Environment effect on grain quality in early common bean cultivars and lines

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ABSTRACT

The objective of the present study was to assess the technological and nutritional quality of seven early common bean cultivars and nine lines. An experiment in completely randomized blocks was carried out in three locations in the wet 2001/2002 growing season. One hundred gram samples were collected from each material at physical maturity to estimate the grain technological and nutritional characteristics and also the weight of 1000 seeds, shape and degree of seed flattening were assessed by the J and H coefficient, respectively. The joint analysis of variance showed significant genotype and environment effect at 1% probability. The genotype x environment interaction was significant at 1% probability for all the characteristics assessed except for the weight of 1000 seeds and the J coefficient. Cooking time showed positive phenotypic and genotypic correlation with percentage of whole grains after cooking, weight of 1000 seeds and seed shape, indicating the possibility of simultaneous selection among these characteristics. However, the total solids in the sauce correlated negatively with these traits that are desirable in the industrial processes of the common bean.

KEY WORDS: *Phaseolus vulgaris*, technological qualities, protein content, earliness.

INTRODUCTION

Brazil is one of the largest common bean (*Phaseolus vulgaris* L.) producers in the world, cropping annually about 4.146.680 hectares with a yield of around 3.016.280 tons (FAO, 2003). The country is also one of the largest world consumers of this legume. The Brazilian consumption per capita is around 16.0 kg/inhabitant/year (CNPAF, 2003). Bean grains are the main protein source in the diet of millions of Brazilians.

In the production of basic foods, common bean cropping has a short cycle. However, the objective of many breeding programs has been the development of early cultivars that complete their cycle in around 65 to 70 days. Early cultivars present several advantages because they stay less time in the field; escape from disease and climatic stress; reduce harvest losses, because harvesting is in the drier period. So they are an option for crop rotation in irrigated and intensive cropping and it allows placing the product on the market early, getting higher prices because there is less offer.

Not only is high yield sought in the development of early cultivars but also improvements in the technological and nutritional quality of the grains in order to attend the demands of the consumer market. The consumer acceptance of common beans depends on the size, shape, color and cooking qualities that include cooking time, presence of whole grains, texture, flavour, color and total solids in the sauce after the cooking.

The technological and nutritional qualities of the bean grains are determined by the genotype and influenced by the environment effect that act during the plant growth and seed development. The numerous environmental factors that influence the bean quality include climatic factors, such as high temperatures at the grain swelling phase; crop management, post-harvest beneficiation, storage conditions and processing technology. The influence of the environment and the cultivar x environment interaction in the traits related to common bean grain quality has been studied by several authors (De Lance and Labuscagne, 2001; Balasubramanian et al., 1999; Kigel, 1999; Santalla et al., 1999; Elia et al., 1997; Escribano et al., 1997; Castellanos et al., 1995; Michaels and Stanley, 1991; Shellie and Hoslfield, 1991).

The nutritional quality of the common bean include protein content, amino acid composition, digestibility and the presence of anti-nutritional factors. Many experiments have shown that nitrogen and sulfur application, especially when these elements are limiting factors of the soil, normally increase the protein and sulfurous amino acids (methionine and cistin) content. However the great quantity of sulfur required to increase the sulfur-rich amino acids in the seeds, as well as its high cost, limit the use of this practice to improve the protein quality of common bean grains (Kigel, 1999).

Cooking bean grains is a step common to many industrial processes and domestic consumption. In the bean canning industry, water absorption before grain processing is essential to ensure the softness, uniformity and expansion in the can during the heat process. The percentage of whole grains after cooking is another characteristic of technological quality in the grains that is desirable and important in the canning, dehydration and dry-freezing industries.

The differences among the cultivars for cooking time are strongly influenced by two characteristics: hard-shell and the hard-to-cook effect. Although the result of both the characteristics is longer cooking time. The heredity mechanism and the environmental conditions under which such characteristics develop are different (Shellie-Dessert and Bliss, 1991).

Hard-shell is a condition of dormancy in the seed. It occurs when the grains do not imbibe water or show low imbibition due to tegument hardening, making it impermeable to water, thus prolonging the cooking time and the germination period (Castellanos et al., 1995). Tegument hardening is an important survival mechanism in the plant under adverse environmental conditions, but the cultivars that develop this condition during the post-harvest period are frequently highly irregular in grain texture when cooked. The genetic control of the hard-shell phenomenon is relatively simple, but this characteristic is significantly affected by stressing moisture conditions during grain formation and maturation (Castellanos et al., 1993).

