PROGRESS IN BREEDING FOR GLANDLESS COTTON IN NEW MEXICO

Jinfa Zhang
John Idowu
Robert Flynn
New Mexico State University
Las Cruces, NM
Tom Wedegaertner
Cotton Incorporated
Cary, NC

Abstract

Breeding for glandless cotton commenced at New Mexico State University (NMSU) commenced when 20-40% yield gap existed between the then best glandless cultivar Acala GLS and the glanded Acala 1517-08. Direct selection breeding and both intraspecific cross breeding and interspecific introgression breeding have been employed to introduce two genetic sources of the glandless trait into Upland cotton. As a result, two commercial glandless Upland cultivars were recently developed, including NuMex COT 15 GLS (carrying Gl_2^e) released in 2015 and Acala 1517-18 GLS (carrying gl_2gl_3) released in 2016. NuMex COT 15 GLS was derived from an interspecific crossing and backcrossing between a dominant glandless trait donor and Chinese Upland cotton. The high-yielding NM 13P1117 was also developed through a similar interspecific introgression breeding scheme. Both NuMex COT 15 GLS and NM 13P1117 were shown to be highly resistant to race 4 of Fusarium wilt and resistant to leaf spot. Glandless cotton was found to respond to Verticillium wilt and thrips damages similarly to glanded cotton, while some glandless lines were even more resistant to thrips. The glandless Acala 1517-18 GLS was derived from a cross between Acala 1517-08 and an obsolete glandless Acala. These three glandless lines are adapted to the New Mexico and far-west Texas environments and have had limited commercial production (several hundred acres) in local cotton farms since their releases.

Introduction

Glandless cotton (i.e., devoid of gossypol) can produce glandless seeds as food for human consumption and feed for animals. Therefore, planting and utilization of glandless cottonseed can add value to cotton production by significantly increasing the net income for cotton producers and cottonseed processers.

There are four genetic sources for glandless cottonseed production:

1. A double recessive glandless cotton conditioned by two recessive alleles, gl_2 and gl_3 in Upland cotton, *Gossypium hirsutum* (McMichael, 1960; Kohel, 1979). All of the glandless cotton germplasm deposited in the National Cotton Germplasm Collection are homozygous recessive gl_2gl_3. The potential of the glandless cotton in production and utilization was not realized in the U.S., although there were cultivars and breeding lines released prior to the 2000s. The yield gap between the last glandless cultivar Acala GLS released in 1999 and Acala 1517-08 was very large, at 20-40% (Idowu et al., 2014; Zhang et al., 2014a,b).
2. An incomplete dominant glandless cottonseed mutation ‘Bahtim 110’ identified in Egyptian ‘Giza 45’ (*G. barbadense*) after irradiation of the seed, controlled by a dominant gene Gl_2^e (Kohel and Lee, 1984). There were no breeding activities using this glandless source in the U.S.
3. A glanded plant and glandless cottonseed trait in a few wild diploid Australian cotton species, as represented by *G. bickii*. The trait has not been successfully transferred into Upland cotton and utilized.
4. A genetically engineered (GE) cotton producing ultra-low gossypol cottonseed (Sunilkumar et al., 2006). Petition for deregulation of the GE low-gossypol trait was recently applied. Introduction of this trait to elite cotton has been on-going.

This poster reports the progress in breeding for glandless cotton based on the naturally occurring glandless traits (i.e., gl_2gl_3 and Gl_2^e) at New Mexico State University since the mid-2000s. Two glandless cultivars (Zhang et al., 2016, 2017) and one breeding line were released for use, and numerous progress reports in annual Beltwide Cotton Conferences have been presented, in addition to several refereed publications (Idowu et al., 2014; Zhang et al., 2014a,b; Zhu et al., 2017).

Timelines in breeding for glandless cotton at NMSU

In the mid-2000s, field tests were conducted to compare the performance of Acala cotton germplasm including one obsolete glandless Acala G8160. In the meantime, introgression breeding between Upland and Pima cotton continued.

