Changes in Breeding Strategy for Needs in a Liberalized Cotton Industry in Uganda

L.K. Serunjogi, S.B. Mukasa, W. Odeke and G. Ochola
Cotton Improvement Programme Serere Agricultural and Animal Research Institute (SAARI)
P.O. Soroti, Uganda

ABSTRACT

Commercial cotton (G. hirsutum L.) production has been based on BPA and SATU varieties, grown in two ecological zones. Both have had a strong world market, the stronger, longer and finer fiber BPA finding a different market niche. The collapse of the seed replacement system developed by the Department of Agriculture and liberalization of the cotton industry has resulted in problems of variety deterioration and mixing, leading to non-uniform and poor quality lint. These new challenges necessitated changes in breeding objectives and strategy. In 1993 breeding work was revived at SAARI with the strategy of developing a variety with good adaptation in the two zones for high yield, resistance to pests and high lint quality. Selections were made from existing and purified BPA and SATU stocks, and progenies arising from intra- and inter-variety crosses. Variety checks and advanced lines of 9 SATU and 11 BPA stocks were compared, using single and combined analysis of variance over 8 locations and 3 years, ordination and cluster analyses. At a three-group level, one group membership was consistent over the three seasons. The members expressed similar response patterns and good yield and constituted the elite entries. G x E interactions were not significant for yield but fiber characteristics of BPA entries were influenced by the environments. SATU and BPA lines performance was comparable except at locations of very low environmental index where SATU was better. Pattern analysis results indicate that the higher quality BPA which is also more bacterial blight resistant, can be grown in a wider range of environments than previously anticipated.

Introduction

Since the early 1960's commercial cotton production in Uganda has been entirely based on two types; "Serere Albar Type Uganda" (SATU) and "Bukalasa Pedigree Albar" (BPA), both *Gossypium hirsutum* race *latifolium* derivatives of the "Nigerian Allen". BPA was selected for the Southern and Western agro-ecological zone of high bimodal rainfall and heavy clay loam soils. SATU was for the Northern and Eastern area, a region with a lower, unimodal rainfall pattern and light loam soils (Arnold *et al.*, 1968, Innes and Jones, 1972). Independent BPA and SATU improvement programmes have developed several new varieties with improved yield and quality (Serunjogi *et al.*, 1998).

By comparison SATU and BPA are different ideotypes, BPA having more vigorous plants with larger bolls (5g/boll seed cotton) than SATU (3.5–4.0 g/boll). The BPA type has longer and finer fibers (Staple 1¼" - $1^{3}/_{8}$", micronaire 3.5) than the coarser SATU (Staple $1^{1}/_{8}$"-1¼", micronaire 4.0) and BPA spins stronger yarns of better appearance than SATU. BPA seeds are fuzzier (Grades 8-10) than SATU (Grades 4-6). Both types though were adopted inter alia for their genetic resistance to bacterial blight, *Xanthomonas campestris* pv *malvacerum* (E.F. Smith) Downson. Recent studies indicate that SATU lines are less resistant to current pathogenic races than BPA and that bacterial blight intensity significantly varies with cotton type and location (Takan *et al.*, 1997). The two types commanded different international market outlets based on their quality attributes.

Up to the early 1970's, the constituted seed issues were made available to farmers in pure farms. Each variety was strictly developed in one agro-ecological zone. The variety or seed issue was then multiplied through a system of seed replacement that was developed by the Department of Agriculture. After initial bulking at Serere and Namulonge Research Stations for SATU and BPA respectively, the nucleus stock of each variety was multiplied in different segregated areas for eventual supply to the respective large commercial production zones. This approach was very effective in reducing seed contamination, that could arise through physical mixing of seeds or through natural out-crossing among genotypes and in controlling seed-cotton marketing and ginning of the different cotton strains (Serunjogi *et al.*, 1998).

