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Research Article

Stability and Adaptability of Cotton (*Gossypium Hirsutum L.*) Genotypes under Multi Environmental Conditions in Mozambique

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Abstract

Cotton (*Gossypium hirsutum*), is an important crop in many developing countries. The crop yield is fundamentally dependent on the environment in which it is grown. One of the major challenges for cultivar recommendation is the genotype by environment interaction when the performance ranking of genotypes over environments is not constant. The identification of cultivars with high adaptability and stability to the growing conditions is an option to deal with this fact. The objective of the present study was to assess the yield stability and adaptability of cotton (*Gossypium hirsutum* L.) genotypes under multi environmental conditions in Mozambique. The trials were established over two years (2014/15 and 2015/16) in Namialo, Cuamba and Balama, in a total of six environments. The plots were established in a randomized complete block design with three replicates of eighteen treatments. The stability and adaptability were assessed using the AMMI (Additive Main Effect and Multiplicative Interaction) multivariate method. The results showed that the most productive new genotype in terms of seed cotton yield was IP63. Among the introduced new genotypes, the Brazilian IMACD 06-6798 were classified as the most stable followed by the other Brazilian IMA1 08-3917 and the Turkish BA 919 compared to the local CIMSAN1 and the Zambian Churedza. The results suggest that the genotypes IMACD 06-6798, IMA1 08-3917 and BA 919 may be recommended for cultivation in Mozambique, since they presented an acceptable adaptability and potential stability.

Keywords: AMMI; Biplot; Genotype X environment interaction; Multivariate analysis; Stability; Triplot; Yield

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Introduction

Cotton (*Gossypium hirsutum L.*), is an important commodity in the world, including in many developing countries. This crop is grown in more than 100 countries. India, China and USA are the main produces in the world [1]. Mozambique is not a big cotton producer country, but cotton assumes a great importance among small scale farmers in rural areas, where involves more than 300.000 families in its production as a cash crop and is the most important agricultural export crop in the country contributing close to 17 percent of total agricultural exports and almost 2 percent of total exports [2,3]. In addition, 10 professional companies have cotton as their core business and create over 20.000 employments throughout it value chain, namely seasonal and permanent workers. Cotton ranks second in merchandise exports Small-scale farmers, comprising 99 percent of all rural households in Mozambique and provide 95 percent of agricultural gross domestic product, where the country's rural economy is heavily reliant on the cotton subsector. This subsector generates nearly 40 million USD in agriculture exports per year [3]. The yield of this cash crop is particularly low in the whole country (500 $kg.ha^{-1}$) compared to the world average yield (800 $kg.ha^{-1}$) and to the neighboring countries such as Malawi (800 $kg.ha^{-1}$), Tanzania (750 $kg.ha^{-1}$) and Zambia (800 $kg.ha^{-1}$) [2,4]. One of the reasons is the low yielding and less adaptable varieties [5]. The cotton research program in the country has been developing and introducing new different germplasm/genotypes, in order to find the suitable varieties to the local edaphoclimatic conditions [5]. However, recommendation of varieties has been a challenge, as it depends largely on the variety adaptability to the soil and climatic conditions of the region where it will be grown and unpredictable weather patterns cause a need for the identification of stable genotypes that have specific adaptation to specific environments [6]. In the previous seasons (2014/15 and 2015/15), Mozambique introduced and evaluated new germoplasms from Brazil, Turkey and China, compared to those grown in the country. This study aimed to assess the yield stability and adaptability of the new cotton (*Gossypium hirsutum L.*) genotypes under multi-environmental conditions in Mozambique.

Material and Methods

Location and seasons

The genotypes were evaluated comparing the used cultivars, during 2 seasons (2014/15 and 2015/16) in Namialo (14S 58' 00 and 39E 51' 00) district of Meconta, province of Nampula; Namara

(13S 22' 58 and 38E 25' 13) district of Balama, province of Cabo Delgado and in Cuamba (14S59'99 and 36E59'99), district of Cuamba, province of Niassa; providing 6 different environments through the combination between locals and seasons (Table 1).