Hard-to-cook is a phenomenon that interferes in the cotyledon cooking capacity. Although the seeds absorb water, the cotyledons are not very easily softened during cooking. The hard-to-cook phenomenon is irreversible and is developed during prolonged storage periods, especially under high temperature and relative humidity conditions. The prolonged cooking time observed in common beans is the principal consequence of the hard-to-cook effect as reported by Castellanos et al. (1995).

The objective of the present study was to estimate the environment effect on morphological, technological and nutritional quality characteristics of early common bean cultivars and lines to orient breeding programs to develop early cultivars with consumer acceptable grain characteristics.

MATERIAL AND METHODS

The morphological, technological and nutritional quality characteristics were assessed in cultivars and lines developed by the IAPAR breeding program or introduced by other research institutions or even collected from farmers. The IAPAR 81 cultivars were used as control for the characteristics assessed (Moda-Cirino et al., 2001). The cultivars studied were Goiano Precoce, Carioca Precoce, Carioca 1070, Carnaval Pitoco, Alúbia and Baronesa, and the lines LP99-2, LP99-3, LP99-4 LP20-87, LP20-88, LP20-89, LP20-90, LP20-91 and G-122.

Experiments

Three experiments were carried out in the wet planting season 2001/2002. The experiments were installed in the Experimental Area at the headquarters of IAPAR in Londrina, PR, at the Florestal Experimental Station in Irati, PR and on a farm located in Capitão Leônidas Marquês, PR. A completely randomized block design was used with three replications and plots consisting of two 5m lines spaced at 0.50m. The sowing density was 20 seeds per linear meter. Basic fertilization of 200kg/ha NPK (4-14-8) and 200kg/ha ammonia sulfate for mulching were used.

Traits assessed

A 100 gram sample was collected from each material studied at the R9 physiological maturity stage (CIAT, 1987) in order to assess the seed technological and nutritional quality where each assessment was made in two replications. The moisture content of the samples was standardized at approximately 12%. The technological characteristics assessed were: cooking time (TCOZ) was estimated from the cooking time index determined with a 25 seed bar-drop cooker, determined by an adapted Mattson cooker. The seeds assessed to TCOZ were selected from after soaking 16 hours. The cooking time index was calculated as the elapsed time from initiation of cooking until 13 of the 25 penetrating bars had dropped and perforated seeds in the cooker (Proctor and Watts, 1987); The percentage before (CAAa) and after (CAAd) cooking water absorption, solids content in the sauce after cooking (ST) and whole beans after cooking (GI) were determinated by modified methodology Plhak et al. (1989) and Garcia-Vela and Stanley (1989). A 10 grams sample was soaked for 16 hours in distilled water and the pre-cooking imbibition was expressed by dividing the drained beans weight by the initial weight of the raw dried beans. The drained beans were added to the 100 ml of distilled water at the ebullition point and they were cooked for 1 hour in the water-bath. The beans were drained and weighed. The post-cooking imbibition was calculated like the CAAa. The amount of solids in the cooking water was determinated gravimetrically by evaporating 20 ml the cooking water to dryness in an forced air oven at 70°-80°C. The residue was weighed and reported as grams in 100 ml of cooking water. The whole beans were counted after draining and reported as percentage of the total number cooker. The nutritional characteristic was determined by the total protein content (TTP) in percentage, estimated from the total nitrogen content of the grain determined by the micro method by Kjeldhal using the 6.25 factor to convert the nitrogen to protein (AOAC, 1980).

The weight of 1000 seeds (P1000) trait was assessed, the seed shape was determined by the J coefficient and the degree of seed flattening by the H coefficient (Puerta Romero, 1961). The J coefficient was estimated by the ratio between the seed length and width and the H coefficient by the ratio between the seed thickness and width, in two replications with 30 seeds from samples taken randomly from each material assessed.

Data analysis

The statistical analyses of the data obtained for the traits assessed were performed using the Genes program (Cruz, 1997) considering the genotype and environment effects as fixed.

