Genotype x environment interaction in common bean yield and yield components

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ABSTRACT

This study assessed genotype x environment interaction effects on common bean yield and its components. Sixteen genotypes were evaluated in two agricultural years in two traditional cropping seasons in Rio Grande do Sul state - Brazil. The results obtained showed significant genotype x years interaction, which changed the genotype rank in each evaluation year. Path analysis showed that correlation between yield and its components was modified by the genotype x years interaction. These results suggest that more years of evaluation are necessary to obtain more reliable and useful estimates.

KEY WORDS: *Phaseolus vulgaris* L., correlations, path analysis, cropping seasons.

INTRODUCTION

In the Central Depression region of Rio Grande do Sul, common bean can be cropped during two seasons, from August to October (Aug/Oct sowing season) and from January to March (Jan/March sowing season). Sowing in Aug/Oct is preferential, and most of the available cultivars have been developed for this season. However, sowing in Jan/March is a worthwhile alternative to improve farmer income and an excellent option for crop rotation in the region.

Although sowing common bean in Jan/March has become increasingly important to the state of Rio Grande do Sul, there is little information on the yield of cultivars registered for the season. Cultivar responses in Jan/March are expected to differ from those in Aug/Oct since the environmental conditions are not similar.

Alteration in the relative performance of the genotypes caused by environmental differences is called genotype x environment effect (Borém, 1997). Significant genotype x years, genotypes x locations and genotypes x years x location interactions have been reported in several studies (Ramalho et al., 1998; Coimbra et al., 1999a; Elias et al., 1999; Jobim et al., 1999a, 1999b, 2000; Duarte and Zimmermann, 1991). However, the effect of the sowing season has been little emphasized in the literature (Ramalho et al., 1998). In the presence of genotype x sowing season interaction, genotypes should be selected in experiments carried out during the cropping appropriate season (Coelho et al., 2002).

Interaction has direct implications on new common bean cultivar registration since the recent Cultivar Protection Law (Law No. 9.456) requires experiments to be conducted in two agricultural seasons only, and in three sites located in the soil-climate region of interest (Cepef, 2000). Such small number of testing environments does not allow minimization of environmental effects through selection of cultivars with higher yield stability. Ramalho et al. (1998) suggested conducting the experiments in two seasons each year as an alternative to improve assessment of cultivar performance in a relatively short period.

The presence of genotype x sowing season interaction alters the yield rank of common bean genotypes (Jobim et al., 1999a) sowed from Aug/Oct to Jan/March. Since the environment can also influence the relationship between traits (Cruz and Regazzi, 1997), the correlation between yield and its primary components is expected to differ between the two cropping seasons. In this case, the path analysis can contribute to improve knowledge on the changes caused by the environment in the inter-relationships between traits of importance in common bean breeding (Santos et al., 1986; Coimbra et al., 1998a, 1998b, 1999c; Ribeiro et al., 2001a, 2001b; Kurek et al., 2001; Furtado et al., 2002).

The objective of this study was to assess the effects of the genotype x environment interaction on the common bean yield and its components.

MATERIAL AND METHODS

The experiments were conducted in an area of the Plant Science Department in the Santa Maria Mapping Unit soil (Brunizem Hydromorphic) at the Santa Maria Federal University. The experiment location presented the following geographic coordinates: 29°41´25” latitude south, 53°48´04” longitude west and 95 m altitude.

The randomized complete blocks experimental design with three replications was used. A total of 15 common bean genotypes, either registered or indicated for cropping (Table 1) in Rio Grande do Sul (Cepef, 2000), and the PR 468 inbred line developed by EMBRAPA were assessed. During the 2000/01 growing season, sowing was carried out on Nov 06, 2000 (Crop 1) and on Feb 06, 2001 (Crop 2), while in the 2001/02 growing season, it was carried out on Oct 19, 2001 (Crop 1) and on Jan 29, 2002 (Crop 2). Crop 1 corresponded to the Aug/Oct sowing and Crop 2 to the Jan/March sowing in the Central Depression of Rio Grande do Sul region. The amount of seeds was adjusted to ensure adequate plant populations for the genotypes of different growth habit (Cepef, 2000).

The plots were formed by four 4-meter long rows, spaced at 0.50 m. The useful area ($3m^2$) was formed by the two central rows after being trimmed 0.50 m from the ends.

