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Stability and adaptability of commercial cotton cultivars (*Gossypium hirsutum* L. race *latifolium* H.) in Mozambique

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Cotton, which is also known as 'white gold', is an important crop in many developing countries. The crop yield is dependent on the environment in which it is grown. One of the major challenges for cultivar recommendation is the genotype x 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 commercial cotton cultivars (*Gossypium hirsutum* L. race *latifolium* H.) in Mozambique. The experiments were set up over three years in Namialo, Montepuez and Morrumbala, in a total of seven environments. Plots were established in a randomized complete block design with four replications of nine treatments. The stability and adaptability were assessed using methodologies by Annicchiarico and Toler and Burrows. The joint analysis of variance showed that there were high environmental variation and high effect of cultivar x environment interaction. The cultivars ISA 205, STAM 42 and IRMA 12-43 showed greater phenotypic stability for cottonseed yield, according to the Annicchiarico method. Regarding the Toler and Burrows methodology, the cultivar STAM 42 presented specific adaptation to low quality environments, while the cultivar CA 324 presented specific adaptation to high quality environments.

Key words: Confidence index, cottonseed productivity, genotype x environment interaction, non-linear regression.

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is cultivated as an annual crop in tropical and subtropical regions in different types of soils (Prentice, 1972). In Mozambique, cotton is a crop with great economic and social importance and is the main income crop after tobacco and has accounted

for 27% of agricultural product exports in the last 10 years (INE, 2009). As an industrial crop, cotton has several sectors in the productive chain that employ and/or supply occupation from the field to the cotton gin. Most cotton is produced by family producers, that is, small aggregates with cropping areas less than 1 ha. These families usually contribute to a little more than 90% of the total Mozambique cotton production (Mahalambe, 2003). The farmers usually commercialize the cottonseed and the fiber is normally commercialized by the cotton exporter

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Generally, the cotton yield in Mozambique has an average of 541 kg ha⁻¹, that is much lower than the world mean yield that is around 1,251 kg ha⁻¹ (FAO, 2009). The cotton production in Mozambique is most concentrated in agro-ecological regions 6, 7 and 8 (INIA, 2000). Region 7 accounts for almost half of the cottonseed production. According to Rohrbach et al. (2001), these regions are mostly in the northern region of the country. The mean agronomic yield of the cotton crop in these regions is very low and one of the main reasons considered for this is the lack of bred cultivars adapted to the local edafoclimatic conditions (Rohrbach et al., 2001). These regions are characterized by the occurrence of degradation and low soil fertility, the practice of successive cotton cropping without fertilization practices (UEM, 2007) and drought.

Agricultural research in the colonial period in Mozambique dating from the period prior to 1974 was marked by negligence of the family sector (Bias and Donovan, 2003). From independence to the signing of the General Peace Agreements in 1992, the efficacy of agricultural research was undermined by political instability and civil war. In this period, the cotton cultivars used predominantly were Remu 40 and A 637, characterized by low fiber yield (34 and 35%), that is almost non-existent in the latter. There was a growing with better fiber technological indicators as a way of demand for bred cultivars that were more productive and improving crop productivity and profitability (Walker et al., 2006).

In an attempt to make up for lost time, technologies have been acquired in other regions of the world. The introduction of bred cotton cultivars from other countries has been the practice most adopted to date (Walker et al., 2006). Some of the accessed cultivars are being used by the farmers, and according to IAM (2007), the CA 324 and Remu 40 cultivars are widely used by the farmers, which together represent about 80% of the total cotton growing area.

Although some of these cultivars are already being used by the producers because of incentive from the fomenting companies, they have not yet been assessed regarding their production stability and adaptability. According to Suinaga et al. (2006), the genotype × environment interaction is one of the major challenges in plant breeding, either in the selection procedure or cultivar recommendation, when the performance ranking of genotypes over environments is not constant. The identification of cultivars with high adaptability and predictable performance under specific or general environmental conditions is an option to deal with this fact (Cruz and Carneiro, 2006). Thus a study is necessary to understand the productive potential and adaptability of the cultivars to provide greater support to the cotton production system in Mozambique and to confirm their suitability to the environmental conditions of Mozambique.

As cotton production in Mozambique is characterized by low levels of productivity, with a low average cotton yield even for Africa and the lowest in all of southern Africa (FAO, 2009), highly adaptable and stable cultivars to the condition of Mozambique should be identified. It was assumed that the introduced cultivars have a different pattern of adaptability and that some are not adapted to the environmental conditions of Mozambique as well as they are to the conditions that they were developed and recommended for. The objective of the present study was to assess the production stability and adaptability of introduced commercial cotton cultivars (*Gossypium hirsutum* L. race *latifolium* H.) to different agro-ecological zones in Mozambique.

MATERIALS AND METHODS

Experiment location and growing season

The experiments were set up in the village of Namialo and Montepuez municipality, located in the northern region of Mozambique, in the 2003/04, 2004/05 and 2005/06 growing seasons, and in the village of Morrumbala located in the central region of the country, in the 2005/06 growing season. All the locations are situated in agro-ecological regions 6, 7 and 8.

