

**FIBER QUALITY COMPARISONS AMONG
VARIETIES FOR CONVENTIONAL, BOLLGARD®
AND ROUNDUP READY® VERSIONS**

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Abstract

Adoption of transgenic cotton varieties that contain Bollgard and/or Roundup Ready has been rapid in the U.S. Some areas of the U.S. have had lower than normal fiber quality in recent years. Questions have been raised regarding the fiber quality of transgenic varieties compared to their recurrent parents. Two general sources of data exist for comparing fiber quality of transgenic and their parent varieties. All potential transgenic varieties are compared against the recurrent parent in small plot replicated trials prior to commercialization. The comparisons also exist in some large scale grower plots. Summary results are reported for seven families of Deltapine varieties grown in small plot replicated trials and for four families of Deltapine varieties grown in large grower plots. Fiber staple length, fiber strength, and micronaire are reported by variety contrast as well as over varieties for gene contrasts for both small and large plots. Some differences in fiber quality exist between transgenic varieties and their recurrent parents. Differences are of minor magnitude and not consistent across variety families for the specific gene traits. Any differences represent the the influence of plant selection in a breeding program. Varieties developed using the backcross method are similar to the parent variety, but not always identical.

Introduction

Comparative data for transgenic and conventional parents was reported by Jones, et al. (1996). Reported literature has concentrated on function of the transgene, yield performance of varieties with the gene of interest, and economic value of the gene. In recent years, some areas of the U.S. have experienced shorter fiber length and higher micronaire than expected. These fiber quality concerns occurred at a time when acreage planted to transgenic cotton varieties has increased. Some have suggested there is a link between the two.

Bassett and Kerby (1996) reported environmental contribution to varietal yield variation over a nine year period in California. Similar data were available for fiber quality, but not published. Kerby, et al. (2000) presented summary fiber quality data for 12 varieties grown over a three period in 16

cotton growing states of the U.S. Location (environment) was shown to account for 85, 48, and 68 percent of the total variation in fiber length, fiber strength, and micronaire, respectively.

Hequet and Ethridge (2000) conducted detailed fiber and spinning performance evaluations of DP 5415 and DP 5690 compared to their Bollgard and Roundup Ready versions. Differences were small. In the few instances of statistically significant differences, they were positive with respect to fiber and spinning quality of transgenic varieties.

This paper presents fiber quality contrasts for seven Deltapine varieties and all their transgenic versions (Bollgard, Roundup Ready, and Bollgard + Roundup Ready). These contrasts occur over years and across many environments.

Material and Methods

Two sets of data are presented. The first comes from small plot replicated studies where the transgenic variety is directly compared to the recurrent parent in studies conducted by Delta and Pine Land Company breeders. These trials are conducted at six locations per year for a two year period prior to the commercial release of the new varieties. The second type of test comes from large scale plots conducted by Delta and Pine Land Company Technical Services in cooperation with growers.

Data for all varieties reported in this manuscript were grown using a conventional system of insect and weed control. Many of the large scale grower plots use a "system" test approach. That is, varieties are grown using the insect management and weed control of the transgenic variety. Hence, system trials do not contain the recurrent conventional parent. Only large scale tests grown in a conventional system are available for comparison here.

Varieties and the number of locations where each variety and transgene group were included in the overall analysis are reported in Table 1. Contrasts are valid only between the specific transgene variety and the recurrent parent of that variety. Not all varieties were grown in the same test (not all released in the same year).

Small replicated plots were harvested with an experimental spindle picker. Approximately 15 pounds of seed cotton was ginned on an experimental 40 saw gin equipped with a lint cleaner. Fiber samples were analyzed using the Delta and Pine Land Company HVI laboratory. Large grower plots were grown according to management practices customary for the grower cooperator. Plots were harvested using grower spindle pickers. Seed cotton and fiber quality samples were handled the same way as for small replicated plots.

