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DECENTRALIZED AND PARTICIPATORY COTTON BREEDING IN BENIN: FARMER-BREEDERS' RESULTS ARE PROMISING

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SUMMARY

Institutional changes in Benin have brought to light farmers' demand for varieties better suited to local growing conditions than existing ones. In response, we initiated a participatory cotton breeding experiment in 1996 to evaluate the relevance of such a methodology for the improvement of a commercial crop grown under rain-fed, semi-intensive cropping systems. This paper compares the performance of the first four mass-selection cycles, implemented by three farmer-breeders (F-B) and one formal breeder, with the original population and two commercial controls over three sites and two years. First results show that genetic changes occurred in all the F-B populations. The highest yielding F-B population (Savalou) was also more exuberant and later maturing than the others. Within the relatively narrow range of environments considered in the trial, there is no evidence that decentralized breeding results in better local adaptation. In Benin, participatory cotton breeding may be considered as complementary to formal on-station breeding and useful for enlarging the genetic variability offered to the farmers. Although the farmers want the approach to be scaled-up, its sustainability relies on a formal partnership between research and farmers institutions.

INTRODUCTION

Formal cotton breeding programmes in French-speaking Africa have long been successful. They have produced many widely-adapted varieties, among which are some grown today on 2 million ha. Although based in central research stations, cotton breeders have always worked in close relationship with the major stakeholders, the crop specialists, the extension services and the ginning industry. However, organizational changes, due to privatization and enhancement of farmers' organizations, are occurring throughout the Benin cotton commodity chain. These changes have revealed farmers' demands for a greater choice of varieties, better suited to local growing conditions. They have encouraged formal breeders to look for relevant methodologies like participatory plant breeding (PPB), as described by Witcombe *et al.* (1996), to face this new challenge.

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Table 1. Parents of the original population AGP0.

Genotypes	Contribution index†	Specific traits	Origin
Stam 18A	0.79	High yielding potential	Ivory-Coast/Togo/Benin
H 279-1	0.86	Fibre quality	
H 279A	1.24	Adapted to local conditions	
Irma 772	0.83	Earliness, % F, fibre quality	
Irma Z856	1.28	High yielding potential	Cameroon
Irma BLT-PF	1.38	Fibre quality (length)	
G 440	0.83	% F and fibre quality	Senegal
Deltapine 90	1.00	High yielding potential	
DES 119	1.03		
Stoneville 907ne	1.03	Compact habit	USA
Stoneville 1324	0.90	Earliness	
Sicala 34	1.07		Australia
Guazuncho II	0.93	Compact habit	
Chaco 520	0.83	Earliness	Argentina

† The contribution index is related to the allelic contribution of each genotype to the population; it is estimated from the number of individual plants that participated to the intercrossing phase, weighted by their flowering abundance (1 is average).

Participatory plant breeding was originally designed for complex, diverse and risk-prone environments, which are more frequently encountered in marginal areas with subsistence agriculture (Hardon, 1996). Major PPB studies like those reported by Ceccarelli *et al*. (2000), Witcombe (1997) or Sperling *et al*. (1993) are based upon two assumptions: (a) farmers, although non-professional plant breeders, can do efficient breeding work, and (b) decentralized breeding is more efficient than centralized on-station breeding to capture genotype × environment (G × E) interactions. Our work was designed to test these two assumptions with cotton and, as suggested by Witcombe (1999), to establish the suitability of the approach beyond its initial domain, i.e. for a commercial crop grown under rain-fed semi-intensive cropping systems and in areas with medium yielding potential.

After presenting the results obtained with the first four breeding cycles, this paper will discuss the conditions needed for sustainable scaling up.

MATERIAL AND METHODS

A genetically variable population was grown in four situations and submitted to different selection pressures according to environments or breeders.

