Stability and adaptability of seedcotton yields of upland cotton genotypes in the state of Minas Gerais, Brazil

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ABSTRACT

Seedcotton yield of *Gossypium hirsutum* L. data from the regional cotton variety trials of the EPAMIG breeding program from 1990 to 1999 were analyzed with the objectives of: estimating both the magnitude of genotype by environment interactions and the genotype adaptability and stability according to the methods proposed by Eberhart and Russell, Lin and Binns and Annicchiarico; and selecting advanced lines to compose the final trials of the program. Four groups of genotypes and environments were assembled and analyzed. For the first one, significant genotype x year and genotype x location x year interactions were detected. The most stable genotypes were MG-864492 and IAC 20. Significant second-order interactions were estimated for the three remaining groups studied. In the second group the most stable strains were MG-863192 (according to Eberhart and Russell method) and MG-863579 (according to Lin & Binn's and Annicchiarico' s methods). For the third genotype-environment group, the most stable genotype under all methods was MG-864133. The cultivar EPAMIG 5 Precoce-1, in the fourth group, presented stable performance also under the three methodologies tested.

KEY WORDS: *Gossypium hirsutum*, genotype x environment interactions, adaptability, stability.

INTRODUCTION

Seedcotton yield is a character of paramount importance in upland cotton breeding because it is one of the traits which most affect producers in a certain way determining the success of the crop in terms of gains or profits. Yield is a trait of polygenic inheritance thus it is strongly influenced by environmental factors, so the phenotypic response of a genotype is determined by the genetic and environmental effects upon it, but with a high frequency of occurrence of a third effect, of no less importance, which is the genotype-by-environment interaction (GEI). Such interaction, in the process of widely adapted cultivar development, constitutes one of the great problems in breeding programs and when recommendation of cultivars for a wide spectrum of environments is to be considered (Vencovsky et al., 1990). Therefore a genotype that presents a good performance in one place does not necessarily perform similarly in another location (Comstock and Moll, 1963; Finlay and Wilkinson, 1963; Eberhart and Russell, 1966).

In the early stages of a breeding program, the presence of genotype x environment interactions may influence the estimates of genetic variance, in turn overestimating expected genetic gains due to selection (Duarte and Vencovsky, 1999). Because of this interference, the utilization of selection indexes is not possible when there exists a great effect of interaction (GEI) (Freeman and Crisp, 1979). Thus a significant genotype-by-environment interaction for quantitatively inherited characters may seriously limit selection of superior genotypes (Shafii et al., 1992). At the later stages of cotton breeding programs, genotypes are commonly tested over various years and locations, in replicated trials. The number of locations and years in which those tests are to be conducted, although should be a representative sample of all environments where cotton is grown, one would have also to consider as well the costs to install and conduct all the experiments (Murray and Verhalen, 1970).

Studies involving genotype-by-environment interactions are of great importance for plant improvement, nevertheless they do not offer detailed information about the performance of cultivars in different environments. In this context, adaptability and stability analyses assume an important role (Cruz and Regazzi, 1997). There are several methods utilized in stability studies. Linear regression analyses are extensively used (Filgueira et al., 1995), but such methods are able to explain only a fraction of the genotype-by-environment interaction. Researchers have developed other methods, utilizing other parameters in order to better quantify stability. Among them, the one developed by Lin and Binns (1988) and the other by Annicchiarico (1992) are considered hereafter. Several studies have been published in Brazil, in which the stability of upland cotton has been considered (Santana et al., 1983; Farias, 1995; Carvalho et al., 1995, 1999; Chiavegato et al., 1999). However the method proposed by Annicchiarico has not yet been used to study the phenomenon in question as far as upland cotton genotypes are concerned.

In the state of Minas Gerais, Brazil, these cotton-producing regions are of paramount importance: the Triângulo Mineiro/Alto Paranaíba (far West), North and Northwest Minas Gerais. During the 1990s, EPAMIG (the state research Institution) has concentrated its advanced strain regional trials in the first two cotton-growing regions. The objective of This research was to estimate the magnitudes of genotype-by-environment interactions as well as the adaptability and stability parameters for seedcotton yield of the genotypes evaluated in those trials, according to the methods proposed by: Eberhart and Russel; Lin and Binns and Annicchiarico. It was also undertaken to provide recommendations for strains to be selected in the EPAMIG cotton breeding program, based on genotypic stability.