Individual analyses of variance were performed for each location for each trait assessed. The homogeneity of the variances was ascertained by the Hartley test, given by the ratio between the largest and smallest variance (Ramalho, 2000). Later joint analysis of variance was performed and the means of the treatments were grouped by the Scott and Knott method at 5% and 1% probability (Scott and Knott, 1974).

The coefficient of genetic variation (CVg), coefficient of environment (CVe) and the B index were estimated for all the traits assessed according to Vencovsky (1969). The coefficient of genotypic determination (h^2) was estimated by the ratio between the genetic and phenotypic variance (Cruz, 1997). The phenotypic (r_F) and genotypic (r_G) correlations among the traits assessed were estimated using the Genes program (Cruz, 1997).

RESULTS AND DISCUSSION

Analysis of variance

The joint analysis of variance presented in Table 1 showed that there was a significant effect for genotype, environment and the genotype x environment interaction at the level of 1% probability for all the characteristics assessed in the cultivars and lines studied. The genotype x environment interaction was not significant except for P1000 and the J coefficient. The significant result of the genotype x environment interaction demonstrated that the environments influenced the grain quality of the cultivars and lines assessed. Significant effects of genotype, environment and their interaction had also been detected in studies carried out previously, for TCOZ, CAAa GI and TTP (De Lance and Labuschagne, 2001; Santalla et al.,1999; Scholz and Fonseca Junior 1999; Escribano et al.1997).

The technological characteristics GI and the P1000 presented the highest estimates for the environmental coefficients of variation (CVe), 24.52% and 13.95%, respectively (Table 1) and were therefore the characteristics most influenced by the environment effect. The B index estimated indicates genetic variability among the lines and cultivars for the characteristics studied. The estimates of the coefficient of genetic determination were high for all the characteristics (Table 1), varying from 88.29% to 99.23%. Similar results were obtained by Elia et al.(1997). The genetic variability detected for TCOZ, GI and TTP demonstrate that is possible to select superior cultivars and lines for these characteristics. But the breeder should not disregard other important

Table 1. Result of the joint analysis of variance, coefficient of variation genetic variability (CVg), environment coefficient of variation estimate (CVe), B index (CVg/CVe) and coefficient of genotypic variation (h^2) estimates of the characteristics assessed in seven cultivars and nine lines of common bean cropped in Londrina, Irati and Capitão Leônidas Marquês in the wet 2001/2002 growing season.

FV	GL	TCOZ[1/]	GI[2/]	ST[3/]	CAAa[4/]	CAAd[5/]	TTP[6/]	P1000[7/]	J[8/]	H[9/]
Environment	2	[10/]	[10/]	[10/]	[10/]	[10/]	[10/]	[10/]	[10/]	[10/]
Genotype	15	[10/]	[10/]	[10/]	[10/]	[10/]	[10/]	[10/]	[10/]	[10/]
Genotype x environment interaction	30	[10/]	[10/]	[10/]	[10/]	[10/]	[10/]	NS	NS	[10/]
Residue	48									
Mean		33.56	16.61	1.16	105.87	141.94	21.14	279.61	1.67	0.79
CVe (%)		5.69	24.52	9.48	2.11	3.37	0.99	13.05	2.15	2.48
CVg (%)		16.53	44.14	12.54	4.58	3.78	4.17	26.34	9.98	4.00
B (CVg/CVe)		2.91	1.80	1.32	2.17	1.12	4.21	2.02	4.64	1.62
h^2 (%)		98.06	95.11	91.30	96.57	88.29	99.07	96.07	99.23	93.99

[1/] cooking time (minutes); [2/] Number of whole grains after cooking (%); [3/] total solids in the sauce after cooking (g/100ml); [4/] water absorption capacity before cooking (%),[5/] water absorption capacity after cooking (%);[6/] Total protein content in the grain (%);[7/] weight of 1000 seeds (g); [8/] seed shape; [9/] degree of seed flattening; [10/] significant at level of 1% probability; NS: not significant.

characteristics that interfere in the commercialization and acceptance of the grain on the consumer market. Although selection is favorable, there is the influence of the environment effect and the genotype x environment interaction that interferes in the grain quality characteristics.

