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BREEDING AND GENETICS

Transgressive Segregation in an Acala Glanded × Acala Glandless Hybrid Population for the Development of Glandless Cotton Germplasm

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ABSTRACT

Improvement in lint yield is vital to commercial production of glandless cotton. The objective of this study was to determine if glanded 'Acala 1517-08' could be converted to glandless cotton without a yield penalty by crossing breeding with an obsolete glandless cotton. From 500 F_2 plants, 18 glandless individuals were selected, and their F_4 lines were compared with both parents. This led to a selection of 77 F_6 lines for further replicated field testing. Only five F_6 lines produced 90 to 96% of Acala 1517-08 lint yield (LY), while three lines had significantly lower LY than the lower parent 'Acala GLS'. Transgressive segregation in the negative direction was also observed for boll weight (BW) and lint percent (LP) in that four and 22 F_6 lines had significantly lower values than the lower parent, respectively. Four F_6 lines had significantly lower fiber length (UHM) than the lower parent Acala 1517-08, while five lines had longer UHM than the higher parent Acala GLS. Ten F_6 lines had weaker fibers than the lower parent Acala 1517-08, but none had stronger fibers than Acala GLS. Most F_6 lines had micronaire (MIC) between the two parents except for one with higher MIC than the higher parent and five with lower MIC than the lower parent Acala GLS. In conclusion, positive transgressive segregation for LY, LP and BW should not be expected in this Acala × Acala cross, while negative transgressive segregations occurred frequently for the three traits and fiber strength. For UHM and MIC, negative transgressive segregations occurred more frequently than positive ones. Overall, there was no transgressive segregation for fiber uniformity, elongation and short fiber content.

There has been considerable interest in research and use of glandless cotton (*Gossypium* spp.) for production of gossypol-free cottonseed to use in food and feed products. Development of glandless cotton that is comparable in yield potential with the current commercial cultivars is the prerequisite. The double recessive glandless trait in Upland cotton (*G. hirsutum* L.) is controlled by $gl_2gl_2gl_3gl_3$ (McMichael, 1959, 1960) located on two homeologous chromosomes c12 and c26 (Kohel, 1979). The glandless genes have no deleterious effects on yield and fiber quality (Halloin et al., 1978). Extensive activities in glandless cotton breeding and research have been conducted since the 1960s, resulting in the release of many glandless cotton germplasms. There were intermittent breeding activities for glandless cotton until the late 1990s (Dobbs and Oakley, 2000; Owen and Gannaway, 1995; Shepherd, 1982; Smith and Niles, 1988), but the best existing high-yielding glandless germplasm still had a 10 to 35% yield gap compared to 'Acala 1517-08' and a 25 to 54% yield gap compared to current commercial transgenic cotton (Idowu et al., 2014; Zhang et al., 2014). Zhang et al. (2014) further showed that selection within the existing glandless germplasm could improve yield, but an 11 to 18% yield gap still existed. Based on the estimate by Meredith and Bridge (1982) that the mean genetic gain in yield improvement was 0.74% per year at the national level in the U.S., 13 to 25 years would be needed to bring the yield potential of glandless cotton up to the level of the current commercial cultivars. Even based on a higher estimate that the cotton yield gain due to breeding was 1.4% per year in the New Mexico Cotton Breeding Program between 1930 and 2004 (Zhang et al., 2005), 7 to 13 years would be still needed to fill a 10 to 20% yield gap. Therefore, lint yield in glandless cotton should be significantly increased through cross breeding before its potential as a food and feed source can be fully realized.

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Recently, breeding populations involving glandless cotton have been released (Gutiérrez et al., 2006; Hinze et al., 2013) and a few new glandless germplasm lines developed (Romano and Scheffler, 2008; Scheffler and Romano, 2012), but no new glandless cotton cultivars have been released. In the late 2000s, the Cotton Breeding Program at New Mexico State University initiated a glandless breeding project aimed at increasing lint yield and improving fiber quality. This program historically has developed Acala cotton cultivars that have been grown in New Mexico and lines with high fiber quality that were used to develop other cultivars, including Acala, for production in California (Bowman et al., 1996; Smith and Cothren, 1999; Zhang et al., 2005).