In 2010-2011, cross breeding for glandless Upland cotton was initiated by crossing Acala 1517 with obsolete glandless cotton.

In 2012, 35 new glandless lines were tested in a replicated trial in Las Cruces, NM. Approximately 70 exotic glandless lines were collected and grown in the field with selections made. More crosses between glandless cotton and glanded cotton were made.

In 2013, 150 new glandless breeding lines were evaluated in several replicated field tests. Numerous new selections were once again made.

In 2014, tests of new glandless lines were performed at three locations (Las Cruces, Artesia, and Tucumcari) of New Mexico and 14 locations across the Cotton Belt. In the meantime, three acres were used for seed increase for new glandless cotton lines. In the greenhouse, the 150 new glandless lines tested in the field in 2013 were evaluated for thrips and Verticillium wilt resistance in the greenhouse. Under both the greenhouse and field conditions, 30 glandless lines together with two glanded checks were also tested for Verticillium wilt resistance.

In 2015, new glandless lines were tested at 14 locations across the Cotton Belt and also in three locations of New Mexico (Las Cruces, Artesia, and Tucumcari). Non-GMO seed increase for new glandless lines was arranged. Two replicated field tests were further performed in both Las Cruces and Artesia with each test having 30 glandless lines and two glanded checks for field performance and Verticillium wilt resistance.

In 2016 and 2017, increased breeding activities for glandless cotton have continued, which included: (1) 400-600 progeny rows; (2) several replicated field tests with 32 lines each; and field and/or greenhouse tests for resistance to thrips, Verticillium wilt, bacterial blight, cotton rust, and leaf spot on an annual basis.

It should be pointed out that, all the field trials in New Mexico did not receive any insecticide applications including no seed treatment since 2010 when bollworms and plant bugs did not cause significant lint yield losses.

Yield, and insect and disease resistance related to the glandless trait

Although both the dominant glandless gene (Gl_2^e) and the double recessive glandless genes (gl_2gl_3 and Gl_2^e) were found to have no deleterious effects on lint yield, other agronomic traits, and fiber quality (Halloin et al., Yuan et al., 2000), our studies showed that the most recent glandless Upland cultivar Acala GLS released in 2000 had a yield gap from Acala 1517-08 and/or Acala 1517-99, i.e., by 20-40% lower (Idowu et al., 2014; Zhang et al., 2014a). Therefore, our breeding program would have to significantly bring the yield of any new glandless cotton cultivar up to be relatively competitive as compared to commercial glanded cotton cultivars. However, past studies indicated that only about 1% increase in lint yield per year can be achieved through cotton breeding.

Another important challenge is the possible susceptibility of glandless cotton to insect pests and diseases, as documented in the past. In several of our studies, we found that glandless cotton as a whole is not more susceptible to thrips damage than glanded cotton, if not more resistant (Zhang et al., 2014b). In several field and greenhouse studies, we have also found that glandless cotton was not more susceptible to Verticillium wilt than glanded cotton. In fact, several new glandless cotton lines were shown to be more resistant to leaf spot in several field trials (Zhu et al., 2017). Two new glandless lines- NuMex COT 15 GLS and NM 13P1117 were found to be as highly resistant to Fusarium wilt race 4 as the resistant Pima cotton PHY 802RF and PHY 811RF. However, we are presently unsure if the resistance is related to the glandless trait or a gene closely linked to the dominant glandless gene (Gl_2^e) on chromosome c12.

<u>NuMex COT 15 GLS (formerly NM 12P1004)</u>

It is the first glandless Upland cotton cultivar from interspecific introgression breeding with *G. barbadense*, released by New Mexico Agricultural Experiment Station in 2015 (Zhang et al., 2016).

Pedigree: F1 between a *G. barbadense* Gl_2^e donor and glanded Upland cotton CRI 12, followed by 5 generations of backcrossing with CRI 35.

Tests: It was tested in four replicated field trials in New Mexico in 2013 and 2014, and 11 tests across nine states in 2014.