Genetic material and breeding

The original population AGP0 was created in 1996. Fourteen genotypes that had originated in West and Central Africa (7), USA (4), Argentina (2) and Australia (1) were chosen for their morphological appearance as well as their agronomic and

technological performances (Table 1). They were planted in two neighbouring plots, each genotype being replicated five times in each plot. One plot was dedicated to pollen production and the other was considered as a pollen receiver only, i.e. the stamens had to be removed manually before flowering. All the pollen was collected as a mixture and applied to the emasculated flowers with a brush. To monitor the reality of panmixis, an indicator called R_i was computed to estimate the contribution of each parent to intercrossing:

$$R_i = \frac{1}{2} \times v \times \left(\frac{M_i}{\sum_{i=1}^{v} M_i} + \frac{C_i}{\sum_{i=1}^{v} C_i} \right)$$

M_i being the number of plants of the ith parent in the 'male' plot, C_i being the number of bolls harvested from the ith parent in the 'female' plot and v being the total number of parents. For most parents, R_i was close to 1, indicating that they could contribute significantly, if not equally, to the genetic variability of AGP0 (Table 1).

Four breeders (or teams) derived populations from AGP0, by mass selection. Three were farmers who conducted the breeding work in their fields located at Djougou (Donga region), Savalou (Collines) and Kandi (Alibori), within the major cotton growing areas of Benin (Figure 1). The formal breeder worked on-station at Okpara (Borgou).

At each location, seeds were planted in 1000 holes spaced at 1×0.40 m (25 000 plants ha^{-1}) and, after emergence, they were thinned to one plant per hole. Each breeder selected and harvested about 200 single plants from his field, in separate bags. The seed cotton was ginned and the fibre quality was tested with a high volume instrument (HVI) run by the cotton development company (SONAPRA). Formal and farmer-breeders met finally to decide the best 50 to 60 plants to keep from each site. Seeds from these plants were sampled equally (up to 50 g per plant) and thoroughly mixed to produce the next breeding cycle.

Breeding populations were identified by combining the name of each site and a number to specify the breeding cycle. For example, the third cycle of selection in the breeding site of Savalou was called Savalou-3 (Figure 2).

Breeding conditions

In order to interpret the results of this experiment for possible G × E interactions, we needed to compare our breeding and experimental conditions with the most common sets of constraints faced by cotton growers in Benin.

We prepared a typology (Table 2) which indicated the constraints that could realistically be addressed by cotton breeding. These are divided into three major groups related to environment (climate, soil, pest and disease pressure), crop management (previous crop, land preparation, level of intensification, labour intensity) or crop destination (market requirements). The most discriminating factors are linked with

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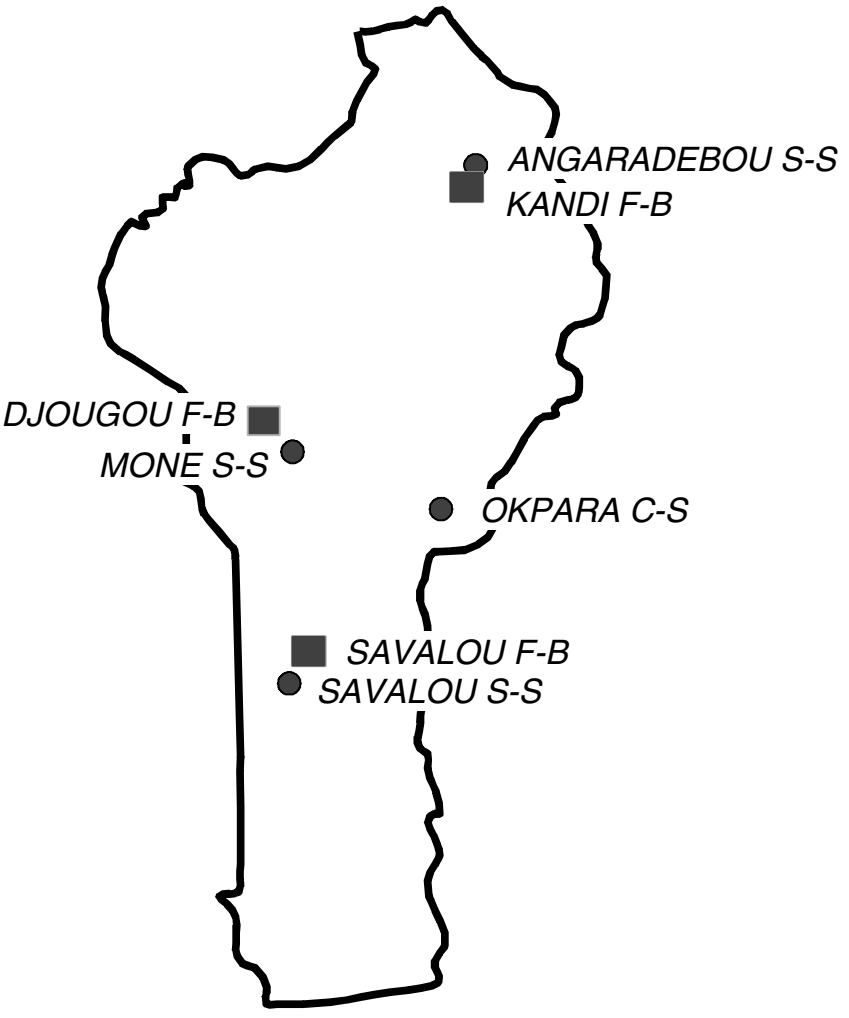