The collapse of cotton research and seed replacement system due to political and economic problems led to deterioration in quality. Cotton production also fell drastically. Quality ginning was not possible, subsequently reducing Uganda's cotton competition at the world markets. Following the launching of the Uganda's Economic Recovery Programme in 1987, a number of structural adjustments in the cotton industry have been effected. These include a policy for increased cotton production, for diversification of sources of foreign exchange earning, and liberalization of production and trade systems. Consequently, the planting seed services, domestic cotton buying, processing and export marketing has been privatized (Anon.1996, 1997). A Statute in 1994 (Anon. 1994) put a regulatory and monitoring organization on seed production, distribution and on marketing, processing and export standards, the Cotton Development Organization (CDO), in place. The private sector operators have come with new requirements that call for adjustments in the breeding strategy. Due to the price premium on BPA, seed producers have extended BPA production in the traditional SATU areas in the north and east. The ginners need a raise in the ginning out turn (G.O.T.) while the exporters have preference for higher quality types. With increased ginning capacity and competition for raw cotton at marketing, farm-gate prices for seed cotton have risen. The farmers need high yielding varieties to exploit the price increases. Simultaneous improvement of a number of yield components such as large bolls, prolific fruiting and high G.O.T through conventional breeding methods, though, is not simple. There are known uncoupled or repulsive and tight linkages let alone adverse pleiotropic gene actions underlying the concerned traits. Additionally, the pedigree selection system in use for acquiring the desired genetic combinations and testing is times consuming.

A study between 1994 and 1997 compared the performance of SATU and BPA varieties and lines simultaneously across the two agro-ecological zones. The objective was to determine whether one of the types could satisfactorily be adopted for all production areas to offer a good average performance. Assessment was made for seed cotton yields, ginning percentage, fiber and spinning quality and for resistance to pests. A single type would pose less problems if different strains of cotton were mixed under liberalized marketing and processing.

Materials and methods

Comprehensive cotton breeding work was revived in 1993 at Serere Agricultural and Animal Production Research Institute (SAARI). The existing variety mixtures were purified based on the earlier genetic descriptors. In earlier season however, intra- and inter-variety crosses had been made to generate an array of progenies. At F5 the progenies were evaluated in replicated row trials using a 7x7 balanced lattice design. At the strain trial a 5x5 balanced lattice design was used. The selected lines were evaluated on-station prior to multi-location trials in the two agro-ecological zones in 4x4 balanced lattice designs.

Twenty stocks, 9 SATU and 11 BPA, selected at random were evaluated over 3 years of 1994-95, 1995-96 and 1996-97, at 8 locations using four locations in each of the two agro-ecological zones. In addition, there were two BPA varieties (BPA 72 and BPA 89) and two SATU varieties [SATU 71, SATU 85 and SA (94) MO.1] as checks for comparison. SA (94) MO.1, a line mixture, was later released as variety SATU 95. The entries were planted in four row plots of 5 x 1.8 m at a spacing of 60 x 30 cm leaving 2 plants per hill after thinning in a randomized block design with 4 replications. Similar routine pest and disease control measures were employed at all locations using 4 pesticide sprays. Seed cotton was harvested from 2 middle rows to give kg/plot values that were converted into tonnes/ha. At harvest, a representative seed cotton sample for each entry was constituted and ginned for derivation of yield, fiber and spinning quality components. Analysis of variance for cotton yield was carried out for each location and year. A randomized complete block design for location (A), with genotype (B) as split plot on A was analyzed over 3 years. For each year, line performance was environment-standardized to give equal environment contribution towards genotype classification using yield and response patterns.

Results and discussion

The two-way analysis of variance indicated significant location effects at P=0.001 (Table 1). Genotype effects were significant for the season 1994-95 (P=0.05) and 1996-97 (P=0.01). The non-significance for 1995-96 and low significance for 1994-95, could be due to high variation between locations; leading to big error terms. Nix (1980) argued that where the target population of environments is highly variable, it would be impractical to obtain adequate information on genotype performance. However, given that most genotypes tested were new with little a priori information on their adaptation, genotype evaluation and selection in these environments would be appropriate.