In general the cultivars and lines showed a different performance for the characteristics studied. The cultivars and lines can be grouped in four groups for the TCOZ characteristic at the level of 1% probability by the Scott and Knott test (Table 2). Carioca Precoce cultivar and LP20-87, LP20-88 and LP20-89 lines presented shorter cooking time, approximately 26 minutes, lower than the TCOZ of IAPAR 81 (control). Cooking time is an important technological quality characteristic because it implies time and energy expenditure for bean preparation, determining the acceptance of early cultivars by the consumers. Alúbia and Baronesa cultivars and LP99-2 line presented the longest TCOZ (41 minutes), decreasing their acceptability for the consumer market.

The Scott and Knott test at 1% probability grouped the technological characteristics GI and ST, desirable in common bean industrial processes, in three and two classes, respectively. Carnaval Pitoco and Goiano Precoce cultivars and LP99-2, LP99-3 and LP99-4 lines presented the highest GI percent, approximately 26%. The ST technological characteristic varied in its contents from 0.96 g/100ml (Goiano Precoce cultivar), to 1.5 g/100ml (LP20-88 line).

Of all the cultivars and lines assessed absorbed water and the values varied from 100.25% to 115.22%. The Scott and Knott test at 1% probability grouped the CAAa of the cultivars and lines in two classes. Alúbia cultivar and LP99-2, LP99-3 and LP99-4 lines absorbed more water during imbibitions, presenting a greater CAAa compared to the other materials tested. Water absorption by the grains is directly affected by the hard-shell phenomenon that decreased the technological quality of the grains. The results obtained make it difficult to identify its occurrence as all the materials presented good water absorption. There was no significant difference among the cultivars and lines for CAAd and constitued in a single class. Cultivars and lines selection with high hydration value is important in this case because it is a desirable characteristic in bean grain processing.

Regarding the grain nutritional quality (Table 2) TTP, the Scott and Knott statistical test grouped the lines and cultivars in five groups at the level of 1% probability, and the protein contents ranged from 19.62% to 23.08%. Goiano Precoce cultivar was outstanding, presenting TTP around 23%. The protein contents found for all the cultivars and lines can be considered satisfactory. The protein contents of

Table 2. [1/] cooking time (minutes); [2/] Number of whole grains after cooking (%); [3/] total solids in the sauce after cooking (g/100ml); [4/] water absorption capacity before cooking (%),[5/] water absorption capacity after cooking (%);[6/] Total protein content in the grain (%);[7/] weight of 1000 seeds (g); [8/] seed shape (J coefficient); [9/] degree of seed flattening (H coefficient) assessed in seven cultivars and nine lines of common bean cropped in Londrina, Irati and Capitão Leônidas Marquês in the wet 2001/2002 growing season.

Genotype	TCOZ[1/]	GI[2/]	ST[3/]	CAAa[4/]	CAAd[5/]	TTP[6/]	P1000[7/]	J[8/]	H[9/]
IAPAR 81	30.67 c	6.58 c	1.07 b	103.22 b	140.52 a	20.39 d	254.22 c	1.66 b	0.76 b
Goiano Precoce	33.17 c	28.03 a	0.96 b	100.55 b	127.48 a	23.08 a	341.94 b	1.51 b	0.79 b
LP99-2	40.67 a	23.52 a	1.01 b	114.62 a	140.85 a	22.05 b	269.26 c	1.85 a	0.79 b
LP99-3	36.67 b	24.49 a	1.04 b	115.22 a	144.09 a	21.96 b	279.65 c	1.93 a	0.84 a
LP99-4	36.33 b	28.40 a	0.98 b	113.38 a	139.09 a	21.74 b	286.63 c	1.90 a	0.83 a
LP20-87	27.33 d	9.54 c	1.33 a	105.80 b	145.99 a	21.48 c	234.00 d	1.58 b	0.75 b
LP20-88	25.50 d	9.31 c	1.50 a	107.42 b	146.98 a	21.53 c	207.29 d	1.53 b	0.78 b
LP20-89	27.17 d	7.66 c	1.38 a	103.17 b	148.52 a	21.14 c	208.44 d	1.54 b	0.81 a
LP20-90	32.83 c	16.96 b	1.18 b	103.47 b	146.78 a	20.80 d	205.97 d	1.56 b	0.82 a
LP20-91	31.00 c	15.03 b	1.24 a	102.95 b	136.85 a	20.31 d	210.68 d	1.57 b	0.82 a
Carioca Precoce	25.83 d	7.32 c	1.20 a	100.89 b	148.99 a	21.66 b	235.29 d	1.57 b	0.77 b
Carioca 1070	30.83 c	17.05 b	1.28 a	100.25 b	142.42 a	21.39 c	199.68 d	1.59 b	0.76 b
Carnaval Pitoco	38.50 b	26.07 a	1.13 b	104.48 b	134.67 a	20.11 e	362.65 b	1.54 b	0.84 a
Alúbia	42.33 a	15.79 b	1.05 b	110.13 a	146.45 a	20.64 d	443.67 a	1.61 b	0.74 b
Baronesa	41.67 a	14.67 b	1.12 b	105.68 b	139.27 a	19.62 e	361.48 b	1.91 a	0.80 a
G-122	36.50 b	15.37 b	1.07 b	102.75 b	142.20 a	20.36 d	372.31 b	1.95 a	0.79 b
Mean	33.56	16.61	1.16	105.87	141.95	21.14	279.57	1.68	0.79