Figure 1. Farmer-breeder sites (F-B), formal breeder site (CS) and testing sites (S-S + C-S), located on the map of Benin, West Africa.

the management of water (pattern and level of rainfall or length of the cropping season), nitrogen (response to intensification) or pests (type and level of infestation).

The most common conditions encountered by the farmers generally fall into categories 2 to 9: many farmers follow, at least partially, the techniques recommended by the extension services, which include moderate levels of insecticide and fertilizer application.

All the breeding sites were managed in accordance with these recommendations which are widely adopted by the cotton growers. Compared to the categories identified in Table 2, the breeding conditions were similar to set 2 for Savalou (although the rainfall pattern was very erratic during the first breeding cycles), set 6 for Kandi and set 7 for Djougou and Okpara.

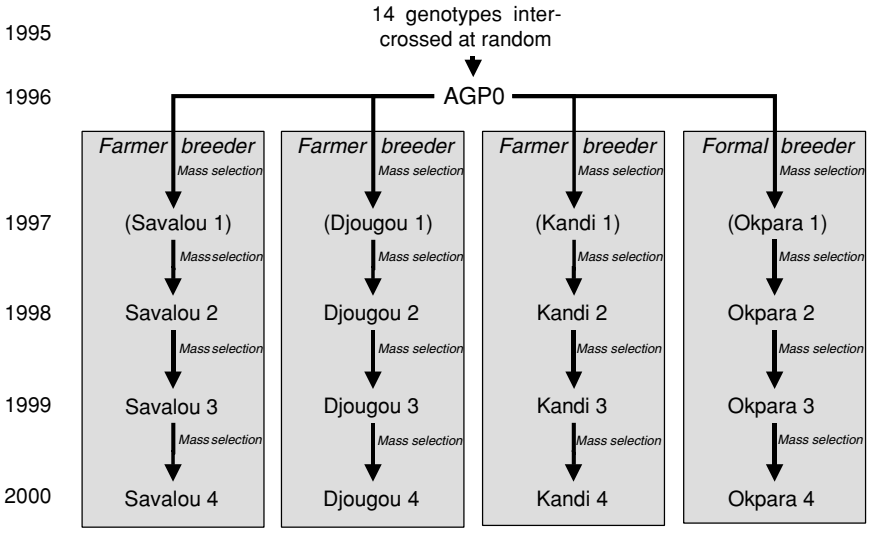

Figure 2. Breeding design indicating the four generations produced on each site. The first generation (in brackets) was not included in the test.

Table 2. Main constraints to cotton production in Benin as determined from a breeder's point of view.

	Environment				Crop Management			
Set N°	Rainfall pattern and regime	Soil fertility†	Major pests‡	Main disease	Rotation	Planting date§	Intensification¶	Destination market
1	2 rainy seasons, 800 to 1000 mm	Low	P/C T/M		Maize/ groundnut	Late		
2	1 rainy season, > 1000 mm	High	P/C		Maize/ Cotton	Early		
3						Late		
4		Low	H/E			Early		
5			M			Late		
6	1 rainy season, 800 to 1200 mm	High	H/S	Bacterial blight	Cotton/ Maize/ Sorghum/ Cowpea	Early	Medium	Commercial crop, mainly for export
7						Late		
8		Low	A/E			Early		
9						Late		
10	1 rainy season, < 800 mm	High	H/S		Cotton/ Sorghum	Early		
11						Late		
12		Low	A/E			Early		
13						Late		

