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Genetic variability for dietary fiber content in common bean populations

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ABSTRACT - *Common bean with its diverse nutrients and fiber is one of the main foods in the staple diet of the Brazilian population. Objectives of this study were therefore the estimation of the general and specific combining abilities in common bean cultivars, to assess their potential of use to increase the dietary fiber content. The crossings were realized in the form of complete diallels and 12 hybrids from the possible combinations among four parents (CNFP 8100, FT 96-1282, Valente and Varre-Sai) were established. The parents and obtained populations were evaluated in the field in a randomized complete block design. The obtained results manifested the presence of genetic variability for dietary fiber content in the populations. The parent CNFP 8100 presented a larger estimate of the effects of the general combining ability. Common bean lines with a higher content of dietary fiber can be obtained through selection in the populations developed based on the crossing CNFP 8100 x FT 96-1282.*

Key words: *Phaseolus vulgaris* L., total dietary fiber, diallel analysis.

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is considered an essential food for human nutrition since it represents an important source of diverse nutrients (proteins, carbohydrates, vitamins and minerals) and fiber (Lajolo et al. 1996).

The fiber content can be determined by different methodologies. The most adequate method is the one that considers the dietary fiber and quantifies the different fiber fractions (soluble and insoluble) besides using enzymes, allowing a closer approximation to the human digestion process (Picolli and Ciocca 1999). Dietary fiber is classified according to the standard of solubility in soluble (pectic, gum, hemicellulose and β–glucane substances) and in insoluble (mostly hemicellulose, cellulose and lignin substances) (Guerra et al. 2004).

The fractions that compose dietary fibers exert a beneficial influence on health, and help to prevent diseases of the digestive system and the heart as well as colon and breast cancer, contributing further to a reduction in cholesterol and to the glycemic control (Olson et al. 1987,

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Moore et al. 1998, Guillon and Champ 2000).

A larger ingestion of fiber in the diet is recommendable and common bean is one of the few integral foods that contain a significant quantity of soluble and insoluble fiber (Lajolo et al. 1996). Considering that it is one of the principal aliments consumed by the Brazilian population, the social benefit of a product with a higher fiber content would be considerable. Besides, common bean is often the only fiber source used daily by low-income families.

The evaluation of the nutritional composition of grains of Brazilian genotypes is yet emerging. Studies on the quantification of the desirable levels of dietary fiber (soluble and insoluble) in grains and an evaluation of the genetic variability in different common bean cultivars were not found in literature. This points to the need for studies along this line, in view of the beneficial effects provided by the ingestion of fiber associated with the nutritional value of common bean (Lajolo et al. 1996).

Common bean grain is composed of tegument which represents about 9% of the dry matter, the cotyledons that make up 90% and the embryonic axis with only 1%. There are indications that fiber is most concentrated in the tegument. Since the tegument is maternal tissue - developed based on the egg wall, the genotype of the F_1 generation will represent the maternal genotype; in other words, the F_1 genotype will only be expressed in F_2 (Ramalho et al. 2000). Consequently, the F_1 generation would only represent the products of fertilization if the highest fiber concentration were found in the cotyledons. In this sense, the use of reciprocal crossings could solve the question since these tissues are from different generations (Paula et al. 2004).

The controlled hybridization techniques used in this crop are somewhat laborious and often little efficient (Peternelli and Borém 1999). In this situation, methodologies of diallel analysis which are based on the combining ability can help define parents with superior genetic variability for the establishment of segregant populations (Ramalho et al. 1993).

In this setting, the objectives of our study were to estimate the general and specific combining abilities of common bean cultivars of the commercial group black to obtain information on their potential usefulness in improvement programs that aim at an increase of the dietary fiber content.

MATERIAL AND METHODS

A previous experiment was conducted in the field in the crop year 2001/02 to quantify the grain fiber content in grains of the Banco de Germoplasma de Feijão da Universidade Federal de Santa Maria (UFSM), Rio Grande do Sul (RS). Based on the fiber content and the genotype performance in the field (yield, plant architecture and other important agromorphological descriptors) four parents were selected for the study of the combining ability (CNFP 8100, FT 96-1282, Valente and Varre-Sai).

The hybrid combinations were structured according to the methodology of complete diallels, with the use of the reciprocals, establishing 12 hybrids (Cruz and Regazzi 1997). The controlled hybridizations were realized in a greenhouse, using a technique without emasculation from February through May, and replicated in the months July through November 2003 (Peternelli and Borém 1999).

The blocks of crossings were conducted in plastic pots holding 5kg soil and two plants per pot. To warrant the normal development of the common bean plants irrigations were realized daily as well as disease and insect control and nitrogen fertilization whenever necessary. The pods of each population were harvested individually when the bean pods attained physiological maturity.

Considering that the genotype of the F_1 generation is expressed in the F_2 generation-maternal effect, F_1 seeds of the different obtained populations were sown out on the field in November 2003, together with the parents. The experiment was conducted on an area of the Departamento de Fitotecnia, of the UFSM-RS, in soil characterized as Alissolo Hipocrômico argilúvico típico. The experiment had a randomized complete block design with two replications in which each plot consisted of a 1m long row with 10 plants a meter.