Variety comparisons were compared for differences by comparing the two varieties across locations (replications) and calculating the probability of having a greater “F” value ($P > F$). The actual values are listed in Tables 2 through 7. Standard errors (S.E.) are presented for each contrast. Contrasts for the parent varieties against the transgenic versions were conducted by testing the transgene group one at a time against the recurrent parents using locations as replications. Thus, the contrast value represents the mean response of all varieties averaged over locations and is weighted according to the number of paired contrasts stated in Table 1. Fiber quality values are reported with one more significant digit than would be normally expected. This is done because differences are small, there are a large number of locations per contrast, and the S.E. is small. This may tend to bring statistical attention to a difference that is not of a sufficient magnitude to be economically important.

Results and Discussion

Fiber qualities are compared across locations where both the recurrent parent and the transgenic version were in the same test. Number of locations where they were compared is provided in Table 1. Comparisons are valid only for the specific contrast of a parent variety and a single transgene version of that variety. In Tables 2 through 7, the only appropriate contrast is for varieties on the same line (row). As can be noted, the same recurrent parent may have a different fiber quality value when compared against Bollgard, Roundup Ready, or Bollgard + Roundup Ready (stacked) versions. These different gene contrasts were made at different locations (environments). Environment is known to have a significant influence on fiber quality (Bassett and Kerby, 1996; Kerby et al., 2000).

Contrasts significant at $\alpha \leq 0.10$ will be noted and discussed. The level of significance can be observed in the “ $P > F$ ” column of tables. The average S.E. reported in Figure 1 represents an average of the values for the two individual sources of data (small plot and large grower plots).

Fiber Length

Fiber length (32nds of an inch) is presented in Table 2 for the small plot replicated data and Table 3 for the large grower plot data. For Bollgard contrasts with the recurrent parent, staple length was less for NuCOTN33 B in both sets of tests, DP 32 B in small plots, and for DP 428 B in the large grower plots. Fiber length for NuCOTN 35 B and DP 50 B was greater than the recurrent conventional parent in large scale grower plots. When staple length of conventional and Bollgard versions were contrasted over varieties, fiber length was identical (Tables 2 and 3) and is visually presented for the average of 486 comparisons in Fig. 1.

For Roundup Ready contrasts with the recurrent parent, fiber staple length was less for DP 5415 RR and DP 90 RR in small plots, and less for DP 425 in both small and large plots. Fiber length for DP 436 RR was greater than the recurrent conventional parent in large scale grower plots. When staple length of conventional and Roundup Ready versions were contrasted over varieties, fiber length was significantly shorter (Tables 2 and 3) and is visually presented for the average of 213 comparisons in Fig. 1. As noted, some Roundup Ready varieties had shorter staple, some the same, and one variety greater length than the conventional parent. The average difference is 0.26 staple. This is not a function of the Roundup Ready gene, but merely represents breeder selection in variety development.

For stacked (both Bollgard + Roundup Ready) contrasts with the recurrent parent, staple length was less for DP 458 B/RR, DP 409 B/RR, and DP 450 B/RR in small plot tests. Fiber length was greater for DP 655 B/RR in the large grower plots. When staple length of conventional and stacked versions were contrasted over varieties, fiber length was identical (Tables 2 and 3) and is visually presented for the average of 179 contrasts in Fig. 1.

Fiber Strength

Fiber strength (g/tex) is presented in Table 4 for the small plot replicated data and Table 5 for the large grower plot data. For Bollgard contrasts with the recurrent parent, fiber strength was less for DP 32 B in small plots and less for NuCOTN 33 B and DP 428 B in large grower plots. When strength of conventional and Bollgard versions were contrasted over varieties, fiber strength averaged 0.25 less for transgenic versions (average of Tables 4 and 5) and is visually presented for the average of 486 comparisons in Fig. 1. It should be noted that NuCOTN 33 B, which is one of only two varieties to show statistically lower strength compared to the recurrent parent, makes up 199 of the 486 comparisons summarized in Fig. 1.