† Response to N applications.
‡ P: *Pectinophora gossypiella*; C: *Cryptophlebia leucotreta*; T: *Thrips sp*; M: *Polyphagotarsonemus latus*; H: *Helicoverpa armigera*; E: *Empoasca sp*; S: *Spodoptera littoralis*; A: *Aphis gossypii*.
§ Early planting means that the rainfall between planting and harvesting exceeds 600 mm.
¶ On a 4 level scale: Very high (10–15 insecticide sprays and over 200 kg N ha^{-1}); High (7–10 sprays and 100–200 kg N ha^{-1}); Medium (4–6 sprays and around 50 kg N ha^{-1}); Low (less than 3 sprays and 20 kg N ha^{-1}).

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Table 3. Present roles of formal and farmer breeders (F-B) in the participatory breeding process[†].

Breeding step	Formal Breeder	Farmer Breeder
Creating genetic variability	++	No
Selecting material		
in the field	No	++
in the lab	++	+
Testing and evaluating	++	No

[†] F-B are not involved in the breeding at Okpara central research Station.

Table 4. Differences in the trials' management.

Site	Year	Yield[†] (t ha^{-1})	Showing date	FOB[‡] (dae)	Useful rainfall[§] (mm)	Set of constraints
Angaradébou	2001	2.00	19/06	107	856	6 or 7
	2002	1.83	21/06	101	921	
Moné	2001	1.84	26/06	110	832	6 or 7
	2002	2.08	17/06	103	932	
Savalou	2001	1.07	28/06	114	478	2 or 3
	2002	0.87	2/07	109	680	
Okpara	2001	1.67	23/06	113	611	6 or 7

[†] Average seed cotton yield in each trial.
[‡] FOB: time to first open boll in days after emergence.
[§] Amount of rainfall received by the crop (from 10 days before sowing to first harvest).

Roles

In comparison with the methods described by Witcombe *et al.* (1996), our PPB approach was similar to set 4 for technological traits and to set 5 for agronomic traits, i.e. farmers played a prominent role in the selection of segregating material.

The parental lines used to create AGP0 were chosen by the formal breeder alone (Table 3), because the F-B were not able to contribute at the start of the project. However, the F-B were fully involved in the following breeding cycles for evaluating the agronomic performance in the field. They were also involved with the formal breeder in screening for technological traits. For simplicity, mass selection was the first method proposed to start improving the original population.

Experimentation

The 12 populations produced by the second, third and fourth cycle of selection in each of the four breeding sites were compared with the original population AGP0 as well as with the two local commercial cultivars, STAM 18A and H279-1. The trials were conducted in the sub-stations located near the F-B sites at Moné (Djougou), Savalou and Angaradébou (Kandi) both in 2001 and 2002 and at Okpara central research station in 2001 (Figure 1).

General crop management and sowing dates in particular were similar in all the experimental sites (Table 4). Yield differences appeared highly related to the amount

Table 5. Description of variables.

Abbreviation	Meaning	Unit
Main		
FF	First flower	Days after emergence‡
HAI	Hairiness	0 to 4 scale†§
BW	Average 20 bolls weight	g(2)
%F	Fibre percentage	%(2)
SI	Seed index	g/100(2)
NFFB	Nodes to the first fruiting branch	§
NVB	Number of vegetative branches number	§
LFB	Length of the longest fruiting branch	cm§
LVB	Length of the longest vegetative branch	cm§
Secondary		
FOB	First open boll	Days after emergence‡
YLD	Yield of seed cotton	kg ha^{-1}‡
EAR	Earliness (first yield weight/total yield weight)	%‡
H	Plant height	cm§
HFFB	Height of the first fruiting branch	cm§
NBV	Number of bolls on vegetative branches	§
NBF	Number of bolls on fruiting branches	§
NBT	Total number of bolls	§

† From 0 (glabrous) to 4 (very hairy): breeder's scale based upon visual and tactile evaluation integrating hair length and density.
‡ Sample based on the entire plot (all plants or total harvest).
§ Sample based on 10 plants per plot.

of water received by the crop (useful rainfall in the table): 2 t ha^{-1} in Angaradébou or Moné for 800 to 900 mm rain, 1.5 t ha^{-1} in Okpara for 600 mm and 1 t ha^{-1} in Savalou for 500 to 700 mm, with a slightly later planting date and time of the first boll opening.

