

Registration of Four Exotic Germplasm Lines Derived from an Introgressed Population of Cotton

L. Zeng,* W. R. Meredith, Jr., and B. T. Campbell

ABSTRACT

John Cotton (JC) cotton germplasm was developed from multiple crosses between *Gossypium hirsutum* L. and *G. barbadense* L. JC14 (Reg. No. GP-921, PI 658308), JC32 (Reg. No. GP-922, PI 658309), JC60 (Reg. No. GP-923, PI 658310), and JC65 (Reg. No. GP-924, PI 658311) were released by the USDA-ARS in 2009 for their exceptional fiber quality or desirable combinations of lint yield and fiber properties. These lines were tested for agronomic performance and fiber quality in 2006, 2007, and 2008 at three locations. JC14 and JC60 averaged 277 and 281 kN m kg⁻¹, respectively, for bundle strength over 3 yr compared with 258 kN m kg⁻¹ for the high quality check 'Phytogen 72' (PHY72). The properties of 50% span length, short fiber content, and fineness in these two lines were also superior to those of PHY72. Lint yield of JC65 averaged 1190 kg ha⁻¹, compared with 1565 and 1090 kg ha⁻¹ for 'Deltapine 555BG/RR' and PHY72, respectively. Elongation (8.06%), short fiber content (3.46%), and fineness (174 mg km⁻¹) in JC65 were all superior to those of PHY72. Lint yield of JC32 averaged 1161 kg ha⁻¹ with 8.21% elongation, 3.52% short fiber content, and 174 mg km⁻¹ fineness. The superior traits in these lines can be incorporated into Upland cotton cultivars for genetic improvement of both lint yield and fiber quality.

Pressure from the global textile market has dramatically increased spinning speed in the modern U.S. textile industry. Acceleration of spinning speeds toward 400 m min⁻¹ requires high fiber quality to reduce the cost to industry (Foulk et al., 2009). Broadening the genetic base in Upland cotton is essential for improvement of fiber quality while simultaneously maintaining a lint yield that meets the needs of both the textile industry and cotton growers. The cotton germplasm lines JC14 (Reg. No. GP-921, PI 658308), JC32 (Reg. No. GP-922, PI 658309), JC60 (Reg. No.

GP-923, PI 658310), and JC65 (Reg. No. GP-924, PI 658311) were released by the USDA-ARS in 2009. The JC germplasm, designated for its originator John Cotton, was developed from crosses involving *Gossypium hirsutum* L. Acala 1517-type cultivars and *Gossypium barbadense* L. The germplasm underwent multiple generations of introgressions. These four germplasm lines were selected from a subpopulation and tested for lint yield and fiber quality in 2006, 2007, and 2008 under six environments. The fiber quality of these lines was exceptional, with relatively high or moderate lint yield. These lines were released as part of a current project to enhance the germplasm of Upland cotton for lint yield and fiber quality.

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Abbreviations: 'Deltapine 555BG/RR', DP555BR; PHY72, 'Phytogen 72'.

Methods

The germplasm was initially developed by John Cotton (USDA-ARS, Las Cruces, NM) in the early 1970s, during which extensive crosses were made to introgress genes from *G. barbadense* to the genetic background of Acala 1517 germplasm (Smith et al., 1999). This population was developed from multiple crosses between *G. barbadense* and Acala 1517-type cultivars. Although the exact parents and crossing patterns were undetermined, it was known that open pollinations were allowed among parental plants and their hybrid progenies in a field at Las Cruces. The population underwent long-term introgression between the 1970s and 1990s based on the knowledge of William R. Meredith. In the 1990s, a subpopulation of this germplasm was transferred to Stoneville, MS and grown under a predominant self-pollinating environment. The population was

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advanced by harvesting one boll from each plant and bulking the harvested bolls for planting the next generation. In 2005, 200 plants were randomly sampled from the population, and 15 to 20 bolls were collected from each plant. The seeds from each plant were planted in single rows in 2006 for evaluation of agronomic performance and fiber quality.

