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 2015/15) 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

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 producers 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 its 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 germplasms/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 germplasms 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
Management and evaluated variables

Weeds were controlled manually using a hoe whenever deemed necessary. Spraying was carried out once with acetamiprid insecticide (222 g.L⁻¹) for the first control of pests in a dosage of 50 ml.ha⁻¹, followed by five applications of Lambda-chlortalidrin (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.
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].

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 scattered 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).

Table 3: Summary of combine ANOVA of seed cotton yield (Kg/ha) and Ginning Outturn (%).

| Source of Variation | DF   | Mean Square | CSY (kg/ha) | GOT (%) |
|---------------------|------|-------------|-------------|---------|
| Blocks/Environment  | 2    | 507360.8    | 12.70089    |
| Environments (E)    | 5    | 3571792.2** | 137.2884**  |
| Genotypes (G)       | 17   | 839548.4**  | 48.76364**  |
| G x E               | 85   | 524928.6*   | 13.60928    |
| Residue (Error)     | 214  | 362432.7    | 11.99569    |
| Total               | 323  |             |             |
| Overall Mean        |      | 2049.392    | 39.58036    |
| CV (%)              |      | 29.37573    | 8.748512    |

** Significant at 1 % of probability, * Significant at 5 % of probability

CSY: Cottonseed Yield; FY: Fiber Yield; GOT: Ginning Outturn.

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

| Source of variation | Source of variation | DF   | SS          | MS          |
|---------------------|---------------------|------|-------------|-------------|
| Interaction (G x E) | %                   | 21   | 20136668.37 | 958888.97*  |
| Principal Components| % Accumulated %     |      |             |             |
| PC1                 | 33.85               | 21   | 16509775.87 | 868935.71*  |
| PC2                 | 27.75               | 19   | 10803671.80 | 635510.23*  |
| PC3                 | 18.16               | 17   | 77560587.20 | 362432.70 **|
| Residue (Error)     | -                   | -    | -           |             |

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. Hence, 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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