According to INIA (2000), agro-ecological region 6 (R6) represents the semi arid region of the Zambezi Valley and South Tete, which is a vast dry area. In contrast, agro-ecological region 7 (R7) is a region of medium altitude in the Zambézia, Nampula, Tete, Niassa and Cabo Delgado provinces, the soil texture is variable and consistent with the topography. In almost all this region, there is great potential for cotton production that has been practiced for several decades. Agro-ecological region 8 (R8) represents the coast of the Zambézia, Nampula and Cabo Delgado provinces and the soils of this region are generally sandy but heavy in the lower zones. Low soil fertility is one of the great limiting factors in this zone. Namialo village is located between agro-ecological regions R7 (medium altitude) and R8 (coastal table) at 157 m altitude, 39°59' longitude east and 14°55' latitude south, in the district of Meconta, Central Eastern Nampula province. The municipality of Montepuez is located in agro-ecological region R7 (medium altitude) at 550 m altitude, 38°59' longitude east and 13°07' latitude south, in the district of Montepuez, southern region of the Cabo Delgado province. The town of Morrumbala is located between agro-ecological R6 (semi arid region of the Zambezi Valley) and R7 (medium altitude) at 392 m altitude, 35°35' longitude east and 17°19' latitude south, in the district of Morrumbala, in the lower Zambeze region, Zambézia Province.

The growing seasons (2003/04, 2004/05 and 2005/06) and the locations representative of Mozambique cotton production (Namialo, Montepuez and Morrumbala) were combined in a total of seven different assessment environments (Table 1).

Climate and soil

The Namialo region is characterized by an Aw type climate according to the Köppen classification, dry sub-humid, where the mean annual rainfall ranges from 800 to 1,000 mm and the mean annual temperature is about 26°C. The soil classification ranges from sandy (ferralic arenosols and sandy textured haplic arenosols) to sandy clays and gleyic arenosols, that occur alternately with hydromorphic sandy soils (MAE, 2005a).

Table 1. Years and locations of the trials in different agro-ecological regions with the highest concentration of cotton production in Mozambique.

Environment	Year	Local	Agro-ecological region	Province	Region
I	2003/2004	Montepuez	7	Cabo Delgado	North
II	2003/2004	Namialo	7 and 8	Nampula	North
III	2004/2005	Montepuez	7	Cabo Delgado	North
IV	2004/2005	Namialo	7 and 8	Nampula	North
V	2005/2006	Montepuez	7	Cabo Delgado	North
VI	2005/2006	Morrumbala	6 and 7	Zambézia	Centre
VII	2005/2006	Namialo	7 and 8	Nampula	North

Table 2. List of cultivars assessed, origin, year of introduction, tolerance characteristics to *E. fascialis* and the cropped area distribution in Mozambique.

Cultivar	Origin	Year of introduction	Tolerance to (<i>E. fascialis</i>)	Cropped area (%) ^{†1}
Albar SZ9314	Zimbabwe	1999	High	4
Albar FQ902	Zimbabwe	1999	High	-
Albar BC853	Zimbabwe	1999	High	-
STAM 42	Senegal	1999	Low	7
CA 222	Ivory Cost	1994	Medium	-
CA 324	Ivory Cost	1994	Medium	47
IRMA 12-43	Cameron	1994	High	-
ISA 205	Ivory Cost	1994	High	4
REMU 40	Mozambique	1980	High	34

^{†1}Area cropped in the 2005/2006 growing season. Source: IAM (2007).

The Montepuez region presents the Aw climate, according to the Köppen classification, semi-arid and dry sub-humid, with average annual rainfall ranging from 800 to 1,200 mm and the mean annual temperature ranges from 20 to 25°C. Hydromorphic soils predominate in this region, whose texture ranges from sandy, sandy on clay and mollic-type dark colored stratified clay soils, gleic and dystic gleysols to haplic and luvic phaeozems (MAE, 2005b).

The Morrumbala region has an Aw climate, according to the Köppen classification, rainy tropical savanna, with mean annual temperature of 22°C and 1,000 mm rainfall. Red soils predominate, ranging from light sandy to clay, with deep ferralitic and lithosols (MAE, 2005c).

Plant materials

Nine cotton cultivars were assessed in this study (Table 2), one of which is local (Remu 40), three introduced from Zimbabwe (Albar SZ9314, Albar FQ902, Albar BC853) and five introduced from West Africa (STAM 42, CA 222, CA 324, IRME12-43, ISA 205).

Experimental design

A randomized complete block design was used in each trial with four replications. The treatment factors were each of the cultivars evaluated (Albar SZ9314, Albar FQ902, Albar BC853, STAM 42, CA 222, CA 324, IRMA 12-43, ISA 205 and REMU 40) and each of the four blocks consisted of a set of the nine different treatments. Each plot in all the experiments consisted of five 5.0 m long rows of plants with 1.0 m between row spacing and 0.20 m between plant spacing in the row, totaling 25 plants per row, corresponding to

50,000 plants ha⁻¹ population density. The useful area of each plot consisted of the three central rows, while the two side rows made up the borders. The evaluated traits were total cottonseed yield (kg.ha⁻¹) and fiber yield (%).

Experiment installation and conduction

Sowing was carried out manually at the start of the rainy season, usually in the first two weeks of December, in hill plots (using a hoe) in rows, placing 4 - 10 seeds per hill plot, approximately 4 cm deep. The first thinning was at fifteen days after planting emergence, leaving two plants per hill plot, at 21 days after emergence the second thinning was carried out leaving only 1 plant per hill plot. Weeds were controlled manually by hoeing 5 to 6 times to prevent them from competing with the crop. No side dressing or mulching were applied so that the experiments were under conditions similar to those predominant in the rural producing fields of the regions.

