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ARTHROPOD MANAGEMENT

Evidence That Light Stink Bug Damage Does Not Influence Open End Yarn Processing Performance

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ABSTRACT

Stink bugs [*Acrosternum hilare* (Say), *Nezara viridula* (L.), and *Euschistus servus* (Say)] have become an important pest of cotton (*Gossypium hirsutum* L.) concurrent with the expansion of acres planted to transgenic cotton cultivars. The objective of this study was to determine the effect of stink bug damage on the textile mill performance of cotton cultivars that represented all combinations of transgenic technology (available in 2002). Six cotton cultivars (Stoneville 474 and its five transgenic siblings; ST 4793R, ST 4691B, ST 4892 BR, ST BXN 47, and ST BXN 49B) were grown with and without insecticide applications for stink bug control in 2002 and 2003. Stink bug damage was assessed in early August and in late August of each season. Cotton yield, fiber properties, and mill performance were measured. Transgenic traits did not substantially affect cotton mill performance. Stink bug damaged bolls were always greater for cotton not treated with insecticides than for cotton that was treated. Average damaged bolls ranged from 2 to 12% for the treated cotton and 9 to 21% for the untreated control. Although damage to bolls was greater for the untreated control, average seed cotton yield was not different between the cotton treated for stink bugs (1767 kg ha^{-1} and 3765 kg ha^{-1} in 2002 and 2003, respectively) and the untreated control (1981 kg ha^{-1} and 3769 kg ha^{-1} in 2002 and 2003, respectively). Fiber properties and yarn and fabric quality were not improved with insecticide applications to control stink bugs. The data indicate that light stink bug damage does not result in reduced textile mill performance of the harvested fiber.

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Stink bugs have increased in economic importance in cotton production in the southeastern United States. Their importance rose with the reduction in broad spectrum insecticide applications following boll weevil (*Anthonomus grandis* Boheman) eradication. Further reductions in pesticide applications came with the introduction and widespread adoption of cotton cultivars containing the Bollgard trait that provides resistance to cotton bollworm [*Helicoverpa zea* (Boddie)] and tobacco budworm [*Heliothis virescens* (F.)].

Because of the rapid increase in the importance of stink bugs, population thresholds for triggering control measures to limit yield losses have been developed only relatively recently. Recommendations include applying insecticides when one stink bug is found per 1.8 m of row or when 10% to 20% of mid-sized bolls exhibit internal signs of stink bug feeding (Greene et al., 2001; Greene et al., 2005). Reductions in yield occur because stink bugs feeding on developing bolls decrease seed cotton weight per boll and increase the percentage of locks that are not harvestable by spindle pickers (Barbour et al., 1990), but the extent of yield reduction appears dependant on when infestation occurs during the flowering period (Willrich et al., 2004a). Willrich et al. (2004b) also reported higher incidence of rotted bolls in association with stink bug feeding.

Less is known about how feeding by stink bugs affects fiber quality. In cage experiments, no differences occurred in lint grade or staple length as the number of stink bugs per cage (approximately 100 plants per cage) increased (Toscano and Stern, 1976). Barbour et al. (1990) observed a trend for higher immature fiber content with longer exposure to stink bugs in one year of a two year experiment using cages. Studying the effects of stink bugs on individual plant canopy positions, Roberts et al. (2005) found that in hand-picked bolls, boll feeding resulted in reduced fiber length and fiber length uniformity and greater short fiber content.

Farmers in southeastern USA have rapidly adopted transgenic technology by planting cotton cultivars with insect resistance (B) and/or herbicide tolerance [glyphosate (R) and bromoxynil (BXN)]. Textile manufacturers have raised concerns about mill performance of the cotton harvested from transgenic cultivars (Jordan et al., 2003). Research indicates transgenic cultivars are not different from conventional cultivars in mill performance (Ethridge and Hequet, 2000; Bauer et al., 2006). The concurrent rise in importance of the stink bug complex in the Southeast with the adoption of transgenic technology prompted this study to simultaneously investigate these two factors for mill efficiency and yarn and fabric quality. The objective of this study was to determine the effects of stink bug damage on textile mill performance in cotton cultivars representing all combinations of transgenic technology (available in 2002).

