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Adaptability and Stability of Six Cotton Genotypes (*Gossypium hirsutum* L.) in Three Cotton Growing Regions of Benin

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Abstract

The objective of this work is to assess the participatory five new selected varieties in the three cotton growing region of Benin in order to compare their performance with the commercial variety. The experiment was carried out in three cotton growing regions in farmers' fields during two years (2011 and 2012). The results indicated that density and cotton seed yield (CSY) were significantly affected by environment (p<0.000). Significant effect of genotypes was observed with boll average weight (BAW). However, there is no significant difference among genotypes for variables density and CSY (p>0.05). In addition, the effect of genotypes × environments interaction on density was highly significant (p≤ 0.01). Savalou and Kandi have more favorable conditions for cotton seed yield for all genotypes. The genotypes Djougou 8/5, H-279-1, Kandi ¾ and Okpara 3/5 were adapted to the environments of Kandi and Savalou and were more stable in the production of bolls and cotton seeds yield. Therefore, these genotypes could be used as breeding stock that could be incorporated in crosses with the objectives of improving the previously mentioned traits.

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Keywords

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Cotton genotypes
Environment
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Introduction

In Benin, the cotton sector is the main source of growth for the national economy and is the powerful and privileged strategic tool for combating poverty (INRAB, 2013). Unfortunately, in recent years, cotton campaigns have seen a stagnation of seed cotton production around 350 000 tons and a trend decline in yield (INRAB, 2013), which are mainly due to climatic disturbances, but also to the infestation of pests etc. According to Mendez del Villar et al. (2006), genetic traits that make it possible to produce more for a lower cost are first of all those that make it possible to remove these constraints. Consequently, researchers have to design new adaptive technologies to meet the diversity of local farming conditions. Courtois et al. (2001) assumed that it is very difficult for a breeder to anticipate farmers' preferences and that his/her participation is necessary to improve breeding efficiency. It is to meet this requirement that the Center for Agricultural Research Cotton and Fibers

(CRA-CF) has introduced in its program the participatory plant breeding of cotton in 1998 (Lançon, 1998). Participatory plant breeding was originally designed for complex, diverse and risk-rone environments more frequent in the contexts of marginal areas and subsistence agriculture (Hardon, 1995). Although there was unavailability of up-to-date information on cotton participatory plant breeding, the study was carried out successfully with the contribution of the cotton growers who were able to identify the type of cotton they needed. From this work, five cotton varieties were participatory selected. The objective of this work is to assess the participatory five new selected varieties in the three cotton growing region of Benin in order to compare their performance with the commercial variety.

Materials and methods

The genetic material tested was composed of six cotton varieties (*Gossypium hirsutum* L.) from which five have seen selected in participatory breeding: Okpara 3/4, Kandi ¾, Okpara 3/5, Savalou 4/33, Djougou 8/5 and the commercial variety H 279-1 as standard control.

The experiment was carried out in three cotton growing regions in farmers' fields during two years (2011 and 2012). One in Department of Alibori in north of Benin, the second in Department of Donga in west and the third one in the center of Benin. Each trail was laid out in randomized complete block design with three replications. Plots were composed of 3 rows, 20 m in length and 0.80m apart with 0.40 m plant spacing. The seeds were sown at the beginning of June in the north and at the end of June in the center with one variety per plot. The seedlings were thinned to 2 plants per hill at 3 weeks after sowing. N.P.K. fertilizer was applied at thinning with the rate of 200 kg/ha 21 days after emergence and N fertilizer was applied with the rate of 50 kg/ha 40 days after sowing. Insect pest was controlled using six fortnightly sprays as fallowing: binaries accaricid and binaries aphicid pesticides, starting from 45 days after emergence according to research recommendations. The observations were made during the harvest in central row on three parameters: yields, weight of boll and population density.

Statistical analysis

Data from each of tree environments were analysis. A combined analysis of variance was performed, considering both environments and genotypes, so that significance of all effects was tested against mean square of error. Adaptability and analysis of Genotype (G) × Environment (E) interaction was evaluated by Multiplicative Interaction (AMMI) model (Zobel et al., 1988). The stable performance of six cotton genotypes tested over three environments was assessed following the Wricke's ecovalence (Wi^2).