Values followed by a same letter belong to a same group, Scott and Knott test at significant at level of 1% probability.

around 20% to 27% have been reported by other authors (Santalla et al., 1999; Escribano et al., 1997; Elia et al., 1997; Shellie and Hosfield, 1991). Environmental influence and the genotype x environment interaction in this trait indicates that selection for high protein content can be difficult; similar results have been reported in other studies (Kigel, 1999; Shellie and Hosfield, 1991).

Cultivars and lines studied were grouped in four classes for P1000, with the values ranging from 199.68g to 443.67g. Alúbia cultivar presented greatest weight, which results from this cultivar presenting a bigger grain.

The indexes estimated J and H grouped the cultivars and lines in only two classes (Table 2). A low environment influence was observed, especially for the J coefficient that was not influenced by the genotype x environment interaction (Table 1). The data obtained in the three locations were very similar for seed shape (Table 3), suggesting this characteristic can be used for cultivar characterization and differentiation.

Correlations among the assessed traits

Estimates of the phenotypic and genotypic correlation among the characteristics assessed in the cultivars and lines studied were shown in table 4. In general the magnitude of the coefficients of genotypic and phenotypic correlation was similar and of the same sign, indicating the influence of the genetic and environmental factors in the correlation among the traits assessed. According to Falconer (1987) when these coefficients show the same signs, the genetic and environmental variations are influenced by the same physiological mechanisms. TCOZ presented significant phenotypic and genotypic correlation with the GI, P1000 and J coefficient and with CAAa. The positive genetic correlation between TCOZ and P1000, as the results obtained by Mwandemele and Nchimbi (1992), suggests that small and medium sized grains could be selected for shorter cooking time.

Table 3. Seed shape based on the J coefficient (mm), degree of flattening based on the H coefficient (mm) assessed in seven cultivars and nine lines of common bean in Londrina, Irati and Capitão Leônidas Marquês in the wet 2001/2002 growing season.

