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CHOICE OF PARENTAL LINES FOR COMMON BEAN (*Phaseolus vulgaris* L.) BREEDING. II. REACTION OF CULTIVARS AND OF THEIR SEGREGANT POPULATIONS TO VARIATIONS IN DIFFERENT ENVIRONMENTS

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ABSTRACT

Twelve parental lines and 32 segregant populations obtained from partial diallel crosses (4 x 8) were tested in six environments. F_3 populations were tested in one environment, F_4 populations in two and F_5 populations in three. Phenotypic stability of grain yield, genetic and environmental variance, as well as variance of genotype x environment interaction were estimated for the 44 populations to determine the reaction of the parental lines and of the segregants to environmental variations. Parental line x environment interaction was more than double the segregant x environment interaction. The materials were also found to differ mainly in terms of deviation from regression and the parental lines were more unstable than the segregant populations, with significant deviation from regression in 75% of them as opposed to only 28% in the segregants. We conclude that the genetically homogeneous populations (parental lines) were more sensitive to environmental variation than the genetically heterogeneous populations (segregants).

INTRODUCTION

Common beans are cultivated in Brazil under the most diverse environmental conditions, especially in terms of climate, soil and cultivation systems. On this basis, genetic breeding programs should consider, among other traits, greater resistance to different pathogens and a certain tolerance to environmental stress factors such as

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soil and climate in order to obtain better cultivar adaptation and more stable production of recommended materials.

Several studies have been conducted to estimate the stability of bean cultivars (Pessanha *et al.*, 1981; Santos *et al.*, 1982; Soares Filho *et al.*, 1984; Beaver *et al.*, 1985; Park, 1987; Pacova *et al.*, 1987; Duarte, 1988). In all cases, it was noted that it is possible to identify materials presenting predictable performance and responding or not to changes in environmental conditions.

There is evidence that cultivar stability depends on the genotypic constitution of each material, i.e., that some genotypes are more stable than others. This fact has been demonstrated for some autogamous plants such as soybeans (Bonato, 1978) and common beans (Santos *et al.*, 1982; Pacova *et al.*, 1987; Duarte, 1988). Thus, stability can be achieved by practicing pure line selection for genotypes that present little interaction with the environment as well as good productivity. Furthermore, cultivars whose composition involves a mixture of genotypes should be more stable (Allard, 1961, 1967), as has been shown for some crops such as soybeans (Probst, 1957), maize (Funk and Anderson, 1964; Rowe and Andrew, 1964; Lemos, 1976), oats (Freu and Maldonado, 1967), barley (Clay and Allard, 1969), wheat (Widner and Lebsock, 1973), sorghum (Patanothai and Atkins, 1974) and common beans (Guazzelli, 1975; Soares Filho *et al.*, 1984).

In the case of autogamous plants such as beans, a heterogeneous population can be obtained by mixing pure lines, a practice followed by many farmers (Carvalho and Vieira, 1972; Wader *et al.*, 1977; Silva, 1982; Debouck *et al.*, 1989) who use their own seeds year after year or seeds from advanced generations of crosses of two or more lines. Studies involving a mixture of pure lines have shown that one or more of the lines tend to predominate over various generations (Colin, 1969; Cardoso and Vieira, 1976), with the consequent need for periodical renewal of these mixtures in order to maintain stability. The objective of the present study was to compare the stability of advanced hybrid bean generations with that of the respective parental bean lines, a type of investigation that has not yet been reported in the literature.

MATERIAL AND METHODS

Twelve common bean cultivars were crossed using a partial diallel cross scheme, in the trial fields of the Department of Biology of the "Escola Superior de Agricultura de Lavras". Two groups of cultivars were formed: group 1 consisted of cultivars ESAL 1, ESAL 501, Pintado and Rio Vermelho, which produce seeds acceptable in the market in the southern region of the State of Minas Gerais, and group 2 consisted of cultivars Milionário, Linea 29, TO, Rio Negro, A 296, A 354, A

242 and BAT 160, which are introduced materials whose seed types are not well accepted by the population.