The field trials were designed as randomized blocks with five replications. Seventeen agro-morphological traits (listed in Table 5) were monitored either on a plot basis (FF, BW, %F, SI, FOB, YLD, EAR) or by sampling 10 individual plants per plot (HAI, NFFB, NVB, LFB, LVB, H, HFFB, NBV, NBF, NBT). Data related to fibre quality are not included in this paper because they were not as complete as the agronomic data.

The seven trials were analysed differently for the description and for the evaluation of the genotypes (Table 6). Because of incomplete records in the 2001 Savalou trial, the genotypes were described on the basis of the other six trials. We had to consider each site × year as a location in the analysis of variance (Table 6). The treatment means were then processed through a Principal Component Analysis (PCA) with STAT-ITCF (Philippeau, 1992). We followed the recommended procedure to select the variables that contributed to the analysis, discarding the ones with no significant genetic effect or those too highly correlated to each other. The PCA used adjusted variables. The productivity of the genotypes was evaluated with full yield data sets, i.e. two years, three sites (Table 6), in order to analyse G × E interactions. Contrasts were estimated with SAS, considering year and site as random effects and using restricted maximum likelihood methods (REML) as the estimation method.

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Table 6. Use of different trials results to characterize the genotypes by Principal Components Analysis (PCA) or to evaluate their productivity.

Trial site	Genotype descriptions (PCA)	Genotype evaluations (G × E)
Djougou	2002	2001 and 2002
Angaradébou	2001 and 2002	2001 and 2002
Savalou	2001 and 2002	2001 and 2002
Okpara	2001	

Table 7. Correlation between the variables and the axis of the Principal Components Analysis.

	Axis 1	Axis 2
Main variables		
FF: First flower	+ 0.73	− 0.01
HAI: Hairiness	+ 0.86	− 0.05
BW: Boll weight	− 0.62	+ 0.68
%F: Fibre percentage	+ 0.62	− 0.28
SI: Seed index	+ 0.30	+ 0.86
NFFB: nodes to the first fruiting branch	+ 0.88	+ 0.19
NVB: Number of vegetative branches number	+ 0.94	+ 0.18
LFB: Length of the longest fruiting branch	− 0.28	− 0.90
LVB: Length of the longest vegetative branch	+ 0.92	− 0.21
Secondary variables		
FOB: First open boll	+ 0.71	+ 0.46
YLD: Yield	+ 0.60	+ 0.16
EAR: Earliness	− 0.85	− 0.13
H: Plant height	+ 0.40	− 0.17
HFFB: Height of the first fruiting branch	+ 0.88	+ 0.31
NBV: Number of bolls on vegetative branches	+ 0.78	− 0.30
NBF: Number of bolls on fruiting branches	+ 0.27	− 0.64
NBT: Total number of bolls	+ 0.28	− 0.61

See Table 5 for abbreviations.

RESULTS

Genotypes characterization and farmer-breeding efficiency

The global analysis of variance (data not shown) indicates that the genetic effects are significant for nine variables out of the 17 listed in Table 5. These variables are considered as main variables for the PCA, i.e. their variability contributes to define the axis. The other eight are considered as supplementary variables: they are components of productivity (YLD, NBV, NBF, NBT), plant height (H) or traits that are strongly correlated with the main variables (FOB, EAR, HFFB).

The PCA illustrates and summarizes the total variability among genotypes. The correlation coefficients of all the variables with the first two axes are given in Table 7. For the main variables, high values indicate high levels of contribution to the axes. The first axis accounts for 52 % (eigen value 4.70) of the total variation and the second for 24 % (eigen value 2.20).

