EXOTIC GERMPLASM INTROGRESSION EFFECT ON AGRONOMIC AND FIBER PROPERTIES OF UPLAND COTTON

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Abstract

Genetic diversity is an important breeder's tool for selection and improvement in crop cultivar development. Any successful breeding program depends on selecting superior quality parents. Lack of genetic diversity limits the potential of the breeder in selecting elite parents. Genetic uniformity predisposes cultivars to many pests and diseases and can make the adapted germplasm pool genetically vulnerable as it is evident from the past hence, there is a need for expanding and improving the genetic base of upland cotton. Our study was designed to study the effect of exotic germplasm introgression on agronomic and fiber quality traits of the adapted cotton gene pool. We developed eight populations derived from crossing two exotic parents (TX 245 and TX 1419) with four adapted cultivars (FM 966, PM 1218, Deltapearl and SG 747). In each population we developed five combinations with 0, 25, 50, 75 and 100 percent exotic germplasm. We tested the experimental material using RCBD with two years, two locations, five blocks and two replications. Across populations, no significant difference was observed for days to first flowering, lodging percent and bolls per plant, whereas seeds per boll, seed cotton yield and lint yield had no significant difference up to 25 percent but upon further introgression significant decline was observed. However, lint mass per seed and lint percent declined significantly with increase in exotic germplasm introgression. Fiber properties declined significantly with increase in exotic introgression except for fiber elongation and short fiber content. Fiber elongation improved significantly with increase in exotic percentage.

Introduction

Cotton is one of the most important commercial cash crops in the world. Cotton enjoys a predominant status among all the commercial crops providing raw material "cotton fiber" for the textile industry. It is also valued for its protein and oil portion of the seed. Even with competition from the synthetic fiber industry, it still holds its premium commercial value in textile industry. However, it is threatened by its narrow genetic base. May et al., 1995 and McCarty, 2007 reported that upland cotton is facing the risk associated with a narrow genetic base. The utilization of closely related parents and many reselections of elite cultivars in the development of current upland cultivars has lead to a narrow genetic base which could cause a potential problem with genetic vulnerability. Genetic uniformity predisposes crops to various abiotic and biotic stresses, which has already been observed in the U.S. corn (Zea mays L.) crop in 1970 (Ullstrup, 1972). Many efforts have been spent to address the genetic uniformity in upland cultivars and yet genetic uniformity is still a threat. Cotton cultivars with increased genetic diversity can offer plasticity to stressful environments and offer genetic variation to help future trait improvement. Since 1990 there has been a decline in yield, along with fiber properties (Lewis, 2000). It has been speculated that the decline in yield and fiber properties is a result of a narrow genetic base in elite cotton germplasm because of using only a fraction of the potential genetic base (Bowman et al., 1996). The use of genetically diverse parents can alleviate genetic uniformity and also may increase transgressive segregates for yield (Rodgers et al., 1983; Cowen and Frey, 1987). The importance of genetic diversity to crop vulnerability was widely acknowledged by many researchers such as Duvick (1984), May et al. (1995) and Cox et al. (1986). It has been shown that primitive upland cotton accessions contain useful genetic variability for cotton development (Meredith, 1990). Early studies on using PIs in soybean breeding indicated that PIs improved the genetic variability for seed yield (Thorne and Fehr, 1970). Plant introductions (PIs) have been used as sources of pest resistance in backcrossing programs but not as sources for yield improvement (Schoener and Fehr, 1979). Plant introductions may offer some solutions for the genetic uniformity problem and may be used to broaden the genetic base. The major problem with the use of genetically diverse parents is that they tend to be from different regions so adaptation is a problem and may also break favorable linkage groups leading to loss of favorable allele combinations. A greater effort to introgress diverse germplasm into locally adapted cultivars without much yield penalty can offer greater rewards in cotton improvement and reduce genetic vulnerability (Van Esbroeck et al., 1998).

Materials and Methods

This research was conducted in summer 2009 and 2010 at Plant Breeding Unit, E.V. Smith Research Center, Tallassee, AL and Pee Dee Research Station, Florence, SC. Eight populations derived by crossing two exotic parents (TX 245 and TX 1419) with four adapted cultivars (FM 966, PM 1218, Deltapearl and SG 747) were used in this study. These exotic parents were selected based on previous observations that they offered moderate resistance to reniform nematode, an observation that later proved to be false (Chapala et al., 2010). The locally adapted cultivars were selected as parents based on their performance and represent elite cotton germplasm for the mid-South and Southeastern production regions.