MATERIALS AND METHODS

Experiments were conducted at the Clemson University Pee Dee Research and Education Center near Florence, SC. Soil type was Norfolk loamy sand (fine-loamy, kaolinitic, thermic Typic Kandiudults) in 2002, and Goldsboro loamy sand (fine-loamy, siliceous, subactive, thermic Aquic Paleudults) in 2003. Treatments were stink bug control (with or without) and cotton genotype. Cyfluthrin (Baythroid 2EC; Bayer CropScience, Research Triangle Park, NC) and dicrotophos (Bidrin 8; AMVAC, Los Angeles, CA) were used to control stink bugs in the assigned plots. Application dates were 16, 23, and 29 July (cyfluthrin at 0.046 kg a.i. ha^{-1}), and 8 and 16 August (dicrotophos at 0.56 kg a.i. ha^{-1}) in 2002, and 28 July and 4, 12, 18, 22, and 29 August (dicrotophos at 0.56 kg a.i. ha^{-1}) in 2003. On those dates, all plots received an application of spinosad at 0.088 kg a.i. ha^{-1} (Tracer Naturalyte; Dow Agrosciences; Indianapolis, IN) for heliothine control. The six genotypes were the conventional cultivar Stoneville 474 (ST; Stoneville Pedigreeed Seed Co.; Memphis, TN) and its five transgenic siblings; ST 4793R, ST 4691B, ST 4892BR, ST BXN 47, and ST BXN 49B. Experimental design was randomized complete block and there were four replications. Plot size was 12 rows each 1 m wide and 30 m long. To encourage stink bug infestation, four rows of soybeans (*Glycine max* L.) were planted between plots.

Cotton was planted following in-row sub-soiling into corn (*Zea mays* L.) residues at 13 seeds m^{-1} with a four-row planter equipped with wavy coulters on 9 May 2002 and 14 May 2003. Aldicarb at 0.84 kg a.i. ha^{-1} (Temik 15G; Bayer CropScience LP) was applied in-furrow at planting. In 2002, 56 kg N ha^{-1} (as NH_4NO_3) was applied as a side-dress to all plots on 22 May and an additional application of 45 kg N ha^{-1} was made on 19 June. In 2003, 117 kg N ha^{-1} was applied as a side-dress on 27 May. Weeds were controlled with a combination of herbicides and hand-weeding. A pre-emergence broadcast application of pendimethalin (Prowl 3.3EC; BASF Corp.; Research Triangle Park, NC), fluometuron (Cotoran 4L; Griffin LLC; Valdosta, GA), and glyphosate (Roundup; Monsanto Co.; St. Louis, MO) was made each year. In both years, a directed-spray application was made approximately 6 wk after planting consisting of monosodium methanearsonate (Bueno 6; KMG Chemicals; Houston, TX) and prometryn (Caparol 4L; Syngenta Crop Protection; Greensboro, NC). In addition, broadcast applications of pyrithiobac (Staple LX; E.E. DuPont de Nemours and Co.; Wilmington, DE) (4 June) for broadleaf weed control and fluazifop-p-butyl (Fusilade DX; Syngenta Crop Protection) (6 June) for grass weed control were made in 2002. In 2003, an application of sethoxydim (Poast Plus; BASF Corp.) was made for grass control on 20 June. All herbicides were applied at rates recommended by the label.

Rainfall was supplemented with irrigation using surface drip irrigation equipment. The equipment was installed on 16 June in 2002 and 18 June in 2003. Irrigation laterals were placed in middle of every other row. Water (approximately 2.5 cm per application) was applied on 16 d from 17 June through 21 August in 2002 and on 7 d from 8 July through 2 September in 2003. Irrigation was scheduled based on weekly rainfall. Target total weekly water amounts were 3.8 cm through the second week after first bloom, 6.4 cm from three through the five weeks after first bloom, and 5 cm of water from six through eight weeks after first bloom.

Stink bugs in the crop canopy of each subplot were measured approximately weekly beginning in early July through 6 August in 2002 and through 18 August in 2003. Counts were made a day or two prior to the treatment insecticide applications. Twenty-five plants were randomly selected from throughout the subplot and individually shaken into a plastic pan. Stink bugs in the pan were then counted. Stink bug damage to young bolls was estimated approximately 4 and 7 wk after first flower on 5 and 20 August in 2002 and on 7 and 26 August in 2003. Twenty-five, 2.5-cm diameter bolls were collected from each plot and the interior of the carpel walls were inspected for callus growth (warts) and bolls were inspected for stained lint (Bundy et al., 2000).

