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Varietal development for varied stakeholders needs in the liberalized cotton industry of Uganda

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Abstract

During the period 1994-2001 four cotton varieties BPA 95, BPA 97, BPA 99, and BPA 2000 have been developed. This rapid out-turn has been catalyzed by a number of factors. The liberalization of the cotton industry in 1994 enabled privatization of local marketing, processing and export of lint. The private operators came up with demands for particular characteristics required for running the industry profitably. The immediate response by scientists was the recommendation for adoption of BPA types for all production areas beginning 1997. The breeders turned to the early generation testing (EGT) technique for reducing the time for developing a new variety. Another strategy was fast multiplication of varieties for quick exploitation of the new attributes by the stakeholders. In the new varieties boll weights have risen from <5.00 g to >6.0 g and ginning out turn (GOT) from 34% to 39% in varieties BPA 89 and BPA 2000 respectively. Farmers' yields of over 3,000 kg ha^{-1} have been recorded under good management. The varieties have strong fibres (30g/tex^{-1}), with staple lengths at ≥ 30mm and micronaire values at 3.5 – 4.0 giving strong yarns of about 2,000 correlated linear strength product (CLSP). The above attributes arising from research have contributed to increased national production from 2,160 to 26,000 MT of lint between 1988 and 2000. Between 1995 and 1999 Uganda earned US $ 82 million from lint exports and 2.5 million Ugandans now depend on cotton for source of income.

Key words: Albar, Bacterial blight, BPA Cotton Varieties, Early Generation Testing, Ginning-out-turn, Gossypium hirsutum, Line-mixtures, Lint, Spinning Quality, Yield Components, Vascular wilts.

Introduction

Since 1960 two cotton types were in production under close supervision by the Ministry of Agriculture and government monopolised seed multiplication, ginning and lint export. The two cotton types were: "Serere Albar Type Uganda" (SATU) and Bukalasa Pedigree Albar" (BPA). The former was selected and developed for the low fertility light loam soils in the semi-arid northern and eastern ecological zones. BPA was for the heavy clay soils in the western and southern areas with bimodal rainfall pattern. SATU and BPA differed in plant vigour, yield components, and in fibre and spinning quality. The two types though shared the attributes of resistance to the bacterial blight disease caused by *Xanthomonas campestris pv malvacearum* (Arnold *et al.*, 1968; Innes and Jones, 1972; Serunjogi et al., 2000). Beginning 1997 season, however, a decision was made to have BPA as the only cotton type all over the production areas. SATU was left at maintenance level for future use and as a source of genes for improvement of BPA. This was done for avoiding mixing up of the two cotton types under the liberalized processing and marketing which started in 1994 during the restructuring of the cotton industry (Anon., 1994a). The decision to keep BPA in production was based on a study made during 1994-1997. It was observed to perform well in wider environments than anticipated before (Serunjogi *et al.*, 2000) but poorly in the very low soil fertility areas.

The liberalization of the cotton industry led to privatization of the processing systems including domestic marketing, ginning, seed multiplication and export. The stakeholders in the private sector came up with new requirements for profitable running of the enterprises. The ginning capacity in Uganda increased to over 500,000 bales (1 bale = 185 kg lint). This was through debt reliefs extended to the ginners in the World Bank/ Government of Uganda funded Cotton Subsector Development Project (CSDP) which ran from 1994 to 2001 (Anon., 1994b and Anon., 2001a). The demand for seed cotton therefore rose. The farmers in turn called for high yielding varieties to exploit this increased demand and the occasional rise in prices. The private ginners needed increases in the ginning out turn (GOT) from the 33-34% levels experienced in Albar varieties. The lint exporters had preference for higher quality type, which could fetch premium prices at the international markets. Responsibility for the planting seed services (multiplication and distribution) was removed from the Ministry of Agriculture to private sector operators. The activities were to be regulated by Cotton Development Organization (CDO) set up in 1994 (Anon., 1994a). The seed scheme was restructured from the original two to six starting points (segregated areas). This was for enabling rapid seed multiplication for speedy exploitation of attributes in the new cotton varieties by all operators across the country (Anon., 1996; Anon., 1997; Serunjogi *et al.*, 2001).

The above new demands required simultaneous improvements in a number of traits in the new cotton varieties. These included inter alia large bolls and prolific fruiting, increasing GOT towards 40%, and increase in staple length, fibre and in yarn strength and appearance. Incorporation of a wide range of traits in a variety through conventional breeding methods is not simple. This is due to existence of uncoupled or repulsive and tight genetic linkages in addition to adverse pleiotropic gene actions underlying the traits (Singh and Singh, 1980; Gupta and Singh, 1984; Kapoor, 1994). Recurrent crossing cycles and selections required to break such genetic linkage blocks would be too slow for acquiring the urgently required new trait combinations (Hauller, 1985).