Results

Genotypes × Environments interaction effects

A combined analysis of variance of the 6 cotton genotypes, based on Wald chi-square tests, tested across 3 environments is presented in Table 1. The main effect differences among genotypes, environments, and the interaction effects were tested. The results indicated that density and cotton seed yield (CSY) were significantly affected by environment (p<0.000). Significant effect of genotypes was also observed with bolls average weight (BAW). However, there is not significant difference among genotypes for variables density and CSY (p>0.05). In addition, the effect of genotypes × environments interaction on density was highly significant (p≤0.01).

Table 1. Analysis of Deviance: Combined Analysis (Wald Chi-square tests).

Source of variability	Df	DENS.		BAW		CSY	
		Chisq.	*p*(>Chisq)	Chisq.	*p*(>Chisq)	Chisq.	*p*(>Chisq)
Genotypes	5	4.9974	0.416NS	16.71	0.005**	3.082	0.687NS
Environments	2	14.481	0.000***	2.215	0.330NS	100.36	2e-16 ***
GXE	10	25.856	0.003**	4.969	0.893NS	3.064	0.220NS

BAW: Bolls average weight; CSY: Cotton seed yield; ** and *** Significant at P < 0.01 and 0.001 levels, respectively; NS: no significant.

Variability of yield characters and genotypic mean performance

Density, Bolls average weight and Cotton seed yield of 6 cotton genotypes in three cotton growing regions of Benin were subjected to analysis of variance for individual location as well as pooled over locations (Table 2).

Table 2. Analysis of Variance for inter and intra-locations.

Variables	Locations	H 279-1*	Djougou8/5	Kandi 3/4	Okpara 3/4	Okpara 3/5	Savalou4/33	*p*(>F)
Density	Djougou	83.58a	86.56a	89.05a	87.06a	89.05a	91.04a	**0.750NS**
	Kandi	67.16b	77.61a	82.08a	72.63b	83.08a	90.04a	**0.015***
	Savalou	77.61a	74.62a	76.11a	78.60ab	70.64a	65.17b	**0.386NS**
	***p*(>F)**	**0.001****	**0.236NS**	**0.138NS**	**0.018***	**0.105NS**	**0.013***	**-**
BAW	Djougou	4.40a	4.65a	4.32a	4.80a	4.76a	4.77a	**0.566 NS**
	Kandi	4.43a	4.76a	4.51a	5.47a	4.56a	4.77a	**0.416 NS**
	Savalou	4.61a	4.87a	4.76a	5.48a	4.65a	4.66a	**0.052 NS**
	***p*(>F)**	**0.445NS**	**0.824NS**	**0.094NS**	**0.505NS**	**0.789NS**	**0.810NS**	**-**
CSY	Djougou	595.83b	469.79b	319.79b	267.70b	486.45a	762.50b	**0.044***
	Kandi	1389.58a	1434.37a	1743.75a	1873.95a	1932.29b	2000.00a	**0.492 NS**
	Savalou	1627.08a	1342.70a	1486.45a	1796.87a	1377.08c	1256.25b	**0.568NS**
	***p*(>F)**	**0.000*****	**0.004****	**0.000*****	**0.000*****	**0.000*****	**0.003****	**-**

H 279-1 *: Genotype control; BAW: Bolls average weight; CSY: Cotton seed yield; ** and *** Significant at $p < 0.01$ and 0.001 levels, respectively; NS: no significant.

Density

The Analysis of Variance (ANOVA) indicated that, within a location, the variance for all the genotypes was not found significant at Djougou and Savalou but it was significant at Kandi where the density ranged from 67.16 (H 279-1, control variety) to 90.04 (Savalou 4/33).

However, the results showed that between the locations, the density varies significantly from one location to another for genotypes H 279-1, Okpara 3/4 and Savalou 4/33. The high density was observed at Djougou for all the genotypes: Okpara ¾ (87.06), Savalou 4/33 (91.04), H 279-1 (83.58), Djougou 8/5 (86.56), Kandi ¾ (89.05) and Okpara 3/5 (89.05). Savalou 4/33 (91.04) had high density and H 279-1 (83.58) had low density.