Trial locations and years and plant generations for the 32 segregant populations are presented in Table I.

Table I - Locations, sowing times and generations for segregant populations tested.

Location	Sowing time	Generation
Patos de Minas (MG)	February 1986	F_3
Ribeirão Vermelho (MG)	July 1986	F_4
Jussara (GO)	July 1986	F_4
Patos de Minas (MG)	July 1987	F_5
Lavras (MG)	July 1987	F_5
Lambari (MG)	July 1987	F_5

The trials for generations F_3 and F_4 have been described by Ramalho *et al.* (1988), and those for generation F_5 were carried out in duplicate using a 7 x 7 simple lattice design, with each plot represented by two rows spaced 0.5 m apart. The soil was fertilized with 400 kg/ha of 4-14-8 fertilizer and 150 kg/ha of ammonium sulfate cover. No pesticides were used and weeds were controlled manually when necessary.

The parental cultivars and the segregant populations were evaluated in terms of grain yield (kg/ha). Data were analyzed by individual analysis of variance followed by joint analysis of variance, considering each trial as a different environment. The degrees of freedom of the mean error and of the interactions were calculated by the method of Cochran (1954). Estimates of variance components were obtained considering the environmental effects to be random and the parental and segregant population effects to be fixed.

Material stability was evaluated by the regression coefficient (b), variance of deviation from regression (s^2d) and variance of mean yield (Eberhart and Russel, 1966). The coefficient of determination (R^2) was also estimated, which shows the extent to which linear regression explains genotype performance in the various environments. The significance of b was calculated using the t test (Steel and Torrie, 1980) for H_O: $b = 1$, and s^2d was calculated by the F test for H_O: $s^2d = 0$.

The genetic control of the stability parameters for each material, b and s^2d, was evaluated using the partial diallel model suggested by Geraldi and Miranda Filho (1988). Two estimates of b and s^2d were obtained for each material, dividing each trial into two groups, each with two replications. The repeatability of the parameters (h^2) was also estimated by the method of Bonato (1978).

RESULTS AND DISCUSSION

The results of joint analysis of variance are presented in Table II. It can be seen that the coefficient of variation was similar to the values normally reported in the literature for trials conducted under similar conditions (Abreu, 1989; Resende, 1989). All of the sources of variation were found to be significant, except for (P vs S) x E interaction. This showed that there was significant variation among the genetic materials tested, the environments and the genotype x environment interaction, essential conditions for determining the possible existence of differences with respect to stability.

Table II - Summary of joint analyses of variance for grain yield (kg/ha) of parental lines and segregant populations.

Source of variation	d.f.	M.S.
Genotypes (G)	(43)	487,027.53**
Parental lines (P)	11	548,699.33**
Segregant populations (S)	31	480,374.52**
P vs S	1	871,238.00*
Environments (E)	5	22,526,070.46**
G x E	(122)	188,548.89**
P x E	31	285,791.21**
S x E	88	154,504.88**
(P vs S) x E	3	174,247.60**
Mean error	492	70,407.57
CV (%)	21.77	
Mean(kg/ha)	1218.81	

*, ** Significant at the 5% and 1% level of probability, respectively.

Table III shows that parental x environment interaction (P x E) was more than double the interaction of segregant populations with environments (S x E) and corresponded to 41% of the variability among parental lines, whereas the interaction of segregant populations with the environments corresponded to less than 5% of the variability among the segregant populations. In principle, these results show that the parental lines presented a more differentiated behavior in the presence of environmental variation than the segregant populations, suggesting that the former are more sensitive to environmental fluctuations. Table IV presents the estimates of stability parameters. It can be seen that mean yield of parental lines and segregant populations was practically identical. The same occurred with the amplitude of variation, indicating the predominance of an additive effect in the control of the trait, as pointed out by Ramalho *et al.* (1988).

Table III - Estimates of variance components related to genetic and environmental diversity, and their interactions.

Variances	Estimates ($*10^{-4}$)
Total genetic (G)[1]	53.48
Parental lines (P)[1]	12.05
Segregant populations (S)[1]	42.09
Environmental (E)	14.08
G x E	2.89
P x E	4.94
S x E	2.04

[1] Variance here refers to a fixed effect.

