EXOTIC GERMPLASM INTROGRESSION EFFECTS ON ADAPTED COTTON GENTOYPES

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Abstract

Genetic uniformity predisposes cultivars to many pests and diseases and can make the adapted germplasm pool genetically vulnerable. Therefore there is a need for expanding the genetic base of upland cotton. Cotton cultivars with increased genetic diversity can offer plasticity to stressful environments and help in trait improvement. Our research is focused on the objective of determining the effect of exotic germplasm introgression on agronomic and fiber properties of adapted cotton germplasm. For this we studied 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). In each population we generated five combinations with 0, 25, 50, 75 and 100 percent exotic germplasm. We conducted RCBD with two years, two locations, five blocks and two replications. Across populations except for days to first flowering and bolls per plant all other agronomic traits showed significant decrease in mean line performance with increase in percent exotic percentage. Fiber properties were also lowered with increase in percent exotic introgression except for fiber elongation, uniformity index and short fiber content. Among populations we looked at some economically important yield characters like lint yield, lint percent and fiber properties like fiber length, fiber strength and fiber fineness. Results indicate that almost all traits decreased with increase in percent exotic introgression but, 25 percent exotic in many populations performed not significantly different from 0 percent exotic if not better.

Introduction

Upland cotton (*Gossypium hirsutum* L.) is an economically important natural fiber crop in the world. Along with fiber, it is also valued for its oil and protein portion of the seed. Even though there is lot of competition from synthetic fiber industry, cotton still holds its prime commercial value in the textile industry. May et al., 1995 and McCarty, 2007 reported that upland cotton with an annual production of around 100 million bales was facing risk associated with a narrow genetic base. Many breeding programs are centered on developing superior cultivars with increased yield and improved fiber qualities within a short span of time. To achieve this, many public and private breeding programs choose superior cultivars which were derived from many reselections and/or successfully grown cultivars which were developed from closely related cultivars as parent material leading to genetic uniformity. During this process of achieving these short term goals, less importance has been given to improving genetic diversity which resulted in genetic uniformity leading to a potential cause for 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). Since 1990 there was 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). Therefore there is a need to expand the genetic base of upland cotton. Cotton cultivars with increased genetic diversity can offer plasticity to stressful environments and help in trait improvement. 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 like 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) were 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 solution 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 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 (Surmelioglu 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 generated with 0, 25, 50, 75 and 100 percent exotic introgression. Parents represented the 0 and 100 percent exotic; for 50 percent exotic $F_{2:4}$ lines were used and 25 and 75 percent exotic were represented by $BC_1F_{1:3}$ lines. Five lines were used for each population/percent exotic combination except for the 0 and 100 % combinations where we used 7 and 3 lines respectively because of limited seed availability of exotic parent. The design followed 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 foot long and 3 foot spacing between rows. Agronomic traits (days to first flowering, 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

Across populations, except for days to first flowering and bolls per plant all other traits showed significantly decreased mean line performance with an increase in percent exotic germplasm (Table 2). Days to first flowering did not show any significant difference up to 75 percent exotic whereas, the 100 percent exotic parent significantly differed from adapted parent. Bolls per plant showed a nonsignificant difference between 0 and all other population/percent exotic combinations except in 50 percent exotic which showed a significant decrease. All other agronomic traits such as boll mass, lint mass per seed, lint percent, seeds per boll, seed cotton yield and lint yield significantly decreased with increase in exotic percentage.

Fiber properties were lowered with an increase in percent exotic germplasm except for uniformity index, fiber elongation and short fiber content (Table 3). Fiber elongation increased significantly with increase in percent exotic germplasm. For short fiber content no significant difference was observed. Uniformity index decreased significantly with increase in percent exotic germplasm from 50 percent exotic onwards whereas no significant difference was observed between 0 percent and 25 percent exotic.