Boll average weight (BAW)

The variation in boll average weight was not significant among the genotypes and locations.

Cotton seed yield (CSY)

Concerning cotton seed yield (Table 2), within a location, the results showed significant variability ($p<0.05$) at Djougou among genotypes. Cotton seed yield ranged from 267.70 (Okpara 3/4) to 762.50 (Savalou 4/33). The genotype Savalou 4/33 proved to be the most effective followed respectively by H 279-1 (control genotype), Okpara 3/5, Djougou 8/5, Kandi 3/4 and Okpara 3/4. Despite the high cotton seed yield values of the different genotypes at Savalou and Kandi, there is no significant difference among the genotypes in these locations ($p>0.05$). Results from analysis of variance also showed that between the locations, there was high significant variability for all genotypes.

Across tree locations, the highest cotton seed yield was given by Savalou (1627.08), followed by Kandi (1389.58) and Djougou (595.83) for H 279-1 (control genotype). For the five other genotypes (Savalou 4/33, Okpara 3/5, Djougou 8/5, Kandi 3/4 and Okpara 3/4), the highest cotton seed yield was given by Kandi, followed by Savalou and Djougou. In general, Savalou and Kandi have more favorable conditions for cotton seed yield for all genotypes. Especially in Kandi where all genotypes, except H279-1, have high cotton seeds yield.The highest cotton seed yield was given by Savalou 4/33 (2000) followed by Okpara 3/5 (1932.29), Okpara 3/4 (1873.95), Kandi 3/4 (1743.75), Djougou 8/5 (1434.37) and H279-1 (1389.58).

Additive Main effects and Multiplicative Interaction effects (AMMI) analysis of variance

Table 3 and graphical representation (Fig. 1 and Fig. 2) of AMMI analysis reveal the main effect means on the abscissa and PC scores of six genotypes as well as three environments based on the boll average weight (BAW) and cotton seed yield (CSY). There were significant effects for genotypes ($p<0.05$), but the effects of environments and GXE interaction were not significant ($p>0.05$).

Table 3. AMMI analysis of variance.

Genotypes and Environments		BAW		CSY	
		PC1	PC2	PC1	PC2
H 279-1 *	**(G2)**	-0.058	0.156	10.423	13.128
Djougou 8/5	**(G1)**	-0.014	0.058	1.552	8.817
Kandi ¾	**(G3)**	0.156	0.236	2.061	-6.016
Okpara ¾	**(G4)**	0.540	-0.160	10.591	-13.011
Okpara 3/5	**(G5)**	-0.383	0.074	-7.735	-5.416
Savalou 4/33	**(G6)**	-0.241	-0.365	-16.893	2.498
Djougou	**(E1)**	-0.589	0.035	-7.627	16.660
Kandi	**(E2)**	0.250	-0.369	-11.766	-14.447
Savalou	**(E3)**	0.339	0.333	19.393	-2.213

Boll average weight (BAW)

The AMMI analysis of variance revealed that PC1 scores ranged from –0.241 to +0.540 for the genotypes and from -0.589 to +0.339 for the environments. PC2 scores ranged from -0.360 to +0.236 for the six genotypes and from –0.369 to +0.333 for the three environments (Table 3). The results from analysis of multiplicative effects showed that the genotypes G4, environments E2 and E3 explained positivity PC1. Genotype G5 and environment E1 showed negative PC1 scores. According to PC2 scores, the results revealed that the genotypes G1, G2, G3 and G6 with PC2 scores responded positively to the environment E3. On the other hand, genotype G6 and environment E2 explained negatively PC2. In addition, all the genotypes and environments have small scores PC1 as well as PC2 scores (either positive or negative).