The soil was prepared conventionally and fertilization applied in the plough furrow, according to an interpretation of the chemical soil analysis. Nitrogen fertilization was split in two nitrogen applications of 40kg ha^{-1} in the growth stages V3 and V4, first and third trifoliate leaves, respectively.

Crop treatments such as insect and weed control were realized whenever necessary, to prevent the crop from any competition. The harvest and screening of the plants were realized manually and after removing the impurities the grains were sun and oven-dried to a mean moisture of 12%.

The dietary fiber content was determined according to a methodology described by the AOAC (1995), which quantifies the total and insoluble fiber content analytically and quantifies the soluble fiber content in the sample by the difference. The evaluations were realized in the grains

of the F_2 seeds - genetic expression of the plants of the F_1 generation and of the four parents - obtained by selfing. The data were subjected to analysis of variance, considering the completely randomized design with two replications and set up in the laboratory, and an analysis of combining ability was realized according to method 1 of Griffing (1956), which considers the treatment effect fixed and estimates the general (GCA) and specific (SCA) combining ability.

RESULTS AND DISCUSSION

The obtained results evidenced significant differences for the dietary fiber content in common bean grains for the different sources of variation (Table 1). The existence of variability in the evaluated populations suggests that superior germplasm for this trait can be identified in more advanced generations of the improvement program**.**

The dietary fiber contents (DFC) in the grains of the different common bean populations varied from 33.39% (Valente) to 39.39% (CNFP 8100 x FT 96-1282) (Table 2). The use of the Scott-Knott test allowed the formation of four groups, and the following classification for dietary fiber was proposed: high DFC (over 37%), low DFC (below 35%) and intermediate DFC (values in-between the aforementioned classes). The populations that presented high DFC were CNFP 8100 x FT 96-1282, Valente x CNFP 8100 Varre-Sai x CNFP 8100, and Valente x Varre-Sai.

Table 1. Variance analysis for dietary fiber content in common bean grains with de composition of the cultivar effects in the general (GCA) and specific (SCA) combining abilities, resultant of the diallel crossings between four common bean cultivars, according to method 1 of Griffing (1956)

Sources of variation	df	Mean square
Cultivars	15	5.2502*
GCA	3	6.1600*
SCA	6	5.1933*
Reciprocal effect	6	4.8523*
Error	15	1.0000
Mean (%)	36.74	
CV%	6.08	

*Significant by the F test at a probability of 5%

After cooking for 40 min in a pressure cooker, the dietary fiber content in red common bean was 15.83% (Oliveira et al. 1999). In white common bean however, the method of Berlin (Becker et al. 1986) quantified 19.8% dietary fiber suggesting that genetic variability for dietary fiber content may be found in common bean grains from different commercial groups. A comparison of the data obtained in this study with those cited for red and white common bean is not possible though, because those studies used other methodologies for the determination of dietary fiber.

An interpretation of the results obtained in the diallel analysis involving the parents CNFP 8100, FT 96-1282, Valente and Varre-Sai verified the existence of a maternal effect for fiber in common bean. In the crossings (♀/♂) - CNFP 8100 x FT 96-1282, Valente x CNFP 8100, Varre-Sai x CNFP 8100, Valente x FT 96-1282, Varre-Sai x FT 96-1282 and Valente x Varre-Sai - it was possible to obtain populations with a higher dietary fiber content than the female parent (Table 2). However, in the reciprocal crossings, the populations obtained in each one of these combinations, presented the same genotype as the female parent throughout. This is possible because the maternal effect in the expression of a particular trait in the descendents may occur for one or two generations (Ramalho et al. 2000).

Knowledge on this type of inheritance is of great importance when deciding on which one of the parents will be used as female in a crossing, since the use of one or the other will lead to different F_1 or F_2 progenies. Besides, since the genotype of the F_1 generation is expressed in F_2, the F_2 genotype in the F_3 generation, and so on, the selection will only occur when one proceeds to the selection among the progenies of each F_2 seed, which corresponds to the F_3 generation (Ramalho et al. 2000).

Table 2. Mean values of dietary fiber (%) in common bean grains obtained from four parents, of their F_2s hybrids and the reciprocals

Cultivars (♀/♂)	1. CNFP 8100	2. FT 96-1282	3. Valente	4. Varre-Sai
1. CNFP 8100	37.44 c*	39.39 a	36.64 c	36.35 c
2. FT 96-1282	36.34 c	35.63 d	33.98 d	36.77 c
3. Valente	38.34 b	37.28 c	33.39 d	37.86 b
4. Varre-Sai	38.10 b	38.30 b	37.08 c	35.03 d

*Groups of means followed by the same letter did not differ by the criterion of Scott-Knott at a probability of 5%

CNFP 8100 presented the highest value of general combining ability ($\hat{g}_i$ = 0.7615) (Table 3). It can therefore be indicated for the use in programs of controlled hybridization, aiming at the increase of the dietary fiber content since the estimates of the effects of $\hat{g}_i$ provide information on the concentration of predominantly additive genes and are highly useful for the indication of parents in intrapopulational improvement programs (Cruz and Regazzi 1997). Thus, a crossing using CNFP 8100 as one of the parents should be potentially superior in the selection of lines, due to the higher $\hat{g}_i$ value (Ramalho et al. 1993).

