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Complex interaction between genotypes and growing seasons of carioca common bean in Goiás/Distrito Federal

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ABSTRACT – *The objectives of this study were to assess the importance of the complex interaction between common bean genotypes and growing seasons in the state of Goiás and the Distrito Federal and verify the need for evaluation and indication of cultivars for each season. Yield data of 16 genotypes in 16 trials conducted in two growing seasons (winter and rainy) were used. The coefficient of determination was estimated in the analyses of variance with decomposition of the genotype x environment interaction. The complex percentage of the interaction was estimated and the Spearman correlation between seasons. Differences were detected between seasons and presence of genotype - season (GS) interaction, with greater significance than the other double interactions with genotypes. The correlations indicated a predominantly complex GS interaction. This predominantly complex nature of the GS interaction calls for an assessment of the genotypes in both seasons, which may however identify cultivars with general adaptation.*

Key words: Phaseolus vulgaris *L.; genotype - environment interaction; Annicchiarico.*

INTRODUCTION

The socio-economic importance of common bean is high in Brazil, where it is grown in several regions and under greatly varied environmental conditions, given by the climate and/or technology level. In view of this diversity, the genotype - environment interaction is highly relevant (Oliveira et al. 2005, Pereira et al. 2009, Gonçalves et al. 2010). This interaction can be divided in two: in a simple part, which is irrelevant for the classification of genotypes, and a complex part that affects the genotype ranking (Cruz et al. 2004).

Factors that affect the genotype x environment (G x E) interaction for common bean are, e.g, year, location and growing season. Among these, the growing season is particularly important since in some states such as Minas Gerais, São Paulo, Goiás and Distrito Federal, there are three different seasons per year: a rainy season (sowing August-November), no irrigation; a dry season (sowing January-March), with optional irrigation; and winter (sowing April-July), in which irrigation is indispensable and temperatures milder.

Ramalho et al. (1998) studied the importance of some factors of the G x E interaction and found that the most significant interactions in the dry and winter seasons in Minas Gerais were genotype - growing season (G x S) and genotype - year (G x Y), ahead of the interaction genotype - location (G x L), showing that the evaluation of genotypes

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in several years and different seasons is more important than the evaluation at various locations. Matos et al. (2007) however reported that the G x L interaction was very important in this state. The results of Pereira et al. (2010), who studied these same factors in the states of Paraná and Santa Catarina, were different in that the G x S interaction was the least important, followed by the interactions of G x Y and G x L.

For the state of Goiás and Distrito Federal no reports were found on this subject. These states produce about 10 % of the national bean production (266,806 tons in 2008). This production is concentrated in the rainy (October-December) (40 %) and winter growing seasons (April - July) (49 %), and the mean yield in these states is the highest of the country (2,296 kg ha^{-1}) clearly exceeding the national average (1,223 kg ha^{-1}) (FEIJÃO 2010). In the dry season, the production in these states is only 11 % of the total, mainly because of the occurrence of the bean yellow mosaic virus, which practically blocks the production of common bean in this season (Del Peloso and Melo 2005).

The official recommendation of common bean cultivars must conform to the rules of the Ministério da Agricultura/Registro Nacional de Cultivares (MAPA/RNC) (BRASIL 2008), which request the indication of state and season-specific cultivars. Therefore, genotypes have been tested in different growing seasons, to compare the performance of genotypes in these seasons, and above all, to check the adequacy in the genotype classification in relation to these seasons. Such tests provide technical information underlying the evaluation and recommendation of cultivars for the rainy and winter growing seasons, which would reduce the number of experiments to be performed and consequently simplify the recommendation of new cultivars.

The objectives of this study were to verify the existence of interaction of genotype x growing season (G x S) in the state of Goiás and Distrito Federal; assess the importance of the complex G x S interaction and its effect on the ranking of genotypes; and to verify if genotypes must be mandatorily assessed in the rainy and winter growing seasons for a subsequent recommendation of specific genotypes for each season.

MATERIALS AND METHODS

The experiments were conducted in 2003 and 2004 in 16 environments in the State of Goiás and Distrito Federal. The evaluation sites were in Planaltina and Rio Verde, in the winter and rainy season in 2003 and in Planaltina, Rio Verde, Santo Antônio de Goiás, Anápolis, Morrinhos and Cristalina in both seasons in 2004. The experiment was arranged in a randomized block design with three replications, with plots of four 4-m-rows, evaluated for yield data in the two center rows. The genetic treatments in each experiment consisted of 16 commercial carioca bean genotypes (CNFC's 9458, 9471, 9484, 9494, 9500, 9504, 9506, 9518, CNFE 8009, Carioca 11, BRS 9435 Cometa, BRS Estilo, Pérola, Iapar 81, Carioca Pitoco, and Magnífico).