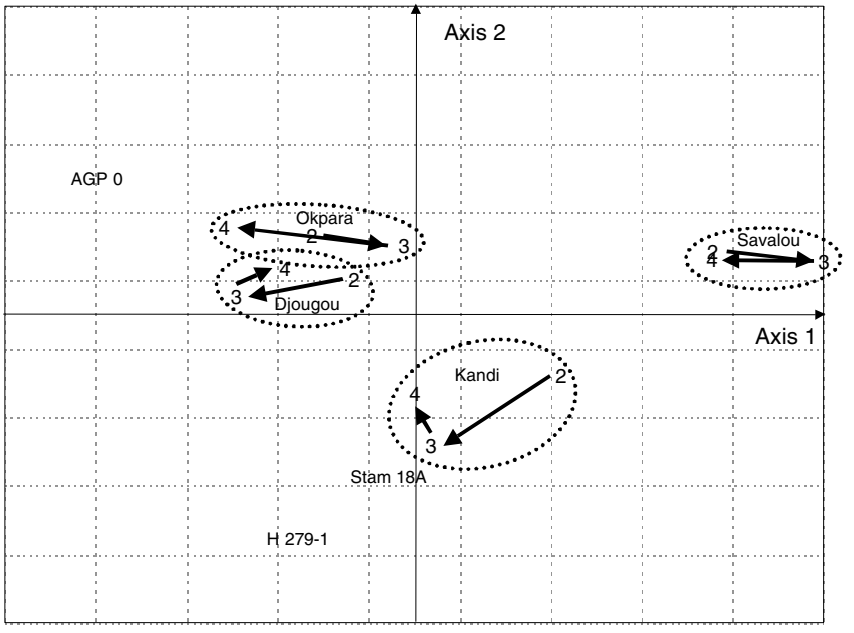

Figure 3. Principal components analysis (PCA): scatter diagram with the 15 genotypes. The first (vigour) axis and second (habit) axis distinguish between genotypes. AGP0, Savalou, and the two controls (Stam18A, H279-1) appear in the most extreme positions. The three F-B groups of populations (Djougou, Kandi, Savalou) appear relatively homogenous and are easily distinguishable from each other.

The first axis may be called the 'vigour' axis. It opposes early (FF), glabrous (HAI) genotypes, with larger bolls (BW) and comparatively low ginning output (%F) to late, hairy, more productive (YLD) and more vegetative genotypes (NFFB, NVB, LVB). It is also well correlated with earliness at boll opening (FOB) or at harvesting (EAR). The second axis, or 'habit' axis, opposes genotypes with large bolls (BW) and large seeds (SI) with genotypes bearing long and productive fruiting branches (LFB, NBF, NBT). These first two axes discriminate between genotypes (Figure 3). AGP0 (East), early and glabrous, Savalou (West), late and hairy, and the two controls (South) appear in the most extreme positions.

The three F-B groups of populations, i.e. Djougou, Kandi and Savalou appear to be relatively homogenous and easily distinguishable from each other. At all sites, breeding cycles 2, 3 and 4 are closer to each other than to AGP0: this indicates that populations differentiated mainly during the first breeding cycles (1 and 2). Kandi and Savalou have moved away from AGP0, indicating that they have changed significantly. Savalou tends to develop the most original genotypes, late, vegetative, hairy and rather productive while Kandi is becoming more like the controls. By comparison, Okpara (formal breeder) and Djougou stand close to AGP0, showing little change in the traits considered for the PCA. Their positions on the graph correspond to rather early and determinate genotypes with large bolls.

The PCA suggests that the generations two, three and four on each site are close enough to be pooled for further analysis. We ended up performing an analysis of

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Table 8. Description of controls and populations (six sites, two years) for the main variables selected in the Principal Components Analysis.

	Type	FF (dae)	HAI (0–4)	BW (g)	%F	SI (g/100)	NFFB	NVB	LFB (cm)	LVB (cm)
Controls†		57.5	3.03	4.57	44.9	7.15	5.59	2.12	42.6	58.2
AGP 0	Initial population	57.7	2.74	5.11	44.1	7.64	5.39	2.04	38.6	50.6
Djougou‡	F-B	57.1	2.88	4.79	44.7	7.77	5.61	2.30	40.3	54.5
Kandi‡	F-B	58.2	2.98	4.69	45.7	7.37	5.73	2.39	40.8	57.8
Savalou‡	F-B	58.7	3.36	4.64	45.3	7.88	6.04	2.78	38.5	62.3
Okpara‡	Formal bred	57.3	2.91	4.90	45.0	7.72	5.69	2.17	39.0	55.4
s.e.d. AC§		0.30	0.10	0.08	0.24	0.13	0.11	0.11	1.27	2.80
s.e.d. PA		0.29	0.09	0.08	0.23	0.12	0.10	0.11	1.20	2.64
s.e.d. PC††		0.23	0.07	0.06	0.18	0.09	0.08	0.08	0.95	2.08