The alternative would be to sub-divide the target area to reduce the strong genotype by location interaction. Four locations represented each of the two agro-ecological zones (Table 2). Best average performance was obtained at Mubuku and Aduku for the BPA and SATU traditional cotton growing areas respectively. Table 2 clearly shows extreme variation in 1995/96 in average cotton yield with a range of 0.685-2.164 t/ha and SE(0.189). Sub-division of locations according to the two agro-ecological zones indicated more variation within than between zones. This poses a big question on the environment term and probably calls for post experiment classification of environment for improved detection of genetic effects. This makes stratification of environments into years and location less important.

Combined analysis of variance over 3 years with genotype as a split plot on locations, showed very significant differences among the genotypes (P=0.001). Stratification of environments into years and locations, showed that differences between years (P=0.0329) were more significant than between locations (P=0.05). The highly significant year term already suggested that challenges changed from year to year. Such a multi-environment test regime that does not reflect repeatable environment challenges derails the opportunity to exploit GXE interactions. This obscures the reliability of selection across several years. In this case, clustering of genotypes based on yield/performance and response patterns across locations for each year was considered.

Members of group 1 of 1996-97 had the smallest dissimilarity value of 0.123 (Table 4). However, the group constituted the poorer yielding genotypes. The 1994-95 and 1995-96 group 1 genotypes and 1996-97 group 2 genotypes were also closely related with dissimilarity values of 0.356, 0.342 and 0.487 respectively. The membership of these groups is constant, except genotype SA(80)13 that only fell in group 1, of 1994-95, that constituted the better performing genotypes. This implied that these genotypes were more related in response pattern across locations and years. DeLacy and Lawrence (1988) used pattern analysis to classify locations that discriminated genotypes. Genotype discrimination was fairly consistent despite the fact that single season 2-way analysis of variance (Table 1) indicated different significance levels of genotype effects for the three years.

Variation among genotypes associated with GXE interaction complicates selection as it introduces a degree of uncertainty into the measure of superiority (DeLacy *et al.* 1990). The combined analysis however, did not detect significant GXE but some minor re-ranking of genotypes could still be noted. This necessitated a more specific detection of pattern of genotype performance across environment by clustering genotypes of similar response pattern (Table 5). Baker (1988) noted that not all interaction types, re-ranking of genotypes, is of consequence in plant breeding.

The apparent absence of GXE could be due to the two genetic backgrounds having similar genetic systems of adaptations in the two agro-ecological zones. However, in extreme marginal areas, SATU lines performed better than BPA. Also at Kuju, (not included in analysis), SATU lines were severely affected by blight that the site could not be used for comparison. It was thought that this could have been due to new strains of bacterial blight and thus the need for their identification. Improvements in SATU selections for staple length to the BPA levels were noted (Table 5), while SATU retained the characteristic coarseness, was reflected in weaker yarns. Variety SATU 85 and SA (94) MO.1 (to become variety SATU 95) were examples of this improvement in staple. SATU yarn appearance was also in the BPA range. This could have arisen from the observations made at SAARI that BPA grown in traditional SATU area departed from the typical BPA “white” lint appearance to the “creamy” SATU appearance. This effect could be due to soil and light intensity differences between the zones. BPA in general still has an upper hand on staple, fiber and yarn strength but BPA types became coarser towards micronaire 4.0 when grown in the SATU zone. Furthermore, both BPA and SATU consistently gave weaker yarns in the SATU zone. This, coupled with poorer yarn appearance when BPA is grown in the traditional SATU zone, may have an adverse effect on the quality of BPA and on its acceptability in the markets. BPA entries exhibited GOT means of 35.2 compared to 34.9% for SATU (Table 3). This is an improvement for both types over the 33% recorded in the 1960’s (Arnold *et al.*, 1968).

