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AGRONOMY & SOILS

Comparative Performance of a Glandless Acala Cultivar and Two Glanded Acala Cultivars in New Mexico

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ABSTRACT

Commercial cultivation of glandless cotton (cotton plants with reduced or no gossypol) will widen the utility of cotton seed beyond its present main use as ruminant animal feed, producing higher income for cotton growers in New Mexico and the Beltwide states as a whole. An Upland cultivar of glandless cotton (Acala GLS) developed for California conditions was evaluated in New Mexico and compared to conventional glanded Acala cultivars (Acala 1517-08 and Acala 1517-99) developed in New Mexico. Four environments (two experimental stations and two commercial farm sites) were selected for testing. Planting was on one m row-spaced beds and irrigation was by furrows and/or sprinklers. A randomized complete block design was used at the research sites (Las Cruces and Artesia, NM), while paired comparisons were used for the commercial farm sites (Anthony and Garfield, NM). The Acala GLS cultivar generally had lower yields (about 12% lower at the research sites) compared to Acala 1517-08. At one of the commercial farm sites, Acala 1517-99 yielded over 50% more than Acala GLS. Fiber quality parameters of the cultivars were very good and within a similar range except for micronaire which was slightly better in the glandless cultivar at the research sites. Location, year and location x year effects were also significant on yield components. This study highlights the need for the development of more adaptable glandless cotton for the New Mexico environment and the need to study seasonal pest pressure for any emerging new insect pests.

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Glandless cotton (*Gossypium hirsutum* L.) is a normal cotton plant without gossypol, a poly-phenolic aldehyde, which inhibits several dehydrogenase enzymes (Cherry and Leffler, 1984). Gossypol is normally present in conventional cotton plants ("glanded cotton") as a natural defense mechanism against pests (Du et al., 2004; Gao et al., 2008). Cotton seed with gossypol is toxic to monogastric animals and must be fed carefully to ruminants to avoid acute gossypol poisoning. Excessive amounts of whole cotton seed or cotton seed meal fed to ruminants can affect the reproductive potential of the calves and cows, and may eventually lead to death (Randel et al., 1992). This limits the utility of cotton seed as food and feed (Fryxell, 1968).

Glandless cotton seed, free of gossypol, can serve as a rich protein source in human food and can also be fed to non-ruminants and aquatic animals such as shrimp and catfish (Lusas and Jividen, 1987; Cai et al., 2010). This can constitute a potentially large market and add significant value to cotton production (Lawhon et al., 1977). However, previous evaluations in many parts of the Cotton Belt indicated that glandless cotton is highly susceptible to chewing, piercing and sucking insect pests such as lygus and boll weevil and vertebrate pests (Benedict et al., 1977; Jenkins et al., 1966). New Mexico may be conducive to growing glandless cotton cultivars, with the eradication of boll weevil and pink bollworm, and lower insect pest populations than some other areas where glandless cotton was evaluated (Pierce et al., 2013). However, there is a lack of information regarding the yield potential of most recently developed glandless cotton. Furthermore, insect populations need to be monitored since insect pests have only been evaluated on the resistant glanded cotton and new insect pests may emerge that could be damaging to the glandless cotton.

The objective of this study was to evaluate the yield potential and the fiber quality of a glandless cotton cultivar (Acala GLS) that was developed under California conditions, in comparison with two established conventional cultivars (Acala 1517-99 and Acala 1517-08) adapted to New Mexico. These Acala cultivars are being compared because of their excellent fiber quality and adaptation to the western Cotton Belt.

MATERIALS AND METHODS

Trials were initiated in New Mexico to evaluate a glandless cotton cultivar Acala GLS (Dobbs et al., 2000), and compare its performance to conventional Acala 1517-99 (Cantrell et al., 2000) and Acala 1517-08 (Zhang et al., 2011) developed for the New Mexico environment. Field trials were set up at two New Mexico State University (NMSU) Agricultural Experiment Stations in Las Cruces and Artesia, NM. Additionally, two commercial farm sites (Anthony and Garfield, NM) were used for the evaluation. Information about the four sites is presented in Table 1.

At the Experiment Stations in Las Cruces and Artesia, Acala GLS was compared to Acala 1517-08 for two years (2010 and 2011 seasons); while at the commercial farm sites, Acala GLS was compared to Acala 1517-99 only, due to limited seed availability of Acala 1517-08. The trials at the commercial sites were conducted only in 2010. The experimental design at the commercial farms was a paired comparison with six replicates. At the Experiment Stations, the cultivars were randomized within the blocks in the field, with a total of four replicates.