See Table 5 for abbreviations.
† Mean of both commercial varieties.
‡ Mean of three generations for each population.
§ Standard error of the difference between AGP0 and the controls.
¶ Standard error of the difference between any population and AGP0.
†† Standard error of the difference between any population and the controls.

variance with six groups of treatments: the two controls, the original population, the three F-B populations and the formal breeder population. The results (Table 8) are consistent with those obtained by PCA. On average, the original population AGP0 is less hairy and it carries larger bolls, heavier seeds and shorter fruiting branches than the local commercial controls, Stam 18A and H 279-1.

Most populations are significantly improved for each trait in comparison with AGP0 or with the controls:

- Savalou populations are the latest to flower, the hairiest and the most exuberant. Compared with the controls, they produce bigger seeds and more vegetative branches.
- Kandi populations give the highest percentage of fibre and they stand in-between the controls and the original population for the other traits.
- Okpara and Djougou populations are the closest to AGP0 for boll size and seed weight.

Although most of the differentiation with AGP0 occurred during the first breeding cycles, there was still room for further development during the following cycles. Table 9 highlights the statistically significant changes that occurred within each population between the second and the fourth cycle. For most traits except earliness (FF) and seed weight (SI), the changes are less than the differences between the populations and AGP0.

Effect of decentralized breeding on productivity

The trials (Table 6) provided the minimum design (three sites × two years) to explore G × E interactions. On average, all the populations produced more seed cotton than AGP0 (Table 10). Compared to the commercial controls, Savalou was

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Table 9. Significant differences between the fourth and the second cycle in four populations over six sites, for the main variables selected in the Principal Components Analysis.

	Type	FF (dae)	HAI (0–4)	BW (g)	%F	SI (g/100)	NFFB	NVB	LFB (cm)	LVB (cm)
Djougou	F-B		− 0.45							
Kandi	F-B			+ 0.13		− 0.27	− 0.15	− 0.17		
Savalou	F-B	+ 1.1					− 0.14			
Okpara	Formal B	− 1.4								

See Table 5 for abbreviations.
A positive sign (+) indicates that differences were in favour of the fourth selection cycle. A negative sign indicates that the differences were in favour of the second selection cycle.

Table 10. Productivity of the populations and the controls over three sites and two years (t ha^{-1} seed cotton).

Genotype	Type	Angara 2001	Angara 2002	Moné 2001	Moné 2002	Savalou 2001	Savalou 2002	Mean
Controls	Local control	2.00	1.43	1.90	2.10	1.13	0.87	1.57
AGP0	Original population	1.69	1.56	1.90	2.07	1.00	0.79	1.50
Djougou	F-B	2.00	1.95	1.90	2.03	1.01	0.89	1.63
Kandi	F-B	2.07	1.72	1.80	2.09	1.12	0.89	1.62
Savalou	F-B	2.14	1.92	1.90	2.22	1.10	0.89	1.69
Okparas	Formal breeder	1.92	2.05	1.69	1.98	1.01	0.82	1.58
s.e.d. AC		0.20	0.17	0.09	0.08	0.09	0.09	0.07
s.e.d. PA		0.19	0.16	0.09	0.08	0.08	0.08	0.07
s.e.d. PC		0.15	0.13	0.07	0.06	0.07	0.06	0.05

See Table 8 for abbreviations.

more productive and the other two F-B populations were similar. Ranking did not vary significantly with testing locations. For example, Savalou out-yielded any other entry almost everywhere and not just when tested at Savalou. By contrast, the formal breeder's population produced about 50 to 150 kg ha^{-1} less seed cotton than the F-B populations.

DISCUSSION

The genetic material obtained by the farmers, especially at Savalou, appears to be quite promising over all the experimental sites and preliminary unpublished results indicate that the fibre produced by the F-B populations will be of sufficient quality for the international market. The final genetic material (lines) will soon be available for on-farm testing in more contrasting cropping systems and environments (Table 2).

