PERFORMANCE OF TRANSGENIC COTTON VARIETIES IN ARIZONA

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Abstract

Transgenic cotton varieties in Arizona were compared to the conventional variety from which they were derived in four field tests at three Arizona locations in 1999 and three tests at the same three locations in 2000. We included a total of 31 transgenic varieties and 11 conventional parents in one or more of these tests. Bollgard (BG) and stacked (BGRR) varieties produced lint yields that were equal to or significantly greater than lint yields of their respective conventional parents, while Roundup Ready (RR) varieties produced lint yields that were similar to their conventional parent. Only one transgenic variety (DP5690RR) produced significantly lower yields than the conventional parent in these tests. Pollen sterility ratings, one measure of heat tolerance, indicated that some transgenic varieties were more heat tolerant, most were similar to, and some were less heat tolerant than their conventional parent. Differences in fiber quality were also observed in these trials, but the variation was not associated with a particular transgene. Our results showed that most transgenic varieties were similar to, but not the same as, their respective conventional parent. Furthermore, our results indicated that differences in non-target traits between transgenic and conventional varieties were most likely the result of breeding and selection during the backcross conversion of the conventional variety, and were not a result of the direct effects of the transgene.

Introduction

Arizona cotton growers readily adopted transgenic upland cotton varieties with Bt expression and glyophosate tolerance into their production programs. Many new transgenic varieties have been developed and released recently, but data on the performance of many of these varieties in Arizona is scarce. In addition, Roundup Ready cotton varieties have not been sprayed with Roundup Ultra in most agronomic variety trials. The purpose of this study was to evaluate the performance of transgenic varieties under the climatic conditions of Arizona relative to the conventional varieties from which they were derived.

Materials and Methods

We conducted a total of seven field tests at three different locations in Arizona from 1999 through 2000. Three tests were located at the Maricopa Agricultural Center (MAC99, MACE99, and MAC00), two at the Marana Agricultural Center (MAR99, and MAR00) and two at the Safford Agricultural Center (SAC99, and SAC00). We used an unbalanced split-plot design in all tests where main plots were "families", which consisted of all Roundup Ready (RR), Bollgard (BG) or stacked (BGRR) transgenic varieties derived from the same varietal background. Split-plots consisted of the different transgenic cultivars within a family. For example, the main plot containing the 'DP415' family included split-plots of DP5415, 'NuCOTN 33B', 'NuCOTN 32B', 'DP448B', 'DP5415RR', and 'DP458BR'.

We planted each variety in two-row plots in the SAC99, SAC00 and MACE99 tests and in four-row plots in the MAC99, MAC00, MAR99, and MAR00 tests. Rows were spaced 36" apart at Safford and 40" apart at Marana and Maricopa and the plots were 38 to 42' long. We used standard cultural practices, including aggressive measures to control Pink Bollworm, lygus and whitefly, and we kept all plots weed-free.

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To keep the experiments to a reasonable size (less than 40 total treatment/entry combinations per test), we did not include all entries in all tests. We included a total of 31 transgenic varieties and 11 conventional parents in one or more of the tests (Table 1). We only present data in this report for varieties that were included in at least two different trials.

All varieties with the RR gene received an application of Roundup Ultra over-the-top at the two to four true leaf stage, and one post-directed at about the 10-node growth stage. Roundup Ready varieties in most experiments received a second post-directed Roundup Ultra application near layby. Topical applications were made using TeeJetXR8002VS nozzles operated at 20 psi to deliver about 10 gallons of water per acre. Post-directed applications were made using two TeeJet8001EVS nozzles per crop row. The nozzles were mounted in swivels on drop tubes that were [pl;aced about nine inches on either side of the crop row. The nozzles were orieted to spray an 18-inch band with the spray patterns overlapping or meeting at the first node (i.e., node above the cotyledonary node) of the cotton stems. The rate of Roundup Ultra applied in all applications was 0.75 lb a.e./A and 17 lb of diammonium sulfate per 100 gallons was added to the spray solution to compensate for alkaline hard water.

Prior to harvest, a random sample of 50 open bolls were hand harvested from three replications of each test to determine lint percent and fiber properties. Two rows were machine-picked from each plot to determine seed cotton yields. Plot weights and gin data were used to calculate lint yield, lint per boll, and bolls per foot of row. Fiber samples from the boll samples were sent to ITC (International Textile Center, Lubbock, TX) for determination of fiber length, fiber strength, and micronaire.

Data for each family were analyzed separately across locations in order to make balanced "head-to-head" comparisons of the transgenic variety compared to its conventional parent. Protected LSDs were calculated using the genotype x environment interaction term for each family. For entries that were tested at only two locations, the pooled error term was used to determine significance of the entry main effect.

