CBAB

CROP BREEDING AND
APPLIED BIOTECHNOLOGY

Estimation of competition parameters in common bean plants

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ABSTRACT - *The objective of this study was to estimate parameters related to the ability of competing or tolerating competition. The experiments were conducted in three seasons, using eight common bean lines with carioca type grains from different origins. Competition at the plant level was evaluated based on the number of pods, number of grains and grain weight (g plant^{-1}). The following competition-related parameters were estimated with the mean data, using a model similar to the diallel: general competing ability (c_i), competition tolerance (t_j), specific competing ability (s_{ij}) and performance per se of every line (a_j). The average performance of lines in self-competition was similar to non-self-competition. None of the lines coupled low competing ability (c_i high) with high competition tolerance. Highest estimates of a_j and c_i were observed in line OPNS 331.*

Key words: common bean, non-self-competition, self competition.

INTRODUCTION

Most subsistence farmers in Brazil do not purchase seed regularly but use grain harvested in previous growing seasons. It has been stated that their "cultivars" are actually mixtures of different lines. These mixtures, so it seems, allow for some advantages, such as greater stability (Becker and Léon 1988, Bruzi et al. 2006).

Another advantage ascribed to the blends would be higher yields, owing to the better performance of plants in non-self-competition, i.e., in competition with plants of other genotypes, than in self-competition (Donald 1963). This comparison was subject of several studies for several decades (Bisognin 1995, Mastrantonio 2004). The advantages of the blends were confirmed in some situations, as for example in common bean (Federer et al. 1982), soybean (Gizlice et al. 1989) and oat (Helland and Holland 2001). Nevertheless, information on this issue, above all on how to estimate self and non-self-competition effects, is still fragmentary.

Common bean improvement programs in Brazil have developed numerous carioca type bean lines, that is, plants with cream-colored, brown striped beans. In terms of market, there are no restrictions to blended lines, since the grains are very similar. It is however important to verify if the strategy is really advantageous. Parameter estimates associated to the ability of competing or tolerating competition at the plant level, involving carioca type bean lines, could show the advantage of a blend and, moreover, identify the most promising lines for a multiline program.

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On this background, the purpose of this study was to compare self- and non-self-competition, estimate parameters related to the plant ability of competing or tolerating competition and identify promising lines for the development of multilines.

MATERIAL AND METHODS

The experiments were conducted on an experimental area of the Universidade Federal de Lavras, in Lavras, a city in the southern region of the state of Minas Gerais (lat 21o58' S, long 45o22' W, 918 m asl).

Eight carioca type lines were used, that is, with cream-colored and brown-striped grains. The description of the lines and phenotypes of some traits are presented in Table 1.

The experiments were conducted in the three possible common bean growing seasons of the region: winter - sowing in July 2005, wet - sowing in November 2005 and dry - sowing in February 2006. Eight different experiments were conducted in each growing season, altering only the competing line (identified by "x" in Figure 1). The plants were arranged in a system of nine hills and data were collected from the central plant (test) while the others of the same line exerted competition. In each row the test hill was replicated eight times. Note that in each experiment the eight lines were subjected to competition of the same line.

The distance between hills was 30 cm. To warrant the same spacing between all hills a sowing furrow was opened at 30 cm distance and the exact hill marked by a ruler at every 30 cm. The test hill was determined previously by a ruler to facilitate sowing. Three seeds were sown per hill and thinned to one plant per hill after
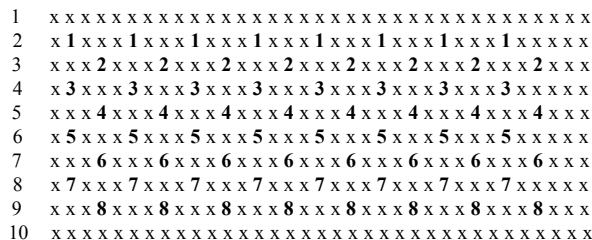
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Figure1. Arrangement of one of the experiments in the competition study of common bean plants, where "x" represents the competing line. One of the eight lines was used in each experiment. Numbers in bold represent lines under competition; each number corresponds to a different line

approximately 15 days. Only plants with the full set of eight neighboring plants were considered to be competing.