The 200 lines of JC germplasm were evaluated for lint yield and fiber quality at Stoneville, MS in 2006 (Zeng and Meredith, 2009a). Four lines were selected from the 200 lines tested in 2006 for lint yield and fiber quality and further tested for yield and fiber quality in 2007 and 2008. In total, the lines were tested at six location-year environments, and the tests included the check cultivars 'Deltapine 555BG/RR' (DP555BR; Delta and Pine Land Co., Scott, MS) and 'Phytogen 72' (PHY72; Phytogen Seed Co., Indianapolis, IN). DP555BR provided a high yield check and PHY72 provided a high quality check. A randomized complete block design was used in all the trials, where entries including the selected JC lines and the cultivars were randomly assigned to each replicate in all environments. In 2006, the entries were planted at two locations at the Delta Research Center at Stoneville, MS with two replicates each (4 replicates for each of check cultivars). In 2007, the entries were planted at the two locations in Delta Research Center at Stoneville, MS with four replicates each. In 2008, the entries were planted in four replicates at one of the two locations at the Delta Research Center, Stoneville, MS and one location at the Clemson University Pee Dee Research and Education Center, Florence, SC. The first and second field sites were located about 1000 m apart at Stoneville, MS, and the third field site was located at Florence, SC. In 2006, plants were grown in single-row plots, each 4.6 m long with a 1.0-m row spacing. In 2007, the plants were grown in single-row plots, each 9.1 m long with a 1.0-m row spacing. In 2008, the plants were grown in single-row plots, each 12.2 and 15.2 m long for field sites at Stoneville and Florence, respectively, with a 1.0-m row spacing. Seeds were planted on 18 April 2006 at Stoneville Location 1; 8 May 2006 at Stoneville Location 2; 20 April 2007 at Stoneville Location 1; 27 April 2007 at Stoneville Location 2; 21 April 2008 at Stoneville Location 1; and 7 May 2008 in Florence. Standard conventional production practices were applied during the trials at all locations. The factor of environment was considered as a replacement for factors of year and location for the purpose of statistical analysis in which six environments were assigned based on the two locations at Stoneville during 2006 and 2007 and one location at Stoneville and one location at Florence during 2008.

At harvest, 25 or 50 bolls from each plot were collected in the different trials and ginned using a laboratory saw gin to determine yield components. Lint samples from these bolls were used to measure fiber quality. Remaining bolls from each plot were collected by hand in the trial of 2006 and harvested by a mechanical picker in the trials of 2007 and 2008 to determine yield. The total seed cotton weight of each plot was the sum of seed cotton weight of the sampled bolls and the remaining bolls in that plot. Each boll sample was used to determine yield components: lint percent, boll weight, lint per seed, and seeds per boll. Lint yield was

calculated from seed cotton weight per plot and lint percent and further converted to kg ha⁻¹ for each line. Twenty grams of lint were submitted to StarLab (Knoxville, TN) for analysis of fiber quality. Fiber strength was measured by a stelometer as the force required for breaking a bundle of fibers. Elongation was the percentage of elongation at the point of break in strength determination. Fiber span length was measured as the average length of the longest 50% of the fibers scanned. Micronaire was measured in micronaire units using the Fibronaire instrument (Motion Control Inc., Dallas, TX). Fibers were also analyzed for mean short fiber content, fineness, and maturity ratio using the Advanced Fiber Information System. Short fiber content was measured as the percentage by weight of the fibers that were less than 12.7 mm. Fineness was measured as the weight per unit of length. Maturity ratio was measured as the proportion of mature fibers to immature fibers.

The General Linear Model procedure of the Statistical Analysis System (SAS Institute, 2004) was used for analysis of variance on the experimental data with a supplemental statement that genotype was a fixed effect and that environment, genotype × environment, and replicates within environments were random effects. Mean separation among genotypes was conducted using protected least significant difference tests.

Characteristics

The JC population is a unique *G. hirsutum* germplasm resource containing exotic *G. barbadense* gene introgressions. A unique feature of this germplasm is the stabilized genome introgressions resulting from long-term introgression and selfing efforts. The utilization of interspecific hybridization between *G. hirsutum* and *G. barbadense* has been problematic because of genetic breakdown in hybrid progenies resulting from segregation distortion (Jiang et al., 2000) and linkage drag (Young and Tanksley, 1989). The availability of germplasm with stabilized genomes displaying combinations of alleles between *G. hirsutum* and *G. barbadense* can be a solution to this problem (Percy et al., 2006) and can provide cotton breeders a resource to select exotic genes for desirable traits. In the initial evaluation of 200 JC lines in 2006, significant genotypic variations were observed among the lines for lint yield and fiber quality (Zeng and Meredith, 2009a). In that evaluation, the genotypic correlation between lint yield and bundle strength was negative ($r = -0.53$). However, some lines, such as JC14, JC32, JC60, and JC65, were identified with exceptional fiber quality and moderate or relatively high lint yield. Although a negative genotypic correlation was identified between short fiber content and fineness ($r = -0.41$) in that study, there were two lines, JC14 and JC60, with exceptional short fiber content and fineness. These results indicate that useful exotic genes exist in JC germplasm and that the exploration of these genes can broaden the genetic base in Upland cotton for lint yield and fiber quality.