For Roundup Ready contrasts with the recurrent parent, fiber strength was less for DP 425 RR in large grower plots and greater for DP 436 RR and DP 420 RR in small plots. When staple length of conventional and Roundup Ready versions were contrasted over varieties, strength was statistically identical (Tables 4 and 5) and is visually presented for the average of 213 comparisons in Fig. 1.

For stacked variety contrasts with the recurrent parent, staple length was less for DP 409 B/RR and DP 450 B/RR in small plots, but statistically similar for all other variety comparisons in both small and larger plots. When fiber strength of conventional and stacked varieties were contrasted over varieties, strength was statistically identical (Tables 4 and 5) and is visually presented for the average of 179 contrasts in Fig. 1.

Micronaire

Micronaire values are presented in Table 6 for the small plot replicated data and Table 7 for the large grower plot data. For Bollgard contrasts with the recurrent parent, micronaire was less for DP 410 B, and DP 20 B in the small plots and for NuCOTN33 B, NuCOTN 35 B, DP 50 B, and DP 428 B in the large grower plots. Micronaire of DP 32 B and DP 428 B was higher in the small plots. There is a reversal in response between small and large plot data for DP 428 B. For small plots, the mean is based on 10 contrasts compared to 44 contrasts in the large grower plot data (see Table 1). When micronaire of conventional and Bollgard versions were contrasted over varieties, micronaire of Bollgard varieties was equivalent in the data from small plots, but less than the recurrent parents in large grower plots (Tables 6 and 7). The average difference is visually presented for the 486 comparisons in Fig. 1.

For Roundup Ready contrasts with the recurrent parent, micronaire was less for DP 429 RR and DP 420 RR in small plots. Neither variety was represented in large grower plots. Micronaire was higher for DP 425 RR in both small and large plots and for DP 436 RR in large plots. When micronaire of conventional and Roundup Ready versions were contrasted over varieties, micronaire was equivalent in small plot data (Table 6) and averaged 0.07 units higher in large plot data (Table 7). The average difference is visually presented in Fig. 1.

For stacked variety contrasts with the recurrent parent, micronaire was less for DP 655 B/RR, DP 688 B/RR, DP 409 B/RR, and 451 B/RR in small plots (Table 6). Micronaire of DP 458 B/RR was higher than the recurrent parent in small plots (Table 6). When micronaire of conventional and stacked versions were contrasted over varieties, micronaire was significantly less in small plots with the same trend in large plots (Tables 6 and 7). Averaged over both groups of tests, stacked varieties have an average micronaire that is 0.07 less than the recurrent parents (Fig. 1).

Summary

Studies presented in this manuscript represent up to seven families of Deltapine varieties in all combinations (conventional parent, Bollgard, Roundup Ready, and Bollgard + Roundup Ready). These data are based upon results from direct comparisons where both were grown side by side in the same field under the same management and environment. Environments are sampled by locations and over years to obtain average differences.

When comparing an individual transgenic variety to the recurrent parent, cases can be found where a variety has an average fiber quality value that is greater, equal to, or less than the parent variety. This simply demonstrates the

variation in fiber quality of progeny selections from a parent. This is normal and is expected in a breeding program. Differences are not consistent across all variety families for a transgene type indicating no effect of the Bollgard or Roundup Ready gene itself. Differences between a transgenic variety and the conventional recurrent parent are of minor magnitude and only statistically significant in some cases due to the very large number of samples in the contrast.

Averaged over all tests and gene groups, transgenic varieties had fiber length values that averaged 35.9 staple versus 36.0 for conventional parents. Similar comparisons for fiber strength averaged 28.8 for conventional varieties and 28.7 for transgenic versions of the same varieties. Micronaire of the transgenic varieties averaged 4.40 compared to 4.43 for the conventional parents. The combined data of these studies, which is based upon multiple varieties grown in hundreds of environments, demonstrate fundamental equivalency between conventional parents and the various transgenic versions of the same varieties.

Acknowledgement

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Table 1. Number of comparisons of transgene types to the recurrent parent by gene group and variety family.

