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CHOICE OF PARENTS FOR DRY BEAN (*Phaseolus vulgaris* L.) BREEDING. I. INTERACTION OF MEAN COMPONENTS BY GENERATION AND BY LOCATION

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ABSTRACT

Four dry bean cultivars (*Phaseolus vulgaris* L.) adapted to the southern region of the state of Minas Gerais, Brazil, were crossed with five exotic cultivars according to a partial diallel design. The nine parents and twenty hybrid populations were tested in six experiments in fully randomized blocks. In one of the experiments, the segregating populations were in the F_2 generation, in three of them they were in the F_3 generation, and in the other two in the F_4 generation. Trials were held at two locations in the state of Minas Gerais and at one location in the state of Goiás in 1986. All twenty nine genetic materials showed heterogeneity concerning grain yield in all trials, with cultivars having a greater effect (additive gene effect) than heterosis (dominance effect), especially in the more advanced generations. No interactions between cultivar x generation effects and cultivar heterosis x generation effects were observed at any location. However, cultivar and cultivar heterosis x location interactions were significant, suggesting that the choice of segregating populations for genetic improvement of common beans should be based on the performance of the populations at the locations where they will be used, but disregarding generation. In this way, because of larger quantities of seed, the material can be evaluated in the F_4 generation. Despite components of means x location interactions, the population ESAL 501 x A 354 was the most promising for selection based on grain yield because of the general combining ability of its parents and of grain quality.

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INTRODUCTION

The main problem faced by breeders in most programs of autogamous plant improvement involving hybridization is the choice of parents. The procedure most often employed to select parents is based on cultivar traits such as resistance to pathogens, good plant architecture and type of grains. This procedure, however, can only be used to solve specific problems. Since for most quantitative traits, additive gene action predominates, the mean performance of a cultivar in test trials is a criterion often used to choose parents.

Diallel crosses have also been widely utilized as an additional option to provide an indication of the potential of parents involved in hybrid combinations and to permit inferences on genetic control and on the possibility of successful selection (Whitehouse *et al.*, 1958; Santos *et al.*, 1985). In these crosses, populations are tested in F_1 or F_2 and normally only at one location. Considering the occurrence of population x location interaction (Rosielle, 1983), hybrids need to be evaluated at additional locations and, if possible, over several more generations so as to obtain estimates of genetic components free from interaction and also to permit a more judicious choice of the segregant population. In the present paper we show the results of trials carried out on several segregant dry bean populations obtained from a diallel cross over several generations and at different locations.

MATERIAL AND METHODS

Crosses were performed at the Department of Biology, "Escola Superior de Agricultura de Lavras" using a partial diallel design. Two groups of cultivars were used, for a total of nine parental lines. Group 1 consisted of Pintado, ESAL 501, and Rio Vermelho, which represent cultivars raised in the area, and group 2 consisted of Linea 29, A 354, A 242, Milionário, and BAT 160, which are introduced cultivars with desirable traits that are not found in the material used in the region. Thus, we tested 20 hybrid populations and the nine parental lines over the locations and generations shown in Table I.

A randomized block design was used in all cases. Plots consisted of two 5-m long rows except for the F_2 generation, which consisted of a single 5-m long row. Fifteen seeds per meter were sown in all cases, with 0.5-m spacing between rows. Standard culture methods were used in all cases.

Grain yield was first evaluated by analysis of variance per trial and later by joint analysis among generations at the same location and among locations in the same generation. Mean genetic components were estimated by the method of Miranda Filho and Geraldi (1984). Mean components relative to interaction by location and by generation were estimated by the method of Oliveira *et al.* (1987).

Table I - Trial locations and generations.

Location	Planting time	Generation	No. of Replications
Patos de Minas (MG)	Feb./86	F_2	2
Patos de Minas (MG)	Feb./86	F_3	4
Ribeirão Vermelho (MG)	July/86	F_3	4
Ribeirão Vermelho (MG)	July/86	F_4	4
Jussara (GO)	July/86	F_3	3
Jussara (GO)	July/86	F_4	4

RESULTS AND DISCUSSION

Wide variation was detected among environments (times and locations) and among populations (Table II). Mean yield performance of cultivars and segregant populations in the six trials ranged from 1083.3 kg/ha (Rio Vermelho x BAT 160) to 1548.6 kg/ha (Milionario), i.e. an amplitude of variation of 465 kg/ha, corresponding to 34% of the overall mean (1362.4 kg/ha).