Although yield reduction in glandless Acala cotton has been reported, mostly due to lygus [*Lygus hesperus* (Knight, 1917)] bug damage, bollworm [*Helicoverpa zea* (Boddi, 1850)], and occasionally armyworm (*Spodoptera exigua* (Hübner)] pests (Benedict et al., 1977; Pierce et al., 2014), New Mexico has relatively low insect pressure. So commercialization of glandless cotton might be possible. The immediate goal is to identify or develop Acala glandless cultivars that have yield and fiber quality comparable to current commercial Acala cotton. To achieve this, the most recently released glanded Acala 1517-08 (Zhang et al., 2011) was crossed with the latest release of glandless 'Acala GLS' (Dobbs and Oakley, 2000) to transfer the gl_2gl_3 genes into Acala 1517-08. Both cultivars have premium fiber quality traits, but with lower lint percentage than most commercial transgenic cultivars. Acala GLS also has longer, stronger, and finer fibers, and larger bolls than most transgenic cultivars and other Acalas (Idowu et al., 2014; Zhang et al., 2014). This Acala × Acala cross also will allow us to address whether transgressive segregation in yield, yield components, or fiber quality traits can be selected in progeny from a cross of Acala × Acala that was low × low in yield and high × high in fiber quality. The objective of this study was to report the progress in breeding for high-yielding glandless Acala cotton from this hybrid combination. Two rounds of pedigree selection were performed. The results might have some implications for other types of crosses in cotton breeding.

MATERIALS AND METHODS

A cross between the glanded Acala 1517-08 (Zhang et al., 2011) and the glandless Acala GLS (Dobbs and Oakley, 2000) was made in 2010 and the F_1 seed was sent to Tecoman, Mexico for generation advance. In the 2011 growing season in Las Cruces, NM, approximately 500 F_2 plants were grown and 18 glandless plants selected (3.6% of the total plants). The F_3 seeds from the individual F_2 plants were sent to Tecoman, Mexico, for seed increase. The resulting F_4 seeds were used for a field test with three replications in 2012 that contained 34 entries, including the 18 new glandless lines and other glandless germplasm lines released by other programs (Owen and Gannaway, 1995; Smith and Niles, 1988). From the 18 F_4 lines, a total of 77 selections were then made, and the F_5 seed sent to Tecoman, Mexico for generation advance to F_6 and seed increase to be used in four replicated tests (designated trials S, T, U, and V) each with 32 entries in 2013. Each test also contained selections from existing glandless germplasm lines released by other programs (Dobbs and Oakley, 2000; Owen and Gannaway, 1995; Smith and Niles, 1988). The results were reported in Zhang et al. (2014). These selections were divided among the four tests based on replications from which selections were made in 2012.

In each test, the two parents, Acala GLS and Acala 1517-08, were included. All the tests were arranged using a randomized complete block design with three replications. The plot size was 1 row × 12.19 m, with a row spacing of 0.92 m. Seeds were planted in early May each year with a seeding rate of 10 seed m^{-1} using a 4-row plot planter. Crop management followed local recommendations except that no seed treatment and no insecticides were applied. All the tests in 2013 were conducted in the same field under the same crop production system. At maturity, 20 open bolls were hand harvested from each plot and ginned using a 20-saw lab gin for measurements of boll weight (BW) and lint percentage (LP). Ginned fiber samples were tested for fiber quality by HVI 1000 at Cotton Incorporated, Cary, NC. Each plot was mechanically harvested using a 2-row plot picker installed with an automatic weighing and computer system (Cotton-Picking 920i, Master Scales, Greenwood, MS) to determine seedcotton yield (SCY). The SCY was converted to lint yield (LY) by multiplying SCY with LP. An analysis of variance (ANOVA) was performed for each test and the least significant difference (LSD) was used to compare entry means. Because segregation in glandless trait was observed in some glandless germplasm lines, data from these entries were used in the ANOVA to calculate LSD but are not included in the reported tables here. To detect transgressive segregation, only the genotypes with significantly higher or lower trait means than the higher or lower parent (at the $p = 0.05$ level), respectively, were considered transgressive segregants.

