UA212NE - A NEW NECTARILESS COTTON VARIETY

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Abstract

Nectariless cotton varieties provide a tool that can be employed to combat tarnished plant bugs (TPB). Nectariless genes were transferred to Upland cotton in the 1960's, and nectariless varieties became commercially available in the 1980's. Insecticide treatments used to control boll weevils and the bollworm/budworm complex often masked the influence of nectariless cotton on TPB populations. My cotton breeding program has sought to develop nectariless lines since 1978. None of my nine nectariless lines released prior to 2018 produced exceptional yield and fiber quality. UA212ne, a conventional, nectariless cotton variety released by the Arkansas Agricultural Experiment Station in 2018, represents an ongoing effort to develop improved genotypes having enhanced yield, yield components, earliness, host plant resistance, and fiber properties. UA212ne was compared to 'DP 393' and 'UA48' over four years and four test sites in Arkansas. Over all test sites, lint yields of UA212ne was 8.4 and 13.6% higher those of DP 393 and UA48, respectively, with higher relative yields on silt loam soils than on clay soils. In the 2016 Regional Breeders' Network Test, UA212ne produced lint yields equal to the highest yielding line at each of the 13 locations. Yields of UA212ne were produced with highly efficient yield components, namely very high values of lint percentage, lint index, fibers per seed and fiber density. Host plant resistance traits measured on UA212ne include bacterial blight resistance, Verticillium wilt tolerance, and resistance to tarnished plant bug. This combination of host plant resistance and yield components should lead to more stable yield production over contrasting environments. Fiber quality of UA212ne exceeded that of DP 393, but was lower than UA48 and was similar to that of UA222 – thus is better than most commercial cultivars.

Introduction

Cotton (*Gossypium hirsutum* L.) production benefits from improved levels of host plant resistance. The nectariless (absence of nectaries) trait has long been associated with improved resistance to *Lygus* spp. plant bugs (Jenkins and Wilson, 1996). Nectaries normally appear on the abaxial midrib of each cotton leaf and at the base of and between bracts of every cotton fruit. A primary role of the nectaries on cotton plants is to attract cross-pollinating insects. Subsequent crossing of flowers leads to greater diversity and enhances the likelihood that the species will survive in wild conditions. However, modern cotton production does not rely upon or need cross-pollination. In addition to attracting cross-pollinating insects, nectaries also attract some harmful insects including tarnished plant bug (TPB, *Lygus lineolaris* (Palisot de Beauvois). TPB currently causes more loss to cotton in Arkansas than any other insect pest (Cook, 2018).

History of Nectariless Cotton

The nectariless trait was derived from the wild tetraploid species of cotton, *G. tomentosum* Nuttall, which is native to Hawaii. Meyer and Meyer (1961) successfully transferred the trait to Upland cotton,, and showed that two recessive genes controlled its expression. In separate studies, no deleterious effects were associated with the nectariless trait (Meredith et al, 1973; Meredith, 1980). In a review, Meredith (1998a) cited 10 studies that showed reductions in *Lygus* spp. populations on nectariless cotton ranging from 26.2 to 66.6% with an average of 48.8%. He indicated that most studies measuring both target insects and their natural enemies showed a greater reduction in target insects than in the natural enemies. Benedict et al. (1981) showed that the genetic background of nectariless lines affected the response of western plant bug (*Lygus hesperus* Knight) to the trait. This finding suggests that a resistance mechanism in addition to the nectariless trait might be present in some lines.

An Australian study, using plot sizes ranging from 0.25 to 10a, suggested that the benefit of nectariless trait lessened as plot size increased (Adjei-Maafo and Wilson, 1983). However, Scott et al. (1988) conducted a definitive study of 33 fields (over two years) ranging from 40 to 150a in the Mississippi River Delta, and found reductions of over 40% in TPB populations in each of two years. They concluded that "nectariless cotton can suppress plant bug

populations over a large area of cotton". The development and release of nectariless varieties by private companies made this large plot study possible.

W.R. Meredith, Jr. was responsible for much of the foundation breeding work associated with the nectariless trait in cotton. His releases included nine nectariless germplasm lines (Meredith, 1977), eight isogenic lines having combinations of sub-okra leaf, smooth leaf, and nectariless trait (Meredith, 1998b), and a nectariless variety (Meredith, 1993). The UA Cotton Breeding program has used several of his lines (specifically MD09ne, MD25ne, MD25-26ne, MD26ne, MD51ne and nectariless isogenic lines of DES119) as nectariless parents.

