 August and 6 September and most of that (17.5 cm) occurred between 25 August and 6 September.

Yield between the transgenic and recurrent parent cultivars was not different (Table 2), and interactions between cultivar types and years or planting dates were not significantly different for yield. Interactions between cultivar type and year and planting date were significant for micronaire and fiber length. These interactions were primar-

Table 1. Cumulative heat units, total rainfall, and average daily solar irradiance from planting to defoliation for three planting dates

Planting date	2000			2001		
	Heat units	Precipitation (cm)^z	Solar irradiance (MJ m^{-2} d^{-1})	Heat units	Precipitation (cm)^z	Solar irradiance (MJ m^{-2} d^{-1})
Mid-April	1476	70.6	20.7	1365	28.9	21.3
Early May	1449	65.5	20.9	1391	33.0	20.7
Mid-May	1411	63.5	19.8	1399	34.4	19.5

^{z} Irrigation supplied approximately 7.5 cm of water in 2000 and 5.0 cm of water in 2001.

Table 2. Effect of cultivar on cotton yield and fiber properties averaged over planting dates and years

Cultivar	Lint yield (kg ha^{-1})	Fiber property^z			
		Length (mm)	Uniformity (%)	Strength (kN m kg^{-1})	Micronaire
Transgenic	1057	27.1*	80.4*	279*	4.0**
Recurrent parent	891	27.0	80.6	277	4.2

^{z} Means follows by * and ** are significantly different at $P \leq 0.05$ and $P \leq 0.01$, respectively, based on single degree of freedom contrast.

ily the result of magnitude differences and not of rank between the cultivar types, so means over years and planting dates are shown in Table 2. The transgenic cultivars had longer and stronger fibers but had lower length uniformity and micronaire. These results for fiber properties are similar to previous research. Jordan et al. (2003) summarized the results of HVI fiber properties of official cultivar trials from 16 states between 1995 and 2000. They reported that compared with the conventional recurrent parent, BG/RR lines had a small (less than 1%) decrease in fiber length, a slight improvement in fiber strength, no difference in length uniformity, and slightly lower micronaire.

Small differences also occurred in fiber quality determined by AFIS between the cultivar types. Before carding and drawing in 2000, the transgenic cultivars had more neps than the recurrent parents, but cultivar types were not different in short fiber content of raw stock cotton (Table 3). After carding and drawing in 2000, the number of neps was not different between the two cultivar types, but the transgenic cultivars had higher short fiber content than the recurrent parents. In 2001, these properties were not different between the cultivar types (Table 3). As expected, carding and drawing removed about two-thirds of the neps from the fiber each year. Maturity ratio of the fiber in this experiment was approximately 0.90 or greater for the raw stock cotton and 0.94 or greater for the finish draw. Maturity ratio of less that 0.80 indicates the fiber is immature (Williams and Yankey, 1996), so the practical significance of main effects or interactions that were statistically significant is negligible because maturity values were so high (data not shown).

The means of the transgenic and recurrent parent cultivars for card waste, yarn quality, and fabric white specks were averaged over planting dates and years (Table 4). Cultivar types were not different for opening card waste (Table 4). Although the difference between cultivar types was significantly different, total card waste was low each year and, the transgenic cultivars averaged only 0.1% more total card waste than the recurrent parents. Lack of differences in waste is not surprising since trash content would not be expected to differ between the cultivar types, since the cultivars were grown with the same weed control and harvesting management.

Ends-down is a measure of spinning efficiency and these data were collected in this study. The variability was quite large (coefficient of variation = 104%), so the results are not reported. Additional study on transgenic effects on ends-down appears warranted. Properties of the spun yarn by cultivar type are shown in Tables 4 and 5. Similar to HVI fiber properties where the transgenic cultivars had greater fiber strength than the recurrent parents (Table 2), and yarn strength of the transgenic cultivars was also slightly higher (Table 4). Yarn elongation was not different among cultivars (Table 4).

