Performance of Bollgard II® Upland Cotton Strains in Arizona

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Abstract

Experimental strains containing the Bollgard II® gene construct have been developed in upland cotton through transformation of DP50B. We evaluated the field performance of two of these new strains at four locations in Arizona. Lint yields of these two lines compare favorably with the parent material used to develop the lines (DP50B), but are significantly lower than other conventional and transgenic varieties that are adapted to Arizona. Fiber quality was not compromised in the Bollgard II strains. In fact, one line, 15813, produced fiber that was of superior quality to DP50B. One of the lines (15985) was similar to DP50B for all traits measured in this test. These results show that the Bollgard II gene construct does not, in itself, compromise agronomic performance. Thus, it should be possible to successfully place Bollgard II into other varieties that are adapted to Arizona in order to produce an agronomically superior variety with the added benefit of the Bollgard II technology.

Introduction

Arizona cotton growers have readily adopted transgenic upland cotton varieties that contain the Bollgard® gene for resistance to pink bollworm. Field performance of the Bollgard® varieties has been exceptional providing growers with consistent, dramatic and selective protection against infestations of pink bollworm (*Pectinophora gossypiella*, PBW).

The Bollgard gene is a *Bt* Cry1 Ac endotoxin derived from the crystalline bacterium, *Bacillus thuringiensis* var. *kurstaki* HD-1. Now, scientists at Monsanto have developed the next generation of *Bt* technology. DP50B, which contained the first generation *Bt* gene (Cry1Ac), was transformed to include a second *Bt* gene (temporarily designated CryX) to create a "stacked variety" with both *Bt* genes residing in the same plant. This new construct has been named Bollgard II®. The potential advantages of the stacked variety include increased efficacy and spectrum against certain pests. Also there may be greater resiliency against the development of resistance to the one-gene product (Bollgard), thus guarding against possible failure of performance in the field.

Two different events (strains) have been selected for possible release as a new commercial variety. These two events, 15985 and 15813, were evaluated at one location in Arizona in 1998 (Sieglaff et. al., 1999). Their results strongly indicated that the new lines provided excellent protection against pink bollworm and acceptable agronomic performance, but further evaluations were necessary on a larger scale to fully evaluate the performance of these lines.

Acceptance of these new transgenic varieties in Arizona will ultimately depend on their yield, fiber quality, and agronomic adaptation to the desert Southwest. The objective of this research is to provide state-wide evaluations of the agronomic performance of these lines in the different cotton-producing regions of Arizona.

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Materials and Methods

The varieties included in our evaluation were the two new Bollgard II lines, 15985 and 15813, as well as DP50B, Deltapine 50, NuCOTN33B, SG747, AP6101, and STV474 at all sites. We also included some local varieties in one or more of the trials for a total of ten to twelve entries at each site (see Tables 1-8).

We planted trials at four University of Arizona Agricultural Centers in 1999: Yuma Valley Ag Center (YVAC), Maricopa Ag Center (MAC), Marana Ag Center (MAR), and Safford Ag Center (SAC). The basic experimental procedures were similar for all of the trials. All plots were four rows wide spaced 36 to 40 in. apart and 36 to 42 ft long. Plots were arranged in a randomized complete block design with four replications at each site. We used a high seeding rate of approximately 30 lbs/A and then thinned all plots to a final stand of three plants per foot of row. We planted the MAC test on April 16, the MAR and the SAC tests on April 23, and the YVAC test on April 19. Emergence was outstanding in all four tests. All tests were grown using standard herbicide and fertility regimes. Aggressive control practices were used to control pink bollworm, lygus, and whitefly, including over the top of all transgenic lines.

Shortly after peak bloom, we counted nodes above white bloom (NAWB) of five plants from two replications of each test to provide an indication of plant maturity.

The plots at Marana were visually evaluated for foliar symptoms of *Verticillium* wilt just after peak bloom and just prior to defoliation. Each plot was given a score ranging from 0 for no visible symptoms to 9 for extensive foliar symptoms.

The last irrigation applied to these plots was on Sept 2 at MAC, Aug 24 at MAR, Aug 19 at SAC, and Aug 25 at YVAC. The plots were harvested on Oct 14 at MAC, Nov 16 at MAR, Nov 10 at SAC, and Oct 19 at YVAC.