Two Endossulfan insecticide (475 g L⁻¹) sprayings were applied for pest control followed by three applications of Lambda-cihalothrin (50 g L⁻¹) at two-weekly intervals starting in the sixth week after emergence, at concentrations of 800 and 400 mL ha⁻¹, respectively, as recommended by INIA (2003). Insecticide was applied with an ultra low volume micro nozzle (ULV).

Characteristics assessed

a) Cottonseed yield: Mean value, expressed in kg ha⁻¹, of the total weight of cottonseed collected from all the plants in the useful area of each plot.

b) Fiber yield: Mean value of the percentage of fiber extracted from the cottonseed collected in each plot. The cotton was cleaned using a cotton gin (Continental C21-10). This characteristic was assessed only for the 2005/06 growing season in all the locations (Namialo, Montepuez and Morrumbala).

Statistical analysis

The cottonseed and fiber yield data were first submitted to single analysis of variance in each environment, involving all the cultivars. The homogeneity of the residual variances was assessed as recommended by Cruz and Regazzi (2001) to ensure the viability of applying the joint analysis of variance, where cultivars were considered as fixed effect and the environments and blocks as random effects. The means were compared by the Tukey test (Tukey, 1971). The stability and phenotypic adaptability were analyzed using the methodologies by Annicchiarico (1992) and Toler and Burrows (1998), considering only the cottonseed yield characteristic.

The methodology by Annicchiarico (1992) has been widely used by plant breeders to analyze phenotypic stability because it is relatively easy to apply and to interpret the generated results. This methodology is based on analysis of variance and considers the estimation of a confidence index (I_i), which represents the chance of a cultivar i not presenting a phenotypic performance inferior to the general mean of the genotype set in which it is being assessed (Nunes et al., 1999). According to Annicchiarico (1992), when the I_i is greater, the respective cultivars are considered more stable and cultivars are preferred to present estimates over 100%. Thus, by the Annicchiarico (1992) methodology, the cultivars that present I_i value superior to 100% should not present phenotypic means lower than the environmental mean. The methodology proposed by Toler and Burrows (1998) considers the use of non-linear regression to estimate the environmental index. The parameters are estimated by an interactive process of least squares (non-linear) through the modified Gauss-Newton method (Gallant, 1987). Thus this methodology predicts that the parameters that reflect the environmental quality do not depend on the phenotypic means of the genotype set, as in the methodologies based on linear regression.

Furthermore, this methodology allows choosing the model that best explains the phenotypic performance of the cultivars, that may be uni or bi-segmented. Rejection of hypothesis $H(\hat{\beta}_{2i} = \hat{\beta}_{1i})$ implies the choice of the bi-segmented model, while the acceptance of this hypothesis implies the choice of the uni-segmented model. The authors suggest a classification of genotypes in groups of adaptability (A, B, C, D and E). The groups A and E are represented by bi-segmented models and express double desirable and double undesirable genotype response pattern, respectively. On the other hand, groups B, C and D are represented by linear models. Group C expresses genotypes with wide adaptability while groups B and D represent genotypes with specific adaptability to high quality and low quality environments, respectively.

The analyses of variance and the stability analysis proposed by Annicchiarico (1992) were carried out using the Genes program (Cruz, 2006) while the methodology by Toler and Burrows (1998) was applied using the Estabilidade software (Ferreira and Zambalde, 1997).

RESULTS

The identification of cultivars with high adaptability and stability to the growing conditions is an option to deal with

the problems of the genotype x environment interaction. It was assumed that the introduced cultivars had different patterns of adaptability and that some were not as well adapted to the environmental conditions of Mozambique as they were to the condition under which they were developed. The joint analysis of variance showed a significant difference ($P < 0.01$) for the cultivar x environment interaction effect, the environmental effect for cottonseed productivity and fiber yield (Table 3). Furthermore, the ratio between the estimates of the components of variance of the interaction (σ_{gxe}^2) and the quadratic component expressing the genotypic variability among cultivars (Φ_g) for both the characteristics was fairly high, indicating that the cultivar x environment interaction played a more significant role in the total phenotypic variation than the cultivar effect itself.

There were no significant differences ($P > 0.05$) in cottonseed productivity among the cultivars in environments E1, E2 and E3 (Table 4). In environment E4, only the Albar BC853 cultivar presented cottonseed productivity significantly lower than the others. The IRMA 12-43, STAM 42, CA 222 and ISA 205 cultivars were outstanding in the E5 environment, with mean yield superior to the environmental mean and the general mean. The cultivars that were shown to be superior in the E6 environment were ISA 205, CA 222, STAM 42 and Albar SZ9314, with mean productivity superior to the environment mean and the general mean. For the E7 environment, the IRMA 12-43 cultivar presented cottonseed mean superior to the environmental mean but not superior to the general mean.

