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Early selection of agronomic traits in segregation black bean populations

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ABSTRACT - *This study evaluated the agronomic performance of six segregating populations of black bean (BRS Supremo x CHP 97-01, BRS Supremo x CHP 97-04, BRS Supremo x CHP 97-05-16, BRS Supremo x CHP 97-26, BRS Supremo x IPR Graúna and BRS Supremo x Uirapuru IPR) in the F_3 generation, conducted by the bulk method. Populations and parents were evaluated in the 2007/08 growing season in a randomized block design with four replications. Results show promising traits of the segregating population BRS Supremo x CHP 97-04, which was superior to parent BRS Supremo, indicating the line for further selection. The segregating populations and their parents were grouped by Ward's method, indicating the similarity of the selected lines.*

Key words: *Phaseolus vulgaris* L., F_3 generation, contrast, cluster analysis.

INTRODUCTION

A major challenge in common bean (*Phaseolus vulgaris* L.) breeding is the development of high-yielding cultivars, adapted to various climatic conditions, with desirable technological characteristics for farmers and consumers. The cultivars available on the market are uniform, especially in terms of adaptive traits and agronomic importance (Rocha et al. 2009), which can hamper the selection. The narrowing of the genetic base of cultivars of common bean drastically reduces the possibility of obtaining different genetic constitutions in segregating generations (Coimbra et al. 2004).

Bean yields have generally been low, far below the genetic potential of the crop. According to Beebe et al. (2008), this legume is the main protein source in the human diet of low-income populations, above all in Latin America and some African countries, and is mainly grown by small farmers under unfavorable conditions with minimal inputs.

In this sense, genetic improvement of common bean is essential to meet the demands for higher productivity. Based on the genetic variability available, the best parents can be chosen which will produce promising segregating populations with genotypes that exceed the current yield levels, even under unfavorable conditions. For improved cultivars a number of favorable attributes must be united that raise the productivity and meet the market requirements.

However, the development of superior genotypes is limited, since the performance of the characters of importance, mostly quantitative, is complex, due to environmental influence and interactions. The selection

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based on one or few traits may therefore be inadequate, resulting in a final product which is superior in terms of the selected traits only (Cruz and Regazzi 1997).

Plant breeding is based on combining variability in controlled crossings followed by cycles of selfing and the selection of autogamous plants normally carried out in segregating populations. However, prior knowledge of the behavior of populations can increase the efficiency of breeding programs, avoiding the formation of little promising populations or indicating their elimination in the early stages of the process of increasing inbreeding. Thus, efforts should be focused on evaluating the most promising segregating populations, ie, those with high mean productivity and greater variability (Barroso and Hofmann 2003, Mendonça et al. 2002).

The objective of this study was to evaluate the agronomic performance of six segregating black bean populations in the F_3 generation.

MATERIAL AND METHODS

Six segregating populations were evaluated (population 1 - BRS Supremo x CHP 97-01, population 2 - BRS Supremo x CHP 97-04, population 3 - BRS Supremo x CHP 97-05-16, population 4 - BRS Supremo x CHP 97-26, population 5 - BRS Supremo x IPR Graúna and population 6 - BRS Supremo x IPR Uirapuru) in the F_3 generation, by the bulk method, along with seven parents. BRS Supremo, IPR Graúna and IPR Uirapuru are commercial cultivars and CHP 97-01, CHP 97-04, CHP 97-05-16, and CHP 97-26 are lines derived from the common bean breeding program Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (SC) - Centro de Pesquisa para Agricultura Familiar (Epagri/Cepaf). The experiment was conducted in Chapecó-SC, in the experimental area of Epagri/Cepaf in the late growing season of 2007/08.

The experiment was evaluated in a randomized block design with 13 treatments (7 parents and 6 segregating F_3 populations), with four replications. The plots consisted of four 4 m-long rows, spaced 0.45 m apart. The two center rows of the plot were used for the evaluations (area of 3.6 m^2). Fertilization was based on soil analysis. Cultural treatments were performed according to technical recommendations for common bean in Santa Catarina (Epagri 1997).

After harvest, the following traits were evaluated: plant height (PH) in cm, insertion height of the first pod (IFP) in cm, number of pods per plant (NPP), number of grains per plant (NGP) 500-grain weight (5GW) in gram, and grain yield (YLD) in kg ha^{-1}, according to the guidelines of IPGRI (2001).