Table 2: Agronomic traits across populations

Exotic percent	DTFF	Bolls per plant	Boll mass (g)	Lint mass/ 100 seed (g)	Lint percent	Seeds/ boll	SCY (lbs/A)	Lint yield (lbs/A)
0%	57.06 (0.76)	8.49 (0.28)	5.39 (0.17)	7.36 (0.16)	42.57 (0.43)	31.04 (0.65)	2961.37 (135.81)	1321.67 (58.94)
25%	56.56 (0.60)	8.19 (0.57)	5.03* (0.18)	6.72* (0.10)	39.91* (0.45)	29.72* (1.24)	2700.97* (168.96)	1136.76* (76.35)
50%	57.40 (0.50)	7.34 * (0.67)	4.76* (0.26)	6.04* (0.17)	37.09* (0.47)	29.10* (1.59)	1912.35* (123.73)	743.32* (52.37)
75%	57.61 (0.84)	7.72 (1.49)	4.84* (0.19)	6.12* (0.24)	36.71* (0.96)	29.15* (1.61)	1532.38* (225.07)	603.90* (106.01)
100%	59.75* (1.13)	9.46 (1.63)	4.88* (0.19)	5.88* (0.21)	34.94* (0.65)	29.24* (1.49)	1315.68* (354.95)	500.70* (140.49)

* Significantly different from 0 percent exotic at p ≤ 0.05 • Values within brackets indicate standard error

Table 3: HVI fiber properties across populations

Exotic percent	Fiber length (inches)	Fiber strength (g/tex)	Fiber Fineness (mic)	Fiber Elongation	SFC	UI
0%	1.11 (0.02)	29.89 (0.87)	4.59 (0.06)	5.15 (0.41)	8.25 (0.15)	83.12 (0.20)
25%	1.05* (0.02)	28.58* (0.68)	4.81* (0.09)	<u>5.76*</u> (0.23)	8.12 (0.15)	82.88 (0.20)
50%	1.02* (0.02)	28.19* (0.57)	4.93* (0.07)	<u>5.82*</u> (0.19)	8.29 (0.20)	82.38* (0.18)
75%	1.00* (0.03)	27.97* (0.72)	5.11* (0.07)	<u>6.02*</u> (0.19)	8.34 (0.12)	81.90* (0.17)
100%	1.00* (0.02)	28.87* (0.65)	5.26* (0.06)	<u>6.19*</u> (0.21)	8.08 (0.15)	82.26* (0.22)

* Significantly different from 0 percent exotic at p ≤ 0.05 • Values within brackets indicate standard error

Within populations some economically important characters like lint yield, lint percent, fiber strength, fiber length and fiber fineness are given in Table 4. In population 1, 3, 6, 7 and 8 there was no significant difference in lint yield between 0 and 25 percent exotic but, there was significant decrease in lint yield with increase in exotic percentage. During 2009 TX-245 derived lines were affected by Fusarium and root-knot nematode (Figure1). Lint percent decreased significantly with increase in percent exotic introgression among populations except in population 6 and 7 where 0 and 25 percent exotic did not show any significant difference. Fiber strength values showed mixed response between combinations and between populations. Populations 1, 2 and 3 showed significant decrease in fiber strength values with increase in percent exotic introgression. Populations 4 and 5 did not show any significant difference between 0 and 25 percent exotic but decrease significantly in 50 and 75 percent exotic. In population 6 and 8 there is no significant difference observed in all combinations except in 50 percent exotic in population 6, 25 and 75 percent in case of population 8, which showed significantly increased fiber strength values. In population 6 and 8 the improved fiber strength values could because of exotic parent which also recorded significantly higher fiber strength compared to 0 percent exotic parents in both populations. In population 7 no significant difference was observed except in 25 percent exotic which fiber strength decreased significantly. Fiber length decreased significantly in all populations except in population 6 and 8. Population 6 did not show significant difference in fiber length values except in 50 percent exotic where fiber length increased significantly compared to 0 percent exotic parent. Even in population 8 there was no significant difference observed with increase in exotic percentage except in 50 percent exotic where fiber length was reduced significantly.