The yield data were subjected to separate analysis of variance, considering the effect of treatments and sites as fixed. Then the selection accuracy (SA) was estimated according to Resende and Duarte (2007) by the expressions:

$$SA = \left(1 - \frac{1}{F_c}\right)^{0,5},$$

for $F_c \geq 1$; and SA = 0, for $F_c < 1$, where F_c is the value of the F test for cultivars.

Thereafter, combined analysis of variance was performed for each growing season. Combined analyses of the two growing seasons were also carried out for the decomposition of the genotype – environment interaction in genotype x season and genotype x location-year. In this case, the effects of genotypes, locations, years, and seasons were considered fixed. Whenever the ratio of the highest by the lowest mean square was greater than seven, indicating that the residual variances were not homogeneous (Pimentel-Gomes 2000), the degrees of freedom of the average error and interaction were adjusted by the method of Cochran (1954).

Means were compared by the Scott Knott test at 10 % probability. This significance level was used to decrease the likelihood of non-discrimination between genotypes due to type II error. According to Zimmerman (2004), this procedure is recommended when small differences are expected between treatments, as in the case of VCU tests.

To identify the significance of each source of variation in the combined analysis, the contribution of each one to the total variation was estimated, using the estimate of the coefficient of determination (R^2), as given by:

$$R_i^2 = \frac{SS_i}{SS_t},$$

where: SS_i is the sum of squares of the source of variation i; and SS_t is the total sum of squares.

To verify the importance of complex interaction, the percentage of the complex interaction was estimated according to Cruz and Castoldi (1991) between pairs of environments in the rainy season, between pairs of environments in the winter and between pairs of environments in different growing seasons. As an alternative way of verifying the importance of complex interaction, the Spearman correlation between the two growing seasons was estimated, based on the overall mean of genotypes in each season.

The analysis of stability and adaptability of genotypes for each season by the methodology of Annicchiarico (1992) was used alternatively to compare the performance of genotypes in the two growing seasons. This methodology assesses the stability from the risk associated to the use of a cultivar, based on the so-called recommendation index related to genotype i (ω_i), considering all environments, estimated by: $\omega_i = \hat{\mu}_i - z_{(1-\alpha)} \hat{\sigma}_{z_i}$, where represents the mean percentage of genotype i; is the standard deviation of the percentage values associated with the ith genotype; $z_{(1-\alpha)}$ is the percentile of the standard normal distribution. In this case the confidence coefficient was set at 75 %, i.e., $\alpha = 0.25$.

The Spearman correlation between the recommendation index of the genotypes in each season was estimated, comparing the ranking of genotypes for stability and adaptability in both seasons.

Data from experiments conducted in Rio Verde and Planaltina in two growing seasons in 2003 and 2004, by analysis of variance, were used to test effects of factors of interest (genotypes, locations, seasons and years) and their interactions, without any confounding. The estimates of R^2 and the Spearman correlation were obtained in the analysis, by the procedure described above.

The statistical analyses were performed using the softwares Genes (Cruz 2007) and Sisvar (Ferreira 1999).

RESULTS AND DISCUSSION

The mean yield of the experiments ranged from 1,091 to 3,853 kg ha^{-1}, indicating great environmental variation. The coefficient of variation (CV) ranged from 9 to 25 %, indicating good experimental accuracy (Table 1). In this sense, the estimates of selection accuracy (SA) confirmed the good accuracy, since the estimates of 10 experiments were considered high or very high (above 0.7), three were moderate (0.5 to 0.7) and three low (below 0.5), according to the classification proposed by Cargnelutti Filho and Storck (2009). Of the eight experiments conducted in the rainy season, the yield of only two was higher than 2,500 kg ha^{-1}, and the experiment with lowest mean yield was conducted in this season (1,091 kg ha^{-1}) as well. In six of the eight winter experiments mean yields were above 2,500 kg ha^{-1}. This confirms the fact that in these states, higher mean yields are possible in the winter than in the rainy season.