MATERIAL AND METHODS

Data of all regional evaluation cotton trials conducted by EPAMIG during the 1990/1999 period in the regions of Triângulo Mineiro / Alto Paranaíba and North Minas Gerais, were utilized in this study. The experimental design originally used for all experiments was a complete randomized-block with five replications, in which each plot was comprised of four five-meter long rows spaced one meter apart with a final density of seven plants per meter. The experimental unit was constituted of the two central rows within a plot.

Due to the dynamic nature of cotton breeding programs, genotypes are discarded and added to trials at variable periods of time, according to discard and selection standards established by breeders. This is the reason why the thirty genotypes (advanced strains and cultivars) evaluated during the period (Table 1) were clustered for the sake of the analyses, according to the criterion of maximizing the number of common environments (years and locations), into four groups. In the first group, eighteen genotypes were analyzed in 1990/91, 1991/92 and 1992/93 at the locations of Janaúba (North Minas Gerais) and Capinópolis (Triângulo Mineiro). In both locations the experiments were cultivated under dryland conditions. The second group comprised twelve genotypes tested in 1993/94 and 1994/95 at Janaúba (under irrigation) and Capinópolis (dryland). The third cluster was formed by fifteen genotypes also at the locations of Janaúba (dryland) and Capinópolis, in 1995/96 and 1996/97. The fourth group consisted of six genotypes grown during the last two growing seasons (1997/98 and 1998/99) at five environments: Janaúba (both irrigated and dryland), Jaíba, Uberaba and Capinópolis – the last three locations under dryland conditions.

The analysis of variance for seedcotton yield was performed for each experiment following the analysis of the experimental groups in which genotype effect was considered fixed and year and location effects were both considered random (Vencovsky and Barriga, 1992). The model applied was:

Yijqk = M + GI + LJ + AQ + (GL)IJ + (GA)IQ + (LA)JQ + (GLA)IJQ + BK(JQ) + EIJQK

where :

Yijqk : the observed value for genotype i, in location j , in year q and block k;

M : overall mean;

GI : effect of genotype i, i =1,2,.....g;

LJ : effect of location j, j = 1,2,......l;

AQ : effect of year q, q = 1,2,.....a;

(GL)IJ : effect of the interaction genotype i by location l;

(GA)IQ : effect of the interaction genotype i by year a;

(LA)JQ : effect of the interaction location l by year a;

(GLA)IJQ : effect of the interaction genotype i by location l by year a;

BK(JQ) : effect of block/ location/year;

EIJQK : mean experimental error.

For the groups of genotypes and environments that presented any statistically significant genotype-by-environment interaction, adaptability and stability

Table 1. List of cotton (*Gossypium hirsutum* L.) advanced strains and cultivars utilized in this research with the groups of genotype-by-environment analyzed and their respective origins or genealogy.

Genotype	Group[1/]	Origin / Genealogy
C – 23 – 7 – 80	1	Introduction from the US
C – 94 –2 – 80	1	Introduction from the US
Deltapine Acala 90	3	Introduction from the US
EPAMIG 4 - Redenção	1,2,3,4	Selection on cultivar IAC-17
EPAMIG 6	3	Pedigree selection - cross Auburn 623 RNR x IAC 17
EPAMIG precoce 1	3,4	Selection on introduction C-25-1-80
HD-precoce 1	3,4	Doubled haploid of introduction C-25-1-80
HD-precoce 2	4	Doubled haploid of introduction GH-11-9-75
IAC – 20	1,2	Selection on cultivar IAC-17
IAC 22	3	Pedigree selection - cross IAC 20 x GH 1197-5
MG – 863579	1,2,3	Pedigree selection - cross Texas CAMD-E x Paraná 1
MG – 864133	1,2,3	Pedigree selection - cross Texas CAMD-E x Paraná 1
MG – 864171	1,2,3	Pedigree selection - cross Texas CAMD-E x Paraná 1
MG – 863585	1,2,3	Pedigree selection - cross Texas CAMD-E x Paraná 1
MG – 863210	1,2,3	Pedigree selection - cross Texas CAMD-E x Paraná 1
MG – 863192	1,2,3	Pedigree selection - cross Texas CAMD-E x Paraná 1
MG – 864411	1,2	Pedigree selection - cross Texas CAMD-E x Paraná 1
MG – 864492	1,2	Pedigree selection - cross Texas CAMD-E x Paraná 1
MG – 862892	1,2	Pedigree selection - cross Paymaster Dwarf x EPAMIG-3
MG – 863841	1	Pedigree selection - cross Texas CAMD-E x Paraná 1
MG – 863927	1	Pedigree selection - cross Texas CAMD-E x Paraná 1
MG – 864438	1	Pedigree selection - cross Yugo Precoce x Paraná 1
MG – 864607	1	Pedigree selection - cross GH-11-9-75 x IAC 17
MG – 862657	1	Pedigree selection - cross Lubbock Dwarf x EPAMIG-3
MG – 9375	4	Selection on cultivar Redenção
MG/UFU – 867147	3	Selection on introduction M73130 (US)
MG/UFU – 867409	3	Selection on introduction M73130 (US)
MG/UFU – 867136	3,4	Selection on introduction M73130 (US)
MG/UFU – 880264	3	Pedigree selection - cross 56046 x IAC 17
SUPER PRECOCE	2	Ind. Plant selection