Planting at all sites (research and commercial) was done on one m row-spaced beds and furrow irrigated at Leyendecker, Garfield, and Anthony sites. At the Artesia site, irrigation water was applied by sprinklers and by furrow irrigation. Plot dimension of the research sites was four rows (one m/row) that were 12 m long; while the plot size for the on-farm trials were on average 182 m x 30 rows. Cultural practices were performed according to those prescribed by New Mexico State University. Planting dates varied between the last week in April and the last week in May, and the harvest dates varied from middle to the end of November.

Close to harvest, 50 open bolls were collected from each plot (two bolls from each plant) and ginned using a 20-saw lab gin for boll weight, lint percentage and fiber quality determination. Quantitative field seed cotton yield was assessed by hand-harvesting seed cotton from the center six m section of the two inner rows within each plot. Lint yield was calculated by multiplying the seed cotton yield by the lint percentage from the 50 boll samples. Fiber quality was analyzed by High Volume Instrument (HVI) at Cotton, Inc., Cary, NC.

For the commercial sites, a t-test was used to assess if significant differences existed between the means of the different measured parameters. For the research sites, an analysis of variance (ANOVA) was performed on the data that were collected, to assess the significance of the effects due to cultivar, year, location and interactions. Mean separation was performed by the Student-Newman-Keuls Test after a significant F-ratio was detected. SPSS statistical package (IBM Corp., 2012) was used for data analysis.

RESULTS AND DISCUSSION

At the research sites, seed cotton, lint and seed yield were significantly different between the glandless cultivar and conventional cultivar, Acala 1517-08 at the 10% probability level (Tables 2 and 3). The glandless cultivar had 12% lower seed cotton yield, 11% lower lint yield, and 12% lower seed yield. The location and year effects were significant at the 1% level for seed cotton, lint and seed yield in that the Las Cruces location had higher yields than the Artesia location, and 2010 yields were significantly higher than 2011 yields (Tables 2 and 3). Higher seed cotton, lint and seed yields of the Acala 1517-08 over the Acala GLS at the research sites were not unexpected, since the former was specifically selected and developed

Table 1. Climatic and soil characteristics of the study sites.

Site	Coordinates	County	Soil Series	Soil Texture (0-0.25m)	Elevation (m)	Annual Rainfall (mm)
[Z]LPSC, Las Cruces, NM	N32.20595 W106.74951	Dona Ana	Agua clay loam	Clay loam	1,205	200 – 250
[Y]ASC, Artesia, NM	N32.753 W104.386	Eddy	Pima silt loam	Silt clay loam	1,128	250 – 400
Anthony, NM	N31.98932 W106.67603	Dona Ana	Harkey loam	Loam	1,192	200 – 250
Garfield, NM	N32.83447 W107.30027	Sierra	Brazito very fine sandy loam	Very fine sandy loam	1,410	200 – 250

[Z]Leyendecker Plant Science Center

[Y]Agricultural Science Center

for the environment of New Mexico (Zhang et al., 2011). Acala GLS was developed for California conditions almost fifteen years ago, and yielded similarly to the then glanded control Acala Maxxa (Dobbs et al., 2000). So, Acala GLS is an unadapted obsolete glandless cultivar. Acala 1517-08 is an improved cultivar over its predecessor, Acala 1517-99, which was tested at the commercial sites. Acala 1517-08 has been documented through the cotton official variety trials (OVT), a multi-state testing of cotton cultivars, to have higher lint yield and oil yield than the Acala 1517-99 (Zhang et al., 2011). For the commercial sites, the seed cotton, lint and seed yields of the Acala 1517-99 were also higher than Acala GLS at the Anthony site (Table 4). Similar to Acala 1517-08, the Acala 1517-99 was also specifically developed for New Mexico (Cantrell et al., 2000), and was expected to perform better than the Acala GLS, which was developed under the California environments and may be less tolerant to higher summer temperatures, which is a common occurrence in New Mexico. In addition, Acala GLS was released at the same time of Acala 1517-99 in 2000, and since then, many advances have taken place in cotton breeding. This cultivar may be obsolete and development of newer cultivars incorporating higher yielding traits is needed to replace it.

Table 2. ANOVA treatment effects and their interactions for yield measurements at the research sites, NM, 2010-2011.