Statistical evaluations were based on univariate and multivariate analysis. The univariate analysis consisted of analysis of variance by the F test for all traits, at 5% probability. The following statistical model was applied:

$$y_{ij} = \mu + t_i + b_j + e_{ij}$$

where: y_{ij} is the observed value of the level i in block j, μ the overall mean; t_i the effect of treatment i; b_j the effect of block j; eij the experimental error associated with y_{ij} and both are considered independent and identically distributed. The following hypotheses were tested: H_0: t = 0 and H_A: t ≠ 0.

To complement the overall analysis of variance, contrasts were used between the F_3 populations and their parents, defined as:

$$C = c_1\mu_1 + c_2\mu_2 + ... c_t\mu_t$$

and evaluated as follows: H_0: c = 0, H_A: c ≠ 0, where c is a linear combination of the expected means of treatments $\mu_1, \mu_2, ... \mu_t$, and $c_1 + c_2 + ... + c_t$ are constant scales where $c_1 + c_2 + ... + c_t = 0$.

The contrasts were previously determined for the F_3 populations and their respective parents in the cross, making up a total of 18 contrasts, evaluated by the F test at 5% probability. The contrasts were performed for all segregating F_3 populations, the first contrast originally formed by combinations of the mean of two parents and the other by the mean of each contrasted parent with the mean of the said segregating F_3 population, as follows: C_1: BRS Supremo *vs*. CHP 97-01; C_2: BRS Supremo *vs*. BRS Supremo x CHP 97-01; C_3: CHP 97-01 *vs*. BRS Supremo x CHP 97-01; C_4: BRS Supremo *vs*. CHP 97-04; C_5: BRS Supremo *vs*. BRS Supremo x CHP 97-04; C_6: CHP 97-04 *vs*. BRS Supremo x CHP 97-04; C_7: BRS Supremo *vs*. CHP 97-05-16; C_8: BRS Supremo *vs*. BRS Supremo x CHP 97-05-16; C_9: CHP 97-05-16 *vs*. BRS Supremo x CHP 97-05-16; C_{10}: BRS Supremo *vs*. CHP 97-26; C_{11}: BRS Supremo *vs*. BRS Supremo x CHP 97-26; C_{12}: CHP 97-26 *vs*. BRS Supremo x CHP 97-26; C_{13}: BRS Supremo *vs*. IPR Graúna; C_{14}: BRS Supremo *vs*. BRS Supremo x IPR Graúna; C_{15}: IPR Graúna *vs*. BRS Supremo x IPR Graúna; C_{16}: BRS Supremo *vs*. IPR Uirapuru; C_{17}: BRS Supremo *vs*. BRS Supremo x IPR Uirapuru; C_{18}: IPR Uirapuru *vs*. BRS Supremo x IPR Uirapuru.

Multivariate analysis for genotype grouping was performed by Ward's method (1963), using the Euclidean distance as dissimilarity measure, considering all traits. The data were estimated using the statistical package SAS 9.1.3 (SAS Institute Inc. 2007).

RESULTS AND DISCUSSION

The results revealed significant differences between treatments for plant height, number of grains per plant and 500-grain weight (Table 1). The mean squares corresponding to the previously established contrasts between parents and F_3 segregating populations for the traits number of pods per plant and grain yield showed significance in some contrasts, not detected by the global analysis of variance (Table 2). If only one of the comparisons involves a marked difference, the F test may fail to show the difference. For this reason, objective comparisons should be planned, by partitioning the degrees of freedom of treatments for more specific information related to the mean behavior of each component of the deployment (Nesi and Garcia 2005). One analysis technique is based on the use of contrasts, for cases where the researcher is interested in testing specific effects of the experiment, by planned comparisons (Corrente et al. 2001). Still, the proper procedure to discriminate the variation between the contrasts of interest must be conducted according to the experimental purpose and the type of factor under study (Bertoldo et al. 2008).

Therefore, the selection of segregating plants carrying traits that favor higher crop yields and facilitate the cultural practices and mechanized harvest operations is essential for the acceptance of the new cultivar by farmers. For a breeding program, it is important to assess the traits related to the harvesting practices, such as stem diameter, plant height and insertion height of the first pod (Shimada et al. 2000), aside from the grain quality. Results indicated wide variability among genotypes for the traits under study, ie, they performed differently (Table 2). However, selection should target superior genotypes in relation to the most important traits. In this sense, it is worth mentioning contrast C_5 (Table 2) involving BRS Supremo *vs*. BRS Supremo x CHP 97-04, with the segregating population BRS Supremo x CHP 97-04 with increased plant height, number of pods per plant, number of grains per plant and 500-grain weight, which is a promising population for higher yields.