Individual analyses of variance according to the diallel model used are summarized in Table III. The coefficients of variation obtained indicate that the experimental precision may be considered good when compared with previous experimental data obtained for dry bean cultures (Vieira, 1970; Santos *et al.*, 1979). In general, the significances of the mean squares of the different sources of variation did not agree, showing that the materials did not behave in a consistent manner.

The results of joint analysis, which was performed to determine generation effect at the same location, are presented in Table IV. It can be seen that significant differences between generations were obtained only for Patos de Minas, where mean F_3 yields were lower than F_2 yields (Table II). Considering that trials were contiguous at each location, this difference was probably due to greater heterosis occurring in F_2, which has a larger proportion of heterozygous loci.

The most striking result in Table IV is the lack of significance of the sources of variation which measure generation x cultivar and generation x cultivar heterosis interactions for both groups. Since these sources of variation are directly related to the general combining abilities of the cultivars (Gardner and Eberhart, 1966), this shows that general combining ability did not interact with the generations utilized.

When a population is treated by the bulk method, the factors that may alter the genetic composition of the population are sampling effect, segregation and competition effect (Empig and Fehr, 1971). All indications are that these factors did not affect the general combining ability of the materials, as demonstrated by the lack of

Table II - Mean grain yield (kg/ha) of group 1 and group 2 cultivars and of their hybrids tested at three different locations.

Populations and experiments	Generation - location/year						
	F_2 Patos/ 86	F_3 Patos/ 86	F_3 R. Verm./ 86	F_4 R. Verm./ 86	F_3 Jussara/ 86	F_4 Jussara/ 86	Mean
Group 1							
Pintado	1140.0	1118.0	2068.5	1763.5	1573.0	1387.0	1508.3
ESAL 501	690.0	731.5	1615.0	1963.5	1783.0	1618.5	1400.2
ESAL 1	880.0	695.5	1536.5	1982.0	1612.0	1579.2	1380.9
R. Vermelho	670.0	626.0	1162.0	1383.5	1851.0	1398.0	1181.8
Group 2							
Linea 29	700.0	578.0	1210.0	1522.0	1634.0	1646.5	1251.1
A 354	840.0	790.8	2039.5	1453.5	1568.0	1560.0	1375.3
A 242	770.0	715.2	1339.0	1404.0	1378.0	1155.5	1127.0
Milionário	810.0	701.0	1651.5	2190.5	2159.0	1779.5	1548.6
BAT 160	920.0	766.0	1770.0	2140.5	1683.0	1680.5	1493.3
Pintado x linea 29	700.0	612.8	1804.5	1165.5	1093.0	1250.0	1465.7
Pintado x A 354	880.0	617.0	1307.5	1571.0	1065.0	1177.0	1517.8
Pintado x A 242	1000.0	690.2	1618.5	1624.5	986.0	981.5	1403.0
Pintado x Milionário	670.0	671.5	1430.0	1844.0	1164.0	1332.5	1510.9
Pintado x BAT	610.0	611.8	1596.5	1586.0	830.0	1265.5	1528.7
ESAL 501 x linea 29	1090.0	754.8	1447.5	1474.5	2111.0	1806.5	1491.3
ESAL 501 x A 354	1057.5	937.2	1827.2	1936.5	1676.0	1672.5	1521.9
ESAL 501 x A 242	550.0	887.8	1779.0	1751.5	1699.0	1751.0	1417.8
ESAL 501 x Milionário	1010.0	708.0	1886.5	1931.0	1653.0	1877.0	1234.0
ESAL 501 x BAT 160	1100.0	818.2	2007.0	1574.5	1785.0	1887.5	1310.3
ESAL 1 x linea 29	850.0	685.5	1767.5	1821.0	1521.0	2023.5	1444.8
ESAL 1 x A 354	1150.0	839.8	1990.0	1711.0	1563.0	1887.5	1523.6
ESAL 1 x A 242	1100.0	846.5	1697.5	1674.0	1419.0	1611.0	1391.3
ESAL 1 x Milionário	800.0	786.5	2020.0	1841.0	1686.0	1781.0	1486.2
ESAL 1 x BAT 160	850.0	709.5	1916.5	1546.0	1779.0	1637.5	1406.4
R. Vermelho x Linea 29	1050.0	737.5	1548.0	2193.0	1754.0	1665.5	1104.3
R. Vermelho x A 354	1060.0	952.2	1771.5	1880.0	1660.0	1806.5	1102.9
R. Vermelho x A 242	1010.0	913.8	1656.0	1704.0	1599.0	1624.0	1150.1
R. Vermelho x Milionário	840.0	665.8	1318.0	1443.5	1524.0	1613.0	1185.3
R. Vermelho x BAT 160	840.0	696.0	1403.5	1761.0	1621.0	1539.2	1083.3
Cultivar mean	824.4	746.9	1599.1	1755.9	1963.4	1533.8	
Hybrid mean	910.9	757.1	1695.2	1701.7	1509.6	1614.0	
Overall mean	884.0	753.9	1665.4	1718.5	1566.6	1586.0	1362.4