Environment	Season/Year		Local	
Env 1	14/15		Namialo	
Env 2	14/15		Balama	
Env 3	15/16		Cuamba	
Env 4	15/16		Namialo	
Env 5	15/16		Cuamba	
Env 6	15/16		Balama	
Local	**Namialo**	**Balama**	**Cuamba**	
District	Meconta	Balama	Cuamba	
Province	Nampula	Cabo Delgado	Niassa	
Climate type	Semi-humid	Semi-arid	Humid tropical	
Soil	Sandy loam	Alluvium	Loam	

Table 1: Locals description and seasons where the multi-environment trials were laid out.

Experimental design

The treatments (Table 2), were set up in a randomized complete block design, with three replications. The plots were consisted of three rows of 5.0 m length, where the two lateral rows were considered as side borders and the central as the useful one, where the data was collected, in a spacement of 0.70 m between the rows and 0.20 cm between the plants. Sowing was carried out manually, putting 4-10 seeds per hole of about 4 cm of depth. The first thinning took place 15 days after the emergency, leaving two plants per hole and the second thinning was carried out leaving one plant per hole at 21 days after the emergency.

Treatment	Genotype	Origin	Continent	Agronomic description	
				Cycle	Leaves and Stem pubescence
1	ALBAR SZ 9314	Zimbabwe	Africa	Late	Medium
2	BA919	Turkey	Europe	Medium	Medium
3	CA324	Mozambique	Africa	Late	Medium
4	CHUREDZA	Zambia	Africa	Medium	Medium
5	CIMSAN 1	Mozambique	Africa	Medium	High
6	FK 37	Burkina Fasso	Africa	Medium	Medium
7	FLASH	Turkey	Europe	Medium	Medium
8	IMA1 -08-3917	Brazil	America	Medium	Medium
9	IMA1 09-1708	Brazil	America	Medium	Medium
10	IMA1 09-278	Brazil	America	Medium	Medium
11	IMACD 058221	Brazil	America	Medium	Medium
12	IMACD 06-6798	Brazil	America	Medium	Medium
13	IMACD 8276	Brazil	America	Medium	Medium
14	IMACD07-6372	Brazil	America	Medium	Medium
15	IMAIAC 26	Brazil	America	Medium	Medium
16	IP 60	China	Asia	Early	Fair
17	IP 63	China	Asia	Early	Fair
18	IP 75	China	Asia	Early	Fair

Table 2: List of treatments with their Agronomic description.

Management and evaluated variables

Weeds were controlled manually using a hoe whenever deemed necessary. Spraying was carried out once with acetamiprid insecticide (222 $g.lt^{-1}$) for the first control of pests in a dosage of 50 $ml.ha^{-1}$, followed by five applications of Lambda-cihalothrin (60 g L^{-1}) every two weeks from the fourth week after the emergency, in a dosage of 250 $ml.ha^{-1}$. Insecticides were applied with a micro-ulva (ULV). The variables evaluated were the seedcotton yield ($Kg.ha^{-1}$) and ginning outturn (%).

Statistical Analysis

Before the Analysis of Variance (ANOVA), the data was submitted to tests of homogeneity of variances and normality [7,8] to ensure the feasibility of ANOVA. For the Individual ANOVA, every combination of local and season/year was regarded as an environment. Before conducting the combine ANOVA, the assessment of homogeneity of the residual variances of the environments was conducted, using the Hartley's Fmax test [9], at 5% of probability, to ensure the feasibility of combine analysis of variance [10]. The combine ANOVA was conducted after the residual variances of all the environments were regarded as homogeneous ($p > 0.05$), considering the effect of genotypes as fixed, and the effect of the environments and blocks as random [10]. When a significant Genotypes x Environments (GxE) interaction was revealed, stability and adaptability analysis based on the AMMI (Additive Main Effects and Multiplicative Interaction) model were applied, where the original GxE interaction was decomposed into the principal component analysis [11-14].