The analysis of variance confirmed the existence of variation among genotypes and the difference between site-year combinations (Table 2). There were also significant differences between growing seasons. The average yield of the rainy season was 2,070 kg ha^{-1}, statistically lower than in the winter, with 2,733 kg ha^{-1} (Table 3). All interactions were significant, including genotype - season (G x S), indicating a differential response of genotypes to the seasons. However, one should not forget that interactions can be predominantly simple, resulting in no change in the genotype classification, or complex, which affects the classification (Cruz et al. 2004).

The mean percentage of complex genotype - environment interaction between the genotype means in the environment pairs within each season was estimated at 77 % (79 % in the rainy and 75 % in the winter growing season), a value slightly below the mean between different seasons (83 %) (Table 4). The difference between these estimates, although small, indicates that variations in the classification of genotypes between the seasons were greater than the variation within a same season and that consequently, the variation between seasons affects the final genotype ranking when considering evaluations in different years and locations.

Another way to verify the importance of the interaction of the complex part is to estimate the Spearman correlation between the means of genotypes in both seasons. This estimate was significantly zero (0.10), indicating that the complex interaction part is predominant, affecting the genotype ranking (Cruz et al. 2004).

The yield means in each growing season showed that the best-performing genotypes were not the same in both seasons. In the rainy season best genotypes were CNFC 9518, CNFC 9471 and CNFC 9500 (Table 3 - analysis with confounding factors). In the winter, the best were BRS Estilo, CNFC 9458, CNFC 9518, Carioca Pitoco, and Iapar 81. Interestingly, only line CNFC 9518 performed well in both seasons, confirming the observation of differential genotype performance in different season.

The Spearman correlation estimate between the recommendation index of the genotypes in the two periods was -0.18, non-significant, showing variation of the most stable genotypes in the two growing seasons (Table 3).

Table 1. Summary of the analyses of variance for grain yield (kg ha^{-1}) in 16 experiments with carioca common bean

Season[1]	Location	State	MSg[2]	MSe[3]	F[4]	Mean[5]	CV[6]	SA[7]
Winter/2003	Planaltina	DF	200,893*	91,425	2.20	2,359	13	0.74
	Rio Verde	GO	494,769**	117,006	4.23	2,710	13	0.87
Rainy/2003	Planaltina	DF	69,367	189,169	0.37	2,106	21	0.00
	Rio Verde	GO	332 277**	88 291	3 76	1 891	16	0 86
Winter/2004	Planaltina	DF	338,856	263,357	1.29	3,853	13	0.47
Rainy/2004	Rio Verde	GO	225,480*	91,255	2.47	3,075	10	0.77
	Santo A. de Goiás	GO	191,454	139,165	1.38	2,729	14	0.52
	Anápolis	GO	567,112	318,029	1.78	2,843	20	0.66
	Morrinhos	GO	194,686	201,545	0.97	1,745	25	0.00
	Cristalina	GO	1,298,155**	311,833	4.16	2,551	22	0.87
	Planaltina	DF	412,128**	102,792	4.01	3,480	9	0.87
	Rio Verde	GO	1,097,641**	145,613	7.54	2,708	14	0.93
	Santo A. de Goiás	GO	269,968**	22,412	12.05	1,091	14	0.96
	Anápolis	GO	475,057**	107,186	4.43	2,307	14	0.88
	Morrinhos	GO	172,761	97,059	1.78	1,687	18	0.66
	Cristalina	GO	582,644**	36,981	15.76	1,286	15	0.97

[1] Growing season/year; [2] Mean square of genotypes; [3] Mean square of the error; [4] Value of the F test for genotypes; [5] Overall mean (kg ha^{-1}); [6] CV – Coefficient of variation (%); [7] Selection accuracy; *, ** significant at 5% and 1% by the F test, respectively.

Table 2. Summary of the combined analysis of variance, with decomposition of the G x E interaction, for grain yield (kg ha^{-1}) in 16 experiments with carioca common bean, in the state of Goiás and in the Distrito Federal, in the rainy and winter growing seasons, in 2003 and 2004

Sources of variation	df	MS	P value	R^2 (%)
Blocks/Environment	32	294,439	0,043	1.6
Genotypes (G)	15	758,354	0,000	1.9
Location-year (LY)	7	39,132,041	0,000	46.4
Season (S)	1	84,543,834	0,000	14.3
G x LY	(79)[1]	536,352	0,000	7.2
G x S	(79)[1]	899,922	0,000	1.7
LY x S	(5)[1]	9,880,655	0,000	8.4
G x LY x S	(79)[1]	508,890	0,000	6.8
Error	(355)[1]	196,319	-	11.8
Total	767			
Mean	2.401			
CV (%)	16			

[1] Interaction and the adjusted error according to Cochran (1954).