Table III - Summary of the analysis of variance of individual trials.

Source of variation	d.f.	Mean Squares (Generation-location/year) x 10^3					
		F_2 Patos/ 86^a	F_3 Patos/ 86	F_3 R.Verm./ 86	F_4 R.Verm./ 86	F_3 Jussara/ 86a	F_4 Jussara/ 86
Populations	(28)	29.46**	14.89**	65.94**	63.65	91.67**	63.09**
Cultivars (Group 1)	3	3.54	2.97	139.93**	43.71	383.97**	283.20**
Cultivars (Group 2)	4	14.29	19.90**	72.16	78.00	62.33**	70.68**
Group	1	5.60	15.60*	0.16	1.13	0.15	7.16
Heterosis	(20)	37.55	15.64	56.89	66.91	58.27	31.35
Mean heterosis	1	43.81*	0.20	57.23	19.22	210.67**	38.84
Group 1 heterosis	3	87.08**	78.02**	151.78**	85.02	184.03**	124.62**
Group 2 heterosis	4	18.65*	7.45	42.91	91.55	41.02*	10.63
Specific heterosis	12	30.95**	4.06	37.80	58.14	19.88	14.32
Residue	84	5.85	3.24	31.18	50.76	14.73	17.70
C.V. (%)		12.20	15.10	21.20	26.20	13.40	16.80

[a] 28 d.f. for the mean residue for F_2 Patos/86 and 56 d.f. for the mean residue for F_3 Jussara/86, respectively due to the use of two and three replications in the trials.

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

significant interaction between generations and variables related to general combining ability (Table IV).

In programs of dry bean breeding, the objective is selection of pure lines. Thus, general combining ability is the most important estimate for the choice of parental lines. The present data then show that any generation can be used to estimate general combining ability, a fact that gives more flexibility to breeders for evaluation of their material under a larger number of conditions by using a larger number of generations. The advantage of this result is that in the F_2 generation the number of seeds available may be a limiting factor for more extensive trials. Hamblin and Evans (1976) have also emphasized the need to test segregant populations over a few generations to identify the most promising ones, rather than simply utilizing the F_2 generation.

In Patos de Minas, generations x mean heterosis and generations x specific heterosis interactions were significant. Generations x mean heterosis interaction occurred because the hybrid mean in F_2 was superior to the mean of the cultivars and

Table IV - Joint analysis of variance of generations by location.