Based on communication with Meredith, private companies developed and released six nectariless cotton cultivars (Zeng et al., 2018). Nectariless varieties listed with Plant Variety Protection (PVP) numbers include 'Stoneville 731N' (PVP 007600048), 'Stoneville 825' (PVP 007900024), 'Deltapine NSL' (PVP 008300112), and 'DP 0935 B2RF' (PVP 200900062). 'MD51ne' (PI 566941) was released as a public variety without PVP (Meredith, 1993). Various studies mention nectariless Acala, Coker (specifically Coker 84-828ne), and other Deltapine lines, but the release status of these lines is unclear.

Stoneville 825 was the most successful of the nectariless varieties. It occupied from 7 to 17% of U.S. acreage (18 to 45% of Arkansas acreage) in the early 1980's and from 9 to 3% of U.S. acreage (19 to 4% of Arkansas acreage) in the late 1980s. Prior to boll weevil eradication and the advent of Bt cotton, the full impact of the nectariless trait on TPB was hindered by systematic treating of fields for boll weevils and the Heliothine (bollworm/budworm) complex. After boll weevils were essentially eradicated and Heliothine spp. were mostly controlled by Bt cottons, the relative importance of TPB as a cotton pest greatly increased. The late maturity of DP 0935 B2RF - a nectariless, Bt variety - may have been hindered its acceptance and popularity.

My Breeding Experience with the Nectariless Trait

A total of 689 different cross combinations were made in my breeding programs from 1978 through 2007, of these 114 (16.5%) were with nectariless lines. Additionally, I made selections from 102 lines obtained from other cotton breeders during this time, of these seven were nectariless. Most of the 102 lines were materials developed by C.W. Smith while he was at the University of Arkansas. From these crosses and materials having an associated nectariless parent, nine nectariless and four nectaried germplasm lines were released (Table 1).

Table 1. Nectariless (ne) and nectaried (NE) germplasm lines developed by F.M. Bourland from materials having at least one nectariless parent.

Line	Pedigree	NE/ne	PI	Citation
Miscot 7813	TX GN-6-76 / TX MAR-22-74	NE	607312	Crop Sci. 27:367 (1986)
Miscot 7918	Stoneville 825 / TX LEBO-2-78	ne	520750	Crop Sci. 29:242 (1988)
Arkot 8102	Stoneville 825 / Miscot T8-27	NE	595852	Crop Sci. 37:1396 (1995)
Arkot A132	Stoneville 825 / FTA 266	NE	598083	Crop Sci. 38:567 (1996)
Arkot 9406ne	LA 850082FN / Ark 8726-22-01	ne	641704	Crop Sci. 46:1833 (1996)
Arkot 9605ne	TX-NBLG8C5SHS-2-93 / Ark 8604-01-13	ne	641705	Crop Sci. 46:1833 (1996)
Arkot 9631ne	MD 51ne / Arkot 8110	ne	641706	Crop Sci. 46:1833 (1996)
Arkot 9608ne	MD 51ne / Arkot 8712	ne	651854	JPR 2:125-128 (2008)
Arkot 9623	DES 119 sl ne / Arkot 8712	NE	651858	JPR 3:69-72 (2009)
Arkot 0403ne	Arkot 9608ne / Arkot 9208	ne	674469	JPR 9:353-357 (2015)
Arkot 0502ne	Arkot 9608ne / Miscot T8-27	ne	677330	JPR 11:66-70 (2017)
Arkot 0504ne	Arkot 9608ne / Arkot 9314	ne	677331	JPR 11:66-70 (2017)
Arkot 0506ne	Arkot 9608ne / Arkot 9208	ne	677332	JPR 11:66-70 (2017)

None of these nine nectariless lines possessed exceptional yield and fiber quality, but each represented improvement in my nectariless germplasm materials. Arkot 9608ne was distinctly better than the previously released nectariless lines, and subsequently served as a good nectariless parent. We began identifying nectariless plants in F_2 through F_4

generations in about 2000 – thus, establishing the nectariless trait in early generations. Previously, crosses having a nectariless parent often produced nectaried lines. The performance of these early nectariless lines and the difficulty of establishing nectariless without direct selection raised some doubt regarding the neutrality of the nectariless trait relative to agronomic performance in this breeding program.