RESULTS AND ANALYSIS

Initial Selections. Based on yield in 2011, 18 F_4 lines were selected from the cross between glanded Acala 1517-08 and glandless Acala GLS for a replicated test in 2012 (Table 1). The SCY ranged from 2841 to 4931 kg ha^{1} and LY ranged from 1133 to 2035 kg ha^{-1}, and the differences were significant between lower and higher yielding glandless lines. The SCY of these lines ranged from 75 to 130% of Acala 1517-08, whereas their LY ranged from 77 to 138% of Acala 1517-08. Although eight lines had LY greater than 10% higher than Acala 1517-08, only one line (10NM11-17) yielded significantly more than both parents. The yield advantage might be due to unexpected lower yield (1471 kg ha^{-1}) from Acala 1517-08 and higher LY (1478 kg ha^{-1}) from Acala GLS in this test. Unexpectedly, both parents had the same LY due, perhaps, to drought stress encountered during the mid-growing season.

For LP and BW, Acala GLS had higher LP and larger bolls than Acala 1517-08. Among their progeny, none had lower LP or BW than the lower parent, and none had higher LP or BW than the higher parent. Even though 10NM11-13 had higher LP and BW than Acala GLS, the difference was statistically not significant at $p \leq 0.05$.

Table 1. Field performance of breeding lines (F_4) selected from a cross between Acala 1517-08 and glandless Acala GLS, Las Cruces, NM, 2012

Line	SCY^z kg ha^{-1}	LY^z kg ha^{-1}	Boll g boll^{-1}	Lint %	UHM^z mm	UI^z %	STR^z g tex^{-1}	ELO^z %	MIC^z unit	SFC^z %
10NM11-1	4261	1675	6.48	39.28	30.48	85.60	36.57	5.27	4.75	6.80
10NM11-2	3709	1476	6.52	39.96	31.50	85.60	36.73	4.83	4.28	6.70
10NM11-3	4586	1881	6.26	41.09	31.24	85.03	36.43	5.70	4.34	7.10
10NM11-4	3517	1407	6.50	39.98	31.50	85.87	37.90	4.57	4.28	6.43
10NM11-5	4139	1704	5.97	41.24	30.73	84.80	37.87	5.83	4.21	7.17
10NM11-6	3954	1563	5.97	39.58	29.97	85.20	37.30	5.77	4.33	6.50
10NM11-7	3661	1498	6.04	41.07	30.48	84.67	34.73	5.37	4.67	6.97
10NM11-8	2936	1241	5.29	42.05	30.23	84.67	36.40	6.83	4.76	6.90
10NM11-9	4288	1698	6.33	39.62	30.23	85.23	38.07	6.43	4.33	6.83
10NM11-10	2841	1133	5.77	39.86	31.50	85.03	39.50	5.17	4.43	6.47
10NM11-11	3980	1651	5.64	41.52	32.26	85.70	37.83	5.40	4.02	6.63
10NM11-12	3133	1249	6.27	39.83	31.24	86.33	37.43	5.43	4.51	6.50
10NM11-13	4466	1892	7.15	42.33	31.75	84.50	37.30	5.20	4.17	6.93
10NM11-14	2948	1200	6.03	40.68	30.73	85.43	36.73	5.67	4.38	6.87
10NM11-15	3978	1624	6.20	40.86	30.23	85.13	37.70	5.80	4.41	6.70
10NM11-16	3739	1528	5.28	40.86	32.26	85.70	39.10	5.70	4.09	6.60
10NM11-17	4931	2035	6.42	41.42	30.99	85.27	37.63	5.43	4.30	6.87
10NM11-18	3686	1490	6.56	40.38	31.75	84.63	34.73	5.43	4.45	7.07
Acala GLS	3555	1478	6.58	41.55	32.26	86.17	39.30	4.90	4.13	6.43
Acala 1517-08	3806	1471	4.38	38.65	32.26	84.53	37.40	6.13	4.60	6.93
LSD 0.05	1106	429	0.91	1.40	1.27	1.16	2.26	0.51	0.27	0.48

^{z} SCY, seed cotton yield; LY, lint yield; UHM, upper-half length; UI, uniformity index; STR, fiber strength; MIC, micronaire; SFC, short-fiber content.