The trait insertion height of the first pod is highly important for common bean, since a greater insertion height makes mechanical harvest possible. Results showed a great uniformity of the cultivars, with no significant differences between genotypes (Tables 1 and 2). According to Coimbra et al. (2004), the common bean varieties available on the market are uniform, mainly in terms of adaptive and agronomically important traits, eg: insertion height of the first pod, cycle, stem diameter and plant height. Breeding programs have been focused on the search for high-yielding genotypes. In this process less attention is paid to some other traits, as in the case of the insertion height of the first pod, resulting in genotypes with low variability among each other.

Aside from the trait grain yield, common bean breeding programs have focused on other characters, such as plant height. Accordingly, the segregating population BRS Supremo x CHP 97-04 with 62.15 cm was 18 cm taller than the parent BRS Supremo, with a height of 44.02 cm (Table 3). This is a very important trait for common bean, since a positive correlation between height and yield was found by Lins and Alves (2002) for mung bean lines. Results indicate that shorter plants can produce fewer flowers per plant and consequently, fewer pods and seeds per plant, leading to reduced yields. Similarly, in the contrasts C_2 and C_{14} (C_2: BRS Supremo *vs*. BRS Supremo x CHP 97-01 and C_{14}: BRS Supremo *vs*. BRS Supremo x IPR Graúna) the trait plant height was also increased, and the mean of the

Table 1. Summary of analysis of variance of plant height (PH), insertion height of the first pod (IFP), number of the pods per plant (NPP), number of grains per plant (NGP), 500-grain weight 5GW) and yield (YLD) of in parents and segregating F_3 black bean populations

Source of variation	df	MS					
		pH (cm)	IFP (cm)	NPP	NGP	5GW (g)	YLD ($kg.ha^{-1}$)
Block	3	6.59	7.98	3.47	55.16	26.68	63,367.74
Genotype	12	99.08*	2.25	9.02	241.88*	86.01*	62,509.40
Error	36	45.39	3.23	6.18	108.37	12.96	61,725.08
Total	51						

* Significant at 5% probability by the F test.

Table 2. Univariate analysis for plant height (PH), insertion height of the first pod (IFP), number of pods per plant (NPP), number of grains per plant (NGP), 500-grain weight (5GW) and grain yield (YLD), evaluated in the contrasts between parents and F_3 segregating black bean populations

Contrast	Mean Square					
	pH (cm)	IFP (cm)	NPP	NGP	5GW (g)	YLD (kg.ha^{-1})
C_1: BRS Supremo *vs*. CHP 97-01	180.50	0.06	2.87	112.35	21.12	244748.07
C_2: BRS Supremo *vs*. P_1	187.21*	1.67	0.18	36.76	91.12*	69754.86
C_3: CHP 97-01 *vs*. P_1	0.06	1.11	1.60	20.58	24.50	53180.39
C_4: BRS Supremo *vs*. CHP 97-04	244.20*	0.06	15.12	396.77	120.12*	29376.46
C_5: BRS Supremo *vs*. P_2	657.03*	0.05	34.49*	1258.76*	60.50*	250837.36
C_6: CHP 97-04 *vs*.P_2	100.11	0.22	3.93	242.11	10.12	108531.40
C_7: BRS Supremo *vs*. CHP 97-05-16	129.60	0.45	11.00	174.66	153.12*	88582.61
C_8: BRS Supremo *vs*. P_3	112.50	0.00	0.03	6.30	91.12*	6475.22
C_9: CHP 97-05-16 *vs*. P_3	0.60	0.44	12.15	247.31	8.00	47158.28
C_{10}: BRS Supremo *vs*. CHP 97-26	42.04	0.08	10.15	141.37	242.00*	307900.59*
C_{11}: BRS Supremo *vs*. P_4	29.26	0.00	3.11	33.50	12.50	168670.13
C_{12}: CHP 97-26 *vs*. P_4	1.15	0.08	2.02	37.24	144.50*	20790.68
C_{13}: BRS Supremo *vs*. IPR Graúna	571.22*	0.15	34.70*	909.30*	253.12*	227788.87
C_{14}: BRS Supremo *vs*. P_5	250.88*	6.05	12.78	240.35	55.12*	80426.57
C_{15}: IPR Graúna *vs*. P_5	64.98	4.31	5.36	214.66	72.00*	37510.60
C_{16}: BRS Supremo *vs*. IPR Uirapuru	177.66	5.51	0.36	100.46	666.12*	263951.98*
C_{17}: BRS Supremo *vs*. P_6	63.28	0.45	0.08	17.49	190.12*	78665.61
C_{18}: IPR Uirapuru *vs*. P_6	28.88	9.12	0.10	34.11	144.50*	54423.60

* Significant at 5% probability by the F test.