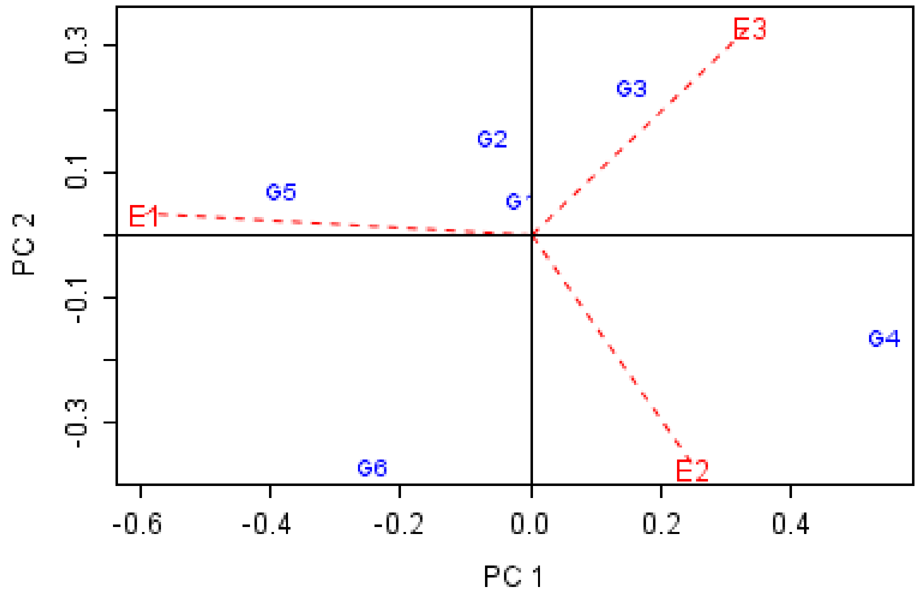

Fig. 1: AMMI biplot display of mean yields and PC scores of six cotton genotypes across three environments based on the boll average weight. E1: DJOUGOU; E2: KANDI; E3: Savalou; G1: Djougou 8/5; G2: H 279-1; G3: Kandi ¾; G4: Okpara 3/4; G5: Okpara 3/5; G6: Savalou4/33.

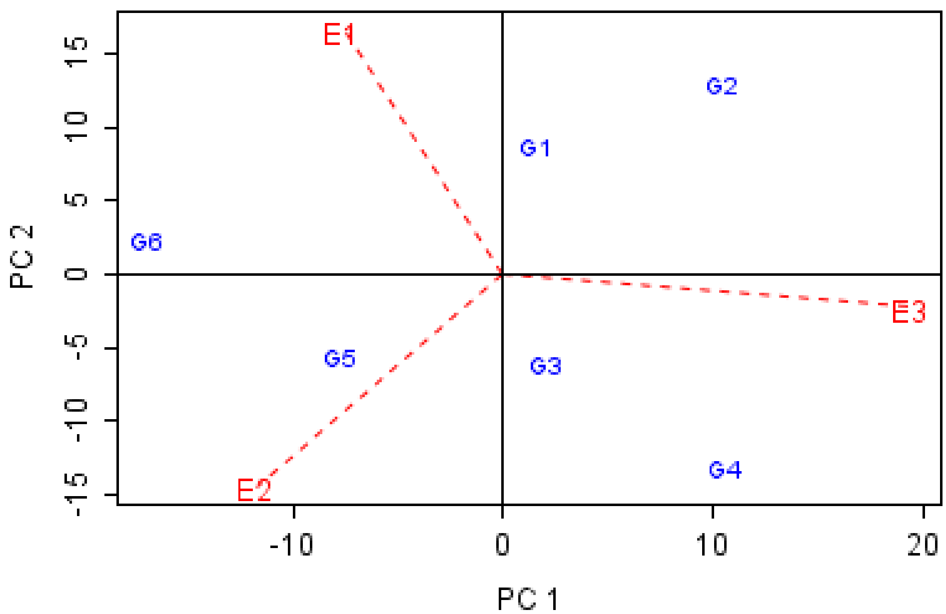

Fig. 2: AMMI; biplot display of mean yields and PC scores of six cotton genotypes across three environments based on the cotton seed yield. E1: DJOUGOU; E2: KANDI; E3: Savalou; G1: Djougou 8/5; G2: H 279-1; G3: Kandi ¾; G4: Okpara 3/4; G5: Okpara 3/5; G6: Savalou4/33.