Although both parents had good fiber quality traits, Acala GLS had similar fiber length, that is, upper-half mean (UHM) to Acala 1517-08, but higher fiber uniformity (UI), high strength (STR), lower micronaire (MIC), lower short-fiber content (SFC) and lower elongation (ELO) than Acala 1517-08. Among their progeny, although all of them had long and strong fibers, nine had the same as or shorter but nonsignificant UHM than the parents, whereas nine other lines had significantly lower UHM. All lines had UI between the two parents and none had significantly lower or higher UI. However, two lines had significantly lower STR than the lower parent, Acala 1517-08, and seven lines had lower STR than the higher parent, Acala GLS. All the lines had fibers with similar or lower micronaire than Acala 1517-08. None had lower ELO than the lower parent, Acala GLS, but one line had significantly higher ELO than the higher parent, Acala 1517-08. Because the two parents had low MIC, all the lines had low MIC falling between the two parents. For example, nine had similar lower MIC to Acala GLS, seven of which had significantly lower MIC than Acala 1517-08. Five had similar SFC to Acala 1517-08 but significantly higher than Acala GLS. None had significantly higher SFC than the higher parent, Acala 1517-08.

Yield. Seventy-seven lines were further selected from these 18 lines in 2012 and divided and evaluated in four replicated field tests (Trials S, T, U, and V) in 2013 (Tables 2, 3, 4, and 5). Of the 15 glandless lines (15 other entries had segregations of glanded and glandless plants and were not reported) in Trial S, none had lower LY than the lower parent or higher LY than the higher parent; two had significantly higher LY than Acala GLS, which were lower (by 8-9%) than Acala 1517-08 but statistically nonsignificant (Table 2). Six of the 14 lines in Trial T had significantly higher LY than Acala GLS, whereas the top two lines had lower but similar (88% and 95%) LY to Acala 1517-08, and all other lines had lower LY (Table 3). Of the 25 lines in Trial U, all had significantly lower LY than Acala 1517-08; one had significantly higher LY than Acala GLS, and other five had LY similar to Acala GLS (Table 4). Out of the 23 lines tested in Trial V, none had significantly higher LY than Acala GLS, whereas one had lower LY than Acala GLS. Thirteen lines had lower LY than Acala 1517-08, and two had LY 91 to 96% of Acala 1517-08 (Table 5).

Overall, three lines had significantly lower LY than the lower parent, Acala GLS. However, none had higher LY than the higher parent, Acala 1517-08. Twenty-eight lines had LY higher than Acala GLS by 13 to 36%, but none had LY higher than the higher-yielding parent, Acala 1517-08. Interestingly, five lines yielded 90 to 96% lint of Acala 1517-08, three of which were from two (10NM11-3 and 10NM11-7) of the eight, high-yielding F_4 lines in 2012.

Boll Weight and Lint Percentage. Acala GLS had 10 to 15% higher BW than Acala 1571-08, and the differences were statistically significant in three tests (i.e., Trials S, T, and V). In Trials S, T, U, and V, seven, five, nine, and six lines (a total of 27) had similar BW to the higher parent, Acala GLS, respectively, but none had significantly larger bolls. Therefore, no transgressive segregation was observed for higher BW. Only two lines each in Trial S and U had significantly lower BW than the lower parent, Acala 1517-08.

Both parents had similar LP except for one test in which Acala GLS had significantly higher LP than Acala 1517-08. In Trial S, no transgressive segregation was detected for LP. In Trial T, six lines had significantly lower LP than the lower parent and none had higher LP than the higher parent. In Trial U, three and six lines had lower LP than Acala GLS and Acala 1517-08, respectively. In Trial V, 12 lines had significantly lower LP than the lower parent, Acala GLS. Overall, 17 lines had LP slightly more than 40%, but none had higher LP than the higher parent. Twenty-two lines had significantly lower LP than the lower parent.

Fiber Quality. Acala GLS had consistently longer fibers, but was only significant in one of the four tests (Trial S). In Trial S, except that one line had significantly longer UHM than the higher parent, Acala GLS, all lines had values between the two parents. Eight lines had UHM similar to the higher parent. In Trial T, one line had significantly longer fibers (UHM), whereas the rest had similar UHM to the two parents. In Trial U, two lines had shorter fibers than Acala 1517-08, whereas three lines had longer UHM than Acala GLS. In Trial V, two lines had significantly shorter UHM than the lower parent, Acala 1517-08. Overall, most lines had UHM between the two parents; five lines had fibers longer than the higher parent, Acala GLS, whereas four lines had shorter fibers than the lower parent, Acala 1517-08.