Further, consideration of the means per cultivar for the fiber yield characteristic (Table 5) showed that it varied between approximately 35 and 40%. The cultivars presented high fiber yield ($> 37\%$) except for the Remu 40 cultivar. In the three environments where the cultivars were assessed for this characteristic, significant difference ($P < 0.05$) was detected among the cultivars within each environment. The adaptability analysis using the methodology by Toler and Burrows (1998) showed that all the cultivars presented uni-segmented performance, because the equality hypothesis between the $\hat{\beta}_1$ and $\hat{\beta}_2$ parameters was accepted for all the cultivars (Table 6). The CA 324 cultivar, classified in group B, were characterized as being more responsive in high-quality environments, $\hat{\beta}_1$ significantly greater than 1.0, therefore it showed specific adaptability to high quality environments (Table 6).

The STAM 42 cultivar presented specific adaptability to low quality environments (group D) because the β_i estimate was significantly lower than 1.0 (Table 6). The regression coefficients for the remaining seven cultivars were not significantly different from unity and they were ranked in group C (Table 6) indicating that these cultivars are recommended for most environmental conditions, that is, they showed wide adaptability.

Table 3. Mean squares referring to the joint analysis of variance of cottonseed productivity (kg ha⁻¹) and fiber yield (%) of nine cultivars assessed in three regions in Mozambique.

Source of variation	D.F	Cottonseed productivity ^{a/}	D.F	Fiber yield ^{b/}
Blocks/Environments	21	414,554.74	9	1.82
Cultivars	8	328,238.43	8	26.59
Environments	6	23,579,295.31**	2	169.59**
Cultivars x Environments	48	214,352.41**	16	36.57**
Residue	168	83,351.18	72	5.84
Total	251		107	
General mean		1,569.63		38.24
CV (%)		18.39		6.32
$\hat{\sigma}_{\text{B}}^2$		4,067.36		0.83
$\hat{\sigma}_{\text{B} \times \text{C}}^2$		29,111.38		6.83
$\hat{\sigma}_{\text{B} \times \text{E}}^2$		7.16		8.23

**Significant (P < 0.01) by F test. ^{a/} assessed in seven environments. ^{b/} Assessed in three environments. (P > 0.05) by the Tukey test.

Table 4. Partition of the cultivar effects on cottonseed productivity of nine cotton cultivars, assessed in three agro-ecological regions in Mozambique in the 2003/04, 2004/05 and 2005/06 growing seasons.

Cultivars	Cottonseed productivity (kg ha ⁻¹)							Mean
	Environments ^{1/}							
	E1	E2	E3	E4	E5	E6	E7	
Albar SZ9314	3,270 a	820 a	1,524 a	1,333 ab	1,186 bc	1,675 abc	725 b	1,505 ab
Albar FQ902	3,519 a	838 a	1,582 a	1,583 a	918 c	1,308 bc	1,183 ab	1,562 ab
Albar BC853	3,053 a	800 a	1,447 a	717 b	1,334 bc	1,247 c	875 ab	1,353 b
STAM 42	3,049 a	872 a	1,672 a	1,600 a	1,594 ab	1,717 abc	1,183 ab	1,670 a
CA 222	3,517 a	647 a	1,372 a	1,117 ab	1,542 abc	1,900 ab	1,100 ab	1,599 ab
CA 324	3,548 a	823 a	1,723 a	1,183 ab	1,075 bc	1,400 bc	942 ab	1,528 ab
IRMA 12-43	3,248 a	884 a	1,460 a	1,383 a	1,980 a	1,165 c	1,450 a	1,653 a
ISA 205	3,210 a	1060 a	1,603 a	1,567 a	1,414 abc	2,078 a	1,100 ab	1,719 a
REMU 40	3,440 a	892 a	1,421 a	1,550 a	1,288 bc	1,189 c	992 ab	1,539 a
Mean	3,317	848	1,534	1,337	1,370	1,520	1,061	1,570
CV (%)	7.05	26.37	19.97	22.26	21.25	25.07	24.29	20.90

^{1/} E1 = Montepuez (2003/004), E2 = Namialo (2003/004), E3 = Montepuez (2004/05), E4 = Namialo (2004/05), E5 = Montepuez (2005/06), E6 = Morrumbala (2005/06), E7 = Namialo (2005/06). Means followed by the same letter in the column do not differ significantly (P > 0.05) by the Tukey test.

Regarding the methodology by Annicchiarico (1992), the ISA 205, STAM 42 and IRMA 12-43 cultivars presented confidence index (*I_i*) estimates over 100%, showing a greater phenotypic stability for cottonseed productivity (Table 6). The Albar BC853 cultivar presented the lowest *I_i* estimate (81.02%) and therefore this cultivar was ranked as the least stable regarding cottonseed productivity (Table 6). The other cultivars also presented

lower predictability (*I_i* estimate less than 100%) and were therefore less promising.

DISCUSSION

Cotton is a rainfed crop in Mozambique, as it is in many other cotton growing countries in sub-Saharan Africa; its

Table 5. Partition of the cultivar effect in fiber yield of nine cotton cultivars, assessed in three agro-ecological regions in Mozambique in the 2005/06 growing season.