According to the biplot (Fig. 1), three genotype groups were generated. The first genotype group includes the single genotype G4 with mean boll average weight of 4.53. This group has the highest positive PC1 scores of +0.540 and low negative PC2 scores for –0.160. It was well adapted to the environment E2. The second group consists of the four genotypes G1, G2, G3 and G5 which have small positive PC2 scores ranged from +0.058 to

+0.236. These genotypes are well adapted to the environment E3. Finally, the last group includes single genotype G6. This group of genotype has small negative PC2 of –0.241 and is well adapted to the environment E1.

Cotton seed yield (CSY)

According to the cotton seed yield, the AMMI analysis of variance revealed high PC1 and PC2 scores for the genotypes as well as environments. Therefore, the results from analysis of multiplicative effects showed that PC1 scores ranged from –16.893 to +10.591 for the genotypes and from –11.766 to +19.393 for the environments. PC2 scores ranged from –13.01 to +13.128 for the six genotypes and from –14.447 to +16.66 for the three environments (Table 4). Three genotypes (G2, G3 and G4) and single environment E1 showed positive PC1 scores, while the genotypes G5, G6 and environment E2 showed negative PC1 scores (Table 3 and Fig. 2). Concerning PC2, the genotypes G1, G2 and environment E1 showed high positive scores. The highest mean cotton seed yield response was shown in environments E2 and E3 which were higher than grand mean yield. While, environment E1 show cotton seed yield response smaller than the grand mean yield, but the genotype G2 (Genotype control) and genotype G1seem to be also adapted to the environment E1.

Wricke's ecovalence (Wi^2)

The ecovalence values (W_i^2) were worked out for six cotton genotypes over three locations based on the boll average weight as well as cotton seed yield and are presented in Table 4. Indeed, ecovalence term was used for the relative contribution of genotype to the overall genotype-environment interaction and considered the mean square as the criteria for stability.

Boll average weight

The results indicated that the genotypes G1, G2 (genotype control) and G3 had the lowest ecovalence values and therefore, would be considered to be the most stable. The ranks of these genotypes for boll average weight were 3, 6 and 5, respectively. Ecovalence values for G1 and G3 were lower but they had lower mean yield than overall mean yield. In addition, genotypes G4, G5 and G6 produced higher ecovalence values and the ranks of these genotypes for boll average weight were 1, 4 and 2, respectively. G4 produced higher ecovalence and higher boll average weight and considered as most unstable genotype.

Cotton seed yield

Concerning cotton seed yield, the results indicated that the genotypes G1, G3 and G5 had the lowest ecovalence values and therefore, would be considered to be the most stable. The ranks of these genotypes for cotton seed yield were 5, 6 and 3 respectively. G5 produced high mean cotton seed yield than overall mean yield but had lower ecovalence. On the other hand, the genotypes G2 (genotype control), G4 and G6 had the highest ecovalence and they had high mean cotton seed yield and considered as most unstable genotypes. The ranks of these genotypes for cotton seed yield were 4, 2 and 1 respectively.

Table 4. Ecovalence and yield mean values for six cotton genotypes over locations.

Genotypes		BAW				CSY			
		Wi^2	RS	YM	RYM	Wi^2	RS	YM	RYM
H 279-1 *	**(G2)**	0.008	2	4.482	6	146894.72	4	1204.167	4
Djougou 8/5	**(G1)**	0.001	1	4.762	3	39572.67	2	1082.292	6
Kandi ¾	**(G3)**	0.027	3	4.534	5	20218.27	1	1183.333	5
Okpara ¾	**(G4)**	0.160	6	5.253	1	147413.40	5	1312.847	2
Okpara 3/5	**(G5)**	0.079	5	4.662	4	48678.95	3	1265.278	3
Savalou 4/33	**(G6)**	0.064	4	4.769	2	166523.61	6	1339.583	1

BAW: Boll average weight; CSY: Cotton seed yield; Wi^2: indicates the stable genotypes; RS: Rank stability; M: Yield Mean; RM: Rank yield mean.