Starting 1995 the breeding procedures were adjusted with objectives of effecting desired trait combinations in a shorter time than before during variety development. This paper describes the procedures used in the development of new varieties: BPA 95, BPA 97, BPA 99 and BPA 2000. The performance of the varieties is discussed together with the seed multiplication protocol adopted for increasing the output at foundation seed stage.

Materials and methods

The bulk of cotton production shifted to northern and eastern regions in the early 1990s. The mandate for cotton research was therefore given to Serere Agricultural and Animal Production Research Institute as a priority research area under NARO's research policy leaving Namulonge Agricultural and Animal Production Research Institute as an outreach station.

Nomenclature of breeding stocks and varieties

The nomenclature of the breeding stocks was based on a letter prefix, which indicated the genetic origin of the material. This was followed by a numerical index in (parentheses) indicating the year when the stock was adopted as a single plant selection (SPS). Next to the parenthesis was the serial number for the SPS. For example, A(82)15 was Albar selection made in 1982 as SPS number 15. The nomenclature for varieties comprised a prefix BPA and a numerical suffix. The suffix denoted the year during which a new variety was multiplied at the foundation seed stage (main farm) for the first time. Line-mixtures were named by a letter prefix indicating the genetic origin of the material. This was followed, in parentheses, by the year in which the mixture was made. Next to the parenthesis a letter M denoted "mixture" followed by a numeral indicating how many generations the *mixture* had been grown. This was followed by a period (.). The period was followed by a numeral, which was a serial number in case more than one line mixture from related genetic stocks was included for testing. For example A(97) MO.1 was an Albar line-mixture, made in 1997 and not grown before. It was mixture number one.

Variety Development

During the 1995-2000 period, pedigree line selection (PLS) continued to be the core of the breeding methods used. Prior to 1994 a lot of breeding material had been lost from the various stages of the PLS. Reinstating the stages formed an important component as breeding research was being revived. This was through introduction of germplasm accessions and varieties from other countries for technology synthesis and reselection from past seed issues i.e. varieties BPA 68, BPA 85 and BPA 89. New crossing cycles were also initiated in 1994 at Namulonge; this was between Uganda BPA (Albar) stocks and wide range crosses (WRC) from West Africa. This crossing was aimed at combining the good fibre quality and resistance to bacterial blight of BPA with the high GOT of WRC, which ranged from 38 to 42% and above. The crosses gave materials, which were coded as BHG, BSRIF and BPAN. The B stood for BPA (recurrent parent) and the suffix for the WRC parent. The segregating generations formed the elite breeding stocks in the 1995-2001 period (NARO, 1998; NARO, 1999; NARO, 2000a and b; NARO, 2001).

The segregating crosses were advanced in generation by selfing. From F_2 onward the single plants were at four weeks after emergence (WAE) artificially inoculated with bacterial blight pathogens for screening resistant genotypes. A suspension of the inoculum was infused through the stomata on the lower side of two leaves on each plant using a pneumatic sprayer. The disease lesions were scored two weeks later. Based on the agreed scale and lesion grades for the season, the susceptible plants were rogued out of the plots. Towards boll maturity (approximately 20 WAE) single plants were selected out of the resistant stocks. Selection criteria included: plant hairiness on leaves and stems for resistance against Jassids, plant habit (angle of branches to the main stem and nodal length), boll size and shape, number of bolls per plant, freeness from pest and disease (mainly bacterial blight and wilts) infestation and earliness to physiological maturity.

Seed cotton from each SPS was processed in the laboratory for derivation of yield components, ginning percentage, lint index and seed index (weight of 100 seeds). Fibre quality was tested for each SPS. Fibre and spinning tests were done on composite samples for the treatments from the replicated yield trials. The testing was initially done at the CDO spinning laboratory at Namulonge. From 1999 onwards only fibre tests could be done at the CDO classification room in Tororo using high volume instrument (HVI).

In 1996-97 season SPS were made in the F_2 Albar ′ WRC crosses for evaluation in yield trials in 1997-98 season. This was in use of Early Generation Testing (EGT) method. The EGT method was adopted in an attempt to reduce time required for variety development. At the conventional pace, yield trials would start at the F_6 stage. The F_2-derived selections were then subjected to stepwise testing and selection in the mainstream pedigree, starting with evaluation of successful SPS in replicated progeny row (RPR) trials. Each entry to the RPR trial had a counterpart single row planted for selfing, evaluation and reselection for future RPR trials. Selected progenies were tested in strain trials (STS) in the following season on-station. Selections from the STS were advanced to line testing stage. Line testing was on-station (Serere and Namulonge) and multi-locationally at 16 Technology Verification Centres (TVCs) rehabilitated under CSDP. Beginning 1997, lines were tested in two sets. Set B comprised new entries from the STS stage and was sited on half of the TVCs. The following season some of these lines and their line-mixtures would go into the elite Set A and tested at the second half of the TVC sites. Meanwhile Set B would be replenished with new selections from STS each season.