Conclusion

This study indicated non-significant differences in yield performance of the BPA and SATU lines across the zones in contrary to that earlier thought. Given the good fiber characteristics of the BPA lines, the slightly higher GOT and better resistance to bacterial blight, it would be appropriate to recommend retention of BPA material for production all over the country. Some advances in quality, however, have also been registered with SATU materials. SATU could be maintained to keep a broader genetic base for future breeding work especially for adaptability to the low fertility or marginal areas. Another change in the breeding strategy has been made. This is in attempt to accelerate genetic gains for combining high G.O.T. into high fiber, spinning quality and resistance to bacterial blight of the BPA genetic background . Crosses have been made between high G.O.T. West African germplasm and BPA. Early Generation Testing (EGT) technique starting at F3 has been tried within the context of the Pedigree Selection (PS) system in attempt to reduce on the period for generation advancement so as to meet the private sector needs in a short time. Straight synthesis of introduced varieties has been also initiated. Another strategy is aimed at selecting for short season genotypes so as to fit cotton in a farming system where it competes for the limited labour and resources with essential food crops (Serunjogi, 1996). The total new strategy is tailored to meet the new cotton industry’s needs and conforms to a situation of demand driven research objectives.

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Table 1. Table of mean squares from single season 2-way analysis of variance.

Source	DF	Mean Square		
		1994-95	1995-96	1996-97
Location	7	3.178***	4.799***	0.283***
Genotype	19	0.046*	0.056	0.033**
Error	133	(0.026)	(0.043)	(0.014)
Non-additivity	1	0.009	0.276*	0.043
Residual	132	(0.027)	(0.041)	(0.013)
Grand Mean		1.235	1.244	0.802
CV (%)		13.17	16.66	14.60

***, **, * Significant at P=0.001, 0.01 and 0.05 respectively

Table 2. Comparison of seed cotton yield (t/ha) across locations in the two agrozones.

Agro-zone	Location	1994-95	1995-96	1996-97	Mean
BPA	Mubuku	1.268	2.164	0.643	1.358
	Ikulwe	1.635	0.967	0.906	1.169
	Namulonge	1.450	1.181	0.762	1.131
	Butemba	0.614	0.777	0.701	0.697
SATU	Aduku	1.542	1.362	0.892	1.265
	Serere	0.960	1.686	0.981	1.209
	Labora	1.624	1.131	0.833	1.196
	Bukedea	0.791	0.685	0.702	0.727
	Mean	1.235	1.244	0.802	
	SE	0.148	0.189	0.107	0.1965

Table 3. Means performance of SATU and BPA genotypes across seasons.

Type	Genotype	Seed Cotton Yield (mt/ha)				GOT
		1994-95	1995-96	1996-97	Mean	%
SATU	SA(80)127	1.316	1.334	0.797	1.149	34.9
	SA(94)MO.1	1.314	1.375	0.945	1.213	35.1
	SATU 71	1.335	1.355	0.832	1.173	34.8
	SA(80)92	1.262	1.337	0.857	1.152	35.4
	SA(66)41	1.185	1.391	0.865	1.147	35.2
	SA(80)13	1.289	1.239	0.798	1.109	35.6
	SA(80)3	1.124	1.191	0.888	1.068	35.1
	SATU 85	1.245	1.114	0.825	1.060	33.3
	SA(75)78	1.154	1.138	0.822	1.038	35.0
BPA	A(82)18	1.384	1.217	0.767	1.123	35.5
	A(82)40	1.283	1.277	0.798	1.119	34.8
	A(82)15	1.267	1.235	0.815	1.106	35.3
	A(83)39	1.260	1.258	0.790	1.103	35.5
	A(83)24	1.215	1.246	0.815	1.092	36.5
	BPA 89	1.259	1.242	0.769	1.090	34.8
	A(82)11	1.234	1.203	0.809	1.082	34.1
	A(82)8	1.175	1.139	0.773	1.029	35.9
	BPA 72	1.098	1.250	0.734	1.027	34.2
	A)79)68	1.149	1.233	0.663	1.015	36.4
	A(79)62	1.162	1.103	0.685	0.983	34.8
LSD (0.05)		0.1610	0.2050	0.1160		
SE		0.0542	0.0699	0.0458	0.0334	

Table 4. Clustering genotypes using Squared Euclidean Distance (SED) as the dissimilarity measure.