The estimates of the effects of the specific combining ability ($\hat{s}_{ij}$) for the total dietary fiber content and the standard deviations (SD) of the effects of two F_2s hybrids are shown in Table 4. The crossings FT 96-1282 x CNFP 8100 ($\hat{s}_{ij}$: 1.5225) and Valente x Varre-Sai ($\hat{s}_{ij}$: 1.4022) presented the highest and positive $\hat{s}_{ij}$ estimates and are therefore the combinations with the greatest specific combining ability.

Although the effects of the specific combining ability are useful for the indication of the best hybrid combinations, they do not specify which one of the parents should be used as male or female in the specific crossing; reciprocal effects are used to obtain this information (Cruz and Regazzi 1997). We therefore suggest the use of the CNFP 8100 as female parent in function of the highest mean DFC obtained in the crossing CNFP 8100 x FT 96-1282.

In the improvement of autogamous plants the cost/benefit relation often makes the production of hybrid seeds unfeasible. Thus, the $\hat{s}_{ij}$ estimates (highest and positive) are not only considered for the acquisition of superior hybrids, but also for its values *per se*. The breeder is therefore interested in combinations with the most favorable estimates of specific combining ability, which involve at least one parent that presented the most favorable effect of the general combining ability (Cruz and Regazzi 1997). This way, the selection in the populations resulting from the crossing CNFP 8100 x FT 96-1282 can be effective for the identification of common bean lines with a higher dietary fiber content.

Considering that the developed populations presented variability for dietary fiber, it is believed that in the long term it will be possible to associate the beneficial effects of the fiber to the nutritional value of the common bean supplying a high-quality food that will, above all, benefit the less favored social groups of the Brazilian population.

Table 3. Estimates of the effects of the general combining ability ($\hat{g}_i$) for dietary fiber content in common bean grains in four cultivars and standard deviations (SD) of the effects of different parents

Cultivars	$\hat{g}_i$
1. CNFP 8100	0.7615
2. FT 96-1282	- 0.0797
3. Valente	- 0.7509
4. Varre-Sai	0.0690
SD (g_i)	0.2165
SD (g_i - g_j)	0.3535

CONCLUSIONS

There is genetic variability of dietary fiber content in common bean. Lines with a higher content of dietary fiber can be obtained through selection in the populations developed based on the crossing CNFP 8100 x FT 96-1282.

Table 4. Estimates of the effects of the specific combining ability ($\hat{s}_{ij}$) for dietary fiber content in common bean grains and standard deviations (SD) of the effects of two F_2s

Cultivars (♀/♂)	1. CNFP 8100	2. FT 96-1282	3. Valente	4. Varre-Sai
1. CNFP 8100	-0.8278	0.4359	0.7372	-0.3453
2. FT 96-1282	1.5225	-0.9553	-0.2816	0.8009
3. Valente	-0.8525	-1.6525	-1.8578	1.4022
4. Varre-Sai	-0.8750	-0.7650	0.3900	-1.8578
SD (s_{ij})	0.3953			
SD (s_{ii})	0.5303			
SD (s_{ii} - s_{jj})	0.7071			
SD (s_{ii} - s_{ij})	0.7906			
SD (s_{ii} - s_{jk})	0.6124			
SD (s_{ij} - s_{ik})	0.6124			
SD (s_{ij} - s_k)	0.5000			

Variabilidade genética para teor de fibra alimentar em populações de feijoeiro

RESUMO - *O feijão é um dos principais alimentos que compõem a dieta da população brasileira, fornecendo diversos nutrientes e fibra. Sendo assim, os objetivos deste trabalho foram estimar as capacidades geral e específica de combinação de cultivares de feijão, para conhecimento do seu potencial de utilização para o aumento do teor de fibra alimentar. Os cruzamentos foram realizados na forma de dialelos completos, obtendo-se 12 híbridos entre as combinações possíveis entre quatro genitores (CNFP 8100, FT 96-1282, Valente e Varre-Sai). Os genitores e as populações obtidas foram avaliados a campo, em delineamento de blocos ao acaso. Os resultados obtidos revelaram presença de variabilidade genética para teor de fibra alimentar nas populações. O genitor CNFP 8100 apresentou maior estimativa dos efeitos da capacidade geral de combinação. Linhagens de feijão com maior teor de fibra alimentar poderão ser obtidas através de seleção nas populações desenvolvidas a partir do cruzamento entre CNFP 8100 x FT 96-1282.*

Palavras-chave: *Phaseolus vulgaris* L, fibra alimentar total, análise dialélica.

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