[1/] 1-Genotypes present in the first group; 2- Genotypes present in the second group; 3- Genotypes present in the third group; 4- Genotypes present in the fourth group.

Table 2. Analysis of variance for a series of experiments and its components of variance (Vencovsky and Barriga, 1992).

Source of Variation	DF	F	E (MS)
Blocks/years/locations	(b-1)ly	MS_1/MS_9	$\sigma^2_E + g\sigma^2_B$
Locations	l-1	MS_2/MS_4	$\sigma^2_E+g\sigma^2_b+bg\sigma^2_{LY}+byg\sigma^2_L$
Years	y-1	MS_3/MS_4	$\sigma^2_E+g\sigma^2_b+bg\sigma^2_{LY}+blg\sigma^2_Y$
L x Y	(y-1)(l-1)	MS_4/MS_1	$\sigma^2_E+g\sigma^2_b+bg\sigma^2_{LY}$
Genotypes	g-1	$(MS_5+MS_8)/(MS_6+MS_7)$	$\sigma^2_E+(g/g-1)b\sigma^2_{GLY}+(g/g-1)bl\sigma^2_{GY}+(g/g-1)by\sigma^2_{GL}+blyV_G$
G x L	(g-1)(l-1)	MS_6/MS_8	$\sigma^2_E+(g/g-1)b\sigma^2_{GLY}+(g/g-1)by\sigma^2_{GL}$
G x Y	(g-1)(y-1)	MS_7/MS_8	$\sigma^2_E+(g/g-1)b\sigma^2_{GLY}+(g/g-1)bl\sigma^2_{GY}$
G x L x Y	(g-1)(l-1)(y-1)	MS_8/MS_9	$\sigma^2_E+(g/g-1)b\sigma^2_{GLY}$
Error	(b-1)(g-1)yl	MS_9	σ^2_E

analysis were performed through the application of three methods: Eberhart and Russell's (Eberhart and Russell, 1966) - a regression-based analysis, in which the regression coefficient (βi), the variance of the deviations from regression (S2di) and the coefficient of determination (R2) are estimated with the mean values of the group analyses; Lin and Binns' (Lin & Binns, 1988) - which considers the deviation in relation to a maximum performance (Pi) and the component of the genotype-by-environment interaction (GE) between the maximum and each genotype tested; and Annicchiarico's (Annicchiarico, 1992) - who has proposed a reliability index (Ii) which estimates the probability of a particular genotype (cultivar) to present a performance bellow the environmental average or below any standard used.

RESULTS AND DISCUSSION

The first group of genotypes and environments was the only one of the four groups to present significant first-order interactions and specifically of the type genotype-by-year (GxA), thus indicating the differential performance of the eighteen strains and cultivars across the three years of testing. Significant in second-order interactions were found in all groups tested (at 5% probability level for the first group and at 1% for the others). Such results indicate inconsistency of the yields presented by the genotypes in the environments in question (Table 3). It can be observed that the magnitude of the variance components indicate that the "year" effects interact with "genotype" effects in the first group, which leads to the necessity of testing genotypes over a longer period of time.

The mean yields of the genotypes in the first three groups were relatively high (2869.48 Kg/ha, 2588.91 Kg/ha and 2176.96 Kg/ha respectively) and the coefficient of variations found were in the range of 9.56% to 11.18% indicating a good control of the experimental conditions. The fourth grouping of genotypes and environments, presented lower mean yield (1928.71 kg/ha) when compared with the others as well as a somewhat higher coefficient of variation (13.14%) Table 4.

Tables 5 through 8 present results of adaptability and stability analyses for the four groups of genotypes and environments. As for the first group (Table 5), the stability analysis according to the method of Eberhart and Russell, brought up the strains MG-864438 and MG-862892 as the outstanding genotypes since according to the method, the ideal genotype is the one that presents a high average for the trait,

Table 3. Degrees of freedom (DF) and mean squares (MS) of the ANOVA's for the group of experiments for seedcotton yield (Kg/ ha).