For example, genotype CNFE 8009 was the 3rd most stable in the winter and 15th in the rainy season.

The coefficient of determination (R^2) (Table 2) shows that the effect of location/year (46 %) was about three times larger than the season effect (14 %), indicating that the variation between location/year is greater than among growing seasons. It is worth remembering that the year effect is confused with the location effect.

The G x S interaction accounted for 1.7 % of the total variation, similar to the value of genotype source of variation. However, the interaction involving the most important source of genotype variation was G x LY (7.2 %), which was approximately four times higher than G x S, indicating that genotype assessments in multiple locations/ years are more important than evaluations in the two growing seasons (Table 2). In a study on the rainy and dry growing seasons in the states of Parana and Santa Catarina, Pereira et al. (2010) found a little relevant G x S interaction, accounting for only 0.9 % of the total variation, while LY x G interaction was responsible for 5.9 %.

The analysis of the data set underlying the separation of the factors year, locations and seasons showed significant differences for all sources of variation (Table 5 - no confounding). Sources of variation of locations and years

Table 3. Mean grain yield (kg ha^{-1}) in the winter, and rainy growing seasons and overall mean, and estimates of recommendation index of Annicchiarico (ω_i) for the 16 common bean genotypes, assessed in 16 experiments and mean grain yield (kg ha^{-1}) of the same genotypes evaluated in eight experiments

Analysis with confounding of the factors									Analysis without confounding of the factors			
Genotype	Mean[1]			Genotype	Stability (ω_i)				Genotype	Mean[1]		
	Overall	Winter	Rainy		Winter	C[2]	Rainy			Overall	Winter	Rainy
BRS Estilo	2,602a	3,027a	2,178b	BRS Estilo	105.61	1	103.32	3	Pérola	2,942a	3,167a	2,718a
CNFC 9518	2,593a	2,844a	2,342a	CNFC 9518	101.50	5	109.45	1	BRS Estilo	2,910a	3,102a	2,718a
CNFC 9471	2,512a	2,735b	2,290a	CNFC 9471	96.52	7	106.33	2	CNFC 9471	2,877a	2,981b	2,773a
CNFC 9458	2,495a	2,922a	2,067b	CNFC 9458	103.93	2	98.90	7	Iapar 81	2,869a	2,954b	2,783a
Carioca Pitoco	2,461a	2,887a	2,034c	Carioca Pitoco	101.96	4	88.75	14	CNFE 8009	2,848a	3,423a	2,273b
Pérola	2,455a	2,714b	2,196b	Pérola	94.37	11	100.11	5	CNFC 9500	2,836a	2,886b	2,787a
Iapar 81	2,450a	2,797a	2,103b	Iapar 81	98.93	6	90.41	11	CNFC 9518	2,821a	3,042a	2,599a
CNFC 9506	2,436a	2,695b	2,178b	CNFC 9506	95.59	9	99.66	6	Carioca Pitoco	2,818a	3,041a	2,595a
CNFE 8009	2,410a	2,930a	1,890c	CNFE 8009	103.09	3	84.92	15	CNFC 9484	2,791a	3,160a	2,423b
CNFC 9500	2,372b	2,509b	2,236a	CNFC 9500	88.43	15	102.15	4	CNFC 9504	2,771a	2,864b	2,679a
CNFC 9504	2,320b	2,624b	2,015c	CNFC 9504	94.76	10	89.89	12	Magnífico	2,765a	3,117a	2,413b
CNFC 9484	2,313b	2,642b	1,983c	CNFC 9484	91.37	14	93.59	10	CNFC 9506	2,732a	2,715b	2,750a
CNFC 9494	2,305b	2,619b	1,991c	CNFC 9494	93.83	13	94.83	9	BRS 9435 Cometa	2,694a	2,879b	2,509b
Magnífico	2,301b	2,669b	1,934c	Magnífico	94.36	12	89.71	13	CNFC 9458	2,689a	2,994b	2,385b
BRS 9435 Cometa	2,276b	2,445b	2,107b	BRS 9435 Cometa	82.25	16	97.38	8	CNFC 9494	2,617b	2,789b	2,446b
Carioca 11	2,121c	2,672b	1,571d	Carioca 11	95.91	8	72.69	16	Carioca 11	2,385c	2,878b	1,892c
Overall[1]	2,401	2,733A	2,070B	-	-	-	-	-	Overall	2,772	2,999A	2,546B

[1] Means followed by the same letter are equal (Scott-Knott, α=0.10); [2] Classification of the genotype for stability in each growing season.