Prior to harvest, we hand picked a random 50-boll sample from three replications at each site. These samples were weighed to determine average boll weight and then ginned on a 10-saw laboratory gin to determine lint and seed percent. The fiber obtained from the boll samples was sent to the International Textile Center, Lubbock, TX for fiber quality analysis using HVI equipment. The middle two rows of each plot were mechanically harvested and the weight of seed cotton was measured. Estimates of lint and seed yield were calculated from the seed-cotton yields using lint and seed percent values from the hand picked boll samples collected before harvest. Plant height was measured from three replications of each test immediately after harvest.

We conducted an analysis of variance on the data for each trait and calculated protected Least Significant Differences (LSD) for all traits that were statistically significant in the analysis of variance. A combined analysis of varince across locations was conducted for the eight varieties that were common to all four tests. Significance of variety effects was tested using the mean square for the variety by location interaction.

Results and Discussion

General description of the tests. Average lint yield of the tests ranged from 1192 lb/A at MAR to 1625 lb/A at YVAC. The climate in Arizona in 1999 generally favored high yields. All four tests were initiated in favorable conditions. Heat stress during the season was minimal, although extended periods of low level heat stress may have been present in the low desert locations due to higher than average night temperatures and an extended monsoon season in 1999. Pink bollworm infestations were heavy at YVAC and SAC and light to moderate at MAC and MAR. Significant symptoms of *Verticillium* wilt were present at MAR.

Agronomic performance of Bollgard II lines. The Bollgard II lines were both very vigorous during emergence and stand establishment (Tables 1, 3, and 7). Our visual observations during flowering and our counts of NAWB both indicate that 15985 and 15813 were early maturing lines, similar to DP50B, Deltapine 50, and STV474 (although 15813 was slightly earlier that 15985 – Tables 1, 3, and 5).

Across all four locations, lint yield of 15985 averaged 1357 lb./A and 15813 averaged 1236 lb./A (Fig 1 and Table 9). These yields compare favorably with DP50B and Deltapine 50, but were 150 to 200 lb./A lower than the lint yields of NuCOTN 33B (1524 lb./A), SG747 (1466 lb./A) and STV474 (1556 lb./A). The lower yields of the DP50 types were due partly to low lint percent.

Fiber quality of the Bollgard II lines was acceptable in these trials. Although micronaire values were in the discount range, average micronaire of all varieties in the test were above 5.0, and the micronaire of 15985 and 15813 were among the lowest in the test.

Comparison of Bollgard II lines with DP50B. One important objective of this research is to evaluate the effects of the Bollgard II gene construct on overall plant development and agronomic performance of the parent line DP50B. Although all three transgenic "50 types" (DP50B, 15985, and 15813) were somewhat similar in plant development and agronomic performance, 15813 did show some important differences when compared to DP50B. We observed that 15813 began to flower 2-3 days earlier, NAWB counts were generally lower, and plant height was shorter than DP50B, indicating that 15813 is slightly earlier.

Perhaps the most striking difference between 15813 and DP50B is in the fiber properties. In all four trials, 15813 produced fiber that was significantly longer, more uniform, and stronger than DP50B. Lint percent of 15813 also was lower than DP50B.

Unlike 15813, the 15985 line was very similar to DP50B in all traits measured in these trials (Tables 1-8).

Conclusions The Bollgard II lines we evaluated in these tests are the first products of the next generation of *Bt* technology. Yields of these two lines compare favorably with DP50B, but are significantly lower than other conventional and transgenic varieties that are adapted to Arizona. Fiber quality was not compromised in the Bollgard II lines. In fact, 15813 produced fiber quality that was superior to DP50B. One line, 15985, was similar to the parent line DP50B for all the traits we measured in this test. These results show that the Bollgard II gene construct does not, in itself, compromise agronomic performance. Thus, it should be possible to successfully place Bollgard II into other varieties that are adapted to Arizona to produce an agronomically superior variety with the added benefit of the Bollgard II technology.