Source of Variation	GROUP 1		GROUP 2		GROUP 3		GROUP 4	
	DF	MS	DF	MS	DF	MS	DF	MS
B/L/Y	24	743137.7 1/	15	996603.1 1/	16	134199.4 2/	40	446691.2 1/
Year (Y)	2	3967213 ns	1	6329864 ns	1	40240998 ns	1	945846.8 ns
Location (L)	1	158124570 1/	1	219221.8 ns	1	28331217 ns	4	4913841 ns
Y x L	2	1554278.3 ns	1	27329739 1/	1	2864369 1/	4	6274285 1/
Genotype (G)	17	1247366.7 ns	11	1378738 ns	14	281821.6 *	5	506026 ns
G x L	17	482723.7 ns	11	937193.6 ns	14	140632.5 ns	20	136976.7 ns
G x Y	34	796663.9 2/	11	447703.5 ns	14	114175.4 ns	5	406108.3 ns
G x L x Y	34	363113.6 2/	11	829610.6 1/	14	296257.6 1/	20	331111.8 1/
Error	340	216446.6	165	27687.6	224	65512.5	200	155369.0
Means	2869.48		2588.91		2176.96		1928.71	
CV (%)	9.56		15.76		11.18		13.34	

1/ and 2/ : Statistically significant at 1% and 5% probability level, respectively; ns: Non-significant.

Table 4. Estimates of components due to genetic and environmental effects and general average and coefficient of variations for or the group of experiments for seedcotton yield (Kg/ ha) *Gossypium hirsutm* L.

Components of Variation	GROUP 1	GROUP 2	GROUP 3	GROUP 4
$\hat{\sigma}^2_G$	16554.63	40773.48	16325.08	6318.28
$\hat{\sigma}^2_{GxL}$	22567.95	0	0	3134.51
$\hat{\sigma}^2_{GxY}$	40978.29	21600.9	0	0
$\hat{\sigma}^2_{GxLxY}$	27673.03	101420.18	43129.9	29290.4

together with a regression coefficient close to the unity, a deviation from regression near zero and a coefficient of determination close to a hundred percent. Only three genotypes in this group obtained regression coefficients statistically different from one: MG-864607 ($\hat{\beta}$ = 1,302) - adapted to favorable environments: IAC 20 and Redenção (= 0,480 and = 0,593 respectively) - both adapted to unfavorable environments. Figure 1 represents, for the group in question, an example linear regressions exhibited by some of the genotypes that presented regression coefficients different from one, in comparison with the general regression ($\hat{\beta}$ = 1,0).

According to the method proposed by Lin and Binns (1988), the ideal genotype must present the least possible deviation (Pi) in relation to a maximum performance. Strains MG-864492 and MG-864411 were the most promising genotypes in this respect, with good stability and high averages for seedcotton yield, as well as their components responsible for interaction have contributed to, respectively, 1,76 and 1,39% of the variation. On the other hand MG-863579 presented the highest Pi value (3078,3) with 9% of the variation attributed to the interaction. In the method proposed by Annicchiarico, the best genotype is the one which, in the worst scenario, presents a performance equal to the environmental average (Ii=100). In this analysis, again the advanced strains MG-864411 and MG-864492, were outstanding because their performance were 3.34% and 1.7% respectively above the environmental mean. The genotypes MG-863579 and MG-863927 showed performances respectively 20,15% and 20,24% bellow the environment mean.

In the second group (Table 6), the majority of the twelve genotypes tested at Capinópolis and Janaúba (irrigated) had general adaptability when the method of Eberhart and Russell was applied to the data. The advanced strains MG-863579 and MG-863585 were adapted to favorable environments. As far the stabilitity was concerned the treatments MG-864171, MG-863579, MG-863585, MG-864492 and MG-862892 showed unpredictable behavior. Strain MG-863192 was the most stable, with a high average (2685 Kg/ha), regression coefficient statistically equal to one, a null deviation from regression and coefficient of determination of 84.67%. When the parameters of the other two methodologies were considered, the

Table 5. Estimates of the adaptability and stability parameters according to the methods proposed by Eberhart and Russell (1966); Lin and Binns (1988) and Annicchiarico (1992) for seedcotton yield (Kg/ha) of *Gossypium hirsutum* L.of genotypes under evaluation in EPAMIG regional competition trials at the locations of Capinópolis and Janaúba (dryland) from 1990 to 1993 .