Genotype	Capitão Leônidas Marquês		Londrina		Irati	
	J[1/]	H[2/]	J[1/]	H[2/]	J[1/]	H[2/]
IAPAR 81	1.68 - Oblong/short kidney-shape	0.76 - half full	1.68 - Oblong/short kidney-shape	0.76 - half full	1.59 - Elipse	0.76 - half full
Goiano Precoce	1.49 - Elipse	0.78 - half full	1.54 - Elipse	0.78 - half full	1.46 - Elipse	0.80 - full
LP99–2	1.85 - Oblong/short kidney shape	0.81 - full	1.90 - Oblong/short kidney-shape	0.79 - half full	1.84 - Oblonga/short kidney-shape	0.77 - half full
LP99–3	1.93 - Oblong/medium kidney shape	0.86 - full	1.97 - Oblong/short kidney-shape	0.84 - full	1.90 - Oblong/mediumrt kidney-shape	0.80 - full
LP99–4	1.91 - Oblong/short kidney-shape	0.84 - full	1.89 - Oblong/short kidney-shape	0.82 - full	1.92 - Oblong/mediumt kidney-shape	0.81 - full
LP20-87	1.58 - Elipse	0.73 - half full	1.60 - Elipse	0.78 - half full	1.55 - Elipse	0.72 - half full
LP20-88	1.54 - Elipse	0.78 - half full	1.55 - Elipse	0.79 - half full	1.50 - Elipse	0.76 - half full
LP20-89	1.54 - Elipse	0.80 - full	1.56 - Elipse	0.81 - full	1.52 - Elipse	0.81 - full
LP20-90	1.56 - Elipse	0.82 - full	1.58 - Elipse	0.83 - full	1.55 - Elipse	0.82 - full
LP20-91	1.60 - Elipse	0.82 - full	1.61 - Elipse	0.83 - full	1.54 - Elipse	0.82 - full
Carioca Precoce	1.55 - Elipse	0.79 - half full	1.61 - Elipse	0.76 - half full	1.55 - Elipse	0.73 - half full
Carioca 1070	1.58 - Elipse	0.76 - half full	1.62 - Elipse	0.77 - half full	1.54 - Elipse	0.72 - half full
Carnaval Pitoco	1.52 - Elipse	0.86 - full	1.58 - Elipse	0.81 - full	1.49 - Elipse	0.83 - full
Alúbia	1.59 - Elipse	0.74 - half full	1.64 - Elipse	0.75 - half full	1.61 - Elipse	0.74 - half full
Baronesa	1.91 - Oblong/short kidney-shape	0.83 - full	1.96 - Oblong/short kidney-shape	0.80 - full	1.94 - Oblong/medium kidney-shape	0.79 - half full
G – 122	1.93 - Oblong/short kidney-shape	0.79 - half full	1.96 - Oblong/short kidney-shape	0.75 - half full	1.97 - Oblong/medium kidney-shape	0.79 - half full

[1/] Ratio between seed length and width and [2/] ratio between seed thickness and seed width, Puerta Romero (1961).

Table 4. Estimates of the phenotypic correlation (upper diagonal) and genotypic coefficient (lower diagonal) among the characteristics entre as características [/] cooking time (minutes); [1/] Number of whole grains after cooking (%); [3/] total solids in the sauce after cooking (g/100ml); [4/] water absorption capacity before cooking (%),[5/] water absorption capacity after cooking (%);[6/] Total protein content in the grain (%);[7/] weight of 1000 seeds (g); [8/] seed shape; [9/] degree of seed flattening assessed in seven cultivars and nine lines of common beans in Londrina, Irati and Capitão Leônidas Marquês in the wet 2001/2002 growing season.

Caracteres	TCOZ[1/]	GI[2/]	ST[3/]	CAAa[4/]	CAAd[5/]	TTP[6/]	P1000[7/]	J[8/]	H[9/]
TCOZ[1/]	1	(0.6099)[10/]	(-0.7264)[10/]	(0.5053)[11/]	NS	NS	(0.7756)[10/]	(0.5910)[10/]	NS
GI[2/]	(0.6279)[10/]	1	(-0.6642)[10/]	NS	(-0.6556)[10/]	NS	NS	NS	(0.5699)[11/]
ST[3/]	(-0.7582)[10/]	(-0.7129)[10/]	1	NS	(0.5326)[11/]	NS	(-0.6303)[10/]	(-0.5354)[11/]	NS
CAAa[4/]	(0.5144)[11/]	(0.4381)[11/]	NS	1	NS	NS	NS	(0.5853)[10/]	NS
CAAd[5/]	NS	(-0.7170)[10/]	(0.5933)[10/]	NS	1	NS	NS	NS	NS
TTP[6/]	NS	NS	NS	NS	NS	1	NS	NS	NS
P1000[7/]	(0.8023)[10/]	NS	(-0.6719)[10/]	NS	NS	NS	1	NS	NS
J[8/]	(0.5992)[10/]	NS	(-0.5625)[11/]	(0.5976)[10/]	NS	NS	NS	1	NS
H[9/]	NS	(0.5999)[11/]	NS	NS	NS	NS	NS	NS	1

[10/] and [11/] significant at level of 1% and 5% probability. [NS] not significant

