ENGINEERING STRESS - TOLERANT COTTON WITH HIGH QUALITY FIBER

Robert G. McDaniel
The University of Arizona
Tucson, AZ

Abstract

A number of selection criteria, both agronomic, physiological, and biochemical have been utilized to judge advanced generation hybrid progeny of interspecific cotton crosses Hybrid seed from reciprocal crosses of selected upland Delta Pine Acala 90 (*Gossympium hirsutum* L.) and extra long staple Pima S-6 (*Gossypium barbadense* L.) have been carried to the F_7 generation, with both open and self pollinated progeny evaluated. Two advanced strains which exhibit superior fiber properties and competitive yields compared to the upland parent and superior stress tolerance (drought and heat) compared to the extra long staple parent have been selected, and are presently under evaluation in multi-location field tests. Several other promising "specialty" cotton germplasm sources have been identified among these advanced generation progeny segregants.

Introduction

Although a number of cotton researchers have described heterosis of interspecific hybrids between *Gossypium hirsutum* L. and *Gossypium barbadense* L. at present hybrid germplasm is not being widely utilized. One of the criticisms of present-daily cotton cultivars is their narrow genetic base. Davis (1974) as well as Krishnamurthy and Henry (1979) among others described some of the advantages and disadvantages of such interspecific hybrids. Tang et al. (1993) discussed the use of F_2 hybrids. The F_2 hybrid concept had a measure of commercial success in the 1990's, via the utilization of chemical gametocide technology. Marani (1968), McDaniel (1995 a and b) and others have investigated the inheritance of fiber quality in interspecific cotton hybrids. It has become most apparent that selection of parental materials in crosses between domesticated tetraploid species is equally as important as careful selection of parental types is for crosses among the wild diploid species.

A major impediment to the development of hybrid lines from *Gossypium hirsutum* (upland) by *Gossypium barbadense* (Pima) crosses has been euheterosis; extremely tall, vigorous, luxuriant, but unproductive F_1 and advanced generation hybrids. Percy and Turcotte have recognized this problem and have approached it by utilizing "unconventional" Pima germplasm. Pima genotypes with short, coarse fiber were utilized as parents; which resulted in shorter stature and earlier maturity, but not as high fiber quality as desired. McDaniel and Dobrenz (1993, 1994) and McDaniel, (1995 a and b) have addressed the problem of improving fiber quality, stress tolerance and productivity of Southwestern cottons through a breeding program utilizing the progeny of interspecific crosses between Deltapine Acala 90, an upland type; and Pima S-6, an extra long staple Pima type, representing two of the tetraploid cultivated species of cotton. This paper is a progress report of that work.

Methodology

The methods and plant materials utilized in the present study have been described by McDaniel, (1995 a and b). Briefly, the original upland and Pima parents were several individuals which exhibited outstanding agronomic characters, chosen from four to ten acre commercial planting blocks at the Marana, AZ Agricultural Center in late summer, 1989. Table one presents the breeding strategy and chronology of the development of the advanced generation progeny described here. After an initial seed increase and rigorous screening for superior seed germination and seedling vigor, all advanced strains were challenged with sub-optimum irrigation levels. This effectively enabled us to distinguish those lines which had the ability to perform well under heat and drought stress, while still maintaining good agronomic characters in the adjacent well-watered plot. For example, one could eliminate types which, while continuing to exhibit good fruit set under the more stressful environment, showed excessive plant height and vegetative tendency under the higher irrigation level.

Results

By the F_3 generation, with both open-pollinated and hand crossed hybrid entries evaluated, one plant showed exceptionally good agronomic characteristics, and was increased for yield testing in 1993 (Table 1) as 'Mac 95'. A second strain was identified, and seed of a few progeny plants was bulked increased and field tested in 1995 as 'Mac 13'.

Table two illustrates the major selection criteria used during these stages of breeding of F_6 through F_8 progeny. Additional or separate criteria utilized during the early stages of this breeding program are described in McDaniel (1995b). In essence, no one selection criterion or environment was deemed adequate to make desired progress in enhancing fiber quality of this germplasm of hybrid origin while maintaining an agronomically acceptable lint yield under heat and drought stress. Rather, an array of agronomic, physiological and biochemical criteria, variously weighted were integrated into the engineering of this germplasm.

Tables three and four detail the progress in improving the performance of this Arizona-bred germplasm. Check

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:1413-1414 (1997)
National Cotton Council, Memphis TN

cultivars have changed because of the decline in acreage of the original parental cultivars, with modern high yielding parental "types" Deltapine 5415 and Pima S-7 substituted for convenience. Data on 'Mac 95' and 'Mac 13' are also included. Table three illustrates that F_7 generation hybrid progeny (some open-pollinated; some with at least one backcross or outcross to related material) exhibit excellent agronomic characteristics as judged by plant height, boll set, single plant seed cotton yield and boll weights. It should be noted that in 1995 and 1996 crop years, all entries were evaluated under less than optimum irrigation levels, and that no significant rainfall occurred until well into the fruiting cycle. The data for all strains except the four hybrid progeny, which are for single plants, represent averages of multiple plant samples, expressed on a per plant basis.

Table four presents the fiber properties of the same strains evaluated at the same location, West Campus Farm, Tucson, in 1996. Data are high volume instrument analyses run courtesy of Cotton Incorporated. These data show that the hybrid strains, presently being yield tested at several locations as 'Mac 95' and 'Mac 13', exhibit fiber properties generally superior to the upland check cultivar. The four selected hybrid progeny shown here for comparison (drawn from a larger sample of progeny under evaluation) serve to illustrate the marked improvement in fiber quality exhibited by a few of these progeny. Some of this genetic material would easily qualify as an "Egyptian type" long staple; but in a strongly upland cotton background. All four of the advanced strains shown here exhibit heat and drought tolerance superior to S-7 when evaluated in the Tucson AZ environment.