Flowers were visually scored for heat-induced pollen sterility at Maricopa in 2000. Ten flowers per plot were assigned a score ranging from 1 to 5. A flower with normal anthers and abundant pollen shed was given a score of 1, while a flower with stunted filaments and all sterile anthers was given a score of 5. Scores were subjected to an analysis of variance using a model that accounted for the split-plot design of the test, and protected LSDs were calculated for within main plot (family) comparisons and among main plot comparisons.

Results and Discussion

Six of the nine BG varieties and four of the ten BGRR varieties produced lint yields that were significantly greater than the lint yield of their conventional parents (Table 2). On the average, the BG and BGRR varieties were 7% higher yielding than their conventional parents. In contrast, eight of the 10 RR varieties produced lint yields that were very similar to the lint yields of the conventional parents. One RR, DP420RR, variety was higher yielding (significant at p=0.10) and one RR variety was lower yielding than the conventional parent in these trials. On the average, RR varieties yielded about 1% more than the conventional parent in these trials.

We observed some differences between the transgenic varieties and their conventional parents in lint per boll, and bolls per foot of row. Several examples of compensatory shifts in these primary yield components were noted. For example, DP5415RR produced fewer bolls per acre than DP5415, but each boll contained more lint per boll, resulting in very similar overall yields. In general, the BG and BGRR varieties produced more bolls per acre than the conventional parent, but there were no consistent trends in yield components associated with any of the transgenic traits (Table 2).

We also observed several examples of fiber quality differences between transgenic and conventional varieties (Table 3). In general, the micronaire of transgenic varieties was similar to or lower than the micronaire of the conventional parent. The fiber length and strength of some transgenic varieties also were lower than that of the conventional parents. There were exceptions noted for each trait, however, and it is difficult to conclude that a particular transgenic trait resulted in poorer fiber quality in the transgenic varieties. Some transgenic varieties produced better quality lint, some produced fiber of similar quality, and some produced fiber of lower quality than the conventional parent.

Pollen sterility ratings indicated that the heat tolerance of some transgenic varieties differed from the conventional variety. Again, some transgenic varieties were significantly more heat tolerant than the conventional variety, some were less heat tolerant, and most were very similar to the conventional parent (Table 4).

Taken as a whole, our results showed that most transgenic varieties are similar to their respective conventional parent, but many of them do differ in some important non-target traits. The variation we observed for most traits, however, was not associated with the transgene itself. These data indicate that the variation in non-target traits between transgenic and conventional varieties is most likely the result of breeding and selection during the backcross conversion of the conventional variety, and is not a result of the direct effects of the transgene per se.

Acknowledgements

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Table 1. Varieties entered in the University of Arizona Transgenic Variety Tests in 1999 and 2000.

	Number of tests			Number of tests	
Variety	**1999**	**2000**	**Variety**	**1999**	**2000**
DP5415	3	3	Deltapine 51	1	3
DP5415RR	2	3	DP425RR	1	3
DP458BRR	3	3	DP451BR	1	3
NuCOTN33B	3	3	DP428B	1	3
NuCOTN32B	3	0			
DP448B	3	3	Deltapine 20	2	3
			DP420RR	0	3
DP5409	2	0	DP422BR	2	3
DP429RR	2	0	DP20B	2	3
DP409BRR	2	0			
			SG125	4	3
Deltapine 90	3	2	SG521RR	0	3
DP90RR	0	2	SG125BR	4	3
DP90B	3	2	SG215BR	0	3
DP5690	3	3	SG501	2	3
DP5690RR	3	3	SG150RR	0	2
DP655BRR	3	3	SG501BR	2	3
NuCOTN35B	3	3			
			PM1560	2	3
Deltapine 50	1	1	PM1560BGRR	2	3
DP436RR	1	1	PM1560BG	2	3
DP450BRR	1	0			
DP50B	1	0	ST474	4	3
			STX9903(RR)	4	0
			ST4892BR	4	3
			ST4691B	4	3

Table 2. Lint yield and lint-yield components of transgenic varieties, (expressed as percent of the respective conventional parent) across locations in Arizona in 1999 and 2000.