Performance may be attributed to the breeding process itself, to the breeder's eye or to a site effect. For example, the hairiness improvement in Savalou (Table 8) was due to the F-B's action. It cannot be interpreted as a genetic response of the population to the selection pressure exerted by jassid leafhoppers (*Empoasca* sp.) as this pest is reported everywhere in Benin. This particular F-B was very dedicated to his breeding work and

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Table 11. Future roles of formal and farmer breeders in the participatory cotton breeding program.

Breeding steps	Research Institution†	Formal Breeder	Farmer Breeder	Farmers Institutions‡
1. Specifications (setting goals)	+	+	+ (collegial)	+ (collegial)
2. Creating genetic variability		++	(consultative)	
3. Selecting material				
→in the field		+	+ (collegial)	
→in the lab		+	+ (collaborative)	
4. Testing and evaluating		++	++ (collegial)	++ (collegial)
5. Variety release and dissemination	+			++ (collegial)

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‡ Fupro: Fédération des Unions de Producteurs. UDP: Union Départementale des Producteurs.

he took the time to observe and to discard the damaged plants during the early phases of the crop, i.e. when the jassid damage was identifiable.

Savalou's productivity (Table 10) could also result from high levels of heterosis remaining in a partially open pollinated population: this possibility needs further investigation as it could undermine the whole design. However, it tends to be invalidated by the low level of allogamy in cotton (about 10–15 % in Benin) and by the uneven results obtained with the other populations.

Okpara (formal breeder) and Djougou remained close to APG0 for their earliness and comparatively compact habit, probably because they were planted late at both sites (set 7 in Table 2). Moreover, formal breeders were definitely looking for early and more determinate genotypes at Okpara (Figure 3) where farmers preferred later maturing plants with numerous (instead of large) bolls.

On the other hand, this experiment does not confirm (or refute) the idea that decentralized breeding produces genotypes with narrow adaptation, i.e. performing better locally. The result is consistent with Bänziger and Cooper (2001) or Atlin *et al.* (2001). Their analysis show that G × E interactions are difficult to obtain when decentralized breeding and multi-location testing are conducted in rather homogenous situations (Tables 2 and 3). To provide clear evidence of G × E interaction, we need more drastically contrasted breeding and testing situations like those created with climate, altitude (Sthapit *et al.*, 1996) or crop management (Ceccarelli *et al.*, 2000).

Sperling *et al.* (2001) consider that a breeding project consists of five different stages: 1) specifications (setting goals), 2) creating genetic variability, 3) selecting material, 4) testing and evaluation and 5) variety release and dissemination. For each stage, they identify three modes of farmers' participation, qualifying their involvement in the decision process as consultative, collaborative or collegial.

This work brings some light on stage 3 and stage 4 but we also need to consider the other stages to develop a more consistent PPB approach. We propose to move towards more collegial forms of participation between F-B and formal breeders (Table 11). Like Sthapit *et al.* (1996) in Nepal, our F-B have proven their ability to conduct efficient breeding. However, the simple mass selection method is not sufficient to produce the stable and homogenous genetic material that is required for a commercial crop

with an industrial destination. Farmer-breeders have increased their skills through several years of common work with formal breeders. They are now able to use more sophisticated breeding techniques, like pedigree selection to produce stabilized lines. They have also developed a broad view of the cotton plant and its products, including fibre technology. Consequently, we can upgrade their modes of participation to step 3 (breeding) and to step 4 (on-farm evaluation).

At the same time, farmer's organizations in Benin are demanding scaling-up the process of participatory cotton breeding to other groups of farmers. As already mentioned by Witcombe *et al*. (2001) for example, this preliminary work tends to confirm that scaling up might be a good way to increase the number of varieties available to the farmers. But we believe also that, in the absence of a commercial market for cotton seed in Benin, participatory cotton breeding will not be socially sustainable unless individual formal and farmer-breeders activities are recognized (and rewarded) as part of a collective process that involves their mother-institutions. In this scheme, research and farmers organizations will play a formal and prominent role in phases 1, 4 and 5, i.e.: characterizing and updating the most important sets of constraints (Table 2), identifying the priority breeding projects, choosing sites, identifying and rewarding F-B, evaluating the products, fund raising and organizing seed multiplication and distribution.

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