Significant ($P \leq 0.001$) genotypic differences were observed for all traits analyzed among the four JC lines and the two cultivars during the trials across 3 yr (Table 1). Although the genotype × environment interactions were significant ($P \leq$

Table 1. Mean squares of yield and fiber properties for four JC lines and two cultivars evaluated in six environments.

Source	df	Lint yield [†]	Lint percent	Boll wt	Seed wt	Lint seed ⁻¹	Seeds boll ⁻¹	MIC [‡]	EL [‡]	T1 [‡]	Length 50% [‡]	SFCw [‡]	FN [‡]	MR [§]
Genotype (G)	5	151***	0.026***	1.9***	4253***	1148***	245***	1.43***	20***	14089***	9.8***	24***	819***	1.6***
Environment (E)	5	142***	0.002***	5.9***	381***	557***	102***	0.69***	1.4**	5820***	4.9***	1.2**	530***	3.4***
G × E	25	13***	0.001***	0.26	80	46	11	0.11*	0.42	340	0.35*	1.2*	56**	0.86**
Error	74	3.4	0.000	0.18	51	35	8.0	0.07	0.55	211	0.20	0.65	24	0.30

[†]Significant at the 0.05 probability level.

^{**}Significant at the 0.01 probability level.

^{***}Significant at the 0.001 probability level.

[†]Values are mean squares of lint yield × 10⁻⁴.

[‡]MIC, micronaire; EL, elongation; T1, bundle strength; Length 50%, 50% span length; SFCw, short fiber content; FN, fineness; MR, maturity ratio.

[§]Values are mean squares of maturity ratio × 10³.

0.05, 0.01, or 0.001) in about half of the traits analyzed, the mean squares of these traits were only a small portion compared to the mean squares for genotype (Table 1). Moreover, crossover interactions were not observed for the traits evaluated during experiments under different environments. There were no obvious changes in ranks among genotypes for lint yield under the six environments. It appears that the significant genotype × environment interaction for lint yield is more related to changes in magnitude. Lint yield of the entries ranged from 595 to 1504 kg ha⁻¹, with an average of 913 kg ha⁻¹ under the environments in 2006, 817 to 1278 kg ha⁻¹, with an average of 1052 kg ha⁻¹ under the environments in 2007, and 969 to 1884 kg ha⁻¹, with an average of 1292 kg ha⁻¹ under the environments in 2008.

JC14 and JC60 were identified for their excellence in fiber quality with moderate lint yield. The yields of JC14 and JC60 were 881 and 833 kg ha⁻¹, respectively, compared with the yields of 1565 kg ha⁻¹ for DP555BR and 1090 kg ha⁻¹ for PHY72 (Table 2). However, the fiber quality of both JC14 and JC60 was superior to that of the high quality check PHY72. JC14 and JC60 displayed bundle strengths of 277 and 281 kN m kg⁻¹, 50% span lengths of 15.4 and 15.7 mm, short fiber contents of 3.93 and 3.21%, and fineness of 167 and 165 mg km⁻¹, respectively (Table 2). The desirable combinations of these fiber properties in these two lines were considered unique. JC65 was unique for the desirable combination of relatively high lint yield and excellence in fiber quality. Compared to the previously released germplasm lines derived from another introgressed population, that is, Species Polycross (Zeng and Meredith, 2009b), JC65