Table 3. Effect of year and cultivar on short fiber content and neps of raw stock and finish drawing cotton

Cultivar	Raw stock[z]						Finish drawing					
	Short fiber (%)			Neps (g^{-1})			Short fiber (%)			Neps (g^{-1})		
	2000	2001	Mean	2000	2001	Mean	2000	2001	Mean	2000	2001	Mean
Transgenic	14.1	12.0	13.0	230	184	207**	15.0	14.0	14.5	61	67	64
Recurrent parent	13.2	12.7	13.0	196	193	195	13.8	14.1	14.0	52	66	59
LSD ($P = 0.05$)	1.7			30			1.0			12		

[z] Means followed by ** are significantly different at $P \leq 0.01$ based on a single degree of freedom contrast.

Table 4. Effect of cultivar averaged across all planting dates in 2000 and 2001on processing waste, yarn spinning performance, yarn quality, and fabric appearance

Cultivar	Processing waste[z]		Yarn strength (kN m kg^{-1})[z]	Elongation (%)	White specks (per 2.58 x 10^4 mm^2)[z]	Classimat yarn analysis[z]		
	Opening card waste (%)	Total waste (%)				Minor faults (per 10^{-5}m)	Long thick (per 10^{-5}m)	Long thin (per 10^{-5}m)
Transgenic	4.4	3.0**	112*	6.9	1.4*	31.2**	1.3	17.5
Recurrent parent	4.4	2.9	109	6.9	1.8	22.7	0.7	19.5

[z] Means follows by * and ** are significantly different at $P \leq 0.05$ and $P \leq 0.01$, respectively, based on single degree of freedom contrast.

Comparisons between the cultivar types for three of the four measures of yarn evenness were dependent on year (Table 5). The only measure of yarn evenness that was consistent across years was low places in the yarn. In both years, the transgenic cultivars had fewer low places than the recurrent parents. Because those cultivars had fewer low places and fewer thick places than their recurrent parents in 2000, the transgenic cultivars had lower yarn irregularity in that year (Table 5). In 2001, cotton from the transgenic and recurrent parent cultivars had similar yarn irregularity. Even though the transgenic cultivars had fewer low places than recurrent parents, yarn neps were higher and thick places were similar in that year.

Over both years, minor faults in the yarn were higher for the transgenic cultivars than for their recurrent parents (Table 4), although a year by cultivar type interaction occurred for this measure of yarn quality because the difference between the cultivar types was greater in 2001 than in 2000 (data not shown). This was perhaps caused by the transgenic cultivars having higher yarn neps in 2001 (Table 5). The cultivar types had similar numbers of long thick and long thin places in the yarn.

Fabric appearance was good for both cultivar types as white specks in dyed knit fabric were very low (Table 4). Averaged over both years, the recurrent parents had more white specks than the transgenic cultivars.

A considerable amount of data exists on the effect of planting date on cotton yield and fiber properties, but less is known about planting date effects on textile mill performance and yarn and fabric quality. In this study, yield was not different among the planting dates in either year (Table 6), although there was a trend for higher yield as planting was delayed in 2000 and a trend for lower yield as planting was delayed in 2001. The lack of a yield response to planting date is not unexpected since all were full season plantings and heat unit accumulations from planting to defoliation were similar among the three dates each year (Table 1). Differences among planting dates for HVI fiber properties was also small, even when significant (Table 6).

Planting date did not influence short fiber content or the number of neps in the raw cotton or in the finish drawing in either year (data not shown). Planting date effects on yarn characteristics and fabric white specks are shown in Tables 7 and 8. Among these parameters, opening card waste was the only variable that was improved (lower amounts) with early planting. For yarn strength, yarn elongation, thick and low places in the yarn, yarn irregularity, and minor faults, the cotton planted in mid-April had lower quality than one or both of the May planting dates. Yarn neps, long thick places, and long thin places in the yarn among planting dates were not