The effect of stink bug damage on the number of hard-locked bolls and boll weight at harvest were determined in each year for ST 4892BR. On 22 and 29 July in 2002 and 24 and 31 July in 2003, 75 dated tags were placed on white blooms in each plot (eight plots total). When nearly all of the surviving bolls with dated tags within a tagging date were open, approximately 25 entire bolls were randomly collected from each of the eight plots. In 2002, seed cotton weight, total lock number, locks that did not fluff, and callus sites on burs from stink bug damage were determined for each boll. In 2003, the same data were collected plus the number of visible punctures (using a magnifying glass) was counted on each burr.

Cotton was chemically defoliated with thidiazuron (Dropp 50WP; Bayer CropScience LP), tribuphos (DEF 6; Bayer CropScience LP), and ethephon (Prep 6L; Bayer CropScience LP) at recommended rates each year. Defoliation dates were 1 October in 2002 and 9 October in 2003. All interior rows of each plot were harvested with a spindle picker on 21 October in 2002 and 22 October in 2003. Seedcotton was ginned on a 20-saw laboratory gin. Ginning was done without lint cleaning, so comparisons for color and trash content are not reported. Low cotton yields occurred in 2002 because an extended rainy period during late August and early September caused a considerable amount of boll rot. To provide enough fiber for textile mill performance analysis, all four replicates of each of the twelve treatment combinations (two stink bug control and six genotypes) were combined into one sample for yarn spinning tests. In 2003, only two of the four replicates were evaluated for textile mill performance.

Ginned cotton was tested and processed in the Pilot Spinning Laboratory at the Cotton Quality Research Station in Clemson, SC. Cotton processing and data collection were as described by McAlister and Rogers (2005). A sample was also evaluated for HVI fiber properties at the 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; Monschengladbach, Germany). The cotton was then fed by chute into a DK 740 card (Truetzschler) 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 (Rieter; Witerthur, Switzerland), produced 3.90 gm^{-1} drawing sliver. Fiber was tested for maturity ratio, short fiber content, and neps using the Advanced Fiber Information System (AFIS; Uster Technologies; Knoxville, TN) 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. Data were collected from various fiber yarn tests, as well as from processing efficiency measurements. Jersey knit fabrics (griege and dyed) were produced from the resultant yarns and evaluated for quality differences.

All data analyzed using the MIXED procedure (Littell et al., 1996) of SAS (SAS Institute; Cary, NC). For yield, stink bug damage, and boll characteristics, analysis was done by year as a split-plot model with replicates considered random. For HVI fiber properties and textile mill performance data, the ANOVA was computed using a randomized complete block model with three replicates using the data from 2002 as one replicate and the two replicates from 2003 as the others. Replicates were considered random. Genotype and interaction means were separated by calculating a least significant difference (LSD) when these sources of variation were significant at $P \leq 0.05$.

RESULTS AND DISCUSSION

Green, *Acrosternum hilare* (Say), and brown, *Euschistus servus* (Say), were the only two stink bug species that were found in the plots each year. Stink bug populations were low in July (only green stink bugs were found in July) and early August each year. On 6 Aug. 2002, populations averaged 0.4 bugs per 25 plants in the untreated control plots and 0.2 bugs per plant in the treated plots (75% green and 25% were brown). On 4 Aug. 2003, there were 0.4 bugs per 25 plants in the control plots and 0.3 bugs per 25 plants in the treated plots (all green). Stink bug numbers increased at the later sampling dates in August of that year, averaging 2.5 bugs per 25 plants for the control plots and 2.4 bugs per 25 plants in the treated plots on 11 August (63% green) and 2.8 bugs per 25 plants for the control plots and 0.8 bugs per 25 plants in the treated plots on 18 August (47% green).