Table 3. Mean and standard deviation (SD) characteristics of plant height (PH) in cm, insertion height of the first pod (IFP) in cm, number of pods per plant (NPP), number of grains per plant (NGP) 500-grain weight (5GW) in g, and grain yield (YLD), in kg ha^{-1}, as assessed in parents and segregating F_3 black bean populations

Genotype	pH		IFP		NPP		NGP		5GW		YLD	
	Means	SD	Means	SD	Means	SD	Means	SD	Means	SD	Means	SD
BRS Supremo	44.02	3.99	14.46	3.37	6.37	1.74	22.09	6.50	90.50	3.51	582.83	160.03
CHP 97-01	53.52	8.36	14.29	2.03	7.57	1.23	29.58	4.93	93.75	3.30	932.65	60.43
CHP 97-04	55.07	10.05	14.29	1.97	9.12	2.63	36.17	12.42	98.25	3.60	704.02	325.93
CHP 97-05-16	52.07	6.72	13.99	1.43	8.72	2.47	31.43	10.65	99.25	2.06	793.28	133.19
CHP 97-26	48.60	7.64	14.27	1.20	8.62	3.41	30.49	13.57	101.50	3.41	975.19	172.52
IPR Graúna	60.92	5.64	14.19	1.70	10.54	2.81	43.41	11.26	101.75	3.60	920.31	257.17
IPR Uirapuru	53.45	5.72	16.12	0.97	6.79	1.72	29.17	10.46	108.75	2.99	946.11	131.61
BRS Supremo x CHP 97-01	53.70	4.92	13.55	1.63	6.67	1.32	26.37	5.55	97.25	3.30	769.58	249.38
BRS Supremo x CHP 97-04	62.15	10.19	14.62	2.17	10.52	3.60	47.17	17.47	96.00	4.70	936.97	321.73
BRS Supremo x CHP 97-05-16	51.52	5.75	14.46	2.16	6.25	1.08	20.31	4.52	97.25	6.02	639.73	68.19
BRS Supremo x CHP 97-26	47.85	2.92	14.47	2.67	7.62	2.41	26.18	8.12	93.00	2.94	873.23	425.25
BRS Supremo x IPR Graúna	55.22	2.85	12.62	0.62	8.90	3.21	33.05	10.04	95.75	5.12	783.36	358.89
BRS Supremo x IPR Uirapuru	49.65	4.31	13.99	0.72	6.57	2.38	25.04	8.82	100.25	2.06	781.15	240.04

two segregating populations was also higher than of the parent BRS Supremo (Table 2), ie, these are populations with potential of selection for taller plants.

According to Fischer et al. (1932), mean segregating population above or below the mean of any of the parents involved in crosses are the result of the effect of non-additive gene action on the trait. In this sense, the yield trait components in the population of cross BRS Supremo x CHP 97-04 compared to the parent BRS Supremo (contrast C_5) number of pods per plant, number of grains per plant and 500-grain weight were higher. The segregating population performed better than parent BRS Supremo, with means of 10.52 and 6.37 cm, respectively, for number of pods per plant, 47.17 and 22.09 for number of grains per plant and 96.00 and 90.50 gr for 500-grain weight (Table 3). These increases in yield-related traits showed that the segregating population BRS Supremo x CHP 97-04 is promising. The selection of genotypes to increase primary grain yield components may represent an effective strategy to optimize genetic gain since the phenotypic and environmental correlations of traits such as number of pods per plant with grain yield are strong (Coelho et al. 2002).

For the trait 500-grain weight the contrasts $C_{2,}$ C_5, C_8, C_{14} and C_{17} (C_2: BRS Supremo *vs*. BRS Supremo x CHP 97-01; C_5: BRS Supremo *vs*. BRS Supremo x CHP 97-04; C_8: BRS Supremo *vs*. BRS Supremo x CHP 97-05-16; C_{14}: BRS Supremo *vs*. BRS Supremo x IPR Graúna and C_{17}: BRS Supremo *vs*. BRS Supremo x IPR Uirapuru) also performed well, exceeding the parent mean of BRS Supremo, indicating a good yield potential of the populations and suitability for programs breeding for larger grains. These results corroborate reports of Coimbra et al. (1999), since these authors found that the direct effect of the traits number of pods per plant and grain weight on common bean grain yield was strongest.

By the Euclidean distances between the genotypes (Figure 1), it was possible to classify the genotypes into three groups from the combined variability of the response variables. The first group comprised BRS Supremo and IPR Uirapuru and the populations BRS Supremo x CHP 97-26, BRS Supremo x CHP 97-01, BRS Supremo x CHP 97-05-16, and BRS Supremo x IPR Uirapuru. The results show the similarity of four of the populations of a cross with the same parent (BRS Supremo), and the low genetic basis among common bean cultivars, since even BRS Supremo and IPR Uirapuru are also included in this group.