Table 1. Parents and populations.

POP 1	Fibermax 966 × TX 245
POP 2	PM 1218 ×TX 245
POP 3	Delta Pearl × TX 245
POP 4	SG 747 × TX 245
POP 5	Fibermax 966 × TX 1419
POP 6	PM 1218 × TX 1419
POP 7	Delta Pearl × TX 1419
POP 8	SG 747 × TX 1419

In each population five combinations were derived with 0, 25, 50, 75 and 100 percent exotic introgression. Adapted parents represented the 0 percent and 100 percent represented the exotic parent; $F_{2:4}$ lines were used for 50 percent exotic: 25 and 75 percent exotic were represented by $BC_1F_{2:4}$ lines. Five lines were randomly selected to represent each combination in each of the eight different populations. The experimental design was RCBD with two years (2009 and 2010), two locations (Tallassee, AL and Florence, SC), 5 blocks and 2 replications. Plots were double rowed with each row 20 feet long and 3 foot spacing between rows. Agronomic traits (days to first flowering, lodging percent, bolls per plant, boll mass, seed cotton yield, seeds per boll, lint percent, lint mass per seed and lint yield) were recorded. Fiber properties (fiber length, fiber strength, fiber fineness, fiber elongation, short fiber content and uniformity index) were measured by HVI analysis at Cotton Incorporated, Cary, NC. Data were analyzed using SAS® PROC GLIMMIX with location, population, percent exotic and replication as class variables. The effect of exotic germplasm percentage was studied by taking each trait as a response variable.

Results and Discussion

Increase in exotic germplasm introgression significantly decreased both agronomic performance and fiber properties. Agronomic performance across populations is given in Table 2. Each value in Table 2 represents the mean value of all the 8 populations mean for that particular percentage. Across populations, no significant difference was observed for days to first flowering, bolls per plant and lodging percent whereas, boll mass, seeds per boll, seed cotton yield and lint yield did not show any significant decrease up to 25 percent exotic percentage but upon further introgression significant decline was observed. Lint percent and lint mass per seed decreased significantly with increase in exotic percentage. Across populations, fiber properties were lowered significantly for all the four economically important traits like fiber length, fiber strength, fiber fineness and uniformity index (Table 3). However, significant improvement was observed for fiber elongation with increase in exotic percentage. Short fiber content didn't show any significant difference from 0 percent exotic parent.

Table 2. Agronomic traits across populations.

Exotic percent	DTFF	Lodging pct	Bolls per plant	Boll mass (g)	Lint mass per seed ($gx10^{-2}$)	Lint percent	Seeds/ boll	SCY (kg/ha)	Lint yield (kg/ha)
0%	**53.99**	**64.6**	**8.76**	**4.83**	**6.83**	**42.21**	**29.7**	**2619**	**1109**
	(3.24)	(2.54)	(0.37)	(0.67)	(0.38)	(0.67)	(3.53)	(405)	(171)
25%	**53.61**	**61.9**	**8.32**	**4.60**	6.25*	39.96*	**29.31**	**2500**	**1005**
	(3.24)	(2.57)	(0.38)	(0.67)	(0.38)	(0.67)	(3.54)	(405)	(171)
50%	**54.30**	**63.4**	**8.07**	4.29*	5.74*	37.90*	28.22*	1982*	751*
	(3.24)	(2.57)	(0.38)	(0.67)	(0.38)	(0.67)	(3.54)	(405)	(171)
75%	**54.50**	**60.3**	**8.04**	4.37*	5.83*	37.58*	28.20*	1815*	690*
	(3.24)	(2.57)	(0.38)	(0.67)	(0.38)	(0.67)	(3.54)	(405)	(171)
100%	55.60*	54.2*	**8.64**	4.33*	5.60*	35.99*	27.76*	1638*	595*
	(3.24)	(2.63)	(0.41)	(0.67)	(0.38)	(0.67)	(3.54)	(406)	(171)

* Significantly different from 0 percent exotic at $p \leq 0.05$ • Values within parenthesis indicate standard error

*Blocked values indicate means which are similar or improved over adapted parent

Table 3. HVI fiber properties across populations.