Sources of variation	d.f. - Mean square x 10^3					
	d.f.	Patos/86[a]	d.f.	R. Vermelho/86[b]	d.f.	Jussara/86[b]
Generations (G)	1	245.40**	1	41.05	1	5.41
Populations (P)	28	34.25**	28	77.18**	28	131.01**
Cultivars (G_1)	3	2.06	3	131.51*	3	634.42**
Cultivars (G_2)	4	29.85**	4	101.21*	4	126.16**
Groups	1	19.94*	1	1.06	1	4.68
Heterosis (H)	20	40.68**	20	68.04*	20	62.79**
Mean heterosis	1	24.93*	1	5.06	1	34.30
G_1 heterosis	3	163.86**	3	151.81*	3	302.28**
G_2 heterosis	4	22.58**	4	73.80	4	39.96*
Specific heterosis	12	17.23**	12	50.42	12	12.90
G x P	28	10.08**	28	52.42	28	23.75
G x G_1	3	4.43	3	52.18	3	32.81
G x G_2	4	4.34	4	48.97	4	6.82
G x Groups	1	1.25	1	0.22	1	2.62
G x H	20	12.52**	20	55.76	20	26.84*
G x mean heterosis	1	19.07*	1	71.39	1	215.22**
G x G_1 H	3	1.24	3	84.99	3	6.37
G x G_2 H	4	3.56	4	60.66	4	11.68
G x specific H	12	17.78**	12	45.51	12	21.30
Mean residue	112	4.55	168	40.97	140	16.21

[a] F_2 and F_3 generations.
[b] F_3 and F_4 generations.
*, **Significant at the 5% and 1% probability levels, respectively.

these means were similar in F_3 (Table II). The generations x specific heterosis interaction is explained in a similar manner: the hybrids differed owing to specific heterosis in F_2 only, as shown in Table III. In Jussara, generations x heterosis interaction occurred because the cultivar mean was superior to the hybrid mean in F_3, a fact that did not occur in F_4 (Tables II and III).

Materials of the same generation are usually tested over various locations in order to select lines of wider adaptability. Thus, joint analyses among locations were performed for generations F_3 and F_4. As mentioned earlier, the general combining ability of cultivars is the most important estimate, and in this diallel model the sources of variations related to this estimate are cultivar effect and cultivar heterosis. As can be seen in Table V, these sources of variation interacted with location in contrast to what was observed for generation effect. This fact is confirmed by the general combining ability ($\hat{g}_i$) estimates shown in Table VI, which, with few exceptions, were not consistent over locations, indicating once again the need to test the materials at several locations.

Table V - Joint analysis of variance of locations by generations.

Sources of variation	d.f.	Mean square x 10^3 F_3 Patcs/R. Verm./Jussara	d.f.	Mean square x 10^3
Locations (L)	2	3540.85**	1	29.35
Populations	28	69.81**	28	60.40*
Cultivars (G_1)	3	219.40**	3	74.69
Cultivars (G_2)	4	46.72*	4	117.25*
Groups	1	5.23	1	1.30
Heterosis (H)	20	55.22**	20	49.84
Mean heterosis	1	14.11	1	1.71
G_1 heterosis	3	169.44**	3	140.70**
G_2 heterosis	4	52.39*	4	79.65
Specific heterosis	12	31.03*	12	21.20
L x P	56	183.97**	28	74.38**
L x G_1	6	705.65**	3	101.94*
L x G_2	8	29.38	4	121.25**
L x Groups	2	15.12	1	1.73
L x H	40	145.08**	20	64.54*
L x mean heterosis	2	489.24**	1	474.71**
L x G_1 heterosis	6	684.05**	3	156.65**
L x G_2 heterosis	8	38.29*	4	14.01
L x specific heterosis	24	17.26	12	24.17
Mean residue	224	16.59	168	34.23

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

The estimates shown in Table VI indicate that, among group 1 cultivars, ESAL 501 showed the highest general combining ability, followed by ESAL 1, and A 354 showed the highest general combining ability in group 2. It should be pointed out that cultivar Pintado, belonging to group 1, showed the lowest combining ability, even

Table VI - Estimates of general combining ability ($\hat{g}_i$), cultivar ($\hat{c}_i$) effect and cultivar heterosis ($\hat{h}_i$) per location, independent of generation, in terms of grain yield (kg/ha).