The regression coefficients (b) ranged from 0.57 (Pintado x Linea 29) to 1.55 (Milionário), showing that the materials respond in a different manner to changes in evironment. However, only line A 296 presented b estimates statistically higher than 1.0, indicating the possibility that this line has the potential to respond to improved environmental conditions with greater intensity.

Performance predictability estimates based on deviation from regression showed that the segregant populations were also more predictable than parental lines. For example, only three of the 12 parental lines tested, i.e., 25%, presented a nonsignificant deviation from regression, as opposed to 23 of the 32 segregant populations tested (72%).

The results of analysis of variance of the diallel table for b and s^2d estimates (Table V) were used to determine the genetic control of stability parameters. The data showed that the parental lines differ in these parameters; however, it was not possible to select segregant populations presenting a greater response to environmental effects and/or even greater performance predictability, since the general and specific combining abilities of these materials had no significant effect.

Table IV - Mean grain yields (kg/ha) of the parental lines and segregant populations with their respective regression coefficients, variances of the deviations and determination coefficients.

Genotype	Yield kg/ha	%	b	s^2d	R^2 (%)
ESAL 1	1372	113	1.06	128.293**	55
ESAL 501	1233	101	1.23	33.535*	83
Pintado	1099	90	0.90	148.123**	44
Rio Vermelho	1184	97	0.66	35.870*	57
Milionário	1339	110	1.55	18.995	91
Linea 29	948	78	1.26	57.747**	77
TO	963	79	1.00	87.617**	61
Rio Negro	1431	117	1.19	32.809*	82
A 296	1302	107	1.35*	0.000	97
A 354	1203	99	0.72	28.051*	64
A 242	1183	97	0.48	52.860**	35
BAT 160	1297	106	1.38	4.028	93
ESAL 1 x Milionário	1420	116	1.04	0.000	93
ESAL 1 x Linea 29	1157	95	1.52	97.386**	76
ESAL 1 x TO	1165	96	0.74	11.164	75
ESAL 1 x Rio Negro	1260	103	1.10	36.000	92
ESAL 1 x A 296	1384	114	0.83	35.943*	67
ESAL 1 x A 354	1312	108	1.09	12.956	86
ESAL 1 x A 242	1313	108	0.82	0.000	96
ESAL 1 x BAT 160	1170	96	0.93	13.974	81
ESAL 501 x Milionário	1436	118	1.24	21.223	86
ESAL 501 x Linea 29	1253	103	0.89	81.313**	56
ESAL 501 x TO	1183	97	0.72	12.965	73
ESAL 501 x Rio Negro	1306	107	1.45	19.764	90
ESAL 501 x A 296	1272	104	0.75	57.685**	54
ESAL 501 x A 354	1336	110	1.03	3.476	89
ESAL 501 x A 242	1280	105	1.01	5.440	88
ESAL 501 x BAT 160	1373	113	0.89	23.521	76
Pintado x Milionário	1102	90	1.19	61.231**	74
Pintado x Linea 29	1000	82	0.57	0.000	77
Pintado x TO	977	80	0.67	7.025	75
Pintado x Rio Negro	974	80	0.59	8.000	76

Continued

Table IV - Continued.

Genotype	Yield kg/ha	%	b	s^2d	R^2 (%)
Pintado x A 296	1207	99	0.99	94.450**	58
Pintado x A 354	953	78	0.94	2.087	88
Pintado x A 242	965	79	0.85	29.123**	71
Pintado x BAT 160	1078	88	0.92	0.000	93
Rio Vermelho x Milionário	1188	97	0.87	7.033	83
Rio Vermelho x Linea 29	1314	108	1.45	0.000	95
Rio Vermelho x TO	1193	98	1.35	12.123	91
Rio Vermelho x Rio Negro	1187	97	0.89	59.151**	62
Rio Vermelho x A 296	1369	112	0.99	28.177*	77
Rio Vermelho x A 354	1401	115	1.01	0.000	92
Rio Vermelho x A 242	1359	111	0.80	3.094	83
Rio Vermelho x BAT 160	1188	97	1.11	0.000	93
Means:					
Parental lines	1213	100	1.07	52.327	70
Segregant populations	1221	100	0.98	21.885	80
Overall	1219	100	1.00	30.187	77

*, ** Significant at the 5% and 1% level of probability, respectively.