		Eberhart & Russell			*Lin & Binns*				*Annicchiarico*
Genotype	Mean	$\hat{\beta}$	$S^2d/1000$	$R^2(\%)$	$P_{(i)}/1000$	Deviation Genetic	Deviation Interaction	Contrib. to Interaction (%)	I_i^{++}
MG-863579	2490	0.900^{ns}	465.64^{ns}	80.37	3078.36	2484.52	593.83	9.057	79.85
MG-863585	2709	1.115^{ns}	1053.43$^{1/}$	73.53	2437.15	1512.56	924.59	14.101	82.63
MG-863841	2688	0.995^{ns}	604.40$^{2/}$	79.39	2221.91	1593.07	628.84	9.591	86.66
MG-863192	2544	1.135^{ns}	306.41^{ns}	90.82	2682.92	2221.70	461.18	7.033	80.81
MG-863210	2858	1.055^{ns}	579.20$^{2/}$	81.89	1618.52	986.37	632.14	9.641	90.42
MG-863927	2623	1.128^{ns}	124.21$^{1/}$	70.68	2846.24	1863.64	982.67	14.987	79.79
MG-864133	2759	1.049^{ns}	400.57^{ns}	86.59	1837.58	1321.68	516.27	7.874	88.26
MG-864171	2808	1.023^{ns}	217.12^{ns}	91.89	1540.54	1151.24	389.29	5.937	92.82
MG-864438	3021	1.270^{ns}	307.16^{ns}	92.50	590.30	540.48	49.81	0.759	98.03
MG-864607	2933	1.302$^{2/}$	624.27$^{2/}$	86.46	845.66	765.81	79.85	1.218	92.53
MG-864492	3172	0.882^{ns}	586.39$^{2/}$	75.75	362.26	246.80	115.46	1.761	101.7
MG-862657	3053	1.266^{ns}	830.07$^{1/}$	81.95	567.08	468.65	98.43	1.501	96.66
MG-862892	3082	0.737^{ns}	483.05^{ns}	72.59	639.22	408.24	230.97	3.522	99.96
IAC 20	2984	0.480$^{1/}$	671.50$^{2/}$	44.68	1004.08	631.09	372.99	5.688	94.81
C-94-2-80	2963	1.072^{ns}	537.99$^{2/}$	83.39	754.21	684.86	69.34	1.057	97.33
Redenção	2903	0.593$^{1/}$	99.61^{ns}	89.27	1107.99	851.180	256.89	3.916	95.70
C-23-7-80	2767	0.934^{ns}	152.27^{ns}	93.09	1355.90	1293.00	62.908	0.959	92.75
MG-864411	3170	1.053^{ns}	798.95$^{1/}$	76.56	341.57	250.43	91.14	1.390	103.34

$\hat{\beta}$ values - estimates of the regression coefficients; S^2d: deviations from the regression; R^2: coefficient of determination; $P_{(i)}$: coefficient of superiority; I_i: reliability index; $^{1/}$ e $^{2/}$: Statistically significant at 1% and 5% probability level, respectively; ^{ns} : Non-significant; $^{+}$: Cutoff point F(0.05)* = 484.956; $P_{(i)}$ smaller than this value are not significantly different from the maximum response (P<0.05); $^{++}$: The significant level adopted was 0.25.

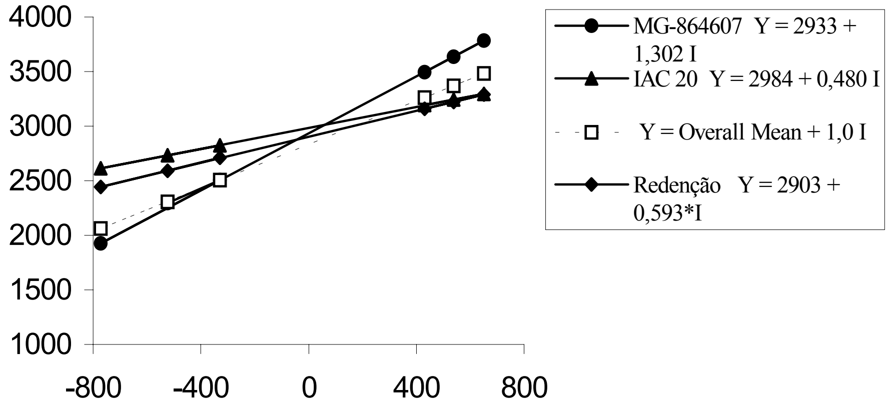

Figure 1. Linear regressions for seedcotton yield of genotypes MG-864607, IAC 20 and Redenção (first group) in function of the environmental indexes in six environments in the state of Minas Gerais.