Lint yield: It produced 50% higher lint yield than glandless 'Acala GLS', and yielded 90% of glanded 'Acala 1517-08' (Fig. 1).

Fiber quality: medium to long staple with high strength and uniformity, with similar fiber quality to other commercial medium staple cultivars, but inferior to both Acala cultivars.

Thrips (*Thrips or Frankliniella* spp.): similar response to Acala 1517-08 and Acala GLS.

Verticillium wilt (*Verticillium dahliae*): similar response to Acala 1517-08 and Acala GLS.

Fusarium wilt (*Fusarium oxysporum* f. sp. *vasinfectum*): resistant to race 4.

Leaf spot (*Alternaria alternata*): significantly lower damage than Acala 1517-08 and other commercial cultivars.

Fig. 1. Field performance of NuMex COT 15 GLS with no insecticide applications, Leyendecker Plant Science Center, New Mexico State University, Las Cruces, NM, 2014.

Acala 1517-18 GLS

It is the first glandless Acala cotton cultivar released in New Mexico in 2016 (Zhang et al., 2017).

Pedigree: Acala 1517-08/Glandless Acala.

Tests: It was tested in 11 field trials in New Mexico in 2013-2016 and 14 tests across 11 U.S. states in 2015.

Lint yield: It yielded 93% of Acala 1517-08 across all the tests, but produced 30% higher lint yield than Acala GLS.

Fiber quality: It possesses Acala type fiber quality, similar to Acala 1517-08 and Acala GLS in fiber length, uniformity, strength and micronaire, with similar or higher elongation and similar or lower short fiber content. It has longer and stronger fibers, higher fiber length uniformity and elongation, but lower micronaire and short fiber content than most of the other medium-staple commercial checks.

Thrips (*Thrips* or *Frankliniell*a spp.): similar to Acala 1517-08 and Acala GLS.

Verticillium wilt (*Verticillium dahliae*): similar or higher level of resistance than Acala 1517-08 and Acala GLS.

Fusarium wilt (*Fusarium oxysporum* f. sp. *vasinfectum*): unknown.

Leaf spot (*Alternaria alternata*): Lower than or similar to Acala 1517-08 and other commercial cultivars.

Acala 1517-18 GLS, Las Cruces, NM, 2015

Acala 1517-18 GLS, Las Cruces, NM, 2015

Fig. 2. Field performance of Acala 15 17-18 GLS with no insecticide applications, Leyendecker Plant Science Center, New Mexico State University, Las Cruces, NM, 2015.

NM 13P1117 (formerly NM 12P1005)

It was the first glandless (carrying dominant glandless Gl_2^e) cotton line with a high yield potential and Fusarium wilt (race 4) resistance. Its release is under consideration by New Mexico Agricultural Experiment Station as a resistance source for Fusarium wilt race 4.

Pedigree: It was derived from a cross between a *G. barbadense* Gl_2^e donor and glanded Chinese Upland cotton.

Tests: It was tested in 11 replicated field trials in New Mexico in 2013-2017 and 11 tests across the U.S. Cotton Belt in 2014.

Lint yield: It had similar yield to Acala 1517-08 across all the tests, but it produced the highest yield among all glandless cotton lines tested.

Fiber quality: similar to NuMex COT 15 GLS, but with a shorter fiber length. It is inferior to Acala 1517-08 and Acala GLS.

Thrips (*Thrips* or *Frankliniella* spp.): similar to Acala 1517-08 and Acala GLS.

Verticillium wilt (*Verticillium dahliae*): similar or higher level of resistance than Acala 1517-08 and Acala GLS.

Fusarium wilt (*Fusarium oxysporum* f. sp. *vasinfectum*): resistant to race 4.

Leaf spot (*Alternaria alternata*): significantly lower damage than Acala 1517-08 and other commercial cultivars.