Relatively high h^2 estimates were obtained for the two stability parameters. This was mainly due to the greater sensitivity of the parental lines to environmental variation, including year and location effects, since the segregant populations, as mentioned earlier, presented homogeneous behavior (Table V). Lower h^2 estimates have usually been reported in the literature (Fantula and Frey, 1976; Eagles an Frey, 1977; Santos *et al.*, 1982; Torres, 1988; Becker and Leon, 1988).

Taken as a whole, the results indicate that the parental lines, which normally consist of a single strain, in general were more unstable than the segregant populations. These data agree with those obtained by Guazzelli (1975) and Soares Filho *et al.* (1984), who observed that genetically heterogeneous populations responded less to environmental changes.

Subsistance farmers tend to use a mixture of lines in their fields (Carvalho and Vieira, 1972; Walder *et al.*, 1977; Silva, 1982; Debouck *et al.*, 1989). According to Vieira (1972), the purpose of this mixture of cultivars is to obtain better protection against pathogens, since a mixture of genotypes contributes to lower vulnerability.

Although the segregant populations tested here are probably different from the mixtures used by farmers because they involve individuals containing loci in homozygosis and heterozygosis, they show that mixing of genotypes, in addition to giving the advantage suggested by Vieira (1972), confers greater stability in the presence of environmental variations such as humidity, temperature and soil fertility.

Table V - Analysis of variance of the diallel table of the stability parameters: regression coefficient (b) and variance of deviation from regression (s^2d).

Sources of variation	d.f.	M.S. (*10^4)	
		b	s^2d[1]
Genotypes	43	1,167.93*	2,201.30**
Parental lines (1)	3	1,134.07**	3,479.04*
Parental lines (2)	7	2,464.74**	3,136.97*
Par. (1) vs Par. (2)	1	1,333.68	4,029.57
Parental lines vs Segregants	1	532.26	6,945.66**
Segregant populations	31	893.53	1,654.35
CGC (1)	3	993.22	1,289.67
CGC (2)	7	293.56	1,580.69
CEC	21	1,079.29	1,669.58
Error	43	674.05	1,065.19
CV (%)		25.96	6.69
Mean		1.00	4.88
h^2		42.29	51.61

*, ** Significant at the 5% and 1% level of probability, respectively.

[1] Log transformed data.

The present results also support the suggestion of Allard and Bradshaw (1964) that the stability of a cultivar consisting of a single genotype presents much more variation with environmental oscillations than a heterogeneous population. This is due to the fact that a segregant population exhibits greater stability by being the result of the expression of the mean performance of the various constituent genotypes - individual buffering - and also of the interaction of these various genotypes - population buffering.

RESUMO

Foram avaliados 12 parentais e as 32 populações segregantes, provenientes de cruzamentos no esquema dialélico parcial (4 x 8), em 6 ambientes, nos quais em um utilizou-se as populações na geração F_3, em dois na F_4 e em três na F_5. Estimou-se a estabilidade fenotípica da produção de grãos dos 44 materiais, bem como as variâncias genéticas, ambiental e das interações de genótipos por ambientes, visando conhecer a reação dos parentais e das populações segregantes frente às variações ambientais. Constatou-se que a interação de parentais por ambientes foi superior ao dobro da interação de populações segregantes por ambientes. Verificou-se também que os materiais diferiram principalmente em relação aos desvios da regressão e que os parentais foram mais instáveis do que as populações segregantes, pois 75% apresentaram desvio da regressão significativos contra apenas 28% das populações segregantes. Infere-se que as populações geneticamente homogêneas (parentais) foram mais sensíveis às variações ambientais do que as populações geneticamente heterogêneas (populações segregantes).

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