strain MG-863579 has obtained the smallest value of P(i) (223,06) with also a low contribution to the interaction (1,73%) and performing 1,6% above the environmental average (value of "Ii"). The treatment MG-863585 was also outstanding with a P(i) value of 442,65 e contribution to the interaction of only 0,87%. The highest P(i) value was obtained by the cultivar IAC 20 (4337,3), with 21% of the variation explained by the interaction and a presenting performance 27,1% below the average of the environment. This cultivar has presented similar behavior when data was analyzed by the Eberhart and Russell method.

For the third group of genotypes and environments (Table 7), the parameters of Eberhart and Russell revealed that only the cultivar Deltapine Acala 90 and the advanced strain MG/UFU-867136, have not presented general adaptability, because their estimates of regression coefficient were significantly different from one. On the other hand, Deltapine Acala 90 presented specific adaptation to favorable environments and the strain MG/UFU-867136 demonstrated adaptation to unfavorable environments. Six genotypes were unstable to environmental changes,

Table 6. Estimates of the adaptability and stability parameters according to the methods proposed by Eberhart and Russell (1966); Lin and Binns (1988) and Annicchiarico (1992) for seedcotton yield (Kg/ha) of genotypes under evaluation in EPAMIG regional competition trials at the locations of Capinópolis and Janaúba (under irrigation) from 1993 to 1995.

Genotype	Mean	Eberhart & Russell			Lin & Binns			Annicchiarico
					Deviation			
		β_1	$S^2d/1000$	$R^2(\%)$	Genetic	Interaction	Contrib. to Interaction (%)	I_i
MG-864171	2599	0.808^{ns}	$1312.6^{1/}$	39.79	1407.25	936.93	470.31	89.91
MG-863579	3013	$1.978^{1/}$	$1193.6^{2/}$	81.31	223.065	110.95	112.09	101.6
MG-864133	2639	0.891^{ns}	51.30^{ns}	95.36	1250.88	820.39	430.48	99.70
Redenção	2207	1.149^{ns}	225.9^{ns}	88.59	2861.52	2460.18	401.33	78.18
MG-863585	2825	$1.854^{1/}$	$976.07^{2/}$	82.38	442.65	386.07	56.57	95.86
MG-863210	2634	0.412^{ns}	76.71^{ns}	74.62	1569.27	834.26	735.00	95.37
MG-863192	2685	1.036^{ns}	258.07^{ns}	84.67	1169.87	697.62	472.25	98.56
EP 5 S Prec	2679	1.564^{ns}	125.82^{ns}	96.27	748.75	714.43	34.31	95.74
MG-864411	2288	0.657^{ns}	241.11^{ns}	70.43	2670.77	2083.86	586.90	83.42
MG-864492	27.52	0.798^{ns}	$863.52^{2/}$	49.51	1323.53	536.76	786.77	97.98
MG-862892	2638	0.683^{ns}	$992.71^{2/}$	38.43	1836.93	824.77	1012.16	92.75
IAC 20	2103	$0.164^{2/}$	647.41^{ns}	5.25	4337.30	2982.28	1355.02	72.87

$\hat{\beta}$ values - estimates of the regression coefficients; S^2d: deviations from the regression; R^2: coefficient of determination; $P_{(i)}$: coefficient of superiority; I_i: reliability index; $^{1/}$ e $^{2/}$: Statistically significant at 1% and 5% probability level, respectively; ^{ns}: Non-significant; $^{+}$: Cutoff point $F(0.05)^{*}$ =736.256; $P_{(i)}$ smaller than this value are not significantly different from the maximum response(P<0.05); $^{++}$: The significant level adopted was 0.25.

such as: MG/UFU-867409, MG/UFU-867136 and EPAMIG 5 - Precoce 1. MG-864133 was the genotype that has met all parameters of both high adaptability and stability as well as reaching the highest average. When the other two methods were applied, the genotypes with best behavior were MG-863210 and MG-864133, since they both present small P(i) values, small contribution for the interaction and performance above the environmental average. EPAMIG 6 was the least promising in all three methods.