Acknowledgements

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References

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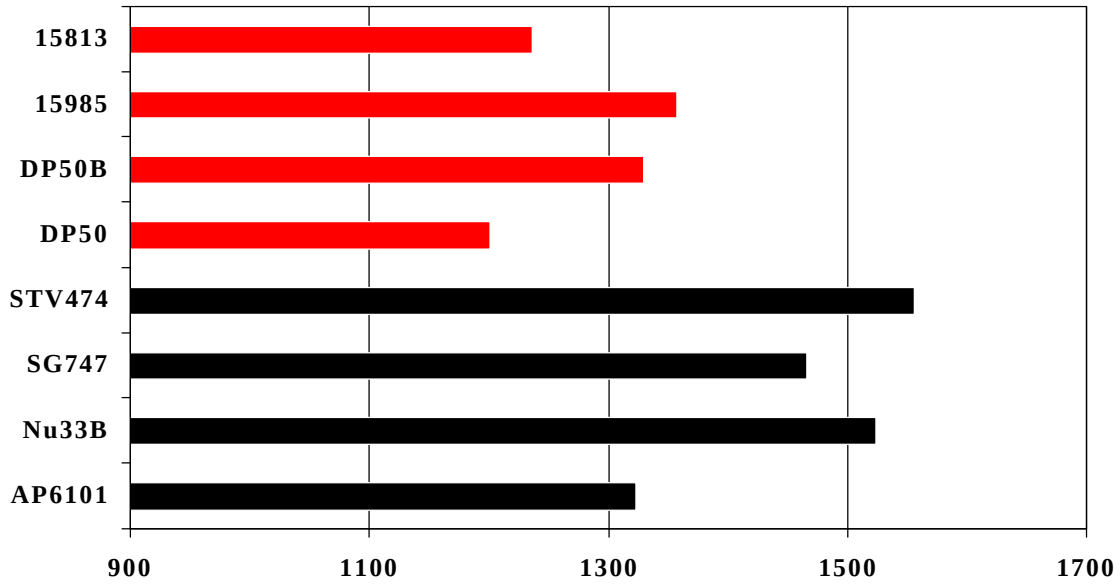

Fig 1. Lint yield (lb/A) of Bollgard II experimental lines and six check varieties in four tests in Arizona, 1999.

Table 1. Performance of Bollgard II experimental lines at the Maricopa Agricultural Center in 1999.

Entry	Lint Yield	Seed Percent	Lint Percent	Seed Cotton Yield	Plant Height	NAWB*	SV*
	lbs/A	%	%	lbs/A	m		
15813CryX	1423	67.1	32.6	4365	0.99	1.5	3.3
15985CryX	1511	65.1	34.3	4404	1.06	3.5	3.0
DP50	1462	64.7	35.2	4155	0.99	1.0	3.3
DP50B	1425	66.7	33.0	4318	1.06	2.5	3.3
AP6101	1499	61.8	37.9	3944	1.21	3.5	3.3
AP7126	1571	60.6	39.0	4007	1.23	2.5	3.3
DP448B	1887	60.1	39.4	4789	1.27	3.0	3.6
DP675	1558	60.6	39.1	3976	1.33	3.5	3.1
NU33B	1597	61.7	38.0	4201	1.33	3.0	4.0
SG248	1459	60.1	39.7	3677	1.42	3.5	2.5
SG747	1730	59.8	40.1	4314	1.07	3.0	2.5
STV474	1846	57.3	42.3	4365	1.21	3.0	2.9
LSD	96	1.4	1.3	253	0.11	1.2	0.7

* Nodes above white bloom

** Visual rating 1= strong vigor 5= weak vigor

Table 2. Fiber quality data of Bollgard II experimental lines at the Maricopa Agricultural Center in 1999.

Entry	Micronaire	Uhml	Uniformity	Strength	Elongation	RD	+b
15813CryX	5.5	1.16	83.4	29.7	5.8	81.2	7.4
15985CryX	5.7	1.12	82.7	27.3	6.0	81.8	7.8
DP50	5.5	1.13	83.0	27.0	6.1	82.0	7.8
DP50B	5.4	1.15	82.2	28.8	6.2	82.0	7.7
AP6101	5.6	1.16	83.8	31.0	5.8	81.3	8.0
AP7126	5.2	1.13	81.5	29.4	5.2	81.1	8.0
DP448B	5.2	1.11	83.0	28.3	5.3	81.8	8.2
DP675	5.5	1.15	84.1	31.6	6.4	79.5	8.6
NU33B	5.4	1.13	82.9	28.3	5.7	81.3	8.1
SG248	5.4	1.15	82.4	31.6	5.2	80.2	8.1
SG747	6.0	1.10	83.5	27.0	6.4	77.9	8.9
STV474	5.6	1.08	83.8	28.3	5.9	79.6	8.8
LSD	0.25	0.04	1.8	1.2	0.6	1.2	0.4

Table 3. Performance of Bollgard II experimental lines at the Marana Agricultural Center in 1999.