Family	Small Plot			Large Plot		
	BG	RR	BG + RR	BG	RR	BG + RR
DP 5415	24	15	14	175	37	41
DP 5690	12	19	14	132	26	28
DP 90	17	15	13	-	-	-
DP 5409	6	7	12	-	-	-
DP 50	14	4	9	37	11	7
DP 51	10	9	6	44	61	28
DP 20	15	9	7	-	-	-
Total	98	78	75	388	135	104

Table 2. Fiber staple length (32nds of an inch) for seven different conventional varieties compared to their various transgenic versions. Data from replicated small plot comparisons.

Variety Contrast		Fiber Length (32nds Inch)		Statistics	
Parent	Transgenic	Parent	Transgenic	P > F	S.E.
DP 5415	NuCOTN 33 B	37.31	37.09	0.09	0.08
DP 5415	DP 32 B	37.25	36.43	<0.001	0.09
DP 5415	DP 5415 RR	36.54	36.35	0.10	0.08
DP 5415	DP 458 B/RR	37.19	36.87	0.007	0.07
DP 5690	NuCOTN 35 B	37.15	37.39	0.17	0.12
DP 5690	DP 5690 RR	36.55	36.70	0.33	0.11
DP 5690	DP 655 B/RR	37.10	37.51	0.07	0.15
DP 90	DP 90 B	36.67	36.69	0.91	0.12
DP 90	DP 90 RR	36.31	35.97	0.08	0.13
DP 90	DP 688 B/RR	37.00	37.24	0.20	0.13
DP 5409	DP 410 B	36.53	36.80	0.22	0.14
DP 5409	DP 429 RR	36.48	36.43	0.84	0.15
DP 5409	DP 409 B/RR	36.77	36.40	0.03	0.11
DP 50	DP 50 B	36.91	37.16	0.30	0.17
DP 50	DP 436 RR	37.28	37.04	0.44	0.19
DP 50	DP 450 B/RR	37.37	36.84	0.01	0.11
DP 51	DP 428 B	36.93	36.93	1.00	0.18
DP 51	DP 425 RR	36.87	36.41	0.03	0.13
DP 51	DP 451 B/RR	36.96	37.17	0.17	0.10
DP 20	DP 20 B	36.35	36.46	0.64	0.16
DP 20	DP 420 RR	36.24	36.00	0.32	0.14
DP 20	DP 422 B/RR	36.62	36.57	0.80	0.13
Parent	Bollgard	36.62	36.61	0.81	0.06
Parent	Roundup Ready	36.60	36.45	0.04	0.06
Parent	BG + RR	36.82	36.81	0.88	0.07

Table 3. Fiber staple length (32nds of an inch) for four different conventional varieties compared to their various transgenic versions. Data from large scale grower plots.

Variety Contrast		Fiber Length (32nds Inch)		Statistics	
Parent	Transgenic	Parent	Transgenic	P > F	S.E.
DP 5415	NuCOTN 33 B	35.63	35.37	0.0003	0.05
DP 5415	DP 5415 RR	35.27	35.04	0.13	0.10
DP 5415	DP 458 B/RR	35.37	35.23	0.33	0.10
DP 5690	NuCOTN 35 B	35.20	35.49	0.0004	0.06
DP 5690	DP 5690 RR	35.24	35.16	0.62	0.12
DP 5690	DP 655 B/RR	35.01	35.30	0.09	0.12
DP 50	DP 50 B	35.64	36.12	0.0001	0.08
DP 50	DP 436 RR	34.92	35.21	0.05	0.09
DP 50	DP 450 B/RR	34.76	34.95	0.35	0.13
DP 51	DP 428 B	35.27	34.94	0.01	0.08
DP 51	DP 425 RR	35.14	34.44	0.0001	0.07
DP 51	DP 451 B/RR	35.38	35.25	0.24	0.08
Parent	Bollgard	35.36	35.35	0.86	0.03
Parent	Roundup Ready	35.15	34.78	0.0001	0.06
Parent	BG + RR	35.20	35.20	0.98	0.06

Table 4. Fiber strength (g/tex) for seven different conventional varieties compared to their various transgenic versions. Data from replicated small plot comparisons.