Exotic percent	Fiber length (inches)	Fiber strength (g/tex)	Fiber fineness (mic)	Fiber elongation	SFC	UI
0%	**1.08**	**30.08**	**4.82**	**5.09**	**8.23**	**82.72**
	(0.02)	(0.22)	(0.21)	(0.27)	(0.70)	(0.88)
25%	1.03*	28.64*	5.01*	**5.61***	**8.27**	82.32
	(0.02)	(0.22)	(0.21)	(0.27)	(0.70)	(0.88)
50%	1.00*	28.40*	5.15*	**5.76***	**8.52**	81.81*
	(0.02)	(0.22)	(0.21)	(0.27)	(0.70)	(0.88)
75%	0.98*	28.40*	5.30*	**5.85***	8.61*	81.46*
	(0.02)	(0.22)	(0.21)	(0.27)	(0.70)	(0.88)
100%	0.97*	28.78*	5.42*	**6.12***	**8.47**	81.55*
	(0.02)	(0.23)	(0.21)	(0.27)	(0.71)	(0.88)

* Significantly different from 0 percent exotic at $p \leq 0.05$ • Values within parenthesis indicate standard error

*Blocked values indicate means which are similar or improved over adapted parent

Mean values of all the five lines within each population is presented below in Table 4 for some economically important traits. Lint yield decreased significantly with increase in exotic percentage however, 5 out of 8 populations showed a non significant difference up to 25 percent and the declined significantly upon further increase in exotic percent. Lint percentage and lint mass per seed declined significantly with increase in exotic germplasm introgression. Three out of 8 populations for lint percentage and 2 out of 8 populations for lint mass per seed showed no significant difference up to 25 percent exotic introgression. Response for boll mass and bolls per plant varied with different exotic parents. Boll mass showed no significant difference in 3 out 4 populations derived using Tx-245 as exotic parent. Population 3 showed significant improvement. However, this was not the case with populations derived using Tx-1419 as exotic parent. Population 5 to 8 showed significant decline with increase in exotic germplasm except with population 6 which showed no significant difference up to 25 percent. Bolls per plant also showed differential response for the two exotic parents. Populations derived from Tx-1419 had a higher boll number compared to the populations derived from Tx-245. The mean values for boll number dropped down drastically in the populations 1 to 4 which could be because of high incidence of *Fusarium* infestation in 2009, which happened to be the field where populations 1 to 4 were planted.

Fiber properties were lowered significantly with increase in exotic percentage. A look within each population for each of the fiber properties showed fiber length, fiber strength, fiber fineness and uniformity index declined with increase in exotic percentage except for a few glimpses of improvement up to 25 percent of introgression. Populations derived from exotic parent Tx-1419 performed relatively better than populations derived from Tx-245.

Populations 6 and 8 showed no significant difference from 0 percent for fiber length, fiber strength, fiber fineness and uniformity ratio.

Table 4. Exotic germplasm effect on some economically important traits.