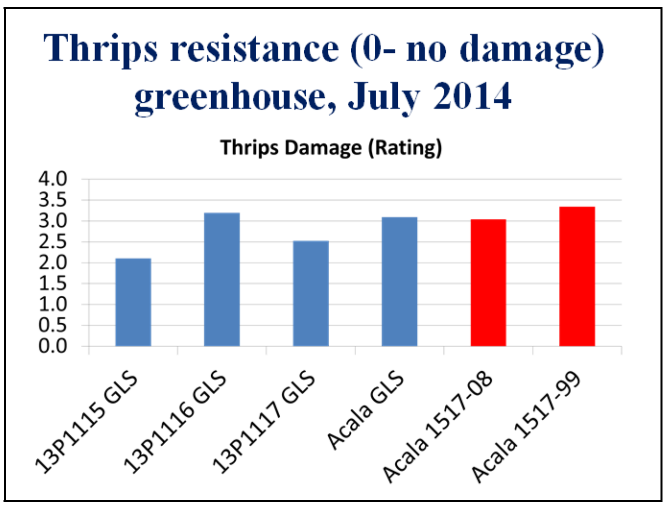


Fig. 3. Thrips resistance based on leaf damage severity rating, Greenhouse, New Mexico State University, Las Cruces, NM, 2014.

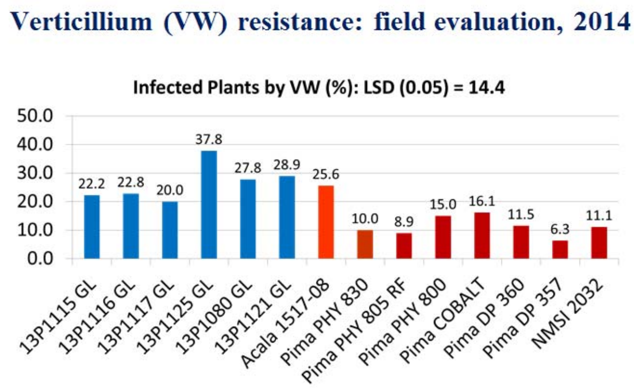


Fig. 4. Verticillium wilt resistance based on percentage of infected plants in the field,
New Mexico State University, Las Cruces, NM, 2014.

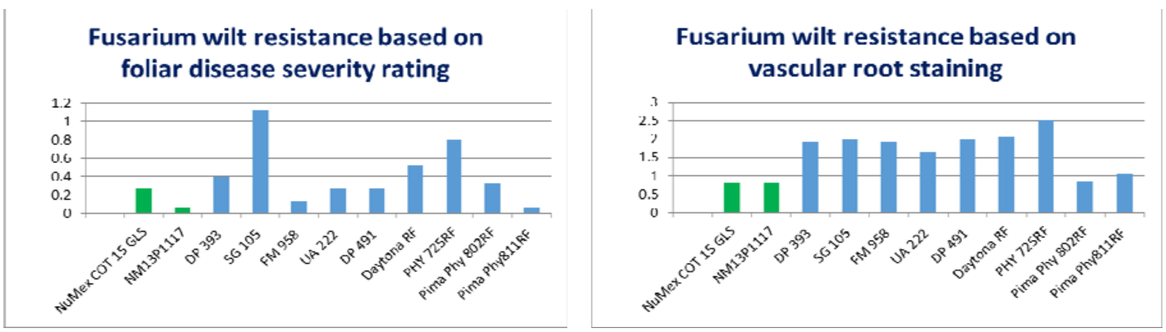
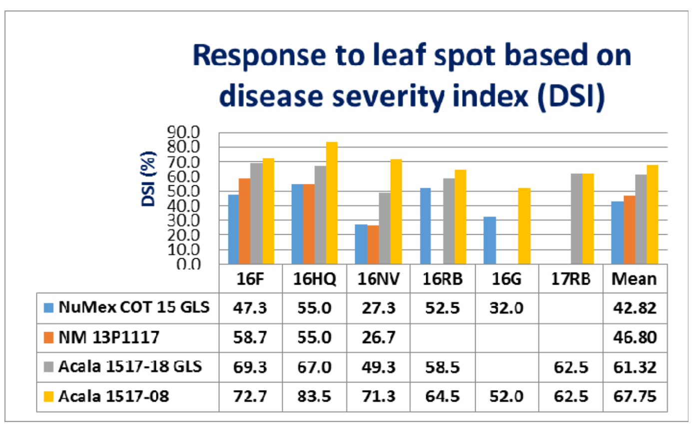


Fig. 5. Fusarium wilt resistance based on leaf disease severity rating and root vascular staining, CA, 2014.