Table 4. Estimates of the complex percentage of the G x E interaction between the pairs of experiments with carioca common bean

Experiments	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 – Rio Verde - Rainy/2003	67	99*	100*	84	93*	92*	87	88	44	83*	100*	98	87*	77*	100
2 – Planaltina - Rainy/2003	-	73*	86*	41	83*	43*	62	20	40	68*	63*	74	95*	27*	79
3 – Anápolis - Rainy/2004	-	-	80*	75*	82*	100*	100*	93*	84*	92*	74*	62*	78*	99*	80*
4 – Santo Antônio de Goiás - Rainy/2004	-	-	-	71*	93*	73*	92*	88*	63*	84*	98*	83*	80*	74*	100*
5 – Rio Verde - Rainy/2004	-	-	-	-	35*	75*	66	99	100	100*	75*	78	85*	95*	76
6 – Morrinhos - Rainy/2004	-	-	-	-	-	88*	80*	79*	57*	67*	78*	92*	97*	46*	100*
7 – Cristalina - Rainy/2004	-	-	-	-	-	-	88*	100*	95*	100*	100*	93*	100*	84*	100*
8 – Planaltina - Rainy/2004	-	-	-	-	-	-	-	96	96	80*	97*	100	100*	75*	100
9 – Rio Verde - Winter/2003	-	-	-	-	-	-	-	-	73	87*	57*	57	82*	78*	74
10 – Planaltina – Winter/2003	-	-	-	-	-	-	-	-	-	64*	62*	61	49*	90*	51
11 – Anápolis – Winter/2004	-	-	-	-	-	-	-	-	-	-	64*	76*	79*	75*	99*
12 – Santo Antônio de Goiás – Winter/2004	-	-	-	-	-	-	-	-	-	-	-	81*	99*	44*	100*
13 – Rio Verde – Winter/2004	-	-	-	-	-	-	-	-	-	-	-	-	75*	62*	85
14 – Morrinhos – Winter/2004	-	-	-	-	-	-	-	-	-	-	-	-	-	64*	100*
15 – Cristalina – Winter/2004	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100*
16 – Planaltina – Winter/2004	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

	N[1]	Mean (with confounding)	N[1]	Mean (without confounding)
Complex % within the rainy seasons	28	79	6	68
Complex % within the winter	28	75	6	67
Complex % within both seasons	56	77	12	67
Complex % between seasons	64	83	16	80

* Pairs not included in the analysis with confounding of factors. [1] N: Number of observations underlying the mean.

Table 5. Summary of the combined analysis of variance, with decomposition of the G x E interaction, for grain yield (kg ha^{-1}) in eight experiments of carioca common bean, conducted in Rio Verde (Goiás) and Planaltina (Distrito Federal), in 2003 and 2004

Source of variation	df	MS	P value	R^2 (%)
Block/Environment	16	222,530	0,061	1.5
Genotypes (G)	15	434,084	0,000	2.8
Locations (L)	1	11,970,937	0,000	5.1
Seasons (S)	1	19,710,937	0,000	8.4
Years (Y)	1	98,384,627	0,000	41.8
G x L	15	297,980	0,007	1.9
G x S	15	615,081	0,000	3.9
G x Y	15	408,843	0,000	2.6
L x S	1	1,877,682	0,000	0.8
L x Y	1	17,031,137	0,000	7.2
S x Y	1	661,178	0,029	0.3
G x L x S	15	299,332	0,007	1.9
G x L x Y	15	347,146	0,002	2.2
G x S x Y	15	359,999	0,001	2.3
L x S x Y	1	1,961,102	0,000	0.8
G x L x S x Y	15	408,942	0,000	2.6
Error	240	136,113	-	13.9
Total	383			
Mean	2,772			
CV (%)	13.6			

represented 5.1 % and 41.8 % of the total variation, respectively (sum of 46.9 %), similar to the result of the analysis with confounding (46.4 %) (Table 2). This shows that the difference between years was much greater than the difference between locations. However, it is important to mention that in the confounding analysis the number of sites was higher than required by current regulations for the registration of common bean cultivars and in the analysis without confounding the number of sites was very close to the required (three locations in two years per growing season). With an increase in the number of locations, the significance of the source of variation could also rise.