Trait	Exotic percent	Pop1	Pop2	Pop3	Pop4	Pop5	Pop6	Pop7	Pop8
Lint yield (kg/ha)	0%	**1182**	**1348**	**1080**	**962**	**1067**	**1262**	**963**	**1006**
	25%	**1075**	1157*	**1128**	766*	774*	**1313**	**914**	**918**
	50%	817*	737*	825*	562*	842*	839*	670*	717*
	75%	585*	619*	683*	439*	**940**	996*	609*	658*
	100%	446*	528*	541*	442*	665*	783*	650*	710*
Lint percent	0%	**41.07**	**42.91**	**41.19**	**44.69**	**41.68**	**42.23**	**41.22**	**42.69**
	25%	39.02*	40.47*	**40.06**	39.23*	37.59*	**42.61**	**40.67**	40.07*
	50%	36.88*	35.92*	37.27*	38.28*	39.49*	37.80*	38.19*	39.44*
	75%	36.05*	33.95*	36.56*	37.67*	40.45*	**41.34**	37.30*	37.33*
	100%	34.03*	34.69*	34.93*	35.15*	36.77*	36.14*	37.59*	38.68*
Lint mass per seed ($g*10^{-2}$)	0%	**7.18**	**6.95**	**6.28**	**7.04**	**7.31**	**6.61**	**6.61**	**6.67**
	25%	6.29*	6.59*	5.86*	6.03*	6.09*	**6.57**	**6.43**	6.20*
	50%	5.73*	5.34*	5.47*	5.76*	6.35*	5.63*	5.64*	6.05*
	75%	5.63*	5.13*	5.39*	5.55*	6.68*	**6.52**	5.84*	5.91*
	100%	5.14*	5.51*	5.11*	5.44*	5.94*	5.77*	6.06*	5.85*
Boll mass (g)	0%	**5.39**	**4.98**	**4.36**	**4.70**	**5.31**	**4.84**	**4.33**	**4.80**
	25%	4.96*	**5.20**	**4.60***	**4.67**	4.48*	**4.87**	4.02*	4.04*
	50%	4.97*	**4.83**	**4.55**	**4.59**	4.11*	3.84*	3.58*	3.91*
	75%	4.79*	**4.84**	**4.67***	**4.62**	4.17*	4.35*	3.74*	3.81*
	100%	4.60*	**5.10**	**4.65***	**4.80**	3.82*	3.92*	3.74*	4.02*
Bolls per plant	0%	**7.73**	**7.46**	**8.36**	**7.01**	**9.62**	**10.87**	**9.59**	**9.50**
	25%	6.77*	**7.44**	7.02*	**6.67**	**9.72**	9.01*	**11.88***	8.08*
	50%	6.14*	5.16*	7.52*	5.38*	**9.87**	**12.48***	**9.35**	8.73*
	75%	4.87*	4.08*	5.39*	4.53*	**10.16***	**12.30***	**12.72***	**10.32***
	100%	5.83*	5.77*	4.59*	5.68*	9.21*	**13.71***	**13.03***	**11.36***
Fiber length (inches)	0%	**1.10**	**1.01**	**1.15**	**1.07**	**1.10**	**1.01**	**1.16**	**1.08**
	25%	1.02*	0.95*	0.98*	1.00*	**1.11**	**1.02**	1.09*	**1.09**
	50%	0.98*	0.90*	0.98*	0.92*	1.02*	**1.07***	1.07*	**1.07**
	75%	0.92*	0.89*	0.92*	0.91*	1.03*	**1.01**	1.10*	**1.08**
	100%	0.95*	0.94*	0.92*	0.92*	1.02*	**1.02**	1.01*	1.04*
Fiber strength (g/tex)	0%	**32.83**	**28.00**	**31.98**	**27.38**	**31.99**	**27.91**	**32.00**	**28.33**
	25%	29.31*	26.60*	27.87*	**27.38**	32.13*	**27.29**	28.82*	**29.47***
	50%	28.34*	26.26*	27.72*	26.17*	29.35*	**30.25***	29.48*	**29.43***
	75%	27.16*	27.10*	26.92*	25.88*	29.63*	**28.37**	31.06*	**30.98***
	100%	27.37*	**27.35**	27.69*	**27.45**	30.08*	**30.27***	30.26*	**29.76***
Fiber fineness (Mic.)	0%	**4.67**	**5.17**	**4.64**	**4.90**	**4.65**	**5.06**	**4.56**	**4.91**
	25%	4.93*	5.40*	5.31*	5.20*	4.82*	**4.94***	4.75*	**4.73***
	50%	5.20*	5.48*	5.19*	5.33*	5.13*	**5.13**	4.97*	**4.80***
	75%	5.42*	5.48*	5.53*	5.49*	5.05*	5.21*	5.12*	5.16*
	100%	5.37*	5.52*	5.53*	5.59*	5.36*	5.27*	5.44*	5.27*
Uniformity Index	0%	**83.18**	**82.23**	**83.04**	**82.04**	**83.06**	**82.48**	**83.23**	**82.65**
	25%	82.47*	81.36*	81.56*	**82.19**	**83.15**	**82.64**	82.20*	**83.13**
	50%	82.02*	80.72*	81.94*	81.20*	81.94*	**82.29**	81.98*	**82.51**
	75%	80.90*	80.48*	81.12*	81.24*	81.65*	81.96*	82.10*	**82.37**
	100%	81.24*	81.03*	80.83*	81.14*	81.72*	**82.09**	82.08*	**82.34**

* Significantly different from 0 percent exotic at $p \le 0.05$ • Values within parenthesis indicate standard error
*Blocked values indicate means which are similar or improved over adapted parent

From these results we can summarize that across populations days to first flowering, lodging pct and boll wt were least effected by exotic introgression whereas seeds per boll, seed cotton yield and lint yield had not shown any significant difference up to 25 percent exotic percentage. Lint percent, lint mass per seed along with all the fiber properties except elongation percent and short fiber content declined significantly with increase in exotic percentage. Fiber elongation improved significantly with increase in exotic percentage.

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