Year	3 Group level membership		
	Group 1	Group 2	Group 3
1994-95	**SATU71, SA(80)13, SA(80)92, SA(80)127, BPA89, SA(94)MO.1, A(82)15, A(82)18, A(83)39** (*0.356*)	SATU85, A(75)78, A(82)11 (*0.455)*	SA(66)41, SA(80)3, A(79)62, A(79)68, A(82)8, A(82)40, BPA72, A(83)24 (*0.581*)
1995-96	**SATU71, SA(80)92, SA(80)127, BPA89, SA(94)MO.1, A(82)15, A(82)18, A(83)39** (*0.342*)	SATU85, A(75)78, A(82)11 SA(80)3, A(79)62, A(79)68 (*0.548*)	SA(66)41, A(82)8, A(82)40, BPA72, A(83)24 **SA(80)13** (*0.777*)
1996-97	A(79)62, A(79)68, BPA72, A(82)8 (*0.123*)	**A(83)39, SA(94)MO.1, SATU71, SA(80)92, SA(80)127, BPA89, A(82)15, A(82)18** (*0.487*)	SATU85, A(75)78, A(82)11, SA(66)41, SA(80)3, A(82)40, A(83)24 **SA(80)13** (*0.595*)

Values in parenthesis are relative group dissimilarity measures (the smaller the values the more similar).

Table 5. Means of fiber and spinning quality for 7 trials in BPA area open figures and 3 trials in SATU area (in parentheses).

	Material	Staple length 32^{nd} inch	Micronaire values	Fiber strength (g/tex)	Yarn strength 40's count	Yarn appearance
10 BPA lines	Range	37.8-42.6	2.47-4.7	17.0-22.6	1595-2229	4C-5E
	Mean	**40.9**	**3.9**	**19.5**	**1805**	
		(38.6-42.4)	(3.6-4.7)	(17.2-22.3)	(1587-1959)	(4D-5E)
		(39.4)	**(4.3)**	**(19.54)**	**(1733)**	
6 SATU lines	Range	37.8-43.3	2.6-4.8	15.9-23.0	1524-2215	4C-5E
	Mean	**40.17**	**4.1**	**19.24**	**1836**	
		(38.1-42.9)	(4.2-4.7)	(17.3-21.3)	(1614-1987)	(4D-5E)
		(41.0)	**(4.4)**	**(19.6)**	**(1790)**	
BPA 72	Range	38.0-41.6	2.74-4.4	17.2-21.6	1643-2143	4C-5E
	Mean	**40.6**	**3.9**	**19.45**	**1865**	
		(38.7-42.0)	(4.4-4.5)	(19.3-22.1)	(1558-2033)	(4D-5D)
		(40.7)	**(4.4)**	**(20.2)**	**(1795.5)**	
BPA 89	Range	40.2-41.9	3.1-4.5	17.9-21.0	1574-2174	4D-4E
	Mean	**40.7**	**4.0**	**19.3**	**1885**	
		(38.6-41.4)	(4.1-4.4)	(18.8-19.3)	(1604-1947)	(4D-5D)
		(40.1)	**(4.3)**	**(19.0)**	**(1743)**	
SATU 71	Range	39.4-41.4	3.2-4.6	17.08-22.3	1646-2084	4D-5D
	Mean	**40.22**	**4.1**	**19.68**	**1871**	
		(39.5-41.2)	(4.2-4.5)	(18.5-20.3)	(1753-1937)	(4D-5E)
		(40.5)	**(4.4)**	**(19.7)**	**(1825)**	
SATU 85	Range	40.0-41.3	3.4-4.3	16.2-22.4	1603-2024	4C-5E
	Mean	**40.6**	**4.0**	**19.48**	**1867**	
		(39.0-41.1)	(4.2-4.5)	(19.5-21.0)	(1586-2016)	(4D-5E)
		(40.3)	**(4.3)**	**(20.0)**	**(1759)**	

* Legend: **1**=very good**; 2**=good**; 3**= fairly good**; 4**=fair**; 5**=moderate**; 6**=poor**; 7**=very poor

A=good; **B**=fairly good; **C**=fair; **D**=moderate; **E**=poor; **F**=very poor