The percentage of bolls damaged by stink bug feeding was greater ($P < 0.05$) in the untreated plots than in treated plots in early in both years and nearly significantly greater ($P = 0.06$) in late August of both years (Table 1). In early August of both years and late August of 2002, damage in the untreated plots was at levels where an insecticide application might be warranted (Greene et al., 2001). In early August, damage exceeded the minimum level for treatment in both the treated and untreated plots in 2003, but damage was below threshold levels for both treatments in late August of that year. There were no stink bug treatment by genotype interactions for boll damage at any sampling time, and genotypes were different for boll damage only at the early August 2003 sampling date (Table 1). It is unlikely that this difference represents genotypic variation in tolerance for stink bug damage, since it was the only sampling time cultivar differences occurred in this study.

Table 1. Effect of insecticide application and cotton genotype on the percentage damaged bolls from stink bug feeding

Variable	Damaged bolls (%)			
	2002		2003	
	5 August	20 August	7 August	26 August
Insecticide control				
Yes	6	2	12	4
No	16	13	21	9
Prob > *F*	0.02	0.06	0.04	0.06
Genotype				
ST 474	12	7	20	5
ST 4793R	12	6	9	7
ST 4691B	4	11	12	4
ST 4892BR	13	6	23	4
ST BXN 47	12	7	20	11
ST BXN 49B	12	9	16	7
Prob > *F*	0.23	0.48	0.03	0.14
LSD ($P = 0.05$) [z]	--	--	9.0	--

[z] LSD values were not calculated when source of variation was not significant ($P \leq 0.05$).

Even though insecticide application reduced stink bug damage during the season, it did not increase seed cotton yield in either year. Average seed cotton yield was not different between the cotton treated for stink bugs (1767 kg ha^{-1} and 3765 kg ha^{-1} in 2002 and 2003, respectively) and the untreated control (1981 kg ha^{-1} and 3769 kg ha^{-1} in 2002 and 2003, respectively). The stink bug treatment by genotype interaction for yield was not significant in either year. All six genotypes had similar yield in 2002 (data not shown). Differences occurred among the genotypes for yield in 2003, but the yield for all genotypes was high, ranging from 3576 kg ha^{-1} for ST BXN 47 to 3873 kg ha^{-1} for ST BXN 49B. Genotype yield was not related to the amount of stink bug damage in early August. Genotype ST4793R, which had the lowest damage (Table 1), was not different from ST BXN 47 in yield. Both of these genotypes had lower yield than ST 474, ST 4892BR, and ST BXN 49B.

Stink bugs pierce the wall of developing cotton bolls and feed on or near the growing seeds. This damage causes a decrease in the proportion of harvestable locks per boll (Barbour et al., 1990). The data collected from this study in 2003 on the characteristics of individual bolls of the ST 4892BR support this concept. In 2002, only about 9% of the harvested bolls (less than 20 total) had damage in each flowering date. With this low number of damaged bolls, there was no relationship between the amount of damage and boll characteristics. In 2003, damage was much higher in both the first (50% of total bolls) and second (34% of total bolls) flowering dates.

The relationship between the number of visible damage marks on the burrs of the bolls and the number of hard locks per boll for both flowering dates in 2003 is shown in Figure 1. For the 24 July flowering date, hard locks per boll increased (over bolls with no punctures) with two or more visible punctures. At that flowering date, there were 10 bolls with three total locks, 140 bolls with four locks, and 48 bolls with five locks. For bolls that flowered on 31 July, the number of hard locks per boll did not increase until more than four visible punctures per boll were found (Fig. 1). At that flowering date, there were two bolls with three locks, 125 bolls with four locks, and 72 bolls with 5 locks. It is not apparent why the two flowering dates had different responses for hard-locked bolls, especially since boll weight decreases with number of punctures were similar up to five punctures per boll (Fig. 2).

There were no differences between stink bug treatments or among cultivars for HVI-determined fiber properties (data not shown). This agrees with the findings of Greene et al. (2001), who found no difference in HVI-determined fiber properties for different stink bug control treatments. Stink bug treatment had no effect on visible or invisible waste during carding and drawing (measured with the Shirley Waste Analyzer), nor any of the AFIS fiber properties of the raw cotton (upper quartile length, short fiber content, maturity, neps, or visible foreign matter). Similarly, stink bug treatment had no effect on upper quartile length, short fiber content, maturity, or visible foreign matter of the finisher drawer cotton (Table 2). Neps in the finisher drawer sliver for ST4691B were lower in plots treated for stink bugs than in the untreated control, but stink bug treatment had no effect on neps for the other five genotypes (Table 2).