Apart from the Albar ′ WRC segregating populations, and the reselections from past seed issues, other material handled during the period included sets of Albar lines A(75), A(76), A(79), A(82) and A (83) developed in the programme prior to 1994. Others were introduced varieties from Malawi and Zambia renown for high GOT ($\geq$ 40%). Balanced lattice designs were used in all the yield trials. Data was taken on agronomic and physiological traits of the entries at all sites each season. Pests were controlled by 3 to 4 sprays of pesticides, recommended by MAAIF, or more where pest populations were high as gauged by pest scouting techniques. At harvest 10 boll samples were picked (on-station only) for estimation of boll sizes and yield components. These were followed by total plot picks. Laboratory processing comprised weighing, sorting and ginning. Composite samples were taken for each entry for fibre and spinning tests. Yield data was analyzed using Genstat Computer Programme. Lines performing better than the variety checks for yield and quality across locations and seasons were then adopted as new varieties. This was either as single lines or in line-mixture composites.

Seed Multiplication

Three stages of multiplication were handled during the period. Breeders seed were multiplied in open pollinated but isolated plots. These comprised counterpart material of the entries to the strain and line trials. Also included were component lines of past and new varieties. As high as 10 ha could be devoted to this stage in a given season. The "nucleus" plots formed the second stage of multiplication. The materials comprised new varieties constituted from breeders' seed on utmost two hectares due to limitations of seed. The nucleus gave source of seed for planting the third stage; the foundation seed plots. The size of this foundation seed plots progressively increased during the period to a peak of 30 ha during the 1999-2000 and 2000-2001 seasons. Twenty and 10 ha were maintained at Serere and Namulonge respectively. The fields in the three stages were inspected at germination, flowering and at boll maturity stages. This was for roguing out of any off-type plants and of disease and pest-infested plants, especially those with wilts. Field inspection and roguing was for ensuring genetic purity and viability of resultant seeds.

Results and discussion

Variety Development

The Constitution of a new variety was preferred to be from lines, which yielded 5% or more than the existing variety over a wide range of production environments. This was coupled with better fiber and spinning quality. In some cases, however, increases in yield *per se* were taken as the criterion while the quality remained the same. This was the case for variety BPA 95 selected for yield advantage over variety BPA 89 with which it was at par in some quality aspects (Table 1A). BPA 95 was made up of six lines buffered with a background of BPA 89 as the seventh component (Table 1 B).

Following multi-location testing of thirteen A(82) 4, 8, 9...45-derived lines in 1995-96 season, five lines were selected to constitute variety BPA 97. A component of BPA 95 was included for further reinforcement of performance by BPA 97.

Table 2 shows the composition of BPA 97 by seed weight. Table 3 gives the performance of the BPA 97 component lines for lint yield and ginning percentage. Data was from 8 testing locations.

Table 1A. Comparison of Fibre and Spinning Quality of BPA 89 and BPA 95: Means of 16 Sites in 2 Seasons

Variety	Effective Length (32^{nd} inch)	Micronaire values	Fibre Bundle Strength (g tex^{-1})	Yarn Strength (CLSP)	Yarn Appearance
BPA 95					
Range	39.9-41.3	3.35-4.5	17.99-21.0	1689-2211	4D-4E
Mean	40.6	3.9	19.30	1892.7	
BPA 89					
Range	39.1-41.8	3.26-4.4	18.7-21.5	1612-2064	4D-5E
Mean	40.6	3.9	19.59	1861.2	
Legend	1 = Very Good	2 = Good 6 = Poor	3 = Fairly Good	4 = Fair, 7 = Very Poor	5 = Moderate
	A = Very Good F = Poor	B = Good G = Very Poor	C = Fairly Good	D = Fair	E =Moderate

Table 1B. Composition of Variety BPA 95

Line	% by wt in BPA 95
A(75) 18	10
A(76) 11	10
A(76) 57	10
A(79) 41	10
A(79) 67	10
A(79) 68	10
BPA 89	40

Table 2. Composition of Variety BPA 97

Line	Lint Yield % BPA 95	GOT	% by Weight in BPA 97
A(82)9	109	36.2	10
A(82)18	104	35.7	10
A(82)28	113	36.5	20
A(82)34	108	35.6	15
A(82)37	106	35.1	15
BPA 95	100	34.9	30

Table 3. Lint Yield Kg ha-1 of 13 A (82) 4, 8, 9,..., 45 Derived Lines at 8 Locations for 1995/96 Season