As for the fourth group in study (Table 8), all genotypes have shown general adaptability, however the highest average was obtained by the cultivar EPAMIG 5 - Precoce 1 (2034Kg/ha) and the poorest mean yield was obtained by the strain HD - Precoce 2 (1760Kg/ha). Practically all treatments in this group were considered stable with the exception of HD - Precoce 2. The best general performance was reached by the cultivar EPAMIG 5 - Precoce 1, which besides obtained the highest average, presented a regression coefficient statistically equal to one, deviation from regression significantly equal to zero e coefficient of determination of 90,98%. The other two methods confirmed the results above mentioned: EPAMIG 5 Precoce 1 presented the smallest P(i) value (91,93), small contribution for the interaction (4,66%) and reliability index of 1% above the environmental average. Again the poorest performance was that of the strain HD - Precoce 2, with the highest P(i) value (689,704), large contribution for the interaction (35,21%) and reliability index of 19% below the average of the environments.

In general, the results described herein as for stability analyses, revealed that in the first and second groups, the genotypes that were superior according to the Eberhart and Russell analysis were different from the outstanding genotypes in the other analyses (Lin and Binns and Annicchiarico). In the last two methods, however, the results were consistent as far as the most promising and the poor genotypes were concerned. In the second group of genotypes and environments a wide variation was observed a wide variation among the coefficients of determination estimates (from 5.25% to 96.27%). For the third and fourth groups, there was a good agreement among the methods when one takes into consideration the indication of high-performance genotypes.

The performance of the cultivar Redenção, present in all groups studied, was outstanding as far as stability, by the criteria of Eberhart and Russell, and as its performance (close to the environmental average

Table 7. Estimates of the adaptability and stability parameters according to the methods proposed by Eberhart and Russell (1966); Lin and Binns (1988) and Annicchiarico (1992) for seedcotton yield (Kg/ha) of genotypes under evaluation in EPAMIG regional competition trials at the locations of Capinópolis and Janaúba (under irrigation) from 1995 to 1997.

Genotype	Mean	Eberhart &e Russell			Lin & Binns			Annicchiarico	
		$\hat{\beta}$	$S^2d/1000$	$R^2(\%)$	$P_{(i)}/1000^+$	Deviation: Genetic	Deviation: Interaction	Contrib. to Interaction (%)	I_i
MG-863210	2322	1.145^{ns}	16.82^{ns}	99.47	45.4355	41.4092	4.02627	0.3467	104.47
MG/UFU-867409	2169	0.876^{ns}	$277.42^{2/}$	86.83	328.314	198.810	129.504	11.151	94.59
MG-863192	2303	1.105^{ns}	57.17^{ns}	98.07	79.991	54.6490	25.3420	2.182	102.77
Deltapine Ac. 90	2288	$1.363^{1/}$	25.00^{ns}	99.44	106.579	66.2189	40.3605	3.475	96.51
MG/UFU-867136	2161	$0.734^{2/}$	$508.09^{1/}$	71.68	453.094	210.540	242.553	20.885	92.63
IAC 22	2156	0.968^{ns}	31.84^{ns}	98.59	245.289	216.972	28.3169	2.438	97.30
Epamig Prec. 1	2229	0.837^{ns}	$467.93^{1/}$	78.10	309.860	122.821	187.038	16.105	96.06
EPAMIG 6	1913	1.028^{ns}	$658.98^{1/}$	79.28	866.366	724.282	142.084	12.234	79.08
MG/UFU-867147	2124	1.098^{ns}	128.77^{ns}	95.71	312.152	266.505	45.6469	3.930	92.32
MG-864171	2264	1.093^{ns}	38.50^{ns}	98.67	92.5626	87.843	4.71886	0.406	101.33
MG-863579	2179	1.086^{ns}	$293.52^{2/}$	90.56	234.564	185.572	48.9921	4.218	93.97
Redenção	2082	0.924^{ns}	27.97^{ns}	98.65	382.616	340.587	42.0293	3.619	93.99
MG/UFU-880264	2040	0.854^{ns}	$323.71^{1/}$	84.31	525.363	421.994	103.368	8.900	87.26
MG-864133	2339	0.982^{ns}	19.42^{ns}	99.16	53.4225	31.806	22.3418	1.923	105.34
MG-863585	2077	0.899^{ns}	168.35^{ns}	91.96	445.180	350.157	95.0226	8.182	91.15

$\hat{\beta}$ values - estimates of the regression coefficients; S^2d: deviations from the regression; R^2: coefficient of determination; $P_{(i)}$: coefficient of superiority; I_i: reliability index; $^{1/}$ and $^{2/}$: Statistically significant at 1% and 5% probability level, respectively; ^{ns} : Non-significant; $^+$: Cutoff point $F(0.05)^* = 437736.038$; $P_{(i)}$ smaller than this value are not significantly different from the maximum response (P<0.05); $^{++}$: $^{++}$: The significant level adopted was 0.25.