Results and Discussion

Shapiro-Wilk's normality of the error [8] and Bartlett's homogeneous variance of errors [7] for the seed cotton yield allowed preceding the individual ANOVA in each of six environments. Then, the assessment of the Hartley's Fmax test [9] indicated homogeneous error variances among the evaluated environments that allowed conducting the combined ANOVA. The combined ANOVA revealed a significant difference among genotypes, environments for both evaluated variables and a significant GxE interaction for seed cotton yield, while the GxE interaction for ginning outturn was not significant (Table 3), which indicates that the environment had an impact over the differentiated performance of the genotypes and the broad range of diversity among them [15]. This is the same from that found by Maleia et al. [5], Pretorius et al. [6] and Maleia et al. [16], when evaluating cotton genotypes in different environments. In addition, it shows that some varieties had better performance in one environment and low performance in others, which provided a change of their performance standard under the environmental variation revealed by the significant of GxE interaction for seed cotton yield (Table 3). This is often observed when studying any complex (multigenic) trait, such as seed cotton yield, a trait governed by multiple genes that cause changes in the performance of genotypes over different environments. Similar significant effects of genotype and GxE interaction for seedcotton yield were observed by Maleia et al. [5], Pretorius et al. [6], Maleia et al. [16], when evaluating cotton genotypes in multi-environmental trials in Mozambique, Pakistan, South Africa and Brazil.

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Source of Variation	DF	Mean Square	
		CSY (kg/ha)	GOT (%)
Blocks/Environment	2	507360.8	12.73089
Environments (E)	5	35731792.2**	137.2884**
Genotypes (G)	17	839548.4**	48.77634**
G x E	85	524928.6*	13.60928
Residue (Error)	214	362432.7	11.99569
Total	323		
Overall Mean		2049.392	39.58936
CV (%)		29.37573	8.748512

Table 3: Summary of combine ANOVA of seed cotton yield ($Kg.ha^{-1}$) and Ginning Outturn (%).

** Significant at 1 % of probability, * Significant at 5 % of probability
CSY: Cottonseed Yield; FY: Fiber Yield; GOT: Ginning Outturn.

The decomposition of GxE interaction into principal components (Table 4), among which the first three (PC1, PC2 and PC3) were significant ($p < 0.01$), explained about 80 % of the detected interaction (33.85 %; 61.60 % and 18.16 for PC1 and PC2, respectively), which makes the stability and adaptability study based on the AMMI method more concise [12].

Source of variation			DF	SS	MS
Interaction (G x E)	%	Accumulated %			
Principal Components	33.85	33.85	21	20136668.37	958888.97*
PC1	27.75	61.60	19	16509778.57	868935.71*
PC2	18.16	79.76	17	10803671.80	635510.23*
PC3	-	-		77560587.20	362432.70
Residue (Error)					

Table 4: Decomposition of GxE interaction of seed cotton yield into principal components.

The AMMI Triplot Graphic (Figure 1), emphasizes that there were a year to year variation indicating the importance of seasonal climatic variation in the same local, as many environments were scatted without any grouping on different quadrants [15]. Maleia et al, [16], found out the similar results when studying the genotype by Environment interaction of different genotypes in Mozambique. The environmental conditions of cotton growing regions in Mozambique are highly diversified and it leads to cultivar environmental variability. Gul et al. [17], studied the genotype by environment interaction and association of yield variables in cotton and found that the seed cotton yield is highly affected by environment complex than genotype itself. So identification of genotypes with high adaptability and stability to the different growing conditions is an option to deal with this fact. Among the introduced new genotypes, the Brazilian IMACD 06-6798 were classified as the most stable followed by the other Brazilian IMA1 08-3917 and the Turkish BA 919 compared to the local CIMSAN 1 and the Zambian Churedza (Figure 1).