Variety	Lint yield	Lint per boll	Boll number	Number of tests
		Bollgard varieties		
DP20B	112*	103	111*	5
DP428B	105	106	101	4
DP448B	115*	109*	106	6
NuCOTN33B	108*	106*	104	6
NuCOTN32B	110*	109*	101	3
NuCOTN35B	108*	101	107*	6
DP90B	112*	93*	120*	5
PM1560BG	96	91*	109	5
ST4691B	103	110*	95	7
		Roundup Ready varieties		
DP420RR	113	108	110	3
DP436RR	98	98	97	2
DP425RR	104	113*	94	4
DP429RR	98	102	93	2
DP5415RR	98	110*	88*	5
DP5690RR	91*	100	90*	6
DP90RR	103	101	106*	2
SG521RR	101	103	107*	3
SG150RR	98	107*	90*	2
STX9903	105	107*	98	3
		Stacked (Bollgard and Roundup Ready) varieties		
DP422BR	107	100	111*	5
DP451BR	113*	104	112*	4
DP409BR	107	102	104	2
DP458BR	102	104	100	6
DP655BR	108*	99	110*	6
PM1560BGRR	111*	96*	120*	5
SG125BR	104	98	108*	7
SG215BR	116*	112*	115*	3
SG501BR	104	102	105	2
ST4892BR	104	110*	95	7

* significantly different from the conventional parent at p=0.05.

Table 3. Fiber properties of transgenic varieties (expressed as a deviation from the respective conventional parent) across locations in Arizona in 1999 and 2000.

Variety	Mic	Fiber strength (g/tex)	Fiber length (in)	Number of tests
		Bollgard varieties		
DP20B	-0.21*	0.7*	0.017	5
DP428B	0.04	0.4	-0.002	4
DP448B	-0.13	-1.4*	-0.002	6
NuCOTN33B	-0.01	-0.4	0.011*	6
NuCOTN32B	0.23*	-1.1*	-0.028*	3
NuCOTN35B	0.03	0.3	0.003	6
DP90B	0.02	-0.1	-0.001	5
PM1560BG	0.21*	-1.5*	-0.038*	5
ST4691B	-0.12*	-0.8*	0.003	7
		Roundup Ready varieties		
DP420RR	0.00	0.1	-0.004	3
DP436RR	-0.18	-0.4	-0.000	2
DP425RR	0.06	0.0	-0.012	4
DP429RR	-0.40*	-0.6	0.012	2
DP5415RR	0.08	-0.4	-0.010	5
DP5690RR	-0.18*	0.3	0.007	6
DP90RR	0.12	-0.5	-0.010	2
SG521RR	0.06	0.0	-0.029*	3
SG150RR	-0.13	-4.1*	-0.030*	2
STX9903	0.04	-1.1*	-0.015*	3
		Stacked (Bollgard and Roundup Ready) varieties		
DP422BR	-0.09	-0.1	0.006	5
DP451BR	-0.02	0.6*	0.008	4
DP409BR	-0.33*	-0.9*	0.002	2
DP458BR	0.12	-0.2	0.005	6
DP655BR	-0.12	-0.4	-0.005	6
PM1560BGRR	-0.08	-1.0*	-0.017*	5
SG125BR	-0.11*	0.4	-0.012*	7
SG215BR	-0.03	-0.1	-0.027*	3
SG501BR	0.14*	-2.0*	-0.031*	2
ST4892BR	0.04	-0.4	-0.012*	7

* Significantly different from the conventional parent at p=0.05.

Table 4. Pollen sterility ratings of conventional and transgenic upland cotton varieties at the Maricopa Ag Center (MAC00) in 2000.

Conventional Variety	Pollen sterility[1]	Transgenic variety	Pollen sterility[1]
Deltapine20	1.5	DP20B	1.6
Deltapine51	1.5	DP428B	1.6
DP5415	2.8	NuCOTN33B	2.2
DP5415	2.8	DP448B*	1.6
DP5690	1.9	NuCOTN35B	2.3
PM1560	1.4	PM1560BG*	2.3
STV474	1.5	ST4691B	1.3
Deltapine50	1.5	DP436RR	1.3
Deltapine51	1.5	DP425RR	1.7
DP5415	2.8	DP5415RR	2.7
DP5690	1.9	DP5690RR	2.0
SG125	1.8	SG521RR	1.7
Deltapine20	1.5	DP422BRR	1.4
Deltapine51	1.5	DP451BRR	1.8
DP5415	2.8	DP458BR	2.9
DP5690	1.9	DP655BR*	2.8
PM1560	1.4	PM1560BGRR*	2.4
SG125	1.8	SG125BRR	1.8
SG125	1.8	SG215BRR	1.5
SG501	2.1	SG501BR	2.0
STV474	1.5	ST4892BR	1.2

1) 1 = flower anthers showed normal morphology and were shedding abundant pollen; 5 = filaments were abnormally short, and no anthers were shedding pollen

LSD to compare means within a family=0.7. LSD to compare any two means=0.9. A '*' next to the transgenic variety name indicates that the transgenic variety was significantly different from the conventional parent at P=0.05.