Cultivars	Fiber yield (%)			Mean
	Environments ¹			
	E5	E6	E7	
Albar SZ9314	41.53 a	38.21 ab	37.48 bcd	39.07 a
Albar FQ902	35.77 b	42.41 a	36.50 cd	38.23 a
Albar BC853	34.68 b	39.40 a	42.90 ab	38.99 a
STAM 42	36.58 ab	39.41 a	43.94 a	39.98 a
CA 222	36.64 ab	36.30 ab	44.81 a	39.25 a
CA 324	35.75 b	39.11 ab	40.35 abc	38.40 a
IRMA 12-43	35.71 b	38.70 ab	41.30 abc	38.57 a
ISA 205	33.54 b	39.93 a	43.28 a	38.92 a
REMU 40	36.86 ab	33.90 b	34.52 d	35.09 b
Mean	36.34	38.60	40.56	38.50
CV (%)	8.35	6.21	4.14	6.32

¹ E5 = Montepuez (2005/06), E6 = Morrumbala (2005/06), E7 = Namialo (2005/06). Means followed by the same letter in the column do not differ significantly ($P > 0.05$) by the Tukey test.

Table 6. Estimates of the stability and adaptability parameters for cottonseed productivity of nine commercial cotton cultivars according to the methods by Toler and Burrows (1998) and Annicchiarico (1992).

Cultivars	Toler e Burrows					Group	Annicchiarico $I_{75} (%)^a$
	$\hat{\alpha}_i$	$\hat{\beta}_{2i} - \hat{\beta}_{1i}$	$\hat{\beta}_{1i}$	$\hat{\beta}_{2i}$	$\hat{\beta}_i$		
ISA 205	1,718.86 a	- 0.48	1.27	0.79	0.89	C	108.49 ⁽¹⁾
STAM 42	1,669.57 a	- 0.50	1.22	0.72	0.83 [*]	D	106.63 ⁽²⁾
IRMA 12-43	1,652.86 a	0.48	0.50	0.98	0.88	C	101.81 ⁽³⁾
CA 222	1,599.29 ab	- 0.36	1.41	1.05	1.12	C	94.80 ⁽⁴⁾
Albar FQ902	1,561.57 ab	0.44	0.74	1.18	1.09	C	94.00 ⁽⁶⁾
REMU 40	1,538.86 ab	0.49	0.67	1.16	1.05	C	94.32 ⁽⁵⁾
CA 324	1,527.71 ab	0.12	1.05	1.17	1.15 [*]	B	91.69 ⁽⁷⁾
Albar SZ9314	1,504.71 ab	- 0.37	1.33	0.96	1.04	C	90.56 ⁽⁸⁾
Albar BC853	1,353.29 b	0.18	0.82	1.00	0.96	C	81.02 ⁽⁹⁾

* Significant ($P < 0.05$); ^a the values in parenthesis indicate the stability ranking in decreasing order. Means with the same letter are not significantly different by Tukey test at 5% of probability.

yield is closely related to climate, in particular to rainfall variability. Cottonseed yields drop during drought seasons or when the rainfall distribution is abnormal during the growing period. The environmental conditions of cotton growing regions are highly diversified and it leads to cultivar environmental variability.

Best (2005) studied the genetic and environmental affecters in cotton and found that there is a large year to year and field to field variation in cotton yield under

different growing conditions. Both the environment and genetics contribute to yield variation with the environmental complex being the primary yield affecter. Some cotton growing regions of Mozambique have low fertility and high acidity levels in their soils (UEM, 2007). Furthermore, the problem of not rotating crops has led to considerable soil degradation, characterized by fertility loss and vulnerability to erosion. According to Isaacman (1996), the ferralytic soils found in the north of

Mozambique are hard, heavy and prone to flooding, because of the high clay content that over several successive cotton cropping cycles become environments unfavorable for the development of cotton plants and significantly limit productivity. A variety of factors such as climate and inputs affect cotton productivity including the low adoption of new technologies by farmers. Bakhsh et al. (2005), emphasized the reorientation of breeding research to evolve high yielding and disease resistant varieties, educating the farmers on priority basis to adopt recommended practices to contribute to higher cotton crop yield.

Table 4 shows that there was variation in the environmental quality, that is interesting for genotype \times environment interaction studies, because Ramalho et al. (1993), emphasized the importance of using two or more contrasting environments in studies of this nature.

The cultivars demonstrated different phenotypic response patterns. Significant cultivar \times environment interaction indicated differential response of cultivars to various environments for cottonseed yield, suggesting that the performance ranking of the cultivars was not constant. Similar results were found by Killi and Harem (2006); Mustafa and Babiker (2007); Hoogerheide et al. (2007), while studying some cotton genotypes for cottonseed yield in Turkey, Sudan and Brazil. The cultivar \times environment interaction justifies stability and adaptability studies (Cruz and Carneiro, 2006).

Analysis of three cotton cultivars (Figure 1), representing the different groups (B, C and D), showed that the CA324 cultivar (group B), responded best to the improvement in environmental quality ($\mu_j > 0$) and had low productivity under adverse conditions ($\mu_j < 0$), and that, in the unfavorable environments. The ISA 205 cultivar, group C, followed the mean response of environments, showing general adaptability. The STAM 42 cultivar, placed in Group D, started from a reasonable yield in unfavorable environments and responded poorly to the improvement in environmental quality, therefore it would be more suitable for the regions with low technology.