Fertilization was applied in the sowing furrow with 300 kg ha^{-1} of the mixture 8-28-16 of N, P_2O_5 and K_2O plus Zn and 150 kg ha^{-1} of ammonium sulphate, applied in top dressing. In the dry and winter seasons the crop was sprinkle-irrigated. Weeds were controlled by the post-emergent herbicides Fomesafen and Fluazifop-p-butil and the common crop practices of the region applied.

The plants in competition were harvested separately. The number of pods, number of grains and grain weight (g plant^{-1}) of each plant was recorded. The plant data were subjected to analysis of variance of the type among and within and count data were transformed by $\sqrt{x}$. The analyses per growing season and per experiment were performed first, followed by the joint analysis of variance of the three seasons, using software SAS-PROC GLM (SAS 2000).

The competition parameters were estimated with the mean data, based on the following model:

Table 1. Phenotypes of some traits of the lines related to self and non-self-competition

Lines	Growth habit[1]	Plant architecture	Diseases			
			[6]Anthrac.	[7]ALS	WHS[2]	Cycle (days)
Pérola	Type II/III	Semi-erect to prostrate	S[3/]	I[5/]	25g	90
VC3	Type III	Prostrate	R[4/]	I	27g	85
OPNS-331	Type II/III	Semi-erect to prostrate	R	I	25g	87
Magnífico	Type III	Semi-prostrate	R	-	22g	90
IAPAR 81	Type II	Erect	I	S	25g	92
Carioca	Type III	Prostrate	S	S	25g	90
Carioca MG	Type II	Erect	R	S	24g	90
Talismã	Type III	Prostrate	R	I	27g	85

[1] II-indeterminate growth habit type II; III-indeterminate type III; [2] Weight of 100 seeds; [3] Susceptible; [4] Resistant; [5] Intermediary; [6] Anthracnose; [7]Angular leaf spot

$\overline{Y}_{ij}=m+c_i+z_j+s_{ij}+e_{ij}$, where: $\overline{Y}_{ij}$: per plant mean of line j under competition of line i; m: overall mean; c_i: competing ability of line i; z_j: competition tolerance of line j. This component involves the *per se* effect of the line in competition (a_j) and the effect of the proper competition tolerance (t_j), that is, $z_j = a_j + t_j$. The *per se* effect of the line in competition a_j was estimated considering that i = j, that is, line i in competition with itself. So, $\hat{a}_j = \overline{Y}_{jj} - \overline{Y}$ and $\hat{t}_j = \hat{z}_j - \hat{a}_j$; s_{ij}: is the specific competing ability of the pair of lines i and j; e_{ij}: experimental error associated to the mean $\overline{Y}_{jj}$, where $e_{ij} \cap N(0, \sigma^2)$.

The least square method was used to estimate the parameters c_i, z_j and s_{ij} in the expression: $\hat{\beta} = (X'X)^{-1}X'Y$, where: $\hat{\beta}$: vector of the parameters to be estimated; X: coefficient matrix of the model; Y: vector of observations. SAS-PROC IML (SAS 2000) was used for resolution of the system.

RESULTS AND DISCUSSION

The summaries of the joint analysis involving all experiments and seasons are presented in Table 2, in which significant differences (P<0.01) between seasons were observed for the three traits. Significant differences (P<0.01) among treatments were stated as well. All sources of variation involving the general competing ability (GCA), competition tolerance (CT) and specific competing ability (SCA) were significant (P<0.01). The significance of the seasons x treatments interactions

suggests that the performance of the competing lines was not coincident in the different seasons. Although the interaction was significant, the differences in terms of estimates of the competition parameters were of small magnitude. In view thereof, our considerations focused on the mean performance of the three seasons.