Fiber fineness also showed mixed response between combinations and between populations. In population 1, 2, 3 and 4 fiber fineness was lowered significantly with increase in exotic percent introgression except for 25 percent combination in population 2 where there was significant difference observed between 0 and 25 percent exotic. In population 5 and 7 there was significant reduction in fiber fineness with increase in percent exotic except in 25 percent exotic which did not show any significant difference. Population 6 and 8 did not show any significant difference in fiber fineness with increase in percent exotic introgression

Table 4: Some economically important traits within population

Trait	Exotic percent	Pop1	Pop2	Pop3	Pop4	Pop5	Pop6	Pop7	Pop8
Lint Yield(Lbs/A)	0%	1548.58	1557.75	1165.38	1230.03	1311.46	1417.01	1181.67	1161.44
	25%	1388.53	1278.98*	1151.33	847.98*	948.94*	1441.01	1060.36	976.94
	50%	869.07*	596.91*	730.28*	627.49*	1007.57*	841.41*	618.82*	655.02*
	75%	302.90*	366.03*	502.7*	399.57*	1032.79*	1096.7*	578.73*	551.76*
	100%	80.83*	187.37*	117.99*	148.45*	929.27*	870.44*	923.82*	747.45*
	Mean	837.98	797.41	733.54	650.70	1046.01	1133.31	872.68	818.52
	(SE)	(288.84)	(265.37)	(199.15)	(185.80)	(68.98)	(128.61)	(119.20)	(110.82)
Lint percent	0%	41.69	43.27	41.56	44.95	42.36	41.89	41.42	43.42
	25%	38.71*	40.67*	39.71*	39.63*	37.93*	42.01	40.77	39.82*
	50%	35.91*	35.64*	37.18*	36.95*	39.86*	36.22*	37.31*	37.70*
	75%	33.98*	33.31*	35.38*	35.81*	40.67*	40.43*	37.50*	36.59*
	100%	33.23*	33.66*	33.61*	33.03*	36.79*	34.82*	37.27*	37.11*
	Mean	36.70	37.31	37.49	38.07	39.52	39.08	38.85	38.93
	(SE)	(1.57)	(1.99)	(1.43)	(2.02)	(0.99)	(1.49)	(0.92)	(1.25)
Fiber strength (g/tex)	0%	32.84	27.88	32.23	27.18	31.95	27.87	31.66	27.49
	25%	29.15*	26.37*	27.80*	27.42	32.51	27.44	28.18*	<u>29.81</u>*
	50%	28.11*	25.74*	28.10*	25.91*	29.44*	<u>30.22</u>*	29.15	28.86
	75%	26.96*	26.20*	26.66*	25.34*	29.51*	27.96	30.27	<u>30.89</u>*
	100%	27.12*	27.45	26.82*	27.23	30.29	30.71*	30.64	30.71*
	Mean	28.84	26.72	28.32	26.61	30.74	28.84	29.98	29.55
	(SE)	(1.08)	(0.40)	(1.02)	(0.42)	(0.63)	(0.67)	(0.60)	(0.63)
Fiber length (inches)	0%	1.13	1.03	1.17	1.09	1.11	1.03	1.18	1.11
	25%	1.03*	0.96*	1.00*	1.03*	1.14*	1.03	1.09*	1.12
	50%	1.00*	0.91*	1.01*	0.96*	1.05*	<u>1.09</u>*	1.09*	1.08*
	75%	0.93*	0.89*	0.96*	0.92*	1.04*	1.02	1.10*	1.10
	100%	0.97*	0.96*	0.94*	0.94*	1.03*	1.06	1.04*	1.07*
	Mean	1.01	0.95	1.01	0.99	1.07	1.05	1.10	1.09
	(SE)	(0.03)	(0.02)	(0.04)	(0.03)	(0.02)	(0.01)	(0.02)	(0.01)
Fiber fineness (Micronaire)	0%	4.48	4.90	4.50	4.72	4.47	4.72	4.34	4.61
	25%	4.88*	5.10	5.09*	5.07*	4.64	4.64	4.60	4.48
	50%	5.00*	5.22*	4.99*	5.03*	4.99*	4.89	4.75*	4.56
	75%	5.22*	5.29*	5.34*	5.31*	4.83*	4.90	5.06*	4.93
	100%	5.17*	5.46*	5.27*	5.47*	5.29*	5.01	5.35*	5.05*
	Mean	4.95	5.19	5.04	5.12	4.84	4.83	4.82	4.73
	(SE)	(0.13)	(0.09)	(0.15)	(0.13)	(0.14)	(0.07)	(0.18)	(0.11)