Cultivars	Patos			Rib. Vermelho			Jussara		
Group 1	$\hat{g}_i$	$\hat{c}_i$	$\hat{h}_i$	$\hat{g}_i$	$\hat{c}_i$	$\hat{h}_i$	$\hat{g}_i$	$\hat{c}_i$	$\hat{h}_i$
Pintado	-127.67	310.12	-282.73	-143.66	231.69	-259.50	-445.07	-120.21	-384.96
ESAL 501	57.35	-108.12	111.42	74.06	104.94	21.60	232.33	100.54	182.06
ESAL 1	27.78	-31.12	43.34	99.99	74.94	62.53	131.63	-4.61	133.94
Rio Vermelho	42.53	-170.88	127.97	-30.40	-411.56	175.38	81.10	24.29	68.96
Deviation	26.12	41.29	27.70	78.39	123.95	83.15	49.32	77.98	52.31
Group 2	$\hat{g}_j$	$\hat{c}_j$	$\hat{h}_j$	$\hat{g}_j$	$\hat{c}_j$	$\hat{h}_j$	$\hat{g}_j$	$\hat{c}_j$	$\hat{h}_j$
Linea 29	-23.92	-120.10	36.13	32.02	-306.05	121.01	93.54	15.85	85.62
A 354	102.71	56.30	74.56	-51.01	74.45	13.78	3.92	-60.40	34.12
A 242	40.79	-16.50	49.04	-10.33	-300.55	139.94	-100.70	-357.65	78.12
Milionário	-65.02	-3.60	-63.22	15.80	248.95	-108.68	19.67	344.85	-152.76
BAT 160	-54.56	83.90	-96.51	24.46	-263.20	-166.06	-16.43	57.35	-45.10
Deviation	30.16	42.65	30.16	90.52	128.02	90.52	56.95	80.53	56.95

though it showed the greatest cultivar effects in at least two locations owing to its good performance (Table II). The Milionario cultivar (group 2) also showed the highest mean (Table II), though it did not exhibit the highest general combining ability (Table VI). This indicates that mean performance is often insufficient to recommend a cultivar as a parental line in a crossing program. Hamblin and Evans (1976) and Quinones (1969) observed that at normal culture densities the parental mean was effective for the estimate of the yielding potential of a cross. Even though the observations by these authors seem to contradict what was stated above, it should be pointed out that they did not use diallel crosses and therefore did not estimate the general combining ability of their cultivars.

For low-heritability traits such as grain yield, selection is of low efficiency in beans and in other autogamous plants and must be postponed to more advanced generations (Briggs and Shebeski, 1970; Knott, 1972; Gregan and Bush, 1977). In view of this fact and considering that the bulk method is most often utilized for beans, advanced segregant populations should be tested at each generation and over the largest possible number of locations.

CONCLUSIONS

1. Grain yield proved to be mainly controlled by additive gene effects, indicating the importance of general combining ability as the criterion to be used in the choice of parental lines in breeding programs.

2. Mean components related to general combining ability showed significant interaction with locations and nonsignificant interaction with generations, showing that segregant populations should be tested in environments that are representative of the culture conditions but during any generation.

3. Cultivars ESAL 501 and A 354 showed the highest general combining ability estimates, and therefore the ESAL 501 x A 354 population is the most promising for selection, also considering that its type of grain is better accepted by consumers.

RESUMO

Quatro cultivares adaptadas à região Sul do Estado de Minas Gerais foram cruzadas com outras cinco cultivares introduzidas em um esquema dialélico parcial. Os nove parentais e as 20 populações híbridas foram avaliadas em seis experimentos, em blocos casualizados, sendo um com as populaçoes segregantes na geração F_2, três na geração F_3 e dois na geração F_4, em dois locais de Minas Gerais e um em Goiás, em 1986. Os 29 materiais mostraram-se heterogêneos quanto a produtividade de grãos em todas as avaliações, com uma participação maior do efeito de cultivares (efeito aditivo dos genes) do que o efeito de heterose (efeito de dominância), principalmente nas gerações mais avançadas. Em cada local não se observou interações dos efeitos de cultivares por gerações e de heterose de cultivares por gerações, no entanto, as interações de cultivares e de heterose de cultivares por locais foram significativas sugerindo que a escolha das populações segregantes para o melhoramento deva ser baseada no desempenho das populações nos locais em que elas serão utilizadas, porém, independente da geração. Desta forma, dada a necessidade de maior quantidade de sementes, as avaliações podem ser feitas até na geração F_4. Apesar das interações dos componentes de média por locais, a população ESAL 501 x A 354 foi a que se mostrou mais promissora para a seleção com base na produtividade de grãos, em função das capacidades gerais de combinação dos parentais e também do tipo de grãos que elas possuem.

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