Table 8. Estimates of the adaptability and stability parameters according to the methods proposed by Eberhart and Russell (1966); Lin and Binns (1988) and Annicchiarico (1992) for seedcotton yield (Kg/ha) of genotypes under evaluation in EPAMIG regional competition trials at the locations of Capinópolis and Janaúba (dryland and irrigated), Jaíba and Uberaba, from 1997 to 1999.

		Eberhart & Russell				Lin & Binns		Annicchiarico	
						Deviation			
Genotype	Mean	$\hat{\beta}$	$S^2d/1000$	$R^2(\%)$	$P_{(i)}/1000^+$	Genetic	Interaction	Contrib. to Interaction (%)	I_i
MG/UFU-867136	1880	0.958^{ns}	201.33^{ns}	81.30	364.20	243.2	121.00	18.97	90.49
Redenção	2018	0.863^{ns}	282.36^{ns}	71.56	163.30	75.32	87.70	13.75	97.70
MG-9375	1921	1.203^{ns}	229.74^{ns}	85.71	297.84	182.88	114.95	18.03	90.93
HD–Prec. 1	1956	1.073^{ns}	107.04^{ns}	91.11	198.83	139.16	59.66	9.35	95.55
HD- Prec. 2	1760	1.042^{ns}	$448.57^{1/}$	69.95	689.70	465.20	224.50	35.21	81.16
EPAMIG Prec. 1	2034	0.853^{ns}	68.79^{ns}	90.98	91.93	62.21	29.71	4.66	101.0

$\hat{\beta}$ values - estimates of the regression coefficients; S^2d: deviations from the regression; R^2: coefficient of determination; $P_{(i)}$: coefficient of superiority; I_i: reliability index; $^{1/}$ and $^{2/}$: Statistically significant at 1% and 5% probability level, respectively; ^{ns}: Non-significant; $^+$: Cutoff point $F(0.05)^* = 299384.5262$; $P_{(i)}$ smaller than this value are not significantly different from the maximum response ($P<0.05$); $^{++}$: $^{++}$: The significant level adopted was 0.25.

in three groups). This cultivar may therefore be considered a good standard and so used as check treatment in the net of regional tests of genotypes in the breeding program for comparison purposes of in the evaluation of stability and adaptability.

CONCLUSIONS

The first-order interaction was of the type genotype-by-year, found only in the first group of genotypes and environments; second-order interactions (genotype-by-location-by-year) were detected in all groups analyzed.

The advanced strains: MG-864438, MG-862892, MG-864492, MG-864411, MG-863192, MG-863579, MG-864133, MG-863210 and the cultivar EPAMIG 5 - Precoce 1 were considered the most promising genotypes to progress further in the breeding program.

RESUMO

Adaptabilidade e estabilidade da produtividade de genótipos de algodoeiro no Estado de Minas Gerais, Brasil

Analisou-se dados de produtividade de algodão, *Gossypium hirsutum* L., em caroço dos ensaios de competição do programa de melhoramento do algodoeiro da EPAMIG no período entre 1990/91 e 1998/99 objetivando estimar: a magnitude das interações genótipo x ambiente, os parâmetros de adaptabilidade e estabilidade dos genótipos segundo as metodologias de Eberhart e Russell, Lin e Binns e Annicchiarico e selecionar linhagens para compor os ensaios finais do programa de melhoramento. Quatro grupos de genótipos e ambientes foram formados e analisados: no primeiro deles foram obtidas interações significativas genótipo x ano e genótipo x local x ano. Destacaram-se como mais estáveis os genótipos MG-864492 e IAC 20. Nos demais grupos ocorreram interações genótipo x local x ano significativas. No segundo agrupamento as linhagens mais estáveis foram MG-863192 (pelo método de Eberhart e Russell) e MG-863579 (pelos métodos de Lin e Binns, e Annicchiarico). No terceiro grupo de genótipos e ambientes destacou-se a linhagem MG-864133 como a mais estável pelas metodologias testadas. Para o quarto grupo o destaque foi da cultivar EPAMIG 5 Precoce-1 que mostrou-se estável segundo as três metodologias.

Termos para indexação: *Gossypium hirsutum,* interação genótipo x ambiente, adaptabilidade.

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