Line/Variety	Locations										
	Butemba	Ikulwe	Mubuku	Namulonge	Namyoya	Nyamugasani	Tororo	Serere	Line Mean	Lint % BPA 89	Mean G.O.T
BPA 85	**224**	**305**	**665**	**410**	**375**	**642**	**480**	**254**	**419**	**100**	**34.5**
BPA 89	**248**	**362**	**684**	**436**	**388**	**562**	**384**	**269**	**417**	**100**	**34.7**
BPA 95*	**265**	**393**	**763**	**480**	**362**	**662**	**460**	**286**	**459**	**110**	**34.952**
A(82)4	**253**	**381**	**792**	**519**	**379**	**700**	**509**	**264**	**475**	**114**	**34.1**
A(82)8	**245**	**338**	**723**	**328**	**354**	**593**	**388**	**254**	**403**	**97**	**35.9**
A(82)9*	**297**	**386**	**847**	**502**	**462**	**633**	**539**	**300**	**496**	**119**	**36.2**
A(82)11	**283**	**354**	**687**	**462**	**353**	**622**	**495**	**275**	**441**	**106**	**33.8**
A(82)15	**289**	**341**	**706**	**483**	**519**	**628**	**532**	**344**	**488**	**117**	**35.2**
A(82)18*	**296**	**388**	**776**	**528**	**349**	**627**	**467**	**353**	**473**	**113**	**35.7**
A(82)28*	**276**	**412**	**862**	**513**	**463**	**635**	**565**	**362**	**511**	**123**	**36.5**
A(82)32	**259**	**354**	**774**	**497**	**333**	**627**	**441**	**304**	**482**	**116**	**36.0**
A(82)34*	**306**	**418**	**786**	**500**	**456**	**594**	**528**	**332**	**490**	**118**	**35.6**
A(82)35	**277**	**377**	**716**	**460**	**444**	**688**	**501**	**325**	**474**	**114**	**35.3**
A(82)37*	**291**	**383**	**773**	**409**	**455**	**690**	**491**	**371**	**483**	**116**	**35.1**
A(82)40	**288**	**426**	**744**	**494**	**400**	**642**	**481**	**331**	**478**	**115**	**34.9**
A(82)45	**259**	**305**	**734**	**392**	**349**	**530**	**426**	**292**	**411**	**99**	**34.9**
S.E±	**15.6**	**33.7**	**68.9**	**21.3**	**126.0**	**36.7**	**43.1**	**23.0**	**-**	**-**	**-**
LocalityMean	272	370.0	752.0	463.0	403.0	630.0	480.0	307	-	-	35.2
C.V.%	12.8	20.2	20.5	10.8	69.9	13.0	19.6	14.4	-	-	-
LSD (P=0.05)	1.6	3.4	7.3	2.7	13.3	4.0	4.4	65.0	-	-	-

*Denotes component lines of BPA 97 variety

Table 4. Quality Performance of Component Lines of Variety BPA 97 (Means for 6 Sites) 1995-96 Season

Variety/Line		Effective Length (32nd Inch)	Micronaire Values	Fibre Bundle Strength (g tex^{-1})	YarnStrength (CLSP)	Yarn Appearance
BPA 89	**Range**	**39.1-41.8**	**3.5-4.4**	**18.8-21.5**	**1612-1895**	**4D - 5E***
	Mean	**40.5**	**4.1**	**19.9**	**1796**	
BPA 95	**Range**	**40.0-41.3**	**3.6-4.5**	**18.6-19.3**	**1687-1939**	**4D - 4E**
	Mean	**40.7**	**4.0**	**19.0**	**1831**	
A(82)9	**Range**	**38.5-41.1**	**3.9-4.7**	**17.0-22.3**	**1655-1890**	**E-5E**
	Mean	**40.1**	**4.3**	**20.0**	**1770**	
A(82)18	**Range**	**39.0-41.0**	**3.6-4.8**	**17.522.0**	**1630 - 1865**	**4D -5E**
	Mean	**40.2**	**4.3**	**19.7**	**1773**	
A(82)28	**Range**	**39.5-40.9**	**3.7 - 44**	**18.7 - 20.0**	**1569 - 1935**	**4C - 4D**
	Mean	**40.3**	**4.0**	**19.1**	**1767**	**4C - 4D**
A(82) 34	**Range**	**39.8 - 41.8**	**3.8 - 4.4**	**16.8 - 21.0**	**1713 - 1912**	**4D - 5E**
	Mean	**40.7**	**4.3**	**19.1**	**1829**	
A (82)37	**Range**	**37.7 - 41.8**	**13.6 - 4.7**	**17.720.8**	**1662 - 1886**	**4D - 5DE**
	Mean	**40.1**	**4.2**	**19.1**	**1809**	**4D -5D**

Legend 1 = Very Good 2 = Good 3 = Fairly Good 4 = Fair, 5 = Moderate 6 = Poor 7 = Very Poor

A = Very Good B = Good C = Fairly Good D = Fair E = Moderate F = Poor G = Very Poor