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

Fig1: Fusarium wilt and root-knot nematode affected plants

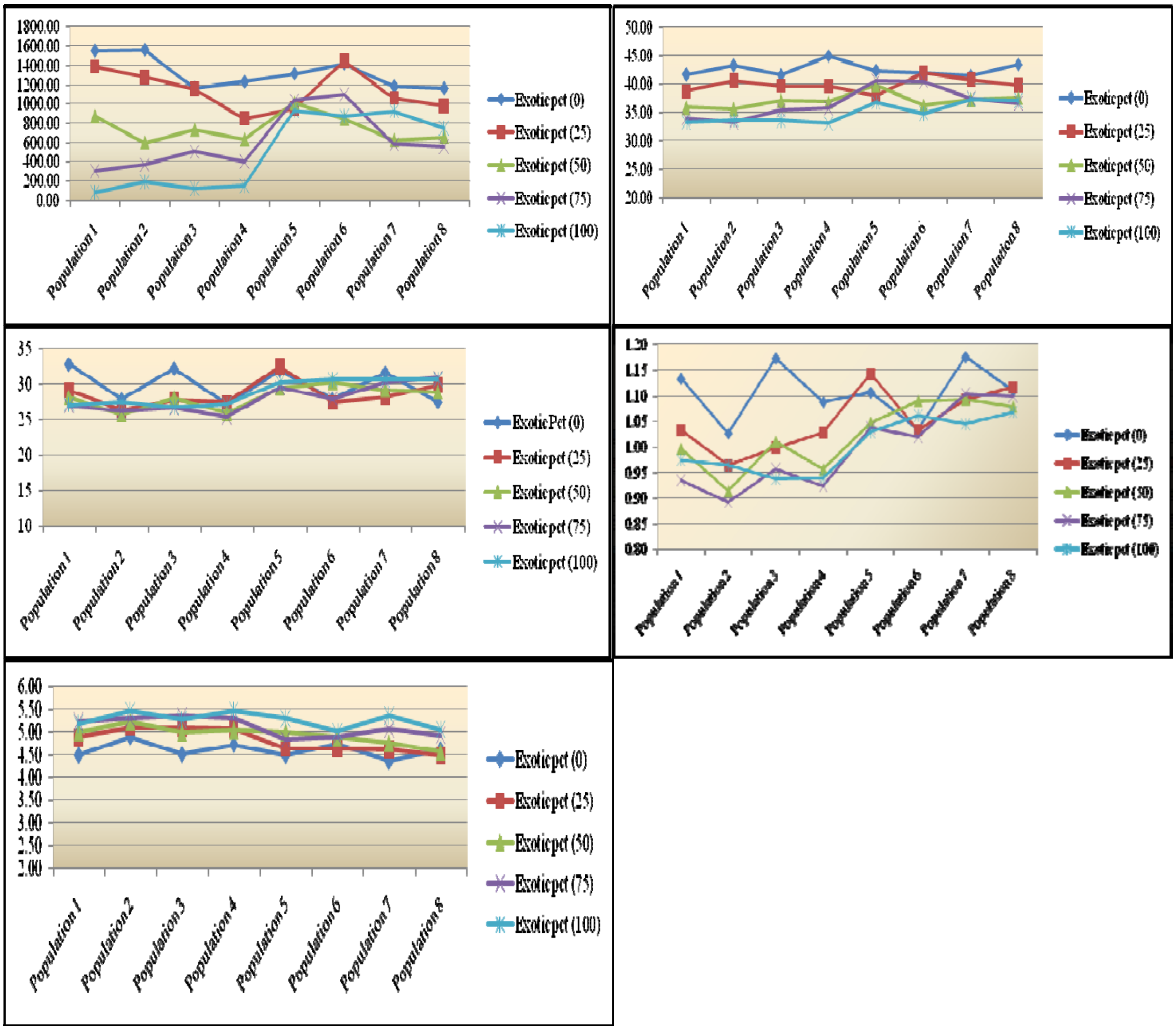

Fig2: Graphs showing the trends of how each trait is spread over population/percent combination (Graph1 (Top left) Lint yield: Graph2 (Top right) Lint percent: Graph3(Middle left)Fiber strength: Graph4(Middle right)Fiber length: Graph 5 (Last) Fiber fineness.

Trend graphs plotted for some economically important traits (lint yield, lint percent, fiber strength, fiber length and fiber fineness) just to give an idea of how these trends are for each parent/exotic combination and the variation present between TX-245 (Populations 1-4) and TX-1419 (Population 5-8). From these 2009 results we can summarize that most of the traits has showed decreased line means with increase in exotic percent introgression. Even though there was a decline in mean values many lines with 25 percent exotic germplasm did not show significant difference from the adapted parent and could possibly be utilized in further research.

References

Bowman, D. T., O. L. May and D. S. Calhoun. 1996. Genetic base of Upland cotton cultivars released between 1970 and 1990. Crop Sci. 36:577-581.

Cowen, N.M., and K.J. Frey. 1987. Relationships between genealogical distance and breeding behavior in oats (*Avena sativa* L.). Euphytica 36:413-424.

Cox, T.S., J.P. Murphy, and D.M. Rodgers. 1986. Changes in genetic diversity in the red and winter wheat regions of the United States. Proc. Natl. Acad. Sci. USA 83:5583–5586.

Duvick, D.N. 1984. Genetic diversity in major farm crops on the farm and in reserve. Econ. Bot. 38:161–178.