The season source of variation explained 8.4 % of the variation. In a study at three locations in the dry and winter growing seasons in Minas Gerais, Ramalho et al. (1998) found the season source of variation to be the most important, explaining 19 % of the total variation, compared to 17 % and 11 % for the factors locations and years.

The genotype x location (G x L), genotype - year (G x Y) and G x S interactions were significant and accounted for 1.9 %, 2.6 % and 3.9 % of the total variation (Table 5), i.e., the G x S interaction is twice as high as the G x L and 1.4 times higher than the G x Y interaction. Ramalho et al. (1998) found R^2 estimates of 1.9 % for the G x S interaction, 1.9 % for G x Y and 1.6 % (non-significant) for G x L, and concluded that assessments in more seasons and years are more important than assessments at more locations. Although these authors focused on dry and winter seasons in Minas Gerais, and this study on rainy and winter growing seasons in Goiás and the Federal District, results were similar. The reason is that differences between growing conditions in the rainy and dry growing seasons are smaller than differences between growing conditions in the winter, especially in terms of temperature and water supply.

On the other hand, the results of Pereira et al. (2010) differed from those of this study and of Ramalho et al. (1998), in that the G x L interaction was most important (5 %), followed by the G x Y (3 %) and G x S interaction (1.5 %). However, it is important to remember that this study was conducted in Parana and Santa Catarina, in the rainy and dry growing seasons, and that in these states the difference between growing seasons is much smaller, especially in relation to temperature and water supply during the growing period.

For the analysis without confounding factors, the mean estimate of the complex percentage of G x E interaction between pairs of environments in the same season was 67 % (68 % in the rainy and 67 % in the dry), lower than the mean between different season pairs (80 %), confirming the difference between growing seasons (Table 4). The estimated Spearman correlation obtained between the genotype mean in the two growing seasons was -0.22 (non-significant).

CONCLUSIONS

The results indicate a difference between the winter and rainy growing seasons in the states of Goiás and the Distrito Federal, and that the complex interaction between genotypes and seasons is marked, causing a significant shift in the genotype classification. The conclusion was drawn that the assessment of genotypes in the winter and rainy growing seasons is indispensable for a recommendation of cultivars for both seasons in Goiás and the Distrito Federal. Results also showed that the indication of specific cultivars for each season can be advantageous. However, it is possible to identify genotypes with broad adaptation to the two growing seasons, e.g., CNFC 9518, without reducing the mean grain yield. In addition, there are other factors that call for the selection and recommendation of a same genotype for both growing seasons, such as the low utilization rate of common bean seeds by farmers, which is about 13 % (Barros 2008), and the high costs associated to the release of new cultivars and seed production for each season separately.

Interação complexa entre genótipos e épocas de semeadura de feijoeiro comum carioca em Goiás/ Distrito Federal

RESUMO - *Os objetivos deste trabalho foram avaliar a importância da interação complexa entre genótipos de feijoeiro comum e épocas de semeadura em Goiás e Distrito Federal e verificar a necessidade de avaliação e indicação de cultivares para cada época. Utilizaram-se avaliações de produtividade de grãos de 16 genótipos em 16 ensaios conduzidos em duas épocas (águas e inverno). O coeficiente de determinação foi estimado nas análises de variância com decomposição da interação genótipos x ambientes. Foi estimada a porcentagem complexa da interação e também a correlação de Spearman entre épocas. Detectaram-se diferenças entre épocas e presença de interação genótipos x épocas (G x E), com maior importância quando comparada às outras interações duplas com genótipos. As correlações mostraram interação G x E predominantemente complexa. Os resultados indicam a predominância de interação G x E do tipo complexa e, consequentemente, a necessidade de avaliação de genótipos nas duas épocas, entretanto, com a possibilidade de indicar cultivares com adaptação geral.*

Palavras-chave: Phaseolus vulgaris, *interação genótipos x ambientes, Annicchiarico.*

REFERENCES

Annichiarico P (1992) Cultivar adaptation and recommendation from alfafa trials in Northern Italy. **Journal of Genetics and Plant Breeding 46**: 269-278.