Table 5. Effect of cultivar averaged across all cultivars on yarn evenness

Cultivar	Yarn neps (914 m^{-1})			Thick places (914 m^{-1})^y			Low places (914 m^{-1})^y			Irregularity (CV)^y		
	2000	2001	Mean	2000	2001	Mean	2000	2001	Mean	2000	2001	Mean
Transgenic	3.4	6.0	4.7	72.5	88.3	80.4**	12.6	40.3	26.5**	13.7	15.1	14.4*
Recurrent parent	3.6	5.3	4.5	82.8	89.0	85.9	15.4	43.1	29.2	14.0	15.2	14.6
LSD (P = 0.05)	0.7			7.8			NS^z			0.2		

^{y}Means follows by * and ** are significantly different at $P \leq 0.05$ and $P \leq 0.01$, respectively, based on single degree of freedom contrast. ^{z}The year by transgenic or recurrent parent interaction was not significant ($P \leq 0.05$) based on a single degree of freedom contrast.

Table 6. Effect of planting date averaged across all cultivars on yield and HVI fiber properties

Planting date	Lint yield (kg ha^{-1})			Fiber property											
				Fiber length (mm)			Length uniformity (%)			Fiber strength (kN m kg^{-1})			Micronaire		
	2000	2001	Mean	2000	2001	Mean	2000	2001	Mean	2000	2001	Mean	2000	2001	Mean
Mid-April	793	1226	1010	26.6	27.7	27.2	80.3	80.9	80.6	272	285	278	4.3	4.2	4.2
Early May	838	1054	946	26.9	27.8	27.3	80.0	81.0	80.3	271	295	283	4.0	4.0	4.0
Mid-May	949	984	966	26.1	27.1	26.6	80.2	81.0	80.6	267	279	273	4.2	4.1	4.1
LSD (P = 0.05)	240		NS	NS		0.2	NS		NS	6		4	NS		0.15

significantly different (Table 8). There was no influence of planting date on the number of white specks in fabric in either year.

Cotton evaluated in this study was not processed like most cotton in marketing channels, since the cotton was ginned on a 20-saw gin without lint cleaning. Lint cleaning increases short fiber content and thereby can reduce processing quality, but also removes trash which can be a source of yarn and fabric imperfections. Nonetheless, the results of this study agree with and expand those of Ethridge and Hequet (2000), whose research was conducted with cultivars with single BG and RR genes, while this research was conducted with stacked cultivars. Both studies demonstrated that there was little evidence that transgenic technology substantially reduced the quality of the fiber for processing. When differences in yarn quality characteristics or fabric appearance were significant, they were generally of the same magnitude or smaller than those of differences in planting dates or years.

Table 7. Effect of planting date average across all cultivars on yarn processing waste and quality

Planting date	Processing waste		Yarn quality		Fabric appearance
	Opening card waste (%)	Total waste (%)	Yarn strength (kN m kg^{-1})	Elongation (%)	White specks (per 2.58 X 10^4 mm^2)
Mid-April	**4.1**	**3.0**	**109**	**6.6**	
Early May	**4.3**	**2.9**	**112**	**6.9**	**1.7**
Mid-May	**5.0**	**2.9**	**110**	**7.2**	**1.5**
LSD (*P* = 0.05)	**0.7**	**NS**	**2.8**	**0.3**	**1.6**

Table 8. Effect of planting date averaged across all cultivars on yarn evenness and Classimat yarn analysis

Planting date	Yarn evenness[y]				Classimat yarn analysis[z]		
	Yarn neps	Thick places	Low places	Irregularity (%)	Minor faults	Long thick	Long thin
Mid-April	**4.9**	**93.1**	**32.2**	**14.7**	**30.0**	**1.9**	**22.7**
Early May	**4.7**	**74.8**	**24.6**	**14.3**	**30.0**	**0.6**	**18.3**
Mid-May	**4.1**	**81.6**	**26.8**	**14.5**	**20.8**	**0.4**	**14.5**
LSD (*P* = 0.05)	**NS**	**7.0**	**4.1**	**0.2**	**7.6**	**NS**	**NS**

[y] **Neps, thick places, and low places based on 914 m of yarn.**

[z] **Minor faults, long thick, and long thin based on 100,000 m of yarn.**

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DISCLAIMER

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

REFERENCES

Bauer, P.J., O.L. May, and J.J. Camberato.1998. Planting date and potassium fertility effects on cotton yield and fiber properties. J. Prod. Agric. 11:415-420.