was more desirable for its combination of lint yield and fiber quality. The yield of JC65 was 1190 kg ha⁻¹, 24% less than that of DP555BR and 9.2% higher than that of PHY72, with 252 kN m kg⁻¹ for bundle strength and 15.1 mm for 50% length, similar to those of PHY72. Other properties in JC65 were 8.06% for elongation, 3.46% for short fiber content, and 174 mg km⁻¹ for fineness with a 0.972 maturity ratio, all superior to those of PHY72 (Table 2). Although lint percent is a critical yield component in maintaining high lint yield, its negative correlation with seed weight, as observed in previous studies ($r = -0.56$ to -0.76) (Zeng et al., 2007; Zeng and Meredith, 2009a), implied compensation between these two yield components in breeding. However, Table 2 shows that the combination of lint percent and seed weight values for JC65 (40.4%, 119 mg) was significantly greater than that of PHY72 (39.5%, 105 mg). Lint yield of JC32 was 1161 kg ha⁻¹, which was 25% lower than that of DP555BR (1565 kg ha⁻¹) and 7% higher than the lint yield of PHY72 (1090 kg ha⁻¹). Although the bundle strength of JC32 (242 kN m kg⁻¹) was lower than that of PHY72 (258 kN m kg⁻¹), other properties, such as micronaire (4.51), elongation (8.21%), short fiber content (3.52%), and fineness (174 mg km⁻¹), were superior to those of PHY72.

A nearly smooth leaf was observed for JC32 while intermediate pubescence of the leaf was observed for JC14, JC60, and JC65. Normal leaf shape was observed for all four released lines. The size of nectarines was 3 to 4 mm for the four lines. Days from planting to first open boll of JC14, JC32, JC60, and JC65 was 121, 121, 123, and 119 d, respec-

Table 2. Mean comparisons for the agronomic performance and fiber properties of selected JC lines and cotton cultivars evaluated in six environments.

Entries	Lint yield	Lint percent	Boll wt	Seed wt	Lint seed ⁻¹	Seed boll ⁻¹	MIC [†]	EL [†]	Bundle strength	Length 50% [†]	SFCw [†]	FN [†]	MR [†]
	kg ha ⁻¹	%	g	mg	mg	no.		%	kN m kg ⁻¹	mm	%	mg km ⁻¹	
JC14	881c [‡]	36.0d	4.87cd	112b	63.6cd	27.7bc	4.38d	6.39cd	277a	15.4ab	3.93bc	167c	0.977bc
JC32	1161b	39.3c	5.32ab	121a	78.2a	26.8cd	4.51cd	8.21a	242c	15.2bc	3.52cd	174b	0.970c
JC60	833c	34.9e	4.65d	118ab	63.0d	25.8d	4.42d	6.68c	281a	15.7a	3.21d	165c	0.984ab
JC65	1190b	40.4b	5.48a	119a	81.0a	27.4bc	4.62c	8.06a	252bc	15.1c	3.46cd	174b	0.972c
DP555BR	1565a	44.5a	5.26ab	84d	67.2bc	34.9a	5.02a	5.91d	212d	13.8d	5.99a	181a	0.970bc
PHY72	1090b	39.5c	5.02bc	105c	69.0b	29.1b	4.83b	7.67b	258b	15.1c	4.12b	177a	0.988a

[†]MIC, micronaire; EL, elongation; Length 50%, 50% span length; SFCw, short fiber content; FN, fineness; MR, maturity ratio.

[‡]Means followed by the same lowercase letters are not significantly ($p < 0.05$) different according to the LSD tests.

tively, compared to 119 d for PHY72 and 128 d for DP555BR. The color of flowers and fibers in the four lines are all white.

In summary, the released lines are unique germplasm containing either exceptional fiber properties or desirable combinations of lint yield and fiber properties. JC14 and JC60 are unique for desirable combinations of fiber bundle strength, 50% span length, short fiber content, and fineness. JC32 and JC65 are unique for their relatively high lint yield and excellent fiber quality. These lines represent a unique source of high-quality germplasm containing exotic genes from interspecific introgressions. The identified superior traits will provide breeders with opportunities for genetic improvement of both lint yield and fiber quality in Upland cotton.

Availability

Small quantities of seeds are available to cotton breeders, geneticists, and other research personnel on written request to Linghe Zeng, Crop Genetics and Production Unit, USDA-ARS, 141 Experiment Station Rd., P.O. Box 345, Stoneville, MS 38776. It is requested that appropriate recognition of the source be given when germplasm lines contribute to the development of a new breeding line, hybrid, or cultivar. Genetic material of this release will be deposited in the National Plant Germplasm System where it will be available for research purposes, including development and commercialization of new cultivars.

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