Entry	Lint Yield lbs/A	Seed Percent %	Lint Percent %	Seed Cotton Yield lbs/A	NAWB 8/3	NAWB 8/17	Plant Height m	Vert* 8/13	Vert** 10/7	SV***
15813CryX	970	66.3	33.2	2913	7.0	3.7	1.10	3.0	4.3	2.5
15985CryX	1022	65.6	34.3	2970	6.5	5.5	1.19	2.5	4.5	2.6
DP50	964	64.6	34.8	2763	7.0	4.3	1.15	3.0	3.8	3.4
DP50B	1035	65.6	33.9	3054	6.4	5.7	1.13	2.8	4.8	3.0
AP6101	1354	60.6	38.4	3527	7.2	5.3	1.33	2.0	2.8	3.8
AP7126	1183	60.2	39.3	3018	7.0	5.9	1.26	2.5	5.0	3.5
DP448B	1456	61.6	37.8	3841	7.3	4.9	1.34	2.3	4.0	3.0
DP675	1421	60.3	39.2	3616	7.5	5.5	1.40	1.8	3.0	3.3
NU33B	1373	60.8	38.0	3617	7.8	5.7	1.33	1.7	6.4	3.7
SG248	1170	60.6	38.6	3023	.	.	1.49	2.3	3.5	3.3
SG747	1105	59.3	39.8	2776	7.1	4.1	1.18	2.3	6.3	2.5
STV474	1245	58.1	41.3	3014	6.8	3.3	1.15	1.8	6.5	3.1
LSD	148	1.2	1.4	407	1.8	1.4	0.11	0.9	1.4	0.8

* Visual rating of resistance to Verticillium wilt 1= no symptons 5= severe symptons

** Visual rating of resistance to Verticillium wilt 1= no symptons 10= severe symptons

*** Visual rating of seedling vigor 1= strong vigor 5= weak vigor

Table 4. Fiber Quality data of Bollgard II experimental lines at the Marana Agricultural Center in 1999.

Entry	Micronaire	Uhml in	Uniformity	Strength g/tex	Elongation	RD	+b
15813CryX	4.8	1.15	82.9	28.3	6.1	81.9	7.4
15985CryX	4.9	1.12	81.8	26.0	6.4	82.8	7.5
AP6101	5.3	1.17	83.3	30.9	6.2	81.9	7.8
AP7126	5.0	1.16	83.5	29.1	6.0	81.3	7.8
DP448B	4.7	1.13	82.4	28.4	6.4	82.4	8.0
DP50	5.2	1.08	81.5	26.0	5.9	82.5	7.9
DP50B	4.9	1.10	80.9	26.6	5.9	81.9	7.7
DP675	5.1	1.12	83.5	31.5	6.6	80.8	8.4
NU33B	5.0	1.11	81.8	27.3	6.2	82.4	7.8
SG248	5.2	1.16	82.8	30.4	5.5	81.6	7.7
SG747	5.4	1.09	82.1	25.6	6.7	78.9	9.1
STV474	5.1	1.08	81.9	26.7	5.7	78.1	9.0
LSD	0.3	0.04	1.9	1.5	0.9	0.7	0.3

Table 5. Performance of Bollgard II experimental lines at the Safford Agricultural Center in 1999.

Entry	Lint Yield	Seed Percent	Lint Percent	Seed Cotton Yield	Plant Height	NAWB 7/29
	lbs/a	%	%	lbs/a	m	
15813CryX	951	65.2	34.0	2796	0.83	5.0
15985CryX	1184	63.6	34.5	3433	0.80	5.0
DP50	1030	62.7	35.7	2883	0.72	5.0
DP50B	1175	65.2	34.6	3386	0.73	5.2
AP6101	1220	60.9	38.4	3178	0.88	6.2
DP5690RR	1222	60.4	38.1	3195	0.95	6.0
DP675	1171	60.0	39.5	2963	0.90	5.8
DP90B	1531	60.5	38.5	3988	0.92	6.0
NU33B	1466	59.9	39.7	3693	0.80	6.7
PM1560BG	1288	59.7	39.7	3244	0.78	4.7
SG747	1361	58.4	40.8	3336	0.80	5.2
STV474	1338	57.1	41.7	3210	0.81	5.2
LSD	241	1.1	1.2	673	0.09	0.8

Table 6. Fiber Quality Data of Bollgard II experimental lines at the Safford Agricultural Center in 1999.