Lewis, C. F. 2000. Cotton yield and quality - yesterday today and tomorrow. In C. H. Chewning, ed., Proc. 13th Annual Engineered Fiber Selection System® Conf. Cotton Incorporated, Raleigh, NC. <http://www.cottoninc.com/EFSConference/>.

May, O.L., D.T. Bowman, and D.S. Calhoun. 1995. Genetic diversity of U.S. upland cotton cultivars released between 1980 and 1990. Crop Sci. 35:1570–1574.

Meredith, W.R., Jr. 1990. Yield and fiber-quality potential for second generation hybrids. Crop Sci. 30:1045-1048.

McCarty, J.C., J.N. Jenkins, and J.Wu. 2007. Use of primitive derived cotton accessions for agronomic and fiber traits improvement: variance components and genetic effects. Crop Sci. 47:100–110.

Rodgers, D.M., J.P. Murphy, and K.J. Frey. 1983. Impact of plant breeding on the grain yield and genetic diversity of spring oats. Crop Sci. 23:737-740.

Schoener, C.S., and W.R. Fehr. 1979. Utilization of plant introductions in soybean breeding populations. Crop Sci. 19:185-188.

Surmelioglu, Çigdem, R. B. Sikkens, R. R. Sharpe, S. R. Moore, E. van Santen, K. S. Lawrence, and D. B. Weaver. 2010. Resistance to reniform nematode from *G. hirsutum* and *G. longicalyx* sources: a comparison. Proc.Beltwide Cotton Conf. New Orleans, LA. 787-788.

Thorne, J.C., and W.R. Fehr. 1970. Exotic germplasm for yield improvement in 2-way and 3-way soybean crosses. Crop Sci. 10:677-678.

Ullstrup, A.J. 1972. The impacts of the southern corn leaf blight epidemics of 1970–1971. Annu. Rev. Phytopathol. 10:37–50.

Van Esbroeck, G.A., and D.T. Bowman. 1998. Cotton germplasm diversity and its importance to cultivar development. J. Cotton Sci. 2:121-129.