Variety Contrast		Fiber Strength (g/tex)		Statistics	
Parent	Transgenic	Parent	Transgenic	P > F	S.E.
DP 5415	NuCOTN 33 B	29.60	29.63	0.92	0.17
DP 5415	DP 32 B	29.41	28.79	0.007	0.13
DP 5415	DP 5415 RR	30.33	30.37	0.82	0.12
DP 5415	DP 458 B/RR	29.53	29.44	0.63	0.12
DP 5690	NuCOTN 35 B	30.95	31.02	0.83	0.22
DP 5690	DP 5690 RR	30.96	30.94	0.92	0.15
DP 5690	DP 655 B/RR	30.88	31.03	0.69	0.26
DP 90	DP 90 B	30.51	30.52	0.99	0.29
DP 90	DP 90 RR	31.07	31.55	0.23	0.28
DP 90	DP 688 B/RR	30.58	31.45	0.11	0.35
DP 5409	DP 410 B	27.87	27.83	0.88	0.14
DP 5409	DP 429 RR	27.97	27.90	0.75	0.15
DP 5409	DP 409 B/RR	27.93	26.86	0.0001	0.13
DP 50	DP 50 B	28.09	27.84	0.3	0.16
DP 50	DP 436 RR	28.15	28.65	0.02	0.07
DP 50	DP 450 B/RR	27.53	26.81	0.0003	0.08
DP 51	DP 428 B	27.11	27.40	0.5	0.29
DP 51	DP 425 RR	27.19	27.22	0.93	0.26
DP 51	DP 451 B/RR	26.40	27.03	0.22	0.32
DP 20	DP 20 B	28.15	27.83	0.33	0.23
DP 20	DP 420 RR	25.43	25.86	0.07	0.12
DP 20	DP 422 B/RR	26.61	26.91	0.27	0.17
Parent	Bollgard	29.24	28.96	0.11	0.14
Parent	Roundup Ready	29.35	29.57	0.24	0.15
Parent	BG + RR	28.94	29.01	0.73	0.18

Table 5. Fiber strength (g/tex) for four different conventional varieties compared to their various transgenic versions. Data from large scale grower plots.

Variety Contrast		Fiber Strength (g/tex)		Statistics	
Parent	Transgenic	Parent	Transgenic	P > F	S.E.
DP 5415	NuCOTN 33 B	29.42	28.95	0.0001	0.08
DP 5415	DP 5415 RR	29.06	29.10	0.84	0.14
DP 5415	DP 458 B/RR	29.06	28.97	0.58	0.12
DP 5690	NuCOTN 35 B	30.67	30.72	0.71	0.10
DP 5690	DP 5690 RR	29.92	30.17	0.29	0.16
DP 5690	DP 655 B/RR	30.29	30.41	0.60	0.17
DP 50	DP 50 B	27.00	27.30	0.15	0.15
DP 50	DP 436 RR	26.77	27.15	0.16	0.18
DP 50	DP 450 B/RR	25.43	25.16	0.52	0.28
DP 51	DP 428 B	26.84	26.37	0.005	0.11
DP 51	DP 425 RR	26.68	26.35	0.04	0.11
DP 51	DP 451 B/RR	26.96	26.66	0.18	0.16
Parent	Bollgard	28.99	28.78	0.04	0.07
Parent	Roundup Ready	27.75	27.69	0.62	0.09
Parent	BG + RR	28.34	28.24	0.50	0.11

Table 6. Microaire for seven different conventional varieties compared to their various transgenic versions. Data from replicated small plot comparisons.