The correlations of the three evaluated traits yield per plant, number of grains per plant and number of pods per plant are normally high and positive (Ramalho et al. 1993). In this study it was further stated that the line performance was very similar in the three traits; the discussion was therefore focused specifically on grain yield per plant.

The effect of self competition, that is, competition of a line with itself, is presented along the diagonal of Table 3 and of non-self-competition, which is competition exerted by plants of other lines, in the values above and below the diagonal. In the overall mean of the growing seasons and eight lines, the plants under self competition produced 3.5% more grains than in non-self-competition, that is, very similar values (Table 4). There are reports in the literature, with other species, where self and non-self-competition were also similar, as observed here (Stringfield 1959). Nevertheless, in several studies the blend performed better than monoculture were observed with common bean, where the mean yield of the blend was 8.35% higher than in monoculture. In this sense, Mastrantonio et al. (2004) stated that the blend of common bean lines may stimulate grain yield. In other crops such as soybean and

Table 2. Summary of the joint analysis of variance involving all experiments and growing seasons for the traits grain yield (w), number of grains per plant ($\sqrt{y}$) and number of pods per plant ($\sqrt{x}$)

SV	df	w	y	x
		MS	MS	MS
Seasons (S)	2	30518.72**	1119.87**	188.39**
Treatments (T)	63	415.03**	26.75**	4.29**
GCA[a]	7	923.38**	66.17**	9.49**
CT[b]	7	598.81**	44.53**	8.73**
SCA[c]	49	316.12**	15.43**	2.93**
S x T	126	446.56**	26.41**	4.09**
GCA x S	14	1173.41**	75.52**	10.68**
CT x S	14	1210.26**	78.11**	11.59**
SCA x S	98	233.62**	12.22**	2.09**
Error	1148	122.76	5.96	0.87
Mean		25.18	9.65	4.30

[**]Significant at 1% probability, by the F test
[a], [b], [c] overall competing ability, competition tolerance and specific competing ability, respectively

Table 3. Means of the three growing seasons for grain yield (w), number of grains (y) and pod number per plant (x) found in the competition experiments involving lines that exert competition and others affected by competition

| | Experiments | Lines under competition | | | | | | | | |
		VC3	IAPAR 81	Carioca MG	Magnífico	Carioca	Pérola	Talismã	OPNS 331	Mean
w	VC3	22.1	25.4	28.5	22.7	20.2	27.4	22.3	21.1	23.7
	IAPAR 81	20.6	24.7	23.8	23.0	21.1	22.8	20.1	18.5	21.8
	Carioca MG	28.8	31.0	27.1	23.4	30.2	28.0	18.4	22.5	26.2
	Magnífico	31.1	27.7	21.7	30.3	23.1	19.4	17.4	28.8	24.9
	Carioca	19.4	22.2	29.2	29.8	20.2	25.2	23.0	18.1	23.4
	Pérola	26.7	27.4	30.3	21.2	21.6	19.3	20.6	31.5	24.8
	Talismã	25.3	34.5	27.9	21.1	30.1	26.8	28.0	23.5	27.1
	OPNS 331	29.0	33.1	26.7	30.4	21.8	32.9	26.8	34.5	29.4
Mean		25.4	28.2	26.9	25.2	23.5	25.2	22.1	24.8	
y	VC3	88.4	98.0	121.0	77.4	72.3	96.0	88.4	74.0	88.4
	IAPAR 81	81.0	82.8	90.3	81.0	68.9	77.4	74.0	56.3	75.7
	Carioca MG	104	125.4	102.0	90.3	114.5	112.4	68.9	79.2	98.0
	Magnífico	116.6	108.2	81.0	134.6	79.2	59.3	72.3	108.2	92.2
	Carioca	75.7	75.7	104.0	121.0	72.3	84.6	86.5	60.8	84.6
	Pérola	104.0	108.2	130.0	81.0	81.0	70.6	82.8	123.2	96.0
	Talismã	90.3	123.2	114.5	79.2	82.8	82.8	90.3	81.0	92.2
	OPNS 331	114.5	132.3	121.0	139.2	86.5	121.0	104.0	132.3	118.8
Mean		96.8	106.7	108.0	100.5	82.2	88.0	83.4	89.4	
x	VC3	17.6	20.3	25.0	16.0	16.0	19.4	17.6	16.0	18.5
	IAPAR 81	16.8	18.5	17.6	14.4	13.7	14.4	16.8	11.6	15.2
	Carioca MG	19.4	27.0	21.2	16.8	22.1	22.1	15.2	16.0	20.3
	Magnífico	22.1	23.0	15.2	26.0	14.4	13.7	16.0	22.1	18.5
	Carioca	14.4	16.8	22.1	23.0	14.4	16.8	18.5	12.3	16.8
	Pérola	20.3	21.2	24.0	15.2	16.0	13.0	16.8	24.0	18.5
	Talismã	16.8	25.0	22.1	14.4	16.0	15.2	18.5	16.8	17.6
	OPNS 331	21.2	27.0	22.1	25.0	17.6	22.1	23.0	24.0	23.0
Mean		18.6	22.4	21.2	18.9	16.3	17.1	17.8	17.8	