Efforts are underway to increase other comparable advanced generation materials for larger scale, multiple location field tests next year. More comprehensive fiber tests are also underway. A selection of other potentially important traits which have arisen among these progeny are outlined in table five.

References

Davis, D.D. 1974. Synthesis of commercial F_1 hybrids in cotton: I Genetic control of vegetative and reproductive vigor in *Gossypium hirsutum* L. and *G. barbadense* L. crosses. *Crop Sci*. 14:745-749.

Krishnamurthy, R. and S. Henry. 1979. Line x tester analysis of combing ability and heterosis, in *Gossypium hirsutum x G. barbadense* crosses. *Indian J. Agric. Science* 49(7):492-499.

Marani, A. 1968. Inheritance of lint quality characteristics in interspecific crosses of cotton. *Crop Sci.* 8:653-657.

McDaniel, R.G. and A.K. Dobrenz. 1994. Water stress and carbon isotope discrimination in cotton. *Proc. Beltwide Cotton Conf.*, Vol.3:1297-1300.

McDaniel, R.G. 1995a. Carbon isotopes and cotton breeding. *Proc. Beltwide Cotton Conf.* pp. 1127-1129.

McDaniel, R.G. 1995b. Fiber quality measurements on progeny of interspecific cotton hybrids in: *Monograph: The Biochemistry of Cotton.* eds. C. Benedict and G. Jividen, Cotton Incorporated. pp. 59-62.

McDaniel, R.G. and A.K. Dobrenz. 1993. Drought tolerance in the progeny of interspecific cotton hybrids. *Cotton: A College of Agriculture Report.* pp. 79-83.

Percy, R.G. and E.L. Turcotte. 1992. Interspecific hybrid fiber characteristics of cotton altered by unconventional *Gossypium barbadense L. genotypes. Crop Sci. 32:1437-1441*.

Tang, B., J.N. Jenkins, J.C. McCarty and C.E. Watson. 1993. F_2 hybrids of host plant germplasm and cotton cultivars: II. Heterosis and combing ability for fiber properties. *Crop Sci. 33:706-710.*

Acknowledgements

The author gratefully acknowledges the support of Cotton Incorporated through a cooperative research agreement. The author wishes to thank Dr. Gay Jividen, of Cotton Incorporated, for his help in facilitating the HVI fiber analyses.

Table 1. Breeding Strategy and Timetable.

Chronology	Strategy
1989	Original Pima S-6 and Delta Pine Acala 90 reciprocal crosses made at Marana Agriculutral Center
1990	Increase of F_1 seed in glasshouse
1991	Initial field trials of F_2 progeny of Tucson
1992	Field trials of F_3 progeny at two irrigation levels
1993	Two location field trials; two irrigation levels; first field test of advanced strain-MAC 95
1994	Multi-location field trials; two irrigation levels; first yield test of advanced strain-MAC 95
1995	Multi-location field trials; first increase of advanced strain - MAC 13
1996	Multi-location field trials of both advanced strains, seed increase of several other candidate lines.

Table 2. Major Selection Criteria Utilized to Advance F_6 through F_8 progeny.

Agronomic
(1) Vigorous early season growth
(2) Prolific early season flowering
(3) Fruit set in clusters or semi clusters
(4) One or few major side branches
(5) Upland flower and leaf characteristics
(6) Superior mid-season boll retention

Physiological or Biochemical
(1) Relatively low, consistent canopy temperature
(2) Relatively low (numerically) carbon isotope ration
(3) Relatively high photosynthetic activity/leaf
(4) Relatively small, but dense, smooth leaves
(5) Short to mid-tall plants
(6) Majority of bolls open full early
(7) Parents exhibit superior fiber quality

Table 3. Relative plant morphology of several advanced hybrid progeny selections and comparable cultivars, West Campus Farm, Tucson, 1996.

	Plant Height(cm)	No. of Bolls	Wt. of seed cotton(g)	Wt. Per boll(g)
Check cultivar Delta Pine 5415	95	23	102	4.4
Check cultivar Pima S-7	120	23	69	3.0
Advanced strain MAC 95	110	34	145	4.3
Advanced strain MAC 13	114	25	104	4.2
Hybrid progeny S5-S-8	90	31	108	3.5
Hybrid progeny S9-4-25	135	10	46	4.6
Hybrid progeny S10-5-1	112	36	159	4.4
Hybrid progeny S11-5-2	108	26	91	3.5

Table 4. Relative HVI fiber characteristics of several advanced hybrid progeny selections and comparable cultivars, West Campus Farm, Tucson, 1996.

	Fiber Length(mm)	Strength g/tex	Micronaire	Uniformity
Check cv. Delta Pine 5415	29.5	27	5.1	83
Check Cultivar Pima S-7	34.8	43	3.7	88
Advanced strain MAC 95	30.5	30	5.3	84
Advanced strain MAC 13	30.5	31	5.1	84
Hybrid progeny S5-5-8	35.0	46	4.2	87
Hybrid progeny S-9-4-25	36.1	44	3.9	86
Hybrid progency S10-5-1	36.6	43	3.8	87
Hybrid progeny S11-5-2	37.9	40	3.1	86

Table 5. Other Selected Characters Which Have Been Identified Among the Progeny of the Original Interspecific Crosses.

Verticillium wilt resistance
Diminutive bracts
Very prolific boll set
“Storm-proof” early set, compact fiber bolls
Colored fiber
“Kinky” fiber; extremely self-adherent fibers
Low micronaire, high strength fibers
chimeras for leaf color and shape