The component lines had out-yielded BPA 95 by 4-13%. Also line A(82) 28 with the highest yield for lint, best GOT (36.5%) and best fibre yarn strength and best appearance among the component lines formed 20% of the composition (Tables 2, 3 and 4). The fibre and yarn strength for all entries were very low at Ikulwe TVC where drought conditions prevailed during the growing season. The decision on the composition (weight) for each component line is based on the intrinsic attributes of the lines at hand. In some cases, however, availability of seed may influence the decisions. Several workers (Walker, 1963; Riggs, 1970; Innes and Jones, 1977) have discussed the advantages of line-mixture varieties. These include inter alia acceleration of seed multiplication, blending in traits where some lines may be falling short, and buffering in performance across varying environments for stability. There are also expectations of heterotic advantages in future generations arising from natural out-crossing between the component lines. As variety BPA 97 was on the 'nucleus' stage of multiplication in 1996/97 season it was being tested as a line mixture control in yield trials as well. This stage of testing enables ascertaining the compatibility of the lines. Performance of single lines may not necessarily be similar to that in combined states. Disparity may arise from competition between different line genotypes in the mixture.

Another set of fourteen A(83) 5, 7, 12,...,39-derived lines was extensively tested for three seasons starting in 1995-96. Six lines were after 1996-97 season selected to constitute a new line mixture A(97) MO.1. Each of the lines A(83) 16, 19, 22, 23, 24 and 26 contributed 12.5% of the seed mixture by weight. The remaining 25% was contributed by BPA 97. The performance of the component lines in 1995-96 season is shown in Table 5. All of the lines outyielded BPA 95 by at least 3% and had higher GOT. The lines in 1996-97 exhibited fibres of similar strength to BPA 95 (19.8 g tex^{-1}) but stronger yarns at a mean of 1863 CLSP compared to 1799 for BPA 95. They gave similar yarn appearances to BPA 95 at 4D. The A(97) MO.1 formed the new variety BPA 99.

BPA 99 however did not give satisfactory performance in 1997-98 where in six sites it was outyielded for lint by 17% by its predecessor BPA 97. Modification was made in 1998 by constitution of A(98) MO.1 line mixture. The component line A(83) 19 in BPA 99 was replaced by the line A(83) 12 which had higher GOT (Table 5). The line-mixture composition was also changed in seed weight percent as follows: A(83) 12-25%, A(83) 16-10%, A(83) 23-15%, A(83) 24-10%, A(83) 26-10% and BPA 97 30%.

In the 1997-99 seasons line testing was devoted to A(94) MO 1, 2, 10,.... and A(95) 8, 21, 29,...82-derived lines. These were the reselections from BPA 68, 85 and BPA 89 seed issues. Marked improvements were noted in fibre strength up to 33 g tex^{-1} (31 g tex^{-1} for BPA) and fibre length of up to 31 mm (30mm in BPA) at Serere. The improvements in GOT in these selections from 34% (BPA 68) to 37% were also achieved but these were not high enough to meet the operator's needs. This reselected cohort was therefore left for use in future crosses (NARO, 2001).Meanwhile more efforts were directed towards development of lines out of the Albar ´ WRC crosses and testing of high GOT varieties introduced from Malawi. Table 6 shows the performance in 1999 – 2000 season of 13 F_5, F_2-derived lines from the Albar ´ WRC crosses. The boll weights were generally at 6.0 g boll $^{-1}$ with GOT at 1% higher than BPA 99 (38%). The fibre tests from several sites showed good fibre qualities in the range of BPA varieties.

Table 5. Performance of Six A(83).... Lines in 1995-96 Season for Lint Kg ha^{-1}

Line/Variety	Location							
	Namulonge	Kihonda	Bukalasa	Ivukula	Serere	Line Mean	Lint % BPA 89	Mean GOT
BPA 89	**299**	**81**	**154**	**199**	**338**	**214**	**100**	**36.7**
BPA 95	**357**	**130**	**230**	**168**	**329**	**243**	**114**	**37.3**
A(82)12	**342**	**105**	**208**	**206**	**372**	**247**	**115**	**38.1**
A(82)16	**342**	**138**	**239**	**255**	**349**	**265**	**124**	**38.4**
A(82)19	**359**	**120**	**210**	**222**	**341**	**250**	**117**	**37.7**
A(82)22	**353**	**107**	**258**	**196**	**381**	**259**	**121**	**37.5**
A(82)23	**406**	**126**	**199**	**223**	**394**	**270**	**126**	**37.4**
A(82)24	**423**	**153**	**271**	**102**	**388**	**267**	**125**	**37.8**
A(82)26	**377**	**150**	**235**	**179**	**405**	**269**	**126**	**38.1**
S.E±	**34.9**	**13.7**	**14.2**	**35.3**	**17.0**	-	-	-
Locality Mean	**362**	**123**	**222**	**194**	**366**	-	-	-
C.V.%	**22.9**	**24.3**	**15.3**	**40.1**	**9.1**	-	-	-
LSD (P=0.05)	**4.1**	**1.3**	**1.4**	**3.7**	**4.8**	-	-	-