From 2008 through 2018, we have made 270 additional cross combination, 68 (25.2%) of them involving one or more nectariless parents. This increased percentage indicates that development of the nectariless trait has become a higher priority in my program. Several nectariless lines are now at various stages of testing.

Performance of UA212ne

The nectariless variety 'UA212ne' (tested as Ark 0812-87ne and released in September 2018) was derived from a 2008 cross between Arkot 0016 (Bourland and Jones, 2011) and JAJO 4141 (nectariless breeding line obtained from Dr. Jack Jones). UA212ne displays the nectariless characteristic, derived from its JAJO 4141 parent.

UA212ne was compared to DP 393 and UA48 over four years and four test sites in Arkansas. Compared to DP 393, UA212ne produced higher lint yields on silt loam soils at Marianna (25.2% higher), Rohwer (6.7%) and Judd Hill (5.5%), but equal yields on clay soil at Keiser (Table 2). Over all test sites, lint yields of UA212ne exceeded those of DP 393 by 8.4% and UA48 by 13.6% (Table 3). The yields of UA212ne were produced with highly efficient yield components, namely very high values of lint percentage, lint index, fibers per seed and fiber density. This combination of yield components should led to more stable yield production over contrasting environments. Considering its relative seed index (seed size), the relative increases in lint index, fibers per seed and fiber density associated with UA212ne are particularly impressive.

Table 2. Lint yields of UA212ne compared to DP 393 and UA48 at locations† in the Mississippi River Delta region of Arkansas from 2014 through 2017.

Line†	Keiser	Judd Hill	Marianna	Rohwer
	lb ac^{-1}	lb ac^{-1}	lb ac^{-1}	lb ac^{-1}
UA212ne	895	1155	1335	1030
DP 393	936	1095	1066	965
UA48	851	1054	1032	927
LSD0.10	87	88	65	77

† Locations are in Mississippi River Delta and are arranged from north (left) to south (right) in table.

Table 3. Yield and yield component-related parameters for UA212ne compared to two check varieties over years from 2014 through 2017 at Arkansas test sites†.

Line	Lint yield	Lint fraction	Seed ac^{-1}	Lint index	Seed index	Fibers seed^{-1}	Fiber density
	lb ac^{-1}	%	no.x 10^{6}	g	g	no.	no. mm^{-2}
UA212ne	1100	42.2	6.243	8.0	10.7	17177	162
DP 393	1015	39.5	6.098	7.6	11.3	15646	141
UA48	968	37.8	5.735	7.7	12.3	13840	117
LSD0.10	45	0.7	0.323	0.2	0.4	573	6

† Each parameter was determined in tests at Keiser, Judd Hill, Marianna, and Rohwer. Lint fraction, seed index, lint index, fiber seed^{-1}, and fiber density were determined from boll samples taken from two replications per test. Lint yield and seed ac^{-1} were determined on four replications per test. Location by line interaction was significant (P = 0.10) for lint yield, seed ac^{-1}, and lint index.

UA212ne was evaluated in the 2016 Regional Breeders' Network Test (http://rbtn.cottoninc.com/files/). Among 28 entries in the test, UA212ne produced the second highest lint yield (only 1 lb ac^{-1} less than the highest yielding line) over all 13 locations, and produced yields equal to the highest yielding entry at each location. Over all locations of this test, lint yields of UA212ne were significantly higher than four check varieties (DP 393, 'SG 105', 'FM 958', and 'DP 491') and was equal to the fifth check, 'UA222'. These yields indicate that UA212ne is broadly adapted to contrasting growing conditions within Arkansas and across the U.S. Cotton Belt.

Plant height of UA212ne in the Arkansas tests was equal to DP 393 and greater than UA48 (Table 4). Open boll percentage of UA212ne was equal to DP 393 and lower than UA48. Both UA212ne and DP 393 would be considered short-season, early maturing genotypes, but slightly later than UA48. UA212ne had slightly lower leaf pubescence ratings than DP 393 but greater than UA48. In these tests, leaf pubescence of UA212ne and DP 393 would be considered "lightly hairy". Stem pubescence of UA212ne did not vary from the check cultivars. Bract trichome density of UA212ne was lower than DP 393 and equal to UA48. Lower bract trichome density is related to reduced trash in fiber samples (Boykin et al., 2013). Other morphological traits of UA212ne were not different from DP 393.