Table 4. Means of self competition and of non-self-competition for grain yield (g plant^{-1}) in the three growing seasons, in the overall mean, and for each line separately

Growing seasons	Self competition	Non-self-competition
Winter 05	33.4	32.1
Wet 05/06	15.0	16.23
Dry 06	29.04	27.00
Mean of the three growing seasons	25.8	24.9
Lines	Self competition	Non-self-competition
VC3	22.1	22.7
IAPAR 81	24.7	28.7
Carioca MG	27.1	26.9
Magnífico	30.3	24.5
Carioca	20.2	24.0
Pérola	19.3	26.0
Talismã	28.0	21.3
OPNS 331	34.5	23.4

oat, gains of the blends were observed compared to monoculture (Bisognin et al. 1995, Helland and Holland 2001). As emphasized above, the methodologies these authors used were not the same as used here.

Based on line OPNS 331 as reference, it was observed that the grain yield in self-competition was 32.2% higher than under non-self-competition. The opposite was true for Pérola, where the performance in non-self-competition was 25.8% higher than in self-competition (Table 4). Analogously, in some studies with common bean and soybean, these differences between lines were stated as well (Bisognin et al. 1995). As had been expected, the

response in non-self-competition was not affected by the fact that the lines differed in growth habit (Table 1).

Four parameters were estimated to evaluate the effect of competition, that is, the *per se* performance of line (a_j): the general competing ability (c_i), competition tolerance (t_j) and specific competing ability (s_{ij}). The highest a_j estimates were obtained for OPNS 331 and Magnífico, evidencing that these lines perform well in self-competition (Table 5).

The more negative the c_i value, the more competitive is the line, in other words, the performance dropped more markedly in the treatment under competition. The most competitive line for the three traits was IAPAR 81. The least competitive, on the other hand (positive c_i estimate), was OPNS 331 (Table 5). As mentioned above, the t_j estimate expresses competition tolerance, which also varied among lines. Note that a positive t_j value indicates a tolerant line. Pérola was least affected by competition (most tolerant) while OPNS 331 was the least tolerant (Table 5). The estimates of correlation c *vs* t, in all growing seasons, were negative and high, confirming the above observation (Table 6). It was concluded that the identification of lines that exert little competition (positive and high c_i) and suffer less competition (positive and high t_j) will be difficult.