Variety Contrast		Microaire		Statistics	
Parent	Transgenic	Parent	Transgenic	P > F	S.E.
DP 5415	NuCOTN 33 B	4.58	4.53	0.55	0.07
DP 5415	DP 32 B	4.46	4.67	0.03	0.06
DP 5415	DP 5415 RR	4.53	4.53	1.00	0.03
DP 5415	DP 458 B/RR	4.51	4.63	0.03	0.04
DP 5690	NuCOTN 35 B	4.68	4.59	0.18	0.04
DP 5690	DP 5690 RR	4.59	4.54	0.32	0.03
DP 5690	DP 655 B/RR	4.59	4.33	0.0005	0.04
DP 90	DP 90 B	4.55	4.55	1.00	0.03
DP 90	DP 90 RR	4.41	4.31	0.14	0.05
DP 90	DP 688 B/RR	4.58	4.48	0.09	0.04
DP 5409	DP 410 B	4.47	4.22	0.06	0.07
DP 5409	DP 429 RR	4.54	4.40	0.09	0.05
DP 5409	DP 409 B/RR	4.40	4.27	0.06	0.04
DP 50	DP 50 B	4.58	4.56	0.80	0.04
DP 50	DP 436 RR	4.73	4.60	0.24	0.06
DP 50	DP 450 B/RR	4.60	4.60	1.00	0.04
DP 51	DP 428 B	4.62	4.73	0.04	0.03
DP 51	DP 425 RR	4.68	4.84	0.04	0.05
DP 51	DP 451 B/RR	4.70	4.60	0.04	0.03
DP 20	DP 20 B	4.39	4.28	0.03	0.03
DP 20	DP 420 RR	4.30	4.18	0.08	0.03
DP 20	DP 422 B/RR	4.37	4.34	0.67	0.05
Parent	Bollgard	4.44	4.43	0.63	0.02
Parent	Roundup Ready	4.48	4.48	0.99	0.02
Parent	BG + RR	4.48	4.41	0.01	0.02

Table 7. Microaire for four different conventional varieties compared to their various transgenic versions. Data from large scale grower plots.

Variety Contrast		Microaire		Statistics	
Parent	Transgenic	Parent	Transgenic	P > F	S.E.
DP 5415	NuCOTN 33 B	4.42	4.32	0.0001	0.02
DP 5415	DP 5415 RR	4.54	4.55	0.69	0.03
DP 5415	DP 458 B/RR	4.49	4.44	0.42	0.04
DP 5690	NuCOTN 35 B	4.28	4.20	0.007	0.02
DP 5690	DP 5690 RR	4.18	4.18	1.00	0.02
DP 5690	DP 655 B/RR	4.39	4.33	0.39	0.05
DP 50	DP 50 B	4.35	4.23	0.003	0.03
DP 50	DP 436 RR	4.66	4.81	0.02	0.04
DP 50	DP 450 B/RR	4.54	4.59	0.24	0.03
DP 51	DP 428 B	4.35	4.29	0.09	0.02
DP 51	DP 425 RR	4.40	4.51	0.0001	0.02
DP 51	DP 451 B/RR	4.40	4.33	0.16	0.04
Parent	Bollgard	4.38	4.29	0.0001	0.01
Parent	Roundup Ready	4.36	4.43	0.002	0.02
Parent	BG + RR	4.42	4.37	0.11	0.02

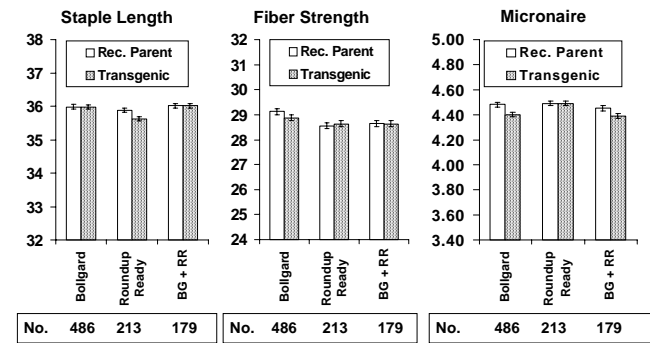


Figure 1. Summary fiber quality of conventional and transgenic versions of seven Deltapine families from small replicated plots and four Deltapine families of varieties grown in large scale grower plots. Values and S.E. represent the average of the two individual groups of data. Number of contrasts for the individual comparisons is provided in the block below the bottom of the figure.