Table 6 . Performance of F_5, F_2 –Derived Albar ´ WRC Lines at Serere 1999-2000 Season

Line/Variety	Boll Weight(g)	Seed Cotton Weight (kg ha^{-1})	GOT	Lint (kg ha^{-1})	100 Seed Weight(g)
BPAN (97)2	6.0	1454	39.0	480	11.2
BPAN (97)21	5.8	1322	38.1	504	10.6
BPAN (97)25	6.0	1364	39.0	532	11.3
BPAN (97)32	6.2	1258	38.8	488	11.3
BPAN (97)43	6.1	1434	40.9	586	10.5
BPAN (97)44	6.1	1523	39.0	594	10.9
BPAN (97)49	5.9	1381	39.6	492	11.1
BSRIF (97)2	5.6	1373	38.5	529	11.0
BSRIF (97)6	5.9	1580	40.0	633	10.8
BHG(97)3	5.7	1281	38.3	490	10.8
BHG(97)12	6.6	1365	39.0	533	12.3
BHG(97)17	5.8	1371	40.7	558	10.5
BHG(97)21	6.2	1334	39.5	527	11.4
BPA 95	5.9	1134	37.2	422	10.5
BPA 97	5.7	1267	37.7	478	10.6
BPA 99	5.8	1239	38.1	472	10.8
S.E±	2.02	142.3	-	58.7	-
C.V%	5.41	16.6	-	17.9	-
LSD(P=0.05)	4.02	284.9	-	117	-

Table 7. Yield of Seed Cotton Kg ha^{-1} and G.O.T for Albar ´ WRC Line Mixtures 2000-2001 Season

Entries	**Site**						
	Namulonge	**Bukedea**	**Aduku**	**Ngetta**	**Serere**	**Mean Yield**	**Mean GOT**
BPAN (2000)MO.1	967	691	1427	1207	2007	1259	40.9
BPAN (2000)MO.2	967	685	1410	1290	1801	1231	40.1
BPAN (2000)MO.3	715	759	1516	1202	2008	1240	40.1
BPAN (2000)MO.4	950	725	1338	1086	1826	1185	41.5
BHG (2000) MO.1	977	913	1110	1370	1869	1248	41.5
BHG (2000) MO.2	930	851	1413	1311	1835	1268	40.1
BHG (2000) MO.3	766	736	1430	1208	1635	1155	41.3
BHG (2000) MO.4	821	715	1332	1328	1752	1190	40.1
BPAN (97)21	596	610	1607	1228	1867	1182	41.2
BSRIF (97) 2	851	668	1342	1247	1868	1195	39.5
BSRIF (97) 6	804	589	1325	1321	2007	1209	40.8
BPA 68	797	722	1342	1197	1867	1185	38.8
BPA 95	889	521	1332	1383	1771	1179	39.3
BPA 97	964	794	1185	1158	1911	1202	39.8
BPA 99	824	650	1383	1226	2113	1239	39.5
BPA 2000	729	787	1219	1347	1886	1193	39.5
Means	**847**	**713**	**1357**	**1257**	**1876**		

SED Treatment	=	**76.3**
SED Site	=	46.7
SED Treatment ´ site	=	186.9
CV%site	=	7.1
CV% Treatment ´ site	=	28.6

Table 8. Means of Fiber Properties for Albar ′ WRC Line-mixtures 2000-2001 Season at Four Sites (Serere, Ngetta, Namulonge and Butemba)