Bilbro, J.D., and L.L. Ray. 1973. Effect of planting date on the yield and fiber properties of three cotton cultivars. Agron. J. 79:513-516.

Bradow, J.M. and P.J. Bauer. 1998. How genotype and temperature modify yarn properties and dye uptake. p. 1070-1073. *In* Proc. World Cotton Research Conference, 2nd, Athens, Greece. 6-12 Sept. 1998.

Culpepper, A.S. and A.C. York. 1998. Weed management in glyphosate-tolerant cotton. J. Cotton Sci. 4:174-185 [Online]. Available at http://www.cotton.org/journal/1998-02/4/174.cfm

Davidonis, G.H., A.S. Johnson, J.A. Landivar, and C.J. Fernandez. 2004. Cotton fiber quality is related to boll location and planting date. Agron. J. 96:42-47.

Ethridge, M.D. and E.F. Hequet. 2000. Fiber properties and textile performance of transgenic cotton versus parent varieties. p. 488-494. *In* Proc. Beltwide Cotton Conf., San Antonio, TX. 4-8 Jan. 2000. Natl. Cotton Counc. Am., Memphis, TN.

Jordan, A.G., P.J. Wakelyn, and O.L. May. 2003. Transgenic cotton and fiber quality. Part 1. Effect of transgenic technology. *In* Proc. Engineered Fiber System Conf., 16th, Greenville, SC. 9-11 June 2003. Cotton Inc., Cary, NC. Available online at www.cottoninc.com/2003ConferencePresentations/TransgenicCotton/TransgenicCotton.pdf

Littell, R.C., G.A. Milliken, W.W. Stroup, and R.D. Wolfinger. 1996. SAS system for mixed models. SAS Institute, Inc., Cary, NC.

Pettigrew, W.T. 2002. Improved yield potential with an early planting cotton production system. Agron. J. 94:997-1003.

Porter, P.M., M.J. Sullivan, and L.H. Harvey. 1996. Cotton cultivar response to planting date on the southeastern coastal plain. J. Prod. Agric. 9:223-227.

McAlister, D.D. III, and C.D. Rogers. 2005. The effect of harvesting procedures on fiber and yarn quality of ultra-narrow-row cotton. J. Cotton Sci. 9:15-23 [Online]. Available at http://www.cotton.org/journal/2005-09/1/15.cfm

Williams, G., and J. Yankey. 1996. New developments in single fiber fineness and maturity measurements. p. 1287 *In* Proc. Beltwide Cotton Conf., Nashville, TN. 9-12 Jan. 1996. Natl. Cotton Counc. Am., Memphis, TN.

Wilson, F.D., H.M. Flint, W. R. Deaton, and R.E. Buehler. 1994. Yield, yield components, and fiber properties of insect-resistant cotton lines containing a *Bacillus thuringiensis* toxin gene. Crop Sci. 34:38-41.

USDA-Agricultural Marketing Service (AMS). 2005. Cotton Varieties Planted 2005 Crop. Agricultural Marketing Service – Cotton Division, Memphis, Tennessee, August, 2005. Available online at http://www.ams.usda.gov/cottonrpts/MNPDF/mp_cn833.PDF. (verified 26 June 2006).

Verhalen, L.M., B.E. Greenhagen, and R.W. Thacker. 2003. Lint yield, lint percentage, and fiber quality response in bollgard, roundup ready, and bollgard/roundup ready cotton. J. Cotton Sci. 7:23-38 [Online]. Available at http://www.cotton.org/journal/2003-07/2/23.cfm

York, A.C., A.S. Culpepper, D.T. Bowman, and O.L. May. 2004. Performance of glyphosate-tolerant cotton cultivars in official cultivar trials. J. Cotton Sci. 8:261-270 [Online]. Available at http://www.cotton.org/journal/2004-08/4/261.cfm