The soil was conventionally prepared (plowing and disking), and the fertilization based on the soil chemical analysis followed the Fertilization and Liming Recommendations for Rio Grande do Sul and Santa Catarina (Rolas, 1995). Insects and weeds were controlled with Metamidofos (Metamidofos Fersol, 750 ml/ha) insecticide and Fluazifop-p-butyl (Fusilade, 850 ml/ha) herbicide, respectively. Remaining weeds were hand removed whenever necessary to allow normal crop development. Diseases were not controlled to check genotype reaction to the pathogens.

Yield (REND) in t/ha was standardized to 13% seed

Table 1. Commercial group, growth habit (HC), release year and institute of origin of the assessed common bean genotypes. Santa Maria, UFSM, 2001.

Genotype	Commercial Group	HC[1/]	Release year	Institution[2/]
Carioca	Carioca	III	1976	IAC[1]
Diamante Negro	Preto	II	2000	CNPAF[2]
TPS Nobre	Preto	II	1996	TPS[3]
Guapo Brilhante	Preto	III	1995	CPATB[4]
Guateian 6662	Preto	II	1979	CPATB[4]
IAPAR 31	Carioca	II	1994	IAPAR[5]
IAPAR 44	Preto	II	1994	IAPAR[5]
Iraí	De cor	I	1981	CPATB[4]
Macanudo	Preto	III	1989	CPATB[4]
Macotaço	Preto	III	1994	CPATB[4]
Minuano	Preto	II/III	1991	CPATB[4]
Pérola	Carioca	III	2000	CNPAF[2]
Rio Tibagi	Preto	I	1976	CPATB[4]
PR 468	De cor	II	2002	CPATB[4]
TPS Bionobre	Preto	II	2001	TPS[3]
TPS Bonito	Carioca	III	2000	TPS[3]

[1/] HC = growth habito: (I): determined; (II): indeterminate with short ‘guias´; (III): indeterminate with long ‘guias´;
[2/] Institution responsible for the development ad/or registration of the genotypes: (1) IAC: Instituto Agronômico de Campinas, Campinas, SP; (2) CNPAF: Centro Nacional de Pesquisa em Arroz e Feijão, Goiânia, GO; (3) TPS: Terassawa Produção de Sementes, Ponta Grossa, PR; (4) CPATB: Centro de Pesquisa Agropecuária de Terras Baixas de Clima Temperado, Pelotas, RS; (5) IAPAR: Instituto Agronômico do Paraná, Londrina, PR.

moisture. All plants with fertile pods in the plot useful area were considered for analysis. Yield component data – number of pods per plant (NLP), number of seeds per pod (NGL) and weight of 100 seeds (PCG) - were obtained from five randomly harvested plants within the plot useful area.

Data were submitted to a joint analysis of variance to test the hypotheses of significance for main effects and interactions. The genotype effect was considered fixed and year, crop and blocks/crop/years effects as random (these effects are random under the cropping conditions of Southern Brazil). Means were compared by the Tukey test at the 5% level of probability of error.

The path analysis was used to determine the direct and indirect effects of the secondary traits on the main yield trait (REND) based on the estimated matrix of coefficients of genotypic correlations (Cruz and Regazzi, 1997; Cruz, 2001).

RESULTS AND DISCUSSION

In the analysis of variance for yield, only the genotype x year interaction effect was significant at the 5% level of probability (Table 2).

The significance of this interaction indicated the existence of genotypes less responsive to the environmental variations, mainly rainfall and maximum and minimum temperatures (Allard and Bradshaw, 1964). The direct consequence for breeding is in the registration of cultivars. Since the VCU (Cultivation and Use Value) for registration (Cepef, 2000) can be obtained from two-year assessment data, cultivars with high mean yield but susceptible to yield oscillations under environmental adversity can be registered.

The mean yield reduction in the Jan/March sowing season (greater than 50%) was similar in both years (Table 3).

As a consequence, nor the sowing season effect neither the genotype x cultivation, years x cultivations and genotype x years x cultivation and interactions were significant (Table 2). The coefficients of variation were always superior in the Jan/March sowing seasons. It is believed that the larger amount of rainfall registered in this period contributed to the greater among plot heterogeneity by increasing the experimental error through the excess of water accumulated in the soil in the lowest areas.