Line		Micronaire Value	Fibre Strength (g tex^{-1})	Staple length (mm)	Uniformity	Elongation
BPAN (2000)MO.1	**Range**	**3.8-4.5**	**25.8-31.6**	**27.7-29.4**	**-**	**-**
	Mean	**38**	**30**	**28.3**	**84.2**	**4.2**
BPAN (2000)MO.2	**Range**	**3.3-4.9**	**26.9-31.4**	**27.0-30.0**	**-**	**-**
	Mean	**4.1**	**29.4**	**28.4**	**85.2**	**4.7**
BPAN (2000)MO.3	**Range**	**3.2-4.5**	**28.3-31.4**	**28.0-30.0**	**-**	**-**
	Mean	**4.0**	**30.1**	**28.3**	**85.8**	**4.9**
BPAN (2000)MO.4	**Range**	**3.4-4.3**	**28.2-31.4**	**27.7-30.0**	**-**	**-**
	Mean	**3.9**	**29.8**	**28.8**	**84.6**	**4.1**
BHG (2000) MO.1	**Range**	**3.4-4.2**	**27.2-30.5**	**27.3-29.4**	**-**	**-**
	Mean	**3.9**	**28.6**	**28.5**	**84.4**	**3.8**
BHG (2000) MO.2	**Range**	**3.3-4.6**	**29.8-33.0**	**28.1-30.2**	**-**	**-**
	Mean	**4.0**	**31.2**	**29.5**	**84.7**	**4.0**
BHG (2000) MO.3	**Range**	**3.4-4.8**	**30.1-34.2**	**27.6-30.1**	**-**	**-**
	Mean	**4.2**	**31.9**	**29.1**	**85.2**	**4.1**
BHG (2000) MO.4	**Range**	**3.5-4.5**	**29.4-32.7**	**27.1-30.0**	**-**	**-**
	Mean	**4.2**	**30.9**	**28.6**	**85.6**	**4.1**
BPA 95	**Range**	**3.4-4.2**	**27.9-31.4**	**27.6-29.3**	**-**	**-**
	Mean	**3.8**	**29.2**	**28.4**	**85.0**	**4.5**
BPA 97	**Range**	**3.7-4.7**	**26.7-30.9**	**26.7-30.0**	-	-
	Mean	4.2	28.3	28.1	84.2	4.2
BPA 99	Range	3.3-4.3	27.9-35.8	27.6-29.3	-	-
	Mean	31.2	28.7	85.3	4.5	3.8
BPA 2000	Range	3.6-4.4	27.7-31.3	27.3-29.0	-	-
	Mean	3.9	30.0	28.1	85.3	4.5

The fibre strengths were up to 33 g tex^{-1} and fibre lengths up to 30 mm.

The performance of the line mixtures made out of these lines and tested in 2000-2001 season is shown in Table 7 as combined analyses for 5 sites. The results clearly indicate the strides taken in the improvement of the Uganda cottons for the GOT trait. All entries exhibited GOT between 39.5-41.2%. The mean yields for seed cotton of 1185 – 1268 kg ha^{-1} with 2007 kg ha^{-1} for three line mixtures is further evidence of the improvement in the potential of the developed varieties. The fibre properties of the line-mixtures are shown in Table 8. The line mixtures and varieties had micronaire values between 3.2-4.9. This is in good conformity with the currently required micronaire range (3.8-4.2) for premium prices. The mean fibre strengths were around 30g tex^{-1} up to 35.8 g tex^{-1}. Six of the entries had staple length up to 30 mm. The uniformity rations of the fibres at 84% and above coupled with elongation factors at 4% in all line mixtures and varieties further exhibit improvements in the developed varieties.

Considering the yield, yield and quality components and plant habit characteristics the BPAN(2000)MO.3 has been earmarked to form or new variety. Among its attribute are the boll sizes at 6.3 g boll^{-1} (5.8 for BPA 2000) dense hairiness on boll leaves and stems and GOT at 40%.

Much has been achieved during the period 1994-2001 in the development of appropriate varieties for the cotton industry. The use of the pedigree line selection technique has particularly contributed to the achievements. The intrinsic attributes of this method include the keeping of records on ancestry of the breeding stocks or cohorts. The method is also efficient in raising magnitudes of genetic gains while selecting for improvements in crop traits (Fehr, 1987; Hauller and Miranda, 1988; Jensen, 1998). Furthermore, the use of EGT has enabled reduction of time for variety development by four years as seen in the development of the candidate variety BPA 2002 from the line-mixture BPAN(2000)MO.3 thus enhancing genetic gains in the required traits. There have, however, been some constraints to the breeding efforts. For example, the high GOT variety introductions from Malawi and Zambia could not be synthesized per se for direct release. They were found to have smaller bolls and shorter fibres than BPA. They were also prone to Alternaria macrospora leaf spots and needed crossing to BPA for correcting the above shortfalls (NARO, 2001).

Table 9. Foundation Seed Production 1995-2001

Season	Variety	GOT	Seed Produced	Remarks (Metric tonnes)
1995-96	SATU 95 BPA 95	35% 36%	10 5	- -
1996-97	SATU 95 BPA 95	35% 36%	5.0 3.5	Re-issues of varieties. No constitutions of SATU 96 or BPA 96 were made.
1997-98	SATU 97 BPA 97	35% 37%	10 4	Last batch of SATU seeds but not released to farmers.
1998-99	BPA 97	37%	8.2	Re-issue of BPA 97. No BPA 98 was constituted.
1999-2000	BPA 99	38%	9.5	-
2000-2001	BPA 2000	39%	15.5	Record production on foundation stage since 1972.
2001-2002	BPA 2000	39%	-	30 ha planted as re-issue of BPA 2000.