The correlations between the estimates of a *vs* t were always negative, i.e., lines with greater yield potential are less competition-tolerant (Table 6). The a *vs* c correlations however were always positive, that is, the lines with highest *per se* performance exert little competition. As they compete strongly with each other (low a_j estimate), they provide conditions that enable

Table 6. Estimate of the correlations between the per se performance of the line (a), general competing ability (c) and competition tolerance (t), for grain yield (w), number of grains per plant (y) and number of pods per plant (x), in the three growing seasons

Growing seasons	Traits	Correlations		
		a and c	a and t	c and t
Winter 05	w	0.70[*]	-0.87[**]	-0.81[*]
	y	0.62	-0.77[*]	-0.72[*]
	x	0.62	-0.77[*]	-0.80[*]
Wet 05/06	w	0.80[*]	-0.80[*]	-0.34[**]
	y	0.79[*]	-0.82[**]	-0.89[**]
	x	0.70[*]	-0.78[*]	-0.86[**]
Dry 06	w	0.68	-0.95[**]	-0.81[*]
	y	0.78[*]	-0.96[**]	-0.84[**]
	x	0.54	-0.97[**]	-0.61
Harvest mean	w	0.73[*]	-0.93[**]	-0.85[**]
	y	0.74[*]	-0.89[**]	-0.83[**]
	x	0.49	-0.85[**]	-0.67

[**], [*] Significant at 1% and 5% probability, by the T test

neighboring plants to express their yield potential.

A negative value of specific competing ability indicates that a pair of lines is not a good combination and vice versa. In this regard, the combination Magnífico - Carioca was an outstanding pair with good performance in the three traits (Table 7).

The use of multilines is a strategy to extend the durability of pathogen resistance (Mundt 2002). In the original proposal, isogenic lines containing different resistance alleles are blended. For this purpose, OPNS 331 would be indicated to obtain isogenic lines, since it exerts little competition and performs better in self than

Table 5. Estimate of the per se performance of the lines (a_j), general competing ability (c_i) and competition tolerance (t_j) for grain yield (w), number of grains per plant ($\sqrt{y}$) and number of pods per plant ($\sqrt{x}$), in the mean of the growing seasons

Lines	a_j			c_i			t_j		
	w	$\sqrt{y}$	$\sqrt{x}$	w	$\sqrt{y}$	$\sqrt{x}$	w	$\sqrt{y}$	$\sqrt{x}$
VC3	-3.7	-0.4	-0.2	-2.5	-0.2	0	3.7	0.4	0.1
IAPAR 81	-1.1	-0.7	0	-3.2	-0.9	-0.4	4.3	1.3	0.4
Carioca MG	1.3	0.4	0.3	1.1	0.3	0.2	0.9	0.4	0
Magnífico	4.5	1.8	0.7	-0.1	0	0	-3.9	-1.4	-0.7
Carioca	-5.6	-1.3	-0.6	-1.6	-0.5	-0.2	4.4	0.7	0.3
Pérola	-6.5	1.3	-0.8	-0.2	0.2	0	5.5	-1	0.6
Talismã	2.2	-0.2	-0.1	2.1	0	-0.1	-5.4	-0.4	0.5
OPNS 331	8.7	1.7	0.6	4.4	1.2	0.5	-9.3	-2.1	-0.8

Table 7. Estimate of parameters of the specific competing ability (s_{ij}) for grain yield (w), number of grains ($\sqrt{y}$) and number of pods ($\sqrt{x}$) per plant, in the mean of the growing seasons