Effects	Seed cotton yield (kg/ha)	Lint yield (kg/ha)	Cottonseed yield (kg/ha)	Lint percentage (%)	Boll weight (g)
Cultivar	+	+	+	ns	**
Location	**	**	**	ns	**
Year	**	**	**	ns	**
Cultivar x Location	ns	ns	ns	ns	*
Cultivar x Year	ns	ns	ns	ns	+
Location x Year	**	**	**	ns	*
Cultivar x Location x Year	*	*	ns	ns	**

**: Statistical significance at the 1% level

*: Statistical significance at the 5% level

+: Statistical significance at the 10% level

ns: no statistical significance

Table 3. Yield parameters of tested cultivars in Artesia and Las Cruces during 2010 and 2011.

Measurements	Locations	2010		2011		Across sites and years		
		Acala 1517-08	Acala GLS	Acala 1517-08	Acala GLS	Acala 1517-08	Acala GLS	[Z]LS
Seed cotton yield (kg/ha)	Artesia	3113	2451	2843	3430			
	Las Cruces	4725	4274	3387	2438			
	Mean	3919	3363	3115	2934	3517	3148	10%
Lint yield (kg/ha)	Artesia	1298	1018	1098	1383			
	Las Cruces	1795	1624	1355	975			
	Mean	1547	1321	1227	1179	1387	1250	10%
Seed yield (kg/ha)	Artesia	1954	1542	1863	2196			
	Las Cruces	3122	2824	2177	1567			
	Mean	2538	2183	2020	1882	2279	2032	10%
Lint percentage (%)	Artesia	41.7	41.6	38.8	40.4			
	Las Cruces	39.5	40.5	40.1	39.5			
	Mean	40.6	41.1	39.5	40.0	40.0	40.5	ns
Boll weight (g/boll)	Artesia	5.40	6.69	5.31	4.81			
	Las Cruces	5.98	6.57	5.33	6.62			
	Mean	5.69	6.63	5.32	5.72	5.51	6.17	1%

[Z]LS – level of statistical significance

Lower yields and the lack of significant difference in the cotton yield parameters between Acala GLS and Acala 1517-99 at the Garfield site (Table 4) may be related to soil nutrient issues. The field used for the trial at Garfield was a sandy loam soil (Table 1) previously under alfalfa production for four years. Soil test results showed sufficient levels of nitrogen in the soil before planting, but it is likely that the nitrogen status of the soil was rapidly depleted due to leaching losses by furrow irrigation in this sandy soil. This led to a mid-season nitrogen deficiency in cotton, observed in the field with cotton plants showing nitrogen deficiency symptoms during the boll development stage. Lack of sufficient vegetative growth at the Garfield site also resulted in an early cutout. Previous studies have documented the importance of nitrogen for successful growth and yield of cotton (Jackson and Gerik, 1990; Read et al., 2006). Nitrogen deficiency in the midseason especially in a full-season cultivar like Acala GLS will lead to severe yield reduction.

At the NMSU research sites, bolls of Acala GLS were about 12% heavier than those of the Acala 1517-08 (Table 3). Similarly at the commercial sites, the bolls of Acala GLS were about 11% heavier than Acala 1517-99 at the Anthony site, and 24% heavier than Acala 1517-99 at the Garfield site (Table 4). However, this heavier boll weight of the Acala GLS did not translate to yield increases, rather, there were yield reductions. Since the lint percentage was not significantly different between all the cultivars tested (Tables 2, 3 and 4), it was likely that Acala GLS had fewer bolls harvested. The heavier boll weight is most likely related to the seed size, as the glandless cultivar has larger seeds than the conventional cultivars.

Many of the fiber quality indicators measured were similar between the two cultivars (Acala GLS and Acala 1517-08) and the fiber qualities of both cultivars, measured at the research sites were generally very good (Tables 5 and 6). However, significant differences were found in micronaire and fiber strength (Tables 5 and 6). The micronaire of Acala GLS (4.25) was in the premium range and was significantly better than that of Acala-1517-08 (4.42). The mean fiber strength of both cultivars though significantly different (35.6 g/tex for Acala 1517-08 and 36.7 g/tex for Acala GLS), were both in the very strong category. For the commercial sites, many of the fiber quality measurements were also similar between the cultivars tested. But where there were significant differences, Acala GLS had better fiber quality than Acala 1517-99 (Table 4).