The slopes of all the individual cultivars are shown in Figures 2a, b, c, d, e, f, g, h and i. CA 324 cultivar, classified in group B should only be indicated for those environments with areas of high soil fertility, neutral pH and with a rainfall regimen that meets the water needs of the cotton crop, carried out by producers with the best technological conditions. Otherwise, it may present significantly reduced yield means because, a genotype that is superior in very specific environments may present mediocre performance in others if the environmental conditions required do not prevail (Vencovsky and Barriga, 1992; Caierão et al., 2006). Furthermore, many of the cotton cropping areas in Mozambique consist of degraded, acid and low fertility soils (Isaacman, 1996; UEM, 2007) that makes the CA 324 cultivar a much less promising genotype in this country. This cultivar represents about 50% of the total cotton growing

area in the country (IAM, 2007). Thus, cotton productivity levels in Mozambique might be low due to the wide use of CA324 by low-income smallholders that do not use high technologies.

Reports of the current situation at the ground by those producers already growing CA324 show that the progressive farmers, who use improved technologies, obtain yields two to three times higher than the national average which is 541 kg ha⁻¹ and about four times higher than the small scale farmers using low technologies (IAM, 2009). It confirms that this cultivar responds more to high technology, but when it is grown in low technology situations, the yield decreases significantly.

STAM 42 (group D) has greater phenotypic response potential in low quality environments than the other cultivars assessed. This cultivar may be ranked as the most promising of the genotypes assessed, because the greater part of the cotton cropping areas in Mozambique are degraded with low response potential, that is, they are unfavorable environments (Isaacman, 1996; UEM, 2007). From the cultivars placed in the group C, greater emphasis should be given to the IRMA 12-43 and ISA 205 cultivars, with $\hat{\beta}_i$ estimates that were not significantly different to 1, and that also presented cottonseed production means greater than the general mean (1,570 Kg ha⁻¹).

The ISA 205, STAM 42 and IRMA 12-43 cultivars had 75% chance to present at least 8.49, 6.63 and 1.81% of cottonseed yield mean, respectively, above the environmental mean yield. That is, these cultivars presented, in general, higher mean yield than the environmental mean yield across all the seven environments and low variance of relative cultivar mean yield (low variability of cultivar mean yield as a percentage of environmental mean yield). Therefore, they were the most predictable (Table 6, Figures 3d, g and h). The Albar BC853 cultivar, due to its lower mean yield than environmental mean yield over the seven environments and high variance of relative cultivar mean yield, appeared to be the most unstable for cottonseed yield (Table 6 and Figure 3c).

However, both methodologies showed that the ISA 205, STAM 42 and IRMA 12-43 cultivars were the most promising, with high stability and phenotypic response patterns favorable to the Mozambique conditions for cottonseed production. It should be pointed out that cultivar yields were three fold greater than the mean for Mozambique. Thus it is evident that the STAM 42, ISA 205 and IRMA 12-43 cultivars were outstanding for high cottonseed productivity, relative stability in the phenotypic performance (Table 6) and high fiber yield (Table 5).