Entry	Micronaire	Uhml	Uniformity	Strength	Elongation	RD	b+
		in		g/tex			
15813CryX	5.0	1.18	83.6	28.2	6.3	82.0	7.9
15985CryX	5.0	1.12	85.1	25.6	6.5	81.9	8.1
DP50	5.0	1.07	81.9	24.6	5.5	81.8	8.4
DP50B	4.9	1.12	82.3	25.7	6.0	82.5	8.0
AP6101	4.6	1.13	84.5	28.6	5.9	81.2	8.4
DP5690RR	4.3	1.09	81.7	28.7	5.5	81.6	8.2
DP675	4.1	1.10	82.4	29.8	7.0	80.4	8.7
DP90B	4.4	1.12	83.2	29.6	5.5	81.5	8.4
NU33B	4.6	1.11	81.7	26.9	5.8	83.2	8.1
PM1560BG	4.8	1.02	83.1	28.2	5.7	81.4	8.1
SG747	5.2	1.10	82.2	25.2	6.6	79.5	9.1
STV474	5.1	1.07	82.3	26.8	5.3	79.4	9.1
LSD	0.3	0.07	1.8	2.1	0.7	1.0	0.3

Table 7. Performance of Bollgard II experimental lines at the Yuma Agricultural Center in 1999.

Entry	Lint Yield	Seed Percent	Lint Percent	Seed Cotton Yield	Plant Height	Seedling vigor	Leaf Crumple
	lbs/a	%	%	lbs/a	m		
15813CryX	1657	71.5	28.1	5896	1.4	2.8	0.5
15985CryX	1778	68.3	30.6	5810	1.4	2.8	1.0
DP50	1430	67.7	30.9	4644	1.3	3.0	0.3
DP50B	1725	69.5	29.4	5866	1.3	3.0	0.8
AP6101	1248	65.5	32.8	3771	1.7	2.8	2.3
AP7115	1689	62.6	35.8	4717	1.4	3.0	0.0
NU33B	1709	66.4	32.2	5307	1.6	3.8	2.5
SG125	1426	63.0	35.5	4145	1.5	2.7	0.3
SG747	1793	61.6	36.7	4885	1.5	2.8	0.3
STV474	1793	61.4	36.7	4885	1.4	3.0	0.5
LSD	184	1.5	1.1	184	0.1	0.7	0.7

Leaf crumple 1=no symptoms, 5=extensive symptoms

Seedling vigor 1=vigorous, 5=weak

Table 8. Fiber Quality Data for Bollgard II experimental lines at the Yuma Agricultural Center in 1999.

Entry	Micronaire	Uhml	Uniformity	Strength	Elongation	RD	b+
		in		g/tex			
15813CryX	5.0	1.19	84.5	29.9	5.7	79.6	7.1
15985CryX	5.0	1.14	82.9	27.3	5.2	79.6	7.4
DP50	5.1	1.14	82.7	27.2	5.3	78.4	7.2
DP50B	5.0	1.16	83.4	28.4	5.3	79.1	7.2
AP6101	4.6	1.19	82.8	31.2	5.5	76.9	7.6
AP7126	4.8	1.09	82.4	28.4	5.0	79.0	7.6
NU33B	4.9	1.16	82.9	31.4	5.4	79.3	7.6
SG125	5.2	1.12	83.5	26.4	5.5	76.5	8.5
SG747	5.5	1.12	84.0	27.3	5.9	76.8	8.5
STV474	5.2	1.14	83.7	29.1	5.0	73.7	8.2
LSD	0.3	.03	1.4	1.4	0.7	1.9	0.5

Table 9. Performance of Bollgard II experimental lines at four locations in Arizona, 1999.

Entry	Lint Yield	Lint percent	Mic	Uhml	Unif. ratio	Strength	Elongation	Rd	+b
	lbs/a	%		in		g/tex			
15813CryX	1236	32.0	5.1	1.17	83.6	29.0	6.0	81.2	7.5
15985CryX	1357	33.4	5.2	1.13	82.4	26.6	6.0	81.5	7.7
DP50	1201	34.1	5.2	1.10	82.3	26.2	5.7	81.2	7.8
DP50B	1329	32.7	5.0	1.13	82.2	27.4	5.8	81.4	7.7
AP6101	1323	36.9	5.0	1.16	82.8	30.4	5.9	80.3	8
NU33B	1524	37.0	5.0	1.13	82.3	28.5	5.8	81.5	7.9
SG747	1466	39.3	5.5	1.10	83.0	26.3	6.4	78.3	8.9
STV474	1556	40.5	5.2	1.09	82.9	27.7	5.5	77.7	8.8
LSD	190	0.4	0.2	0.02	0.7	0.9	0.3	1.1	0.2