Mean yield was similar in the two years assessed; however, the environmental variations caused different genotype responses (Table 4). Genotypes developed by local breeding programs (Guapo Brilhante, PR 468, Iraí, Macotaço and Minuano) were higher yielding, which suggested their better adaptation to the region cropping conditions (Manara et al., 1993; Piana et al., 1999). In addition, the Iapar 31, Carioca, TPS Nobre and TPS Bionobre cultivars, developed for programs in other states, showed good performance in the two assessment years. Coincidently, the highest yielding genotypes were those assessed in more environments (locations and years) before being indicated as cultivars for cropping.

Type I plants are basically characterized by a determined growth habit and short cycle. Thus it was expected that the Iraí and PR 468 cultivars would be more vulnerable to the environmental variations and present unstable yield, as already observed for Iraí

Table 2. Joint analysis of variance and variation coefficient (CV%) for grain yield (t/ha) of common bean genotypes. Santa Maria – RS, UFSM, 2002.

Source of variation	Degrees of Freedom	Mean Square
(Block / Seasons) Years	8	3.0796^{ns}
Genotypes (G)	15	0.7906^{ns}
Years (Y)	1	0.0229^{ns}
Seasons (S)	1	60.8389^{ns}
G x Y	15	0.2068$^{1/}$
G x S	15	0.1715^{ns}
Y x S	1	1.7781^{ns}
G x Y x S	15	0.8437^{ns}
Residue	120	0.0861^{ns}
Mean	1.39	
CV (%)	21.06	

$^{1/}$: significant by the F test at 5% probability; ns: not significant.

Table 3. Genetic parameters for grain yields (REND) in growing seasons 1 (2000/01) and 2 (2001/02), in crops 1 (Aug/Oct sowing season) and 2 (Jan/March sowing season) of common bean genotypes. Santa Maria – RS, UFSM, 2002.

Year	Crop	REND (t/ha)	CV (%)[1/]	VAR. GEN. [2/]	h^2 [3/]
1	1	1.8495	17.39	0.1408	0.8032
1	2	0.9162	22.56	0.0792	0.8476
2	1	2.0639	19.66	0.0385	0.4127
2	2	0.7456	24.64	0.0443	0.7974

[1/] CV(%): variation coefficient in percent; [2/] VAR. GEN: genetic variability; [3/] h^2: heredity in the broad sense = $h^2 = s^2 G / s^2 F$; where: $s^2 G$ = genetic variability and $s^2 F$ = phenotypic variability.

Table 4. Common bean genotype grain yield in two agricultural years, mean of two crops (Aug/Oct and Jan/March sowing seasons). Santa Maria – RS, UFSM, 2002.

Genotype	Yield (t/ha)		
	2000/01	2001/02	Mean
Guapo Brilhante	1.896 a	1.678 a	1.787
Minuano	1.847 a	1.739 a	1.793
PR 468	1.809 a	1.635 ab	1.722
Iraí	1.764 a	1.266 abc	1.515
Macotaço	1.665 ab	1.413 abc	1.539
Iapar 31	1.543 abc	1.470 abc	1.506
Carioca	1.452 abcd	1.535 abc	1.494
TPS Nobre	1.367 abcde	1.584 abc	1.475
Macanudo	1.353 abcde	1.315 abc	1.334
TPS Bionobre	1.340 abcde	1.528 abc	1.434
Rio Tibagi	1.146 bcde	1.008 c	1.077
Guateian 6662	1.131 bcde	1.219 abc	1.175
Pérola	1.099 bcde	1.270 abc	1.184
Diamante Negro	1.001 cde	1.425 abc	1.213
Iapar 44	0.933 de	1.070 bc	1.002
TPS Bonito	0.781 e	1.319 abc	1.005
Média	1.382	1.405	1.393
CV (%)	19.97	22.14	21.06

[1/] Genotype means followed by the same letter differ by the Tukey test at 5% probability.

(Piana et al., 1999; Jobin et al., 1999a). However, both were shown to be highly adapted to the prevalent Santa Maria region environmental conditions for the 2000/01 and 2001/02 cropping seasons.