Table 10. National Production, Seed Distribution and lint production During the Period 1993-2001

Season	Seed Distributed (Metric Tonnes)	Lint Production (Bales)	Remarks
1987-88	**-**	**11,700**	**Lowest ebb**
1993-94	**-**	**25,000**	**-**
1994-95	**4,770**	**32,800**	**-**
1995-96	**4,616**	**57,400**	**-**
1996-97	**7,755**	**112,400**	**-**
1997-98	**6,200**	**32,500**	**Production reduced by El nino**
rains			
1998-99	**7,000**	**82,300**	**La Nino effects**
1999-2000	**8,500**	**115,700**	**- 2000-2001 7,752**
98,251			**Drought during season**
2001-2002	**5,362**	**130,000**	-

Source: Serunjogi et al, 2001 and Anon 2001a and b

Further constraints have risen from emergence of cotton wilt diseases caused by Fusarium Oxysporum f.sp vasinfectum and Verticillium dahliae. These vascular wilts have been observed to be associated with root-knot nematodes (Meloidogyne spp). Efforts have now been directed towards breeding for resistance to the three pests. Germplasm has been collected comprising multiple adversity resistance (MAR) accessions from the University of Texas A & M (NARO, 2001) and crosses to Albar have been made. Development of resistant varieties combining the desired traits (GOT and fibre quality) is underway. This is however being hindered by lack of a spinning laboratory for data on yarn strength and appearance.

Other efforts in variety development are geared towards development of plant ideotypes suitable for intercropping and mechanical harvesting. Towards this goal, *germplasm* was acquired for branchless or "zero" cotton plants introduced from Uzbekistan and crosses have been made to Albar. The breeding for short duration cottons (Serunjogi, 1996) is continuing as a way of fitting cotton better in the cropping systems where it competes for labour with food crops. All the varieties at hand mature at 140-150 days after emergence. Breeding for resistance to insect pests and disease will continue to be a major component in the breeding programme. This is in support of the shift in the Integrated Pest Management (IPM) programme towards judicious use of chemicals in view of environmental concerns. Traits of "okra leaf" and nectariless, which are known to confer tolerance to pests are being incorporated into the Albar genetic background.

Seed Multiplication

The trends of foundation seed production for the period 1995-2001 are shown in Table 9. Issues of SATU varieties were ended in 1996-97 season leaving BPA as the sole type in production. Multiplication of BPA varieties reached a peak of 15.5 metric tonnes in the 2000-2001 season on 30 ha. Yields of 2000-kg ha^{-1} were obtained at Serere for seed cotton yields.

The availability of new foundation seed has enabled flushing out of the seed scheme the BPA 89 variety. BPA 89 has since 1994 been highly adulterated by private ginners who bring in cottons from neighbouring countries mainly from the Democratic Republic of Congo. The unauthorised imports have also brought in disease problems, for example, bacterial blight and Altenaria macrospora leaf spots. In the 2000-2001 seasons only the varieties shown in Table 9 have been in production. BPA 95 has gone through the stages of seed multiplication and has reached commercial stage prior to being phased out for crushing in the oil industry. The current planting seed requirement is about 8,000 metric tones per season.

The new developed varieties coupled with new production recommendation for crop and pest management has led to increases in productivity.

National productivity were 350 and 550 kg ha^{-1} seed cotton in 1994-95 and 1996-97 seasons respectively (Serunjogi et al, 2001). National production has also been on the increase since 1994 (Table 10) in comparison to the lowest ebb in 1987-88 season. The increase in production is attributed to the new high yielding varieties in addition to improved agronomic practices developed through research efforts. Yields of over 3000 kg ha^{-1} seed cotton are now common on Kasese farmers' plots, which are endowed with young fertile volcanic soils.

At the current production and restructured ginning industry, 2.5 million people depend on cotton for their source of income. This is through direct production and indirectly through employment. The national production increased from 2,160 to 26,000 MT of lint between 1998 and 2000. The high fibre quality earns Uganda an additional premium of 10 US cents per pound of lint at international markets. Between 1995 and 1999 Uganda earned US $ 82 million from lint exports. The cotton industry therefore is increasingly contributing to the Government policy of poverty eradication. The contribution will go higher with value addition to cotton products planned for moving away from exporting lint in raw forms and exploitation of the USA's offer under the African Growth Opportunity Act (AGOA).

Conclusions

New varieties have been developed meeting requirements for the cotton industry. There is need for the operators to observe processing regulations set up by CDO. This includes inter alia desisting unauthorized imports of seed cotton from neighbouring countries and crushing planting seed for oil. Failure of this will lead to uncontrolled mixing of cotton stocks and loss of market slots for the Uganda cotton. New production constraints have come up including the cotton wilts. Breeding efforts are already directed to these. There is however lack of a spinning laboratory to keep track of the spinning ability of the new genetic stocks under development. Exploitation of the AGOA offer would lead to high foreign exchange earning. This could be ploughed back in buffering the farm-gate prices against fluctuating international lint prices.

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