Experiments		VC3	IAPAR 81	Carioca MG	Magnífico	Carioca	Pérola	Talismã	OPNS 331
					Lines under competition				
w	VC3	-0.3	-0.3	3.8	-0.4	-1.0	-4.2	3.1	-0.8
	IAPAR 81	-1.2	-0.4	-0.3	0.5	0.6	1.9	1.5	-2.7
	Carioca MG	2.7	1.6	-1.2	-3.4	5.3	2.8	-4.6	-3.1
	Magnífico	6.2	-0.5	-5.4	4.8	-0.6	-4.6	-4.3	4.4
	Carioca	-4.0	-4.5	3.6	5.9	-1.9	2.7	2.9	-4.7
	Pérola	1.9	-0.7	3.3	-4.2	-2.0	-4.6	-1.0	7.2
	Talismã	-1.8	4.1	-1.4	-6.7	4.2	0.6	4.1	-3.1
	OPNS 331	-0.4	0.4	-4.9	0.4	-6.3	4.4	0.6	5.7
y	VC3	-0.1	-0.2	0.8	-1.0	-0.4	0.7	0.5	-0.4
	IAPAR 81	0.2	-0.2	0.0	-0.2	0.2	0.3	0.5	-0.8
	Carioca MG	0.2	0.6	-0.6	-0.9	1.3	1.0	-1.1	-0.6
	Magnífico	1.1	0.1	-1.5	1.5	-0.2	-1.6	-0.6	1.1
	Carioca	-0.6	-1.1	0.3	1.4	-0.1	0.3	0.7	-1.0
	Pérola	0.3	-0.1	0.8	-1.2	-0.2	-1.1	-0.1	1.7
	Talismã	-0.2	0.9	0.3	-1.2	0.1	-0.2	0.5	-0.2
	OPNS 331	-0.3	0.0	-0.7	0.5	-1.0	0.4	0.0	1.0
x	VC3	-0.1	-0.2	0.4	-0.4	0.0	0.3	0.1	-0.2
	IAPAR 81	0.2	0.0	-0.1	-0.2	0.0	0.1	0.3	-0.4
	Carioca MG	0.1	0.3	-0.1	-0.4	0.5	0.4	-0.4	-0.3
	Magnífico	0.4	0.1	-0.8	0.7	-0.2	-0.5	-0.2	0.5
	Carioca	-0.3	-0.5	0.3	0.6	-0.1	0.2	0.3	-0.5
	Pérola	0.2	-0.1	0.3	-0.5	0.0	-0.5	-0.1	0.7
	Talismã	-0.1	0.3	0.2	-0.5	0.0	-0.2	0.2	0.0
	OPNS 331	-0.1	0.0	-0.4	0.2	-0.3	0.1	0.1	0.4

in non-self-competition. However, if a multiline involves a blend of non-isogenic lines that contain different alleles of pathogen resistance, aiming not only at durable resistance but greater grain yield stability as well (Becker and Léon 1988, Bruzi et al. 2006), the lines to be blended must associate high a_j, c_i and t_j, which is not easily obtained. An alternative would be to evaluate the performance of line blends, rather than only the combination of two lines, as some authors have reported (Federer et al. 1982, Helland and Holland 2001).

Estimação de Parâmetros de Competição entre Plantas do Feijoeiro

RESUMO - *O trabalho objetivou estimar parâmetros relacionados à capacidade de exercer ou tolerar a competição. Os experimentos foram conduzidos em três safras, utilizando oito linhagens de feijão, com grãos tipo carioca, de diferentes origens. A competição foi avaliada em nível de planta, sendo obtido o número de vagens, o número de grãos e o peso dos grãos (g/planta). Com os dados médios, utilizando modelo semelhante ao dos cruzamentos dialélicos, foram estimados os parâmetros associados à competição: capacidade geral de exercer competição (c_i), capacidade de tolerar a competição (t_j),*

capacidade específica de competição (s_{ij}) e o desempenho per se da linhagem (a_j). A performance média das linhagens em autocompetição foi semelhante à alocompetição. Nenhuma linhagem associou baixa capacidade de exercer competição e alta capacidade de tolerar a competição. A linhagem OPNS 331 apresentou a maior estimativa de a_j e c_i.

Palavras-chave: autocompetição, alocompetição e feijoeiro.

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