At the research sites, the effect of location proved highly significant for many of the measured parameters (Tables 2, 3, 5 and 6). Out of the five agronomic parameters measured and presented in Table 2, four measurements gave highly significant location effect at the 1% level. Similarly, four out of the six fiber quality parameters measured gave significant location effect (Table 5). This is an indicator that performances of these cultivars are highly affected by their testing locations. Generally, cotton yields were higher in Las Cruces compared to Artesia (Table 3), possibly due to the longer growing season in Las Cruces. Both Acala GLS and Acala 1517-08 are full season cultivars, and will be able to utilize the longer growing season in Las Cruces for greater photo-assimilate production, compared to Artesia with a slightly shorter season. Generally, the mean fiber quality measurements (except for micronaire) were similar between the two locations and where there were significant differences, they were not much of economic significance. The micronaire in Artesia (4.2) was in the premium range while the micronaire in Las Cruces (4.4) was in the base range (Table 6).

On average, the yields of seed cotton, lint and cotton seed were 19% higher in 2010 than in 2011 (Table 3). This was due to the very different weather patterns between the two years. In 2011, the weather in many cotton growing areas of New Mexico was characterized by extremely hot weather. In fact, many parts of cotton growing areas had the hottest summer on record. It was very hard to keep up with irrigation because the soil dried out so quickly. It is possible that the high temperatures in 2011, which led to high amounts of evapo-transpiration, may have resulted in reduced water availability in the soil profile. Also, field observations showed that there were more incidences of flowers and young bolls dropping during the period of excessive temperature. It is also worth noting that the lint yield dropped across New Mexico by an average of 10% between 2010 and 2011 according to the USDA crop statistics (USDA, 2012).

The effect of year on fiber quality was minimal (Tables 5 and 6), only the uniformity index and fiber strength differ significantly between the seasons. However, the values for this measurement did not prove to be economically significant (Table 6) since the measurements for both cultivars were in high to very high ranges.

Table 4. Results of yield and fiber quality measurements in Anthony and Garfield, NM.

Measurements	Anthony, NM			Garfield, NM		
	Acala 1517-99	Acala GLS	P-value	Acala 1517-99	Acala GLS	P-value
Seed cotton yield (kg/ha)	5020	3207	0.03*	1951	2161	0.07ns
Lint yield (kg/ha)	1908	1219	0.03*	742	821	0.07ns
Seed yield (kg/ha)	3112	1988	0.03*	1210	1340	0.06ns
Lint percentage (%)	37.9	38.8	0.59ns	42.3	40.9	0.56ns
Boll weight (g/boll)	6.30	7.07	0.006**	5.80	7.19	0.01*
Micronaire	4.63	4.25	0.07ns	4.95	4.76	0.07ns
Fiber length (mm)	30.99	32.51	0.04*	31.50	30.48	0.02*
Uniformity index (%)	85.18	86.90	0.06ns	86.65	85.90	0.47ns
Fiber strength (g/tex)	34.13	36.13	0.03*	33.80	37.10	0.04*
Fiber Elongation (%)	5.95	5.54	0.04*	6.13	6.15	0.94ns
Short fiber content (%)	6.95	6.35	0.06ns	6.78	6.63	0.10ns

**: Statistical significance at the 1 % level.

*: Statistical significance at the 5 % level

ns: no statistical significance

Table 5. ANOVA treatment effects and their interactions for fiber quality measurements at the research sites, NM, 2010-2011.

Effects	Micronaire	Fiber length (in)	Uniformity index (%)	Fiber strength (g/tex)	Fiber Elongation (%)	Short fiber content (%)
Cultivar	*	ns	ns	*	ns	ns
Location	*	+	**	ns	ns	*
Year	ns	ns	*	**	ns	ns
Cultivar x Location	*	ns	ns	ns	**	ns
Cultivar x Year	ns	*	**	ns	**	**
Location x Year	*	ns	ns	**	**	ns
Cultivar x Location x Year	*	ns	ns	ns	**	ns

**: Statistical significance at 1% level

*: Statistical significance at 5% level

+: Statistical significance at 10% level

ns: no statistical significance

While cultivar × location and cultivar × year interactions were not significant for yield (Table 2), the location × year interaction was highly significant for both the lint and seed yields. Yields were much higher for both cultivars in Las Cruces than Artesia site in 2010; however, in 2011, the yield differences between both sites were lower (Table 3). In fact, while Acala 1517-08 still yielded higher in Las Cruces than Artesia in 2011, the Acala GLS yielded lower in Las Cruces than Artesia (Table 3). It appeared that Acala GLS suffered more from heat during 2011 season in Las Cruces compared to Artesia. Although the interaction effects were significant for some of the fiber quality measurements (Tables 5 and 6), their values were mostly within the same ranges, which did not prove to be economically significant.

