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J. Delfini
Agronomic Institute of Paraná State, jessica_delfini@hotmail.com

J. Dos Santos Neto
Agronomic Institute of Paraná State

V. Moda-Cirino
Agronomic Institute of Paraná State

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Delfini, J.[1]; Dos Santos Neto, J.[1]; Moda-Cirino, V.[1]

[1]Plant Breeding and Genetics Area. Agronomic Institute of Paraná State. Londrina - Paraná – Brazil
jessica_delfini@hotmail.com

INTRODUCTION

In Brazil beans are of great economic and social importance, as it is cultivated by small and large producers in all Brazilian regions. Diversified production systems and sowing times are used, therefore, the crop is subject to the most diverse environmental conditions. The presence of the interaction genotypes x environments hinders the work of the breeders, as it results in the variable behavior of the genotypes on the different environments, making selection difficult, especially for quantitative characteristics (CARGNIN et al., 2006). Several studies have reported that G x E interactions can be reduced using either specific cultivars in particular environments or cultivars with wide adaptability and stability (RAMALHO et al., 2012). Thus, the aim of this study was to evaluate the influence of G x E interaction on grain yield of common bean cultivars with carioca grain type.

MATERIAL AND METHODS

Twenty common bean cultivars belonging to the carioca commercial group were used. All cultivars come from breeding programs of public or private institutions from Brazil, and indicated for cultivation in the state of Paraná. The trials were established in four environments in the state of Paraná-BR, two in the 2014/2015 rainy season, in Ponta Grossa and Guarapuava, and two in the dry season of 2015, in Ponta Grossa and Santa Tereza do Oeste. The experimental design was a randomized complete block design with three replicates and plots consisting of four rows of 4 meters spaced 0.5 m, with a population of 12 plants per linear meter, considering the two central lines as a useful plot. The grain yield was obtained by weighing grams of the two central rows of the plot, adjusted to 13% of humidity and extrapolated to kg/ha. The results were submitted to analysis of individual variance of each environment and the test of homogeneity of error variance, followed by analysis of joint variance, considering the effects of genotype and environment as fixed. For the study of adaptability and stability, the methodology proposed by EBERHART & RUSSELL (1966) was used. All analyzes were processed in the Genes software (CRUZ, 2013).

RESULTS AND DISCUSSION

The estimate obtained by the ratio between the largest and the smallest mean square of the residues was less than seven (5.76), indicating homogeneity of the residual variances, allowing the joint analysis, which revealed a significant effect for all the sources of variation tested (Table 1). The significant effect of the cultivar x environment interaction reveals that cultivars have a differentiated response to environmental changes.

When analyzing the factors of adaptability and phenotypic stability by the criterion of EBERHART &

Table 1. Summary of the joint analysis of variance for grain yield (kg/ha) evaluated in 20 common bean cultivars of carioca grain type.

SV	Df	Mean Square	
Blocks/Environment	8	411440	
Cultivars (C)	19	1076498	**
Environments (E)	3	23377149	**
C x E	57	470051	*
Error	152	47444411	
Average		2564,31	
CV (%)		21,79	

**/* Significant at 1 and 5% levels, respectively, by the F test

RUSSELL (1966), 80% of the cultivars presented wide adaptability ($\beta_{li}=1$) (Table 2). The cultivars Dama, Pérola and IPR Maracanã showed adaptability to favorable environments ($\beta> 1$), that is, they respond favorably to environmental improvements. On the other hand, the cultivar IPR Curió presented $\beta <1$, evidencing to be adapted to unfavorable environments, not presenting increase in grain yield with the improvement of the environment. For phenotypic stability, 90% of the cultivars showed regression

deviation equal to zero ($\sigma^2_{di}=0$), indicating a high predictability of behavior (Table 2). In contrast, the cultivars IPR Campos Gerais and IPR Curió presented significant regression deviations ($\sigma^2_{di}\neq0$), evidencing unpredictable behavior in the environments.

Cultivars	Mean (kg/ha)	β_1	σ^2_{di}		R^2 (%)
IPR Bem-te-vi	3127.91	1.163	80926.255	NS	81.03
FT-65	2895.21	0.573	-87162.797	NS	91.90
BRS Notável	2873.06	1.023	-66496.279	NS	94.21
Dama	2869.01	1.642*	-71132.046	NS	97.95
Bola Cheia	2867.68	1.089	-67232.933	NS	94.96
Pérola	2771.34	1.722*	-36626.765	NS	96.25
IPR Campos Gerais	2739.88	0.729	222159.813	*	48.75
Carioca	2627.55	0.886	115548.841	NS	67.60
IPR Tangará	2620.77	1.162	91742.530	NS	80.11
IAC Formoso	2572.59	0.836	-70153.840	NS	92.33
IPR Andorinha	2542.51	0.704	-49975.461	NS	84.25
IAPAR 81	2517.36	1.078	-59704.009	NS	93.87
Gol	2514.98	1.079	123513.902	NS	74.94
BRS Estilo	2432.09	0.827	-85983.744	NS	95.67
IAC Alvorada	2394.17	1.308	48297.248	NS	86.79
IPR Maracanã	2387.01	1.651*	74648.408	NS	89.92
IPR Quero-quero	2300.96	0.797	-41209.440	NS	85.53
IPR Curió	2196.96	-0.006**	290793.355	*	0.005
IAC Imperador	2142.66	0.706	-4765.221	NS	74.59
IPR Eldourado	1892.66	1.034	177340.547	NS	68.93

Table 2. Mean grain yield (kg/ha) and estimates of the parameters (regression coefficient (β_1), regression deviation (σ^2_{di}) for adaptability and stability according to EBERHART & RUSSELL (1966), in 20 common bean cultivars of carioca grain type, at four experimental sites.

NS, * e **: non significant, significant at 5 e 1%, by t test (h_0: $\beta_{1i} = 1,0$) and the F test F (h_0: σ^2_{di}).

Considering the results obtained by the analysis of EBERHART & RUSSEL simultaneously with the average grain yield of the cultivars, it is verified that the majority of the genotypes showed high predictability of behavior and wide adaptability. In addition, the IPR Bem-te-vi, FT-65 and BRS Notável cultivars deserve to be highlighted, as they presented, together with these parameters, high grain yield. In addition, these genotypes showed high determination coefficients ($R^2 > 75\%$), indicating that most of their total variations are explained by the adopted model (Table 2).

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