Table 2. Field performance of advanced breeding lines (F_6) from cross between Acala 1517-08 and glandless Acala GLS in Trial S, Las Cruces, NM, 2013

Selection	Source	SCY[z] kg ha^{-1}	LY[z] kg ha^{-1}	Boll g boll^{-1}	Lint %	UHM[z] mm	UI[z] %	STR[z] g tex^{-1}	ELO[z] %	MIC[z] unit	SFC[z] %
12G1030-1	10NM11-10	2939	1086	5.58	36.90	32.00	84.80	37.30	4.67	4.44	6.63
12G1001-2	10NM11-11	3152	1233	5.84	39.15	33.02	86.37	35.73	4.83	4.06	6.33
12G1001-3	10NM11-11	2805	1133	5.72	40.45	32.51	85.70	34.83	5.27	4.22	6.57
12G1001-1	10NM11-11	2672	1026	5.58	38.27	32.00	85.40	37.57	5.00	4.11	6.80
12G1029-1	10NM11-14	3270	1335	6.46	40.64	29.46	84.30	32.73	4.10	5.05	7.07
12G1026-1	10NM11-15	3348	1319	6.41	39.45	30.73	84.87	34.50	4.97	4.41	6.73
12G1013-1	10NM11-16	2970	1209	5.25	40.38	31.50	85.63	35.53	5.33	4.15	6.63
12G1004-1	10NM11-18	3286	1310	5.61	39.82	30.73	85.27	34.37	4.40	4.26	6.90
12G1024-1	10NM11-2	3601	1332	6.04	37.05	32.51	84.83	36.23	5.37	4.26	6.60
12G1016-1	10NM11-4	3068	1162	6.38	38.08	31.75	85.80	36.13	4.37	4.30	6.70
12G1009-1	10NM11-5	3314	1268	6.50	38.26	31.75	84.37	34.40	5.90	4.47	7.00
12G1014-1	10NM11-7	3685	1497	6.12	40.64	30.73	85.10	31.97	5.50	4.51	6.43
12G1014-3	10NM11-7	3153	1243	5.84	39.46	29.97	84.53	34.23	4.77	4.74	7.13
12G1014-2	10NM11-7	2959	1197	6.07	40.45	29.72	84.20	32.90	5.37	4.69	6.93
12G1003-1	10NM11-8	3688	1475	4.79	39.97	29.97	83.93	32.17	6.57	4.59	7.20
Parent 1	Acala GLS	2940	1179	6.56	40.07	31.75	85.07	36.60	4.17	4.43	6.80
Parent 2	Acala 1517-08	4400	1628	5.94	37.22	30.48	84.77	35.40	5.40	4.63	6.87
LSD 0.05		610	253	0.59	2.88	1.02	1.26	1.66	0.46	0.28	0.55

[z] SCY, seed cotton yield; LY, lint yield; UHM, upper-half length; UI, uniformity index; STR, fiber strength; MIC, micronaire; SFC, short-fiber content.

Table 3. Field performance of advanced breeding lines (F_6) from cross between Acala 1517-08 and glandless Acala GLS in Trial T, Las Cruces, NM, 2013

Selection	Source	SCY[z] kg ha^{-1}	LY[z] kg ha^{-1}	Boll g boll^{-1}	Lint %	UHM[z] mm	UI[z] %	STR[z] g tex^{-1}	ELO[z] %	MIC[z] unit	SFC[z] %
12G2022-2	10NM11-1	2820	992	6	35.14	31.24	84.63	35.93	4.43	4.25	6.7
12G2016-1	10NM11-12	3050	1130	5.89	37.07	30.99	85.77	36.3	4.67	4.31	6.6
12G2002-1	10NM11-13	3302	1327	5.97	40.17	30.73	83.97	34.1	4.73	4.53	7.33
12G2004-1	10NM11-16	3350	1295	5.2	38.7	32.51	86.47	37.2	5.4	4	6.37
12G2018-1	10NM11-17	2930	1132	5.53	38.63	31.24	85.1	36	4.3	4.42	7.07
12G2007-1	10NM11-2	3175	1274	6.36	40.07	30.99	85.33	35.07	4.87	4.45	6.7
12G2010-2	10NM11-3	4214	1591	5.49	37.51	30.99	85.13	34.47	5.03	4.44	6.87
12G2010-1	10NM11-3	3627	1467	6.46	40.44	30.48	83.8	33.6	4.87	4.32	7.57
12G2019-1	10NM11-4	3410	1300	6.36	38.08	31.50	85.17	35.47	4.4	4.38	6.73
12G2019-2	10NM11-4	2695	1051	5.77	38.95	30.99	84.37	34.93	4.23	4.45	6.87
12G2011-2	10NM11-5	2393	966	6.26	40.38	31.50	83.8	36.67	5.47	4.04	7.2
12G2011-1	10NM11-5	1874	687	5.97	36.77	30.73	84.07	30.97	4.3	4.12	7.4
12G2021-1	10NM11-7	3025	1202	6.16	39.82	30.99	85.43	34.3	5.1	4.5	6.57
12G2015-1	10NM11-9	2917	1067	5.58	36.6	31.24	85.87	37.5	5.23	4.23	6.6
Parent 1	Acala GLS	2373	956	6.34	40.37	31.24	85.23	37.83	4.3	4.28	6.73
Parent 2	Acala 1517-08	4115	1676	5.51	40.77	30.73	84.87	35.73	5.13	4.64	7.1
	LSD 0.05	765	305	0.60	1.76	1.27	1.42	1.81	0.44	0.29	0.55