Results showed that the Chinese genotype IP 63 were the most productive compared to other evaluated genotypes and the most productive local were Cuamba in the two seasons, 2014 /15 and 2015/16 (Figure 2).

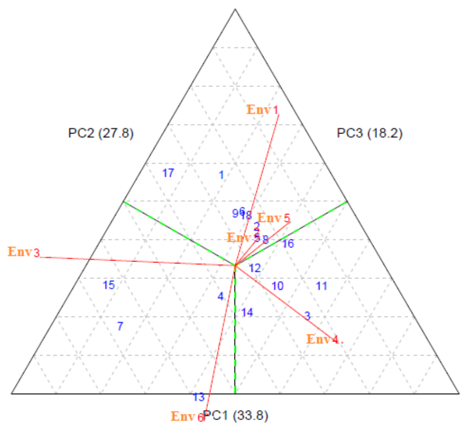

Figure 1: Graphic triplot of PC1, PC2 and PC3 of 18 genotypes in 6 environments for Seedcotton yield.

1. ALBAR SZ 9314; 2. BA919; 3. CA324; 4. CHUREDZA; 5. CIMSAN 1; 6. FK37; 7. FLASH; 8. IMA1 -08-3917; 9. IMA1 09-1708; 10. IMA1 09-278; 11. IMACD 058221; 12. IMACD 06-6798; 13. IMACD 8276; 14. IMACD07-6372; 15. IMAIAC 26; 16. IP 60; 17. IP 63; 18.IP75.

ENV1: Namialo 2014/15; ENV2: Balama 2014/15; ENV3: Cuamba 2014/15; ENV4: Namialo 2015/16; ENV5: Cuamba 2015/16; ENV6: Balama 2015/16.

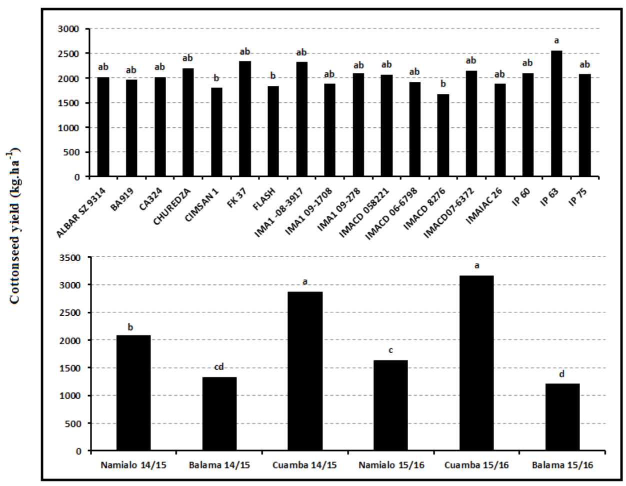

Figure 2: Comparison of cottonseed yield general mean ($kg.ha^{-1}$) of 18 genotypes evaluated in 6 environments.

Means with the same letter are not significantly different by Tukey's Studentized Range (HSD) Test.

Conclusion

The AMMI was useful to study the GxE interaction and to assess the stability and adaptability on the multi-environmental trial. The results illustrated that the genotypes and environments showed dissimilarity once they were positioned in opposing quadrants and the most stable genotypes across to the different environments were not the most adaptable. Thence, the most productive and adaptable new genotype in terms of seed cotton yield was IP63, but it was unstable. Among the introduced new genotypes, the Brazilian IMACD 06-6798 were classified as the most stable followed by the other

Brazilian IMA1 08-3917 and the Turkish BA 919 compared to the local CIMSAN 1 and the Zambian Churedza. The results suggest that the genotypes IMACD 06-6798, IMA1 08-3917, BA 919 should be recommended for cultivation in Mozambique, since they presented an acceptable adaptability and potential stability.

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