Discussion

In agricultural experimentation, a large number of genotypes are normally tested over a wide range of environments (locations, years, growing seasons, etc.). Stability analysis for genotypes allows identification of promising varieties with wide and specific adaptations. The differences between genotypic values may increase or decrease from one environment to another which might cause genotypes to even rank differently between environments (Baker, 2002). In this study, results from analysis of variance showed that between the locations, there was high significant variability for all genotypes. The highest cotton seed yield was given by Savalou, followed by Kandi and Djougou for H 279-1 which is control genotype. For the other genotypes i.e., Savalou 4/33, Okpara 3/5, Djougou 8/5, Kandi 3/4 and Okpara 3/4, the highest cotton seed yield was given by Kandi, followed by Savalou and Djougou. In general, Savalou and Kandi have more favorable conditions for cotton seed yield for all genotypes. These results indicated that cotton seed yield was highly influenced by the genotypes and the change in environments. There is then an interaction between the genotype and the environment for the cotton seeds yield.

According to Falconer and Mackay (1996), the phenotypic expression of one genotype might be superior to another genotype in one environment but inferior in a different environment. In addition, the occurrence of the genotype-environment interaction effect further complicates the selection of superior genotypes for a target population of environments. In the absence of genotype-environment interaction, the superior genotype in one environment may be regarded as the superior genotype in all, whereas the presence of the genotype-environment interaction confirms particular genotypes being superior in particular environments (Shafii and Price, 1998). Thus it is important to study adaptation patterns, genotypes response and their stability in multi-location trials.

Stability analysis can help to characterize the response of varieties to changing environments and to determine the best locations representative of the environmental diversity (Mohammadi et al., 2008). In this case, genotypes with good performances and stability should be the most preferred and the genotypes with good stability are most targeted for environmental conditions which are highly unpredictable (Bantayehu, 2009). Therefore, the results from analysis of multiplicative effects (AMMI) based on the boll average weight, showed that the genotype Okpara ¾ was well adapted to the environment Kandi and Savalou. In addition, the genotypes Djougou 8/5, H 279-1, Kandi ¾ and Okpara 3/5 were well adapted to Savalou and the genotype Savalou 4/33 is well adapted to Djougou. For this trait, the genotypes Djougou 8/5, H 279-1, Kandi ¾, Okpara ¾ and Okpara 3/5 were identified as dominant in environment Savalou.

Concerning cotton seed yield, the genotypes H 279-1, Kandi ¾, Okpara ¾ and Djougou showed positive PC1 scores, while the genotypes Okpara 3/5, Okpara ¾ and Kandi showed negative PC1 scores. These results indicated that the genotypes H 279-1, Kandi ¾, Okpara ¾ were well adapted to the environment Djougou, while the genotypes Okpara 3/5 and Okpara ¾ were adapted to Kandi. The genotypes Djougou 8/5 and H 279-1 presented their most performance in Djougou. According to these assumptions, it could be concluded that the genotypes might exhibited not only broad adaptability to the environments but also highly predictable yields.

Based on the boll average weight, the Wricke's ecovalence indicated that the genotypes Djougou 8/5, H 279-1 (genotype control) and Kandi ¾ had the lowest ecovalence values and therefore, would be considered to be the most stable. Concerning cotton seed yield, the genotypes Djougou 8/5, Kandi ¾ and Okpara 3/5 had the lowest ecovalence values and would be considered to be the most stable. The study suggests that genotypes Djougou 8/5, H 279-1, Kandi ¾ and Okpara 3/5 may be selected for stability in boll average weight and cotton seed yield. These results indicate that cotton breeders should consider environmental conditions and stability as a criterion for selecting high yielding cultivars (Dewdar, 2013).

Conclusion

The study shows that the genotype H-279-1 and Savalou 4/33 were adapted to the three environments (Djougou, Kandi and Savalou), while the genotypes Okpara 3/5, Djougou 8/5, Kandi 3/4 and Okpara ¾ were adapted to two environments (Kandi and Savalou). No genotype has superior performance in all environments but Savalou 4/33 presented the highest cotton seed yield in two environments (Djougou and Kandi). The genotypes Djougou 8/5, H-279-1, Kandi ¾ and Okpara 3/5 were adapted to the environments of Kandi and Savalou. Moreover, these genotypes are more stable in the production of bolls and cotton seeds yield. These materials can be used in fine cotton breeding program as a source of genes for stability.

Conflict of interest statement

Authors declare that they have no conflict of interest.

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