Overall, the Acala GLS under optimal growing conditions in New Mexico consistently gave lower lint and seed yields compared to the conventional Acala cultivars (Acala 1517-08 and Acala 1517-99). Apart from adaptability issues of the Acala GLS, another possible problem for the relative lower performance of this cultivar may be related to its higher insect pressure. Pierce et al. (2012) has shown that the glandless cotton experienced more damage from the beet armyworm feeding compared to the conventional cotton with gossypol. Insect pest data collected in 2010 during the mid-season in Artesia showed that the Acala GLS plots had an average of 6% damaged squares due to pest pressure, and this was significantly higher than the 1% damaged squares in Acala 1517-08 plots. However in 2011, there were no significant differences in averages of the damaged squares between the glandless (5.1%) and the glanded cultivars (5.9%). We did not observe any late season pest pressure during both years of study. The pest pressure may need further investigation.

CONCLUSIONS

A study was conducted to evaluate the performance of a glandless cotton cultivar developed in California (Acala GLS), in comparison to two locally adapted Acala cultivars (Acala 1517-08 and Acala 1517-99) in New Mexico. Comparison between Acala GLS and Acala 1517-08 was conducted at two research sites (Las Cruces, NM and Artesia, NM) during 2010 and 2011. The commercial site test was a side-by-side comparison between Acala GLS and Acala 1517-99 in 2010. The results show that there were significant differences between the cultivars in yield and fiber quality measurements. The locally developed cultivars yielded on average 12% more than the Acala GLS at the research site. While one of the commercial sites experienced nutrient stress, the other site at Anthony gave a drastic yield difference between the Acala GLS and Acala 1517-99 with the traditional cultivar yielding over 50% more than the glandless cultivar. Although there were significant differences in fiber quality measurements between the cultivars tested, most differences were very minimal and often without economic significance. Yield measurements were higher in Las Cruces than in Artesia, while the yields were higher during 2010 compared with 2011 growing season. Location x year interaction effects was significant for yields, and in Las Cruces yields were more affected by the seasonal variation compared to Artesia site.

This study highlights the need for research to develop new glandless cotton that will give higher lint and seed yields in the New Mexico production conditions. Agronomic evaluations of glandless cotton across multiple sites are also needed, to screen

Table 6. Fiber quality parameters of tested cultivars in Artesia and Las Cruces during 2010 and 2011.

Measurements	Locations	2010		2011		Across sites and years		
		Acala 1517-08	Acala GLS	Acala 1517-08	Acala GLS	Acala 1517-08	Acala GLS	ZLS
Micronaire	Artesia	4.48	4.16	4.04	4.30			
	Las Cruces	4.45	4.17	4.79	4.37			
	Mean	4.47	4.16	4.41	4.34	4.42	4.25	5%
Fiber length (mm)	Artesia	29.72	30.99	30.48	29.46			
	Las Cruces	31.50	32.00	31.75	29.97			
	Mean	30.61	31.50	31.12	29.72	30.86	30.61	ns
Uniformity index (%)	Artesia	83.50	85.20	84.10	83.18			
	Las Cruces	84.98	86.53	84.90	84.30			
	Mean	84.24	85.86	84.50	83.74	84.33	84.80	ns
Fiber strength (g/tex)	Artesia	35.38	36.73	36.63	35.93			
	Las Cruces	33.70	35.60	36.80	38.43			
	Mean	34.54	36.16	36.71	37.18	35.55	36.67	5%
Fiber Elongation (%)	Artesia	5.88	5.08	4.43	6.83			
	Las Cruces	6.25	5.75	5.87	4.70			
	Mean	6.06	5.41	5.15	5.76	5.59	5.59	ns
Short fiber content (%)	Artesia	7.55	6.73	6.98	8.05			
	Las Cruces	7.20	6.73	6.77	7.03			
	Mean	7.38	6.73	6.87	7.54	7.15	7.13	ns

ZLS – level of statistical significance

cultivars adapted to different cotton growing regions of New Mexico. Additionally, research into insect pest pressure and constant monitoring of glandless cotton fields to detect emergence of new pests will be necessary for the successful commercial production of glandless cotton.

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