	16F	16HQ	16NV	16RB	16G	17RB	Mean
NuMex COT 15 GLS	47.3	55.0	27.3	52.5	32.0		42.82
NM 13P1117	58.7	55.0	26.7				46.80
Acala 1517-18 GLS	69.3	67.0	49.3	58.5		62.5	61.32
Acala 1517-08	72.7	83.5	71.3	64.5	52.0	62.5	67.75

Fig. 6. Leaf spot resistance based on leaf damage severity rating, Leyendecker Plant Science Center,
New Mexico State University, Las Cruces, NM, 2016-2017.

References

Halloin, J.M., J.H. Turner Jr., and P.E. Hoskinson. 1978. Comparison of seed and fiber properties and yield of glanded and glandless cottons. Crop Sci. 18:519-520.

Idowu, O.J., J.F. Zhang, R.F. Flynn, J.B. Pierce, and T. Wedegaertner. 2014. Comparative performance of a glandless Acala cultivar and two glanded Acala cultivars in New Mexico. J. Cotton Sci. 18:122-128.

Kohel, R.J., and J.A. Lee. 1984. Genetic analysis of Egyptian glandless cotton. Crop Sci. 24:1119-1121.

McMichael, S. C. 1960. Combined effects of glandless genes g12 and g13 on pigment glands in the cotton plant. Agron J. 52:385-386.

Sunilkumar, G., M. Campbell, L. Puckhaber, R.D. Stipanovic, and K.S. Rathore. 2006. Engineering cottonseed for use in human nutrition by tissue-specific reduction of toxic gossypol. Proc. Natl. Acad. Sci. (USA) 103:18054-18059.

Yuan, Y.L., Y.H. Chen, C.M. Tang, S.R. Jing, S.L. Liu, J.J. Pan, R.J. Kohel, and T.Z. Zhang. 2000. Effects of the dominant glandless gene Gl_2^e on agronomic and fibre characters of upland cotton. Plant Breed. 119:59-64.

Zhang, J.F., O.J. Idowu, R. Flynn, T. Wedegaertner, and S.E. Hughs. 2014a. Genetic variation and selection within glandless cotton germplasm. Euphytica 198: 59-67.

Zhang, J.F., O. J. Idowu, T. Wedegaertner, and S.E. Hughs. 2014b. Genetic variation and comparative analysis of thrips resistance in glandless and glanded cotton under field conditions. Euphytica 199: 373-383.

Zhang, J.F., J. Idowu, R. Flynn, S.E. Hughs, D.C. Jones, and T. Wedegaertner. 2016. Registration of glandless 'NuMex COT 15 GLS' cotton. J. Plant Reg. 10: 223-227.

Zhang, J.F., T. Wedegaertner, O. J. Idowu, S. Sanogo, R. Flynn, and S.E. Hughs, and D.C. Jones. 2017. Registration of a glandless 'Acala 1517-18 GLS' cotton. J. Plant Reg. (accepted).

Zhu, Y., P. Lujan, S. Dura, R. Steiner, T. Wedegaertner, J.F. Zhang, and S. Sanogo. 2017. Evaluation of commercial Upland (*Gossypium hirsutum*) and Pima (*G. barbadense*) cotton cultivars, advanced breeding lines and glandless cotton for resistance to Alternaria leaf spot (*Alternaria alternata*) under field conditions. Euphytica (submitted Nov. 2017).