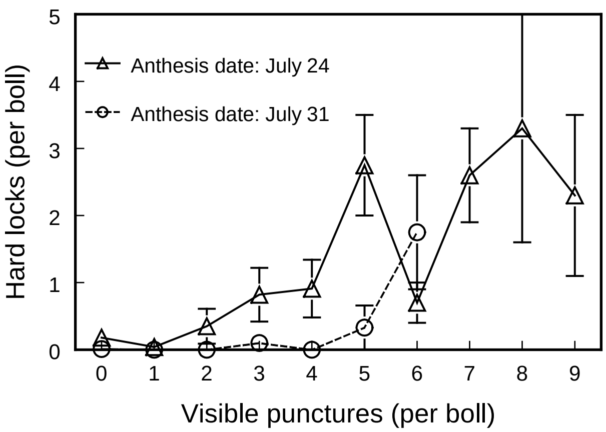

Figure 1. Effect of stink bug puncture number on hard locks per boll for bolls at two anthesis dates in 2003. The cultivar was Stoneville 4892BR. Vertical lines indicate standard deviation of means. Pearson correlation coefficients between bug punctures and hard locks were r = 0.71 (P < 0.01) for the 24 July anthesis date and r = 0.56 (P < 0.01) for the 31 July anthesis date.

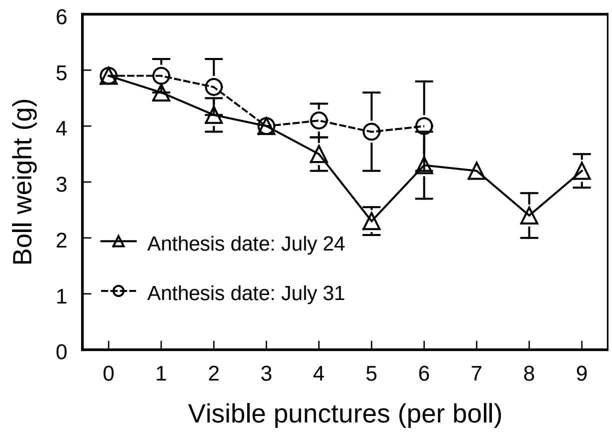

Figure 2. Effect of stink bug puncture number on boll weight for bolls at two anthesis dates in 2003. The cultivar was Stoneville 4892BR. Vertical lines indicate standard deviation of means. Pearson correlation coefficients between bug punctures and boll weight were r = -0.53 (P < 0.01) for the 24 July anthesis date and r = -0.34 (P < 0.01) for the 31 July anthesis date.

Table 2. Effects of cotton genotype and insecticide control for stink bugs on AFIS fiber properties of finisher draw cotton

Variable	Neps (no./g)			Upper quartile length (mm)	Short fiber content (%)	Maturity (%)	Visible foreign material (%)
	No control	With control	Mean				
Insecticide control							
No			32.8	29.1	11.8	92.2	0.11
Yes			32.3	29.0	12.0	92.5	0.11
Prob > F			0.80	0.32	0.54	0.58	0.79
Genotype							
ST 474	27.2	33.2	30.2	29.0	11.6	92.8	0.10
ST 4793R	30.2	24.3	27.3	28.7	10.7	92.8	0.10
ST 4691B	37.7	27.5	32.6	29.0	12.8	92.1	0.12
ST 4892BR	25.8	33.3	29.6	29.1	11.0	92.3	0.10
ST BXN 47	33.2	30.7	31.9	29.1	12.1	92.3	0.10
ST BXN 49B	42.8	44.8	43.8	29.3	13.3	91.8	0.12
Prob > F	0.05		<0.01	<0.01	<0.01	0.23	0.07
LSD (P = 0.05) [z]	8.7		6.2	0.3	1.2	--	--

[z] LSD values were not calculated when the source of variation was not significant ($P \le 0.05$).