[z] SCY, seed cotton yield; LY, lint yield; UHM, upper-half length; UI, uniformity index; STR, fiber strength; MIC, micronaire; SFC, short-fiber content.

Acala GLS had consistently stronger fibers than Acala 1517-08 and the differences were significant in two tests (Trials T and V). In Trials S, T, U, and V, four, two, three, and one lines had STR lower than the lower parent, Acala 1517-08, respectively, whereas many lines had similar STR to the higher parent, Acala GLS, but none was stronger. In Trial T, one of the two lines with the lowest STR also had the second highest LY and LP and largest bolls. In Trial V, the line (12G3011-4) with the weakest fibers also had significantly shorter fibers than the lower parent, Acala 1517-08. Overall, 32 lines had STR similar to Acala GLS, but none was stronger. However, 10 lines had weaker fibers than the lower parent, Acala 1517-08.

Acala GLS had consistently lower MIC than Acala 1517-08 and the differences were significant in three tests (Trials T, U, and V). In Trial S, one line had higher MIC than the higher parent, Acala 1517-08, whereas another had lower MIC than the lower parent, Acala GLS. All lines in Trial T had MIC between the two parents. In Trials U and V, each had two lines with significantly lower MIC than the lower parent, Acala GLS. Overall, most lines had MIC between the two parents; one had higher MIC than the higher parent, whereas five lines had lower MIC than the lower parent.

Table 4. Field performance of advanced breeding lines (F_6) from cross between Acala 1517-08 and glandless Acala GLS in Trial U, Las Cruces, NM, 2013