Conclusion

Assessment of the production stability and adaptability of

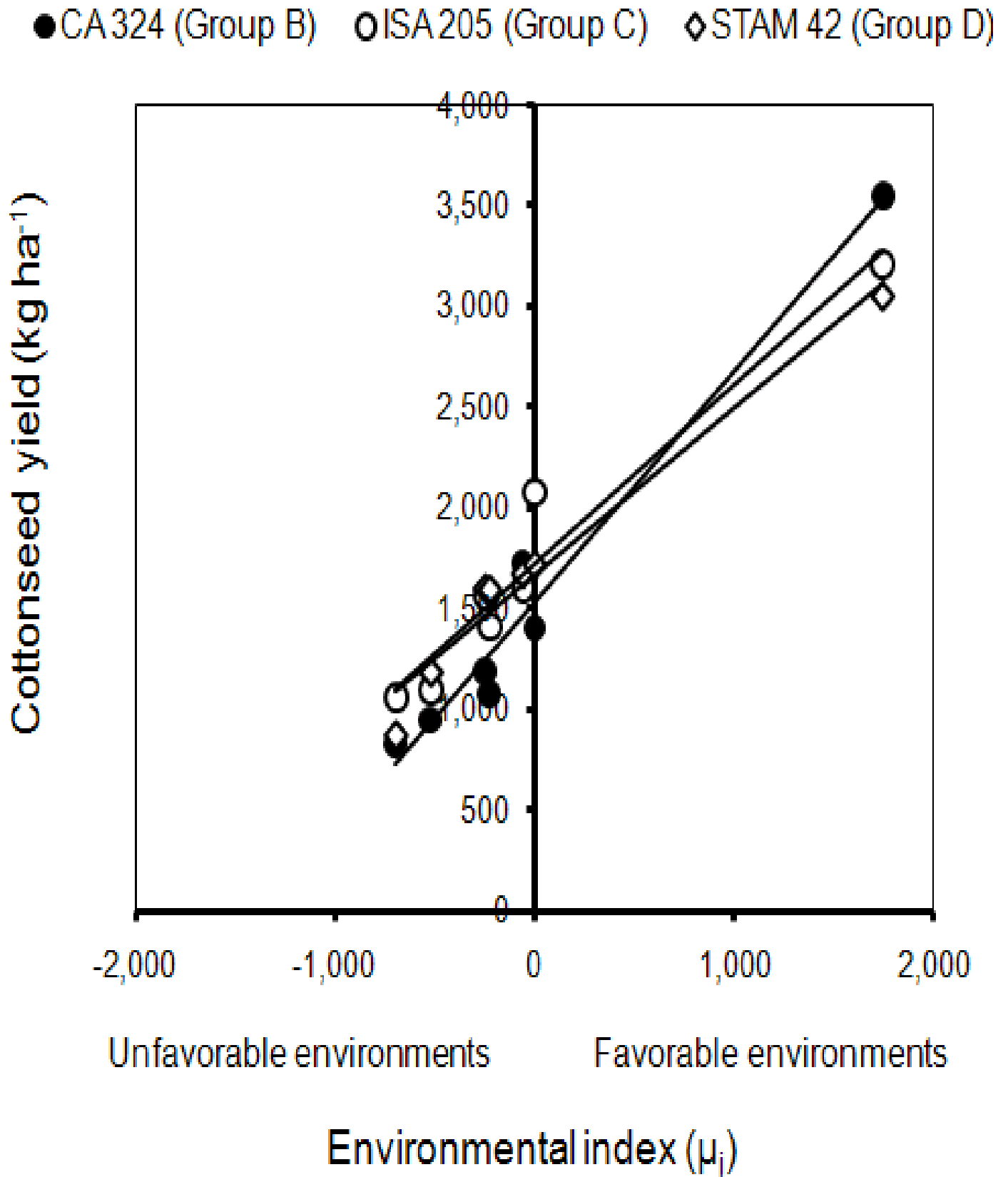


Figure 1. Slopes of three representative cotton cultivars to groups B, C and D for cottonseed yield in the unfavorable and favorable environments.

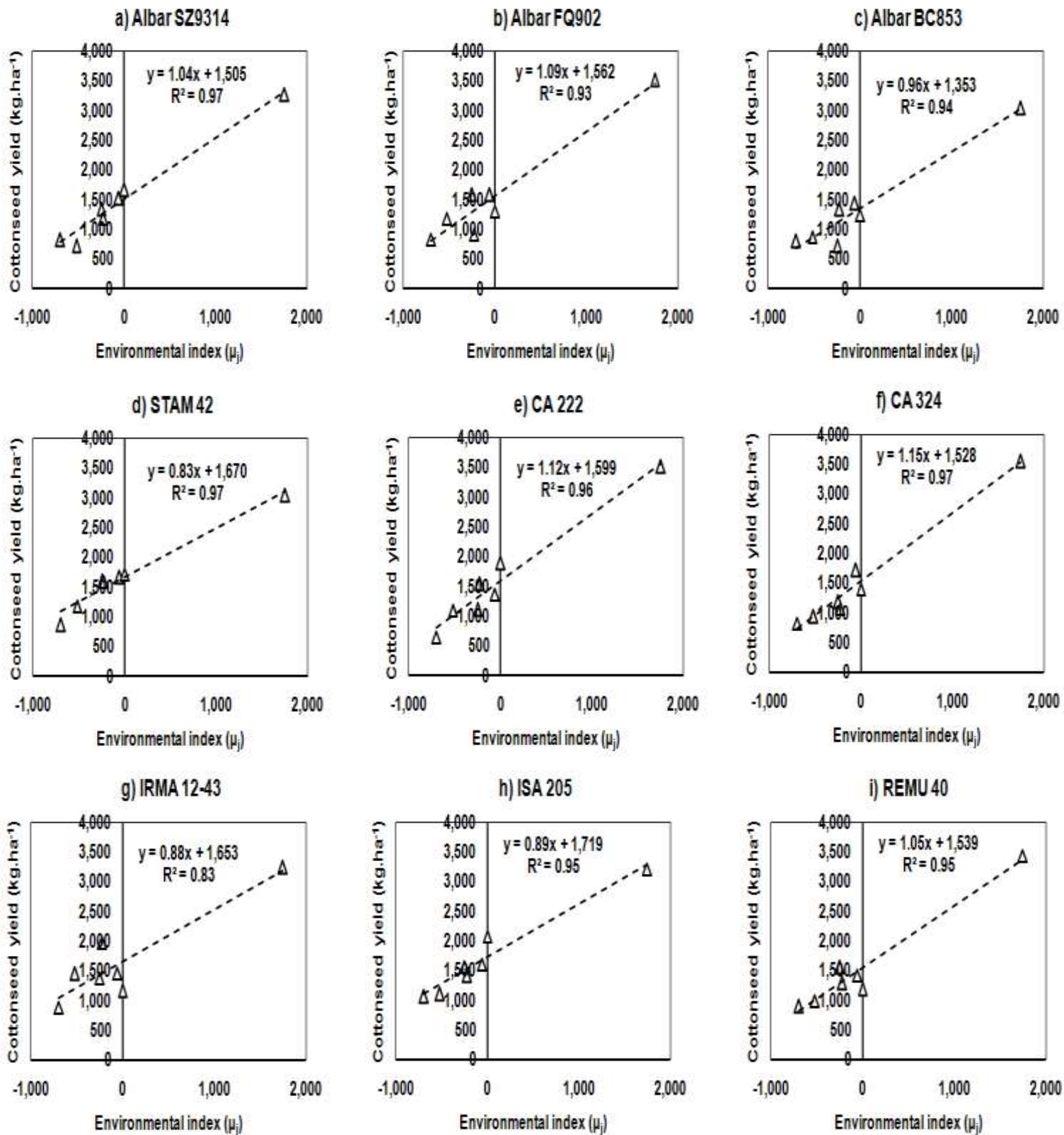


Figure 2. Slopes of nine cotton cultivars for cottonseed yield over seven environments.