Barros ACSDA (2008) A estatística da produção de sementes no Brasil: indicativos do crescimento da agricultura brasileira. **SEED News 12**: 16-18.

BRASIL. Instrução Normativa nº 25, de 23 de maio de 2006. Anexo I. Requisitos mínimos para determinação do valor de cultivo e uso de feijão (*Phaseolus vulgaris*) para a inscrição no registro nacional de cultivares - RNC. **Diário Oficial da República Federativa do Brasil**, Brasília, DF, June 19, 2006. Available at <http://extranet.agricultura.gov.br/sislegisconsulta/servlet/VisualizarAnexo?id=11376> Assessed on Nov. 10, 2008.

Cargnelutti Filho A and Storck L (2009) Medidas do grau de precisão experimental em ensaios de competição de cultivares de milho. **Pesquisa Agropecuária Brasileira 44**: 111-117.

Cochran WG (1954) The combination of estimates from different experiments. **Biometrics 10**: 101-129.

Cruz CD (2007) **Genes v.2007.0.0**: aplicativo computacional em genética e estatística. Universidade Federal de Viçosa, Departamento de Biologia Geral, Viçosa. Available at < http://www.ufv.br/dbg/genes/genes.htm> Assessed on December 2007.

Cruz CD and Castoldi F (1991) Decomposição da interação genótipos x ambientes em partes simples e complexa. **Revista Ceres 38**: 422-430.

Cruz CD, Regazzi AJ and Carneiro PCS (2004) **Modelos biométricos aplicados ao melhoramento genético**.Editora UFV, Viçosa, 480p.

Del Peloso MJ and Melo LC (2005) **Potencial de rendimento da cultura do feijoeiro comum.** Embrapa Arroz e Feijão, Santo Antônio de Goiás, 131p.

FEIJÃO: dados conjunturais do feijão (área, produção e rendimento) - Brazil - 1985 to 2007. Available at <http://www.cnpaf.embrapa.br/apps/socioeconomia/index.htm> Assessed on Jul. 25, 2010.

Ferreira DF (1999) **Sistema para análise de variância para dados balanceados (Sisvar)**. UFLA, Lavras, 92p.

Gonçalves JGR, Chiorato AF, Morais LK, Perina EF, Farias FL and Carbonell SAM (2010) Estudo da estabilidade fenotípica de feijoeiro com grãos especiais. **Ciência e Agrotecnologia 34**: 922-931.

Matos JW, Ramalho MAP and Abreu AFB (2007) Trinta e dois anos do programa de melhoramento genético de feijoeiro comum em Minas Gerais. **Ciência e Agrotecnologia 31**: 1749-1754.

Oliveira GV, Carneiro PCS, Dias LAS, Carneiro JES and Cruz CD (2005) Factor analysis in the environment stratification for the evaluation of common bean cultivars. **Crop Breeding and Applied Biotechnology 5**: 166-173.

Pereira HS, Melo LC, Faria LC, Díaz JLC, Del Peloso MJ, Costa JGC and Wendland A (2009) Stability and adaptability of carioca common bean genotypes in states of the central South Region of Brazil. **Crop Breeding and Applied Biotechnology 9**: 181-188.

Pereira HS, Melo LC, Faria LC, Del Peloso MJ, Díaz JLC and Wendland A (2010) Indicação de cultivares de feijoeiro comum baseada na avaliação conjunta de diferentes épocas de semeadura. **Pesquisa Agropecuária Brasileira 45**: 571-578.

Pimentel-Gomes FP (2000) **Curso de estatística experimental**. Nobel, São Paulo, 466p.

Ramalho MAP, Abreu AFB and Santos PSJ (1998) Interações genótipos x épocas de semeadura, anos e locais na avaliação de cultivares de feijão nas Regiões sul e Alto Paranaíba em Minas Gerais. **Ciência e Agrotecnologia 22**: 176-181.

Resende MDV and Duarte JB (2007) Precisão e controle de qualidade em experimentos de avaliação de cultivares. **Pesquisa Agropecuária Tropical 37**: 182-194.

Zimmermann FJP (2004) **Estatística aplicada à pesquisa agrícola.** Embrapa Arroz e Feijão, Santo Antônio de Goiás, 402p.