Cultivars with lower yield such as Pérola, Diamante Negro and TPS Bonito were more recently registered after having met the VCU norms (Cepef, 2000), for which fewer environments were considered. Rio Tibagi, Guateian 6662 and Iapar 44 have been available for cropping for many years and, probably, have problems of susceptibility to main crop diseases, which could explain the low yield presented. These results suggest that the methodology for new common bean cultivar registration should be revised, since variations between years can be large. The inclusion of more assessment years seems advantageous to minimize the effects of the years x genotype interaction that were also observed by other authors (Elias et al., 1999, Coimbra et al., 1999a; Ramalho et al., 1998; Piana et al., 1999).

Mean estimates for the direct and indirect effects of the secondary variables on yield varied in magnitude and sign in the two assessed years (Table 5). The PCG (0.5628) and NGL (0.4847) traits presented the largest direct effects on yield in 2000/01. On the other hand, in 2001/02 , the importance of the contribution of these variables to yield was inverted, that is, NGL (0.6593) was followed by PCG (0.5296).

It seems that the estimates obtained by the path analysis varied in function of genotypes, locations, years and sowing seasons, which would explain the variations in magnitude, sign and order of importance found in the literature (Santos and Vencovsky, 1986; Nienhuis and Singh, 1986; Peternelli et al., 1994; Santos et al., 1986; Coimbra et al., 1998a, 1998b, 1998c, 1999b, 1999c, 2000; Kurek et al., 2001; Ribeiro et al., 2001a, 2001b; Coelho et al., 2002; Furtado et al., 2002).

The indirect effects were relatively low and mostly negative. Similar results have been reported by Santos et al. (1986); Ribeiro et al. (2001a, 2001b); Kurek et al. (2001); Coimbra et al. (1998a, 1998b) and Furtado et al. (2002).

These findings suggest that to obtain more precise and useful correlation estimates, a larger number of years should be used for assessment. Differences observed for rainfall and maximum and minimum temperatures have most probably brought about the results obtained by the path analysis.

CONCLUSIONS

The presence of genotype x year interaction altered the relative rank of the common bean genotypes and the relationships between yield and its components in each agricultural season.

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Table 5. Estimates of the direct and indirect genetic effects of the plant population traits (POP), number of pods per plant (NLP), number of grains per pods (NGL) and weight of 100 grains (PCG) on the grain yield of common bean genotypes – RS, UFSM, 2002.

Traits	2000/01	2001/02
Number of plants (NP)		
Direct effect on REND	0.4088	0.0011
Indirect effect via NLP	-0.0999	-0.0859
Indirect effect via NGL	-0.0084	-0.1566
Indirect effect via PCG	0.1601	0.0322
Total	0.4606	-0.2092
Number of pods per plant (NLP)		
Direct effect on REND	0.3022	0.3519
Indirect effect via NP	-0.1351	-0.0003
Indirect effect via NGL	0.0449	-0.0028
Indirect effect via PCG	-0.0645	0.0823
Total	0.1475	0.4311
Number of grains per pods (NGL)		
Direct effect on REND	0.4847	0.6593
Indirect effect via NP	-0.0071	-0.0003
Indirect effect via NLP	0.0280	-0.0015
Indirect effect via PCG	-0.1603	-0.1557
Total	0.3452	0.5018
Weight of 100 grains (PCG)		
Direct effect on REND	0.5628	0.5296
Indirect effect via NP	0.1163	0.0001
Indirect effect via NLP	-0.0346	0.0547
Indirect effect via NGL	-0.1381	-0.1938
Total	0.5064	0.3906

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RESUMO

Efeitos da interação genótipo X ambiente no rendimento de grãos de feijoeiro e em seus componentes

Este trabalho teve como objetivo avaliar os efeitos da interação genótipos X ambientes no rendimento de grãos de feijoeiro e em seus componentes. Para tanto um experimento com 16 genótipos foi conduzido em dois anos agrícolas e em duas épocas comuns de semeadura na região da Depressão Central do Rio Grande do Sul. Os resultados obtidos evidenciam a ocorrência de interação significativa para genótipos X anos, o que altera a classificação relativa dos genótipos em cada ano agrícola avaliado. A análise de trilha mostra que o inter-relacionamento entre o rendimento de grãos e seus componentes em feijoeiro é modificado em função da interação genótipos X anos, sugerindo a avaliação em maior número de anos para a obtenção de estimativas mais precisas e úteis.

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