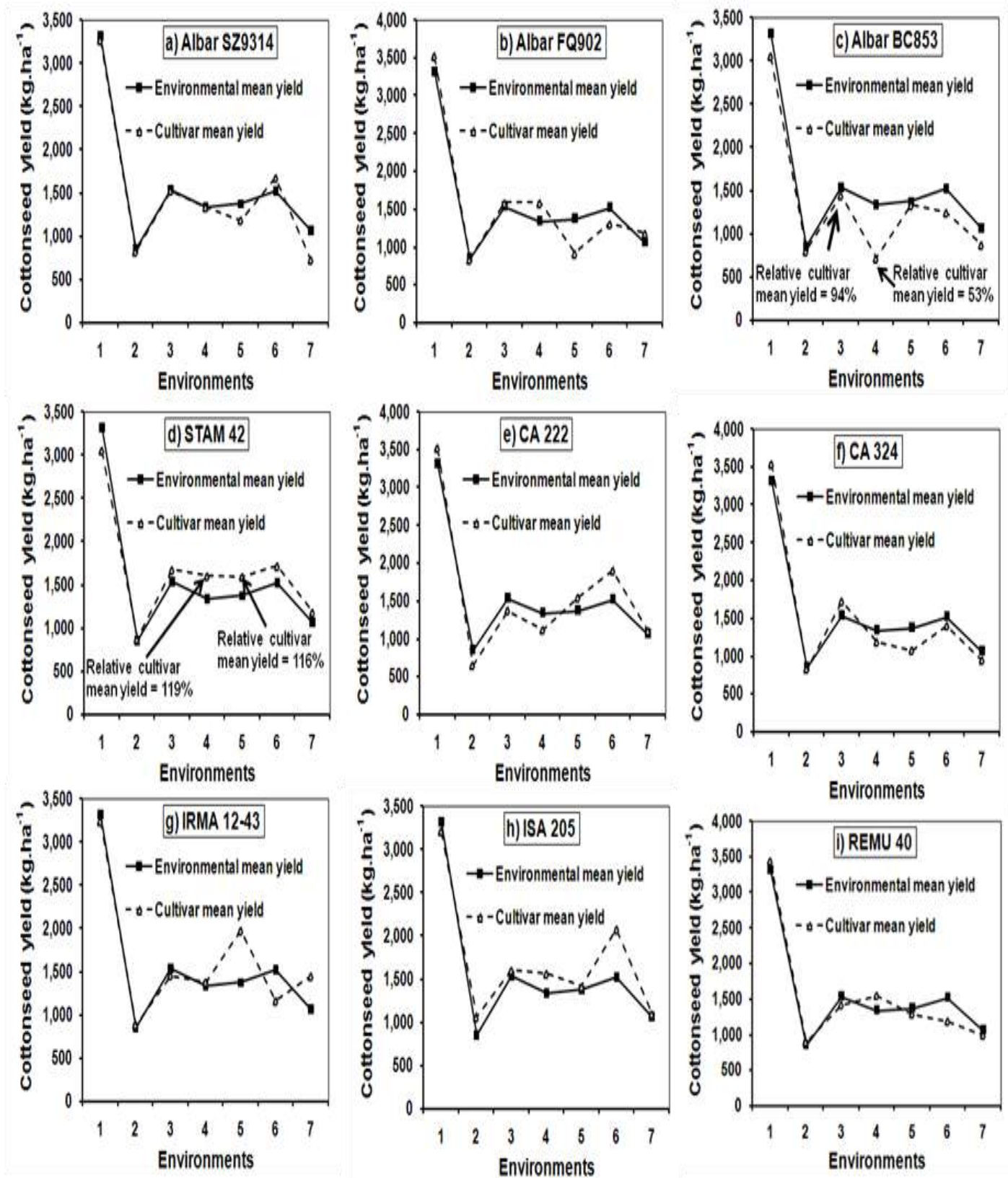


Figure 3. Yield responses of nine cultivars for cottonseed productivity across seven environments according to the Annicchiarico (1992) concept of stability.

introduced commercial cotton cultivars (*G. hirsutum* L. race *latifolium* H.) to different agro-ecological regions in Mozambique showed that:

- 1) There were high environmental variation and high effect of cultivar x environment interaction.
- 2) The phenotypic response patterns for cottonseed production of the nine cultivars were represented by the uni-segmented model.
- 3) The CA 324 cultivar presented a better response pattern in quality environments and it presented low stability.
- 4) The STAM 42 cultivar presented specific adaptability to low quality environments, and presented high stability.
- 5) The ISA 205 and IRMA 12-43 cultivars were characterized as the most stable with wide adaptability.

In conclusion, the cultivars had different adaptability and stability patterns under different environmental conditions. Thus, to ensure increase in cotton productivity in Mozambique by the farmers, the most stable and high yielding cultivars, ISA 205 and IRMA 12-43, should be recommended for planting in all the cotton-producing regions under all environmental and technological conditions of the country, while STAM 42, should be recommended only for low quality environments with low technologies.

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