Selection	Source	SCY[z] kg ha^{-1}	LY[z] kg ha^{-1}	Boll g $boll^{-1}$	Lint %	UHM[z] mm	UI[z] %	STR[z] g tex^{-1}	ELO[z] %	MIC[z] unit	SFC[z] %
12G3001-5	10NM11-27	3563	1389	5.97	39.14	31.24	85.03	35.33	4.87	4.69	6.90
12G2031-1	10NM11-6	3704	1312	5.92	35.41	30.48	85.10	37.87	5.03	4.13	6.90
12G2023-1	10NM11-14	3448	1305	6.35	37.86	30.99	84.50	35.97	4.57	4.22	7.03
12G2030-1	10NM11-8	3444	1301	5.48	37.79	30.48	84.83	35.17	5.23	4.29	6.97
12G2033-1	10NM11-18	3320	1270	5.59	38.31	31.75	85.00	34.03	4.40	4.51	7.10
12G3001-2	10NM11-17	3331	1255	5.93	37.68	32.26	86.43	34.87	5.13	4.29	6.47
12G3005-4	10NM11-7	3077	1219	6.52	39.62	30.48	84.43	34.07	5.10	4.62	6.83
12G3005-5	10NM11-7	3114	1165	6.70	37.42	30.23	84.30	32.70	5.00	4.69	7.17
12G3001-1	10NM11-17	3149	1163	5.85	36.94	32.00	85.97	36.70	4.70	4.12	6.87
12G2024-2	10NM11-11	3050	1137	6.65	37.23	31.50	85.50	37.50	4.57	3.98	6.67
12G3001-3	10NM11-17	3061	1118	5.75	36.45	31.75	84.40	35.40	4.57	4.15	6.97
12G2025-2	10NM11-15	2780	1113	6.39	40.03	29.46	84.13	36.87	4.40	4.73	6.60
12G3005-2	10NM11-7	2913	1113	5.97	38.18	30.23	84.97	34.53	4.60	4.70	7.00
12G2024-1	10NM11-11	2778	1094	5.82	39.35	32.51	85.03	36.67	4.90	3.85	6.80
12G2025-1	10NM11-15	2743	1067	6.31	38.80	29.72	84.80	36.20	4.30	4.40	6.93
12G3005-1	10NM11-7	2761	1049	6.58	38.09	30.99	84.90	34.90	4.47	4.48	6.97
12G2025-4	10NM11-15	2901	1037	5.92	35.76	30.99	85.50	35.23	4.27	4.19	6.67
12G2031-2	10NM11-6	2799	1035	6.13	36.95	32.26	85.50	37.40	4.83	4.03	6.60
12G2033-2	10NM11-18	2971	1011	5.49	34.46	31.50	85.67	36.13	4.67	4.51	6.67
12G2023-4	10NM11-14	2740	1009	5.93	36.79	30.48	84.83	33.50	4.57	4.46	6.83
12G2033-3	10NM11-18	2684	1005	5.58	37.35	31.24	84.93	35.33	4.60	4.45	6.87
12G2025-6	10NM11-15	2575	955	5.75	37.05	30.48	85.27	36.23	4.13	4.30	6.70
12G3005-6	10NM11-7	2352	902	6.46	38.22	30.48	84.23	33.33	5.03	4.46	7.13
12G2025-3	10NM11-15	2463	889	5.97	36.03	30.73	85.73	35.23	4.43	4.03	6.70
12G3005-3	10NM11-7	2052	805	6.40	39.18	32.26	85.03	34.80	4.53	4.42	6.63
Parent 1	Acala GLS	2930	1128	6.84	38.49	31.24	86.17	37.97	4.03	4.26	6.57
Parent 2	Acala 1517-08	4593	1796	6.19	39.09	30.99	84.60	35.90	5.33	4.59	7.07
	LSD 0.05	598	232	0.66	2.26	1.02	1.42	2.32	0.44	0.26	0.61

[z] SCY, seed cotton yield; LY, lint yield; UHM, upper-half length; UI, uniformity index; STR, fiber strength; MIC, micronaire; SFC, short-fiber content.

Table 5. Field performance of advanced breeding lines (F_6) from cross between Acala 1517-08 and glandless Acala GLS in Trial V, Las Cruces, NM, 2013

Selection	Source	SCY[z] kg ha^{-1}	LY[z] kg ha^{-1}	Boll g boll^{-1}	Lint %	UHM[z] mm	UI[z] %	STR[z] g tex^{-1}	ELO[z] %	MIC[z] unit	SFC[z] %
12G3006-1	10NM11-1	3037	1217	5.58	40.07	30.48	84.60	32.97	5.10	4.67	7.10
12G3016-2	10NM11-10	2294	848	5.62	36.89	32.26	85.27	35.90	4.93	4.24	6.60
12G3016-1	10NM11-10	2079	748	5.32	35.99	32.51	85.83	37.60	4.00	4.18	6.50
12G3030-2	10NM11-14	3409	1348	5.79	39.56	31.75	85.60	35.27	5.87	4.59	6.77
12G3030-1	10NM11-14	2427	966	6.34	39.88	30.23	85.47	35.67	5.57	4.68	6.70
12G3013-3	10NM11-15	2744	1115	5.22	40.62	31.24	86.07	34.67	5.43	4.47	6.67
12G3013-2	10NM11-15	2076	794	5.65	38.23	30.23	86.07	35.73	5.07	4.46	6.53
12G3013-1	10NM11-15	1667	634	5.77	37.99	29.97	85.63	35.33	4.70	4.41	6.63
12G3019-2	10NM11-16	3224	1208	5.15	37.58	32.26	86.57	36.63	5.10	3.95	6.43
12G3019-1	10NM11-16	1807	716	5.08	39.89	30.73	85.00	35.53	5.70	3.87	6.83
12G3028-3	10NM11-2	2815	1098	6.24	39.00	30.99	85.17	36.43	4.80	4.20	6.93
12G3028-1	10NM11-2	2745	998	5.97	36.30	32.51	84.33	34.73	4.13	4.12	7.00
12G3011-3	10NM11-3	3119	1275	6.50	40.92	31.50	85.07	34.60	4.87	4.39	6.73
12G3011-5	10NM11-3	2872	1158	5.81	40.48	30.48	84.23	33.57	5.23	4.57	7.03
12G3011-2	10NM11-3	2802	1089	5.16	38.85	30.73	84.80	34.53	6.00	4.66	6.93
12G3011-4	10NM11-3	2435	992	6.07	40.72	29.97	83.60	31.60	4.60	4.63	7.50
12G3011-1	10NM11-3	2146	810	5.93	37.79	31.75	85.30	34.33	5.27	4.11	7.00
12G3023-2	10NM11-4	2876	1118	5.84	38.86	31.50	85.57	35.53	4.50	4.31	6.67
12G3023-1	10NM11-4	2324	912	6.00	39.18	31.24	84.83	36.07	4.03	4.17	7.00
12G3029-1	10NM11-5	2197	850	5.55	38.70	32.00	86.03	35.47	5.07	4.34	6.57
12G3029-2	10NM11-5	1979	739	5.15	37.36	30.48	85.23	34.63	5.33	4.20	6.60
12G3024-1	10NM11-8	3084	1252	5.85	40.58	30.73	85.27	34.23	6.60	4.68	6.63
12G3024-2	10NM11-8	2359	925	4.98	39.18	30.48	84.80	33.47	5.93	4.70	6.90
Parent 1	Acala GLS	2555	1033	6.33	40.38	31.75	85.87	36.83	4.33	4.25	6.67
Parent 2	Acala 1517-08	3410	1401	5.54	41.13	31.24	83.90	34.23	5.13	4.64	7.43
	LSD 0.05	860	320	0.43	1.33	1.27	1.30	1.87	0.49	0.27	0.55