The significant and positive correlation between TCOZ and CAAa contrasts with the results obtained by Kigel (1999); Escribano et al. (1997); Elia et al. (1997); Castellanos (1995) and Shellie and Hosfield (1991) who reported a high negative correlation between TCOZ and CAAa. The results obtained suggest that the hard-to-cook effect occurred in possibly four materials: Alúbia cultivar and the LP99-2, LP99-3 and LP99-4 lines. These cultivars and lines presented high, TCOZ and CAAa, above average, making the correlation obtained positive and significant, indicating a high probability of the occurrence of hard-to-cook. In the growing season when these experiments were conducted, meteorological data obtained from the IAPAR Agrometeorological Area (data not shown) indicated the occurrence of high temperatures and water shortage during the seed formation and maturation that could have caused the occurrence of the hard-to-cook defect, thus increasing the cooking time. The elimination of the hard-to-cook problem by genetic breeding could probably reduce the cooking time of these cultivars and lines. The positive and significant correlation of TCOZ with GI, P1000 and the J coefficient indicates that in addition to tegument permeability to water, other characteristics such as seed shape and size can be also affect the cooking time.

The traits GI and the H coefficient presented positive and significant phenotypic and genotypic correlation (Table 4). Positive genotypic correlation was reported among the GI and CAAa technological characteristics. Positive and significant phenotypic and genotypic correlations were further observed between CAAd and ST and between CAAa and the J coefficient. The correlations reported indicate that the grains with a high value of thickness-width and great water absorption presented a great percentage of whole grain after cooking, a desirable characteristic for the canning industry. Water absorption before cooking was higher in oblong or kidney shaped beans. Beans that absorbed more water after cooking presented greater soluble solids in the sauce. However, it must be emphasized that such characteristics are influenced by environment.

The ST technological characteristic presented significant negative phenotypic and genotypic correlation with TCOZ, GI, P1000 and J coefficient (Table 4). Early cultivars and lines with shorter cooking times, smaller grain weight and fewer whole grains after cooking had a greater quantity of total solids in the sauce. The GI technological characteristic presented significant and negative phenotypic and genotypic correlation with CAAa at 1% probability, indicating that the quantity of whole grains after cooking was greater in cultivars and lines that absorbed less water after cooking.

The nutritional characteristic TTP did not correlate significantly with the characteristics assessed, indicating the difficulty in selecting for this trait.

CONCLUSIONS

The effect of environment and the genotype x environment interaction interfered in the early common bean grain quality in addition to the genotype effect;

Carioca Precoce cultivar and LP20-87, LP-2088, and LP20-89 lines can be selected for shorter grain cooking time because they presented shorter cooking times;

Carnaval Pitoco and Goiano Precoce cultivars and LP99-2, LP99-3 and LP99-4 lines can be recommended for the bean canning industry, which searches for materials with a high percentage of whole grains and lower total soluble solid content in the sauce;

The hard-to-cook phenomenon detected in some cultivars and lines studied probably interfered in the phenotypic and genotypic correlation between cooking time and water absorption;

Besides the water imbibition capacity of the beans, characteristics such as seed shape and size interfered directly in the cooking time and in the percentage of whole grains after cooking the bean;

The total protein content in the grain did not correlate with the other characteristics assessed, showing, therefore, that it is a difficult trait to select by breeding.

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RESUMO

Efeito do ambiente na qualidade de grãos de cultivares e linhagens precoces de feijoeiro

O objetivo do presente estudo foi avaliar a qualidade tecnológica e nutricional de sete cultivares e nove linhagens precoces de feijoeiro. Para tanto, um experimento em blocos casualizados foi conduzido na safra das águas 2001/2002 em três locais. Na maturidade fisiológica retiraram-se amostras de 100g de cada material para as avaliações de características tecnológicas e nutricional dos grãos, avaliando-se ainda o peso de 1000 sementes, forma e grau de achatamento da semente por meio dos coeficientes J e H, respectivamente. A análise de variância conjunta revelou efeito significativo de genótipo e de ambiente, a 1% de probabilidade. A interação genótipo x ambiente também foi significativa, a 1% de probabilidade para todas as características avaliadas, exceto para peso de 1000 sementes e coeficiente J que não foram significativos. O tempo de cozimento mostrou correlação fenotípica e genotípica positiva com

porcentagem de grãos inteiros após o cozimento, com o peso de 1000 sementes e com a forma da semente, indicando a possibilidade de seleção simultânea entre essas características. Entretanto, a quantidade de sólidos totais no caldo apresentou-se correlacionada negativamente com tais características, tanto na correlação fenotípica quanto genotípica, podendo afetar negativamente essas características, desejáveis no processo de industrialização do feijão.

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