Averaged over all genotypes, stink bug treatment was not different for any measure of yarn processing performance, yarn properties, or fabric quality (Table 3). Mean data were numerically very similar for almost all variables. Stink bug treatment did affect yarn evenness parameters for three genotypes, as the stink bug treatment by genotype interaction was significant for thick places in the yarn and yarn irregularity. Two genotypes exhibited opposite responses for thick places. Genotype ST 4793R had more thick places in the untreated control than in the treated, but ST BXN 47B had more thick places in the treated than the untreated control (Table 4). For yarn irregularity, both ST 4793R and ST 474 had lower yarn irregularity with insecticide control for stink bug than without (Table 4).

Table 3. Effect of insecticide application for stink bug control on processing waste, yarn spinning performance, yarn quality, and fabric appearance

Parameter	Insecticide applied		
	No	Yes	Prob > *F*
Processing waste			
Opening card waste (%)	5.3	5.3	0.53
Total waste (%)	5.4	5.4	0.50
Spinning performance			
Ends down (no. per 1000 rotor hours)	15.4	10.8	0.46
Yarn Quality			
Yarn strength (kN m kg^{-1})	116	117	0.38
Elongation (%)	6.4	6.3	0.35
Yarn evenness			
Yarn neps (no. 914 m^{-1})	6.4	6.0	0.63
Thick places (no. 914 m^{-1})[z]	123	121	0.78
Low places (no. 914 m^{-1})	80	78	0.70
Irregularity (CV)[z]	15.6	15.5	0.71
Classimat			
Major faults (no. 100,000 m^{-1})	0.14	0.17	0.87
Minor faults (no. 100,000 m^{-1})	4.7	9.0	0.24
Long thick (no. 100,000 m^{-1})	0.6	1.7	0.24
Long thin (no. 100,000 m^{-1})	21	12	0.21
Fabric appearance			
White speck (no. per 2.58 x 10^4 mm^2)	1.4	1.4	0.91

[z] The insecticide application by cotton genotype interaction was significant ($P \leq 0.05$). See Table 4.

Table 4. Effect of insecticide application for stink bug control and cotton genotype on yarn evenness measures of thick places, low places, and irregularity

Genotype	Thick places (no./914m)			Low places (no./914m)			Irregularity (no./914m)		
	Without control	With control	Mean	Without control	With control	Mean	Without control	With control	Mean
474	134	117	126	91	77	84	15.8	15.5	15.6
4793 R	159	124	141	97	87	92	16.0	15.6	15.8
4691 B	110	118	114	67	72	70	15.4	15.5	15.4
4892 BR	118	116	117	82	82	82	15.6	15.5	15.5
BXN 47	110	120	114	75	79	77	15.4	15.6	15.5
BXN 47 B	107	130	118	69	74	71	15.4	15.6	15.5
Prob > *F*	<0.01		<0.01	0.18		<0.01	<0.01		<0.01
LSD (*P* = 0.05)[z]	22		14	--		9	0.3		0.2

[z] LSD values were not calculated when the source of variation was not significant ($P \leq 0.05$).

Yarn evenness parameters were the only yarn and fabric quality measures that were different among genotypes. For thick places, low places, and irregularity, ST 4793R had higher values than the other genotypes except for ST 474 (Table 4). It is interesting to note that for thick places and for irregularity, the two parameters for which the stink bug treatment by genotype interaction was significant, there were differences among the genotypes only in the untreated control, while genotypes had similar means when treated for stink bugs.

In summary, there was no evidence that light stink bug damage causes a reduction in cotton textile mill performance. Although stink bug damage in this study was not high enough to reduce seed cotton yield, it was greater when insecticides applied to control stink bugs were not used. It is likely that many bolls damaged by stink bugs have locks that do not fluff, so they do not get harvested by spindle pickers (Barbour et al., 1990; Fig. 1). McAlister and Rogers (2005) reported higher quality fiber for spindle picker-harvested than for stripper-harvested cotton grown in ultra-narrow row widths (cotton grown in 19-cm rows). A stripper harvester would be able to collect hard lock cotton. It would be interesting to know how much of the reduction in quality might be due to stink bugs. Although differences among genotypes did occur for some traits in this study, the findings support previous research in that transgenic traits do not reduce mill performance (Ethridge and Hequet, 2000; Bauer et al., 2006).

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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.

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