[z] SCY, seed cotton yield; LY, lint yield; UHM, upper-half length; UI, uniformity index; STR, fiber strength; MIC, micronaire; SFC, short-fiber content.

Except for one line (which also had the longest fiber) in Trial S that had higher UI than the higher parent, Acala GLS, no transgressive segregation was detected. Also in Trial S, one line (12G2003-1) had higher ELO than the higher parent, but it also had the weakest fiber and higher SFC. This line also had the second highest LY and smallest bolls among the 15 lines. In Trials T, U, and V, all lines had UI, ELO, and SFC between the two parents except for three lines that had higher ELO than the higher parent, Acala 1517-08, in Trial V.

SUMMARY

In this study, 18 F_2-derived F_4 lines were selected from a total of approximately 500 F_2 individuals from a cross between glanded Acala 1517-08 and glandless Acala GLS. Whereas Acala 1517-08 had higher LY, Acala GLS had larger BW, higher UI, lower SFC and ELO, and fibers that had longer UHM, greater STR, and were finer (MIC). In the F_4 lines, due to unexpectedly lower LY in Acala 1517-08 and higher LY in Acala GLS, none had significantly lower or higher LY than both parents except for one with significantly higher LY. No lines had significantly lower or higher means than the lower parent or higher parent for BW, LP, UI, ELO, MIC, and SFC. However, half of the lines had shorter UHM than the parents that had the same UHM, whereas two lines had significantly lower STR than the lower parent, Acala 1517-08. The high-yielding results in F_4 were not confirmed in their F_6 lines. Only five

of the 77 F_6 lines yielded 90 to 96% lint of Acala 1517-08, three of which were selected from two of the eight high-yielding F_4 lines. These lines should be tested in more environments to assess more fully their potential. Transgressive segregation for lower trait values was observed. For example, two through four lines had lower LY and BW than the lower parents, and 22 lines had lower LP than the lower parent. No transgressive segregation for higher LY and LP or higher BW was observed in F_6. Sixteen lines had longer fibers than Acala 1517-08 including five lines with significantly longer UHM than the higher parent, Acala GLS, whereas four had fibers shorter than the lower parent, Acala 1517-08. Many lines had similar STR to Acala 1517-08 and Acala GLS including five lines with significantly stronger fibers than Acala 1517-08, but none was stronger than Acala GLS. However, 10 lines had significantly weaker fibers than Acala 1517-08. Five lines had significantly lower MIC (3.85-4.15) than the lower parent, Acala GLS; 28 lines had significantly lower MIC (< 4.32) than Acala 1517-08; and only one line had significantly higher MIC than Acala 1517-08. The lines with relatively high yield potentials (> 80% of Acala 1517-08) usually had shorter and weaker fibers. In general, no transgressive segregation was detected for UI, ELO, and SFC.

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