The second group consists of the genotypes CHP 97-01, 97-05-16 CHP, CHP 97-26, CHP 97-04 and the population BRS Supremo x IPR Graúna. The first four genotypes are lines obtained in crosses in the framework of the breeding program of Epagri. Clustering these lines in the same group shows the similarity between them, mainly due to the narrow genetic base of the parents used in breeding programs, resulting in genotypes with low variability for important traits in common bean. Consequently, once a certain balance is achieved in the improved population, additional yield gains become more difficult and generally the cultivars adapted to or selected for a given production area are genetically similar (Naoe et al. 2001). By molecular markers it was possible to verify that the domestication process has sharply reduced the genetic diversity of common bean descendents (Sonnante et al. 1994). The morphological traits of the crop, which are very similar in commercial genotypes, express this reduction in variability.

The last group (group 3) consisted of one genotype, cultivar IPR Graúna and the population BRS Supremo x CHP 97-04, with similar morphological characteristics (Table 3).

The results indicate that: i) segregating population BRS Supremo x CHP 97-04 may be promising for the traits

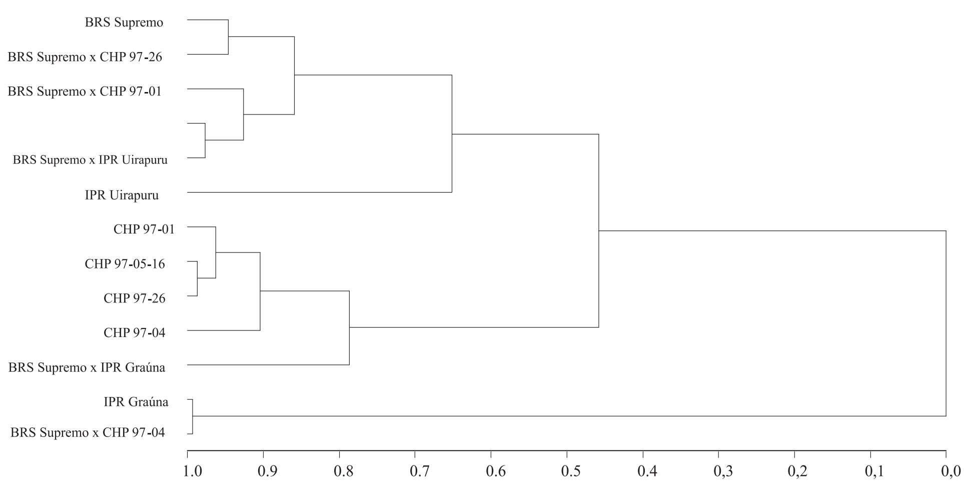

Figure 1. Dissimilarity dendrogram of the seven parents and six segregating F_3 black bean populations, for plant height, insertion height of the first pod, number of pods per plant, number of grains per plant, 500-grain weight and yield, grouped by Ward's hierarchical method, based on the Euclidean distance.

plant height, number of pods per plant, number of grains per plant and 500-grain weight, and performs better than parent BRS Supremo; it should therefore be maintained for further selection, ii) the contrasts were effective for a comparison of the performance of segregating populations with the parents; iii) the information of the dendrogram was relevant and effective in determining differences between segregating populations and their parents. The data indicated their genetic similarity with the genotypes selected for breeding programs for a particular producing region.

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Seleção precoce para caracteres agronômicos em populações segregantes de feijão preto

RESUMO - *Este trabalho teve como objetivo avaliar o comportamento agronômico de seis populações segregantes de feijão do grupo comercial preto (BRS Supremo x CHP 97-01, BRS Supremo x CHP 97-04, BRS Supremo x CHP 97-05-16, BRS Supremo x CHP 97-26, BRS Supremo x IPR Graúna e BRS Supremo x IPR Uirapuru), na geração F_3, conduzidas em bulk. As populações e os genitores foram avaliados no ano agrícola de 2007/08 (safrinha), utilizando-se o delineamento de blocos ao acaso, com quatro repetições. Os resultados revelam que a população segregante BRS Supremo x CHP 97-04 foi promissora para os caracteres avaliados, sendo superior em relação ao genitor BRS Supremo, justificando a continuidade da seleção. O método de Ward permitiu o agrupamento das populações segregantes e seus genitores, sendo possível verificar a similaridade entre os genótipos selecionados.*

Palavras-chave: *Phaseolus vulgaris* L., geração F_3, contrastes, análise de agrupamento.

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