Table 4. Morphological and host plant resistance traits for UA212ne and check varieties in 2014 through 2017.

Line	Plant height	Open bolls†	Leaf pubes.‡	Stem pubes.‡	Bract trichomes§	Vert. wilt¶	Damaged flowers#
	cm	%	Rating	rating	no. cm^{-1}	%	%
UA212ne	104	52	3.5	5.5	26.5	42	51
DP 393	101	55	3.9	5.7	35.7	43	55
UA48	95	59	2.5	5.5	28.9	44	67
Sus. check	-	-	-	-	-	-	92
LSD0.10	10	5	0.4	ns	3.1	12	4

† Percentage of open bolls visually estimated at approximately time of defoliation in each test. Location by line interaction was significant (P = 0.10).

‡ Leaf and stem pubescence visually rated on 6 plants per plot (4 reps) at Keiser, AR, from 1 (smooth) to 9 (pilose) using rating system developed by Bourland et al. (2003).

§ Number of marginal bract trichomes determined on 6 plants per plot (4 reps) at Keiser, AR, using methods described by Bourland and Hornbeck (2007).

¶ Percentage of plants showing visual leaf symptoms of Verticillium wilt in the 2016 and 2017 Verticillium Wilt Tests at Judd Hill, AR. To encourage wilt symptoms, plots were arranged adjacent to irrigation pipe and plant stands were thinned to approximately two plants row ft^{-1}.

Percentages of flowers with discolored anthers were determined in tests (8 reps) at Keiser, AR, in 2015 through 2017, with all lines included in same test each year. Discolored anthers were due to feeding by tarnished plant bugs (Maredia et al., 1994). Susceptible check was a Frego-bract breeding line. Year by line interaction was not significant (P = 0.10).

In three years of TPB tests, UA212ne had lower damaged flowers than DP 393, UA48, and the susceptible check (Table 4). In these small plot tests, high populations of TPB may overwhelm the effects of the nectariless trait. In a large plot test, UA212ne had lower populations of TPB and incurred less yield loss than other conventional varieties in untreated plots (Studebaker et al., 2018). Additionally, UA212ne is resistant to bacterial blight, and displayed good tolerance to Verticillium wilt as indicated by visual evaluation and by lint yield at Judd Hill.

Quality score, fiber length, and length uniformity index of UA212ne exceeded values for DP 393 but was less than UA48 (Table 5). Micronaire of UA212ne was lower than DP 393 and UA48, indicating that it has less coarse fibers - a favored characteristic in Mid-south cotton regions where cotton is apt to be penalized for high micronaire values. Over 13 locations of the 2016 RBTN, quality score of UA212ne was equal to that of UA222 and greater than the other four check varieties. Its micronaire was lower than DP 393, SG 105, and DP 393 and equal to FM 958 and UA222. The fiber quality of UA212ne is certainly within a desirable range, and exceeds most varieties.

Table 5. Fiber traits for UA212ne compared to two check varieties over years from 2014 through 2017 at Arkansas Test sites†

Line	Quality score‡	Micro-Naire	Fiber length	Uniformity index	Fiber strength	Elongation
			in.	%	g tex^{-1}	%
UA212ne	62	4.51	1.22	85.7	31.7	7.3
DP 393	48	4.81	1.19	85.2	32.6	7.3
UA48	73	5.03	1.27	87.1	36.4	5.4
LSD0.10	8	0.10	0.02	0.8	1.1	0.5

† Fiber parameters were determined in tests at Keiser, Judd Hill, Marianna, and Rohwer. Location × line interaction was not significant (P = 0.10) for any fiber trait. Fiber parameters were determined by high volume instrument (HVI) on lint from boll samples taken from two replications per test.
‡ Quality score (Bourland et al., 2010) is an index based on four fiber parameters (relative weight): fiber length (50%), micronaire (25%), uniformity index (15%), and strength (10%).

Final Nectariless Consideration

Neonicotinoid insecticides are widely used in controlling TPB. Some evidence suggests that honeybees (Apis mellifera L.), which commonly forage on cotton flowers, might be adversely affected by these insecticides. This issue could lead to prohibiting the use of neonicotinoid insecticides on flowering cotton. Without nectar present to attract bees, nectariless cotton should be exempt from any such restriction. Thus, the importance of TPB as pest and the possibility of insecticide restrictions enhances the need for nectariless cottons.

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