Genotype x environment interaction and correlation among technological traits of soybean grains

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ABSTRACT

Many of the technological processes in soybean industrialization start with imbibition and finish with cooking. With the growing use of soybean in human nutrition and the increase in the consumption of its derivatives, there is a need to study the genetics of its physical and chemical characteristics and their correlation. The objective of this study was to evaluate technological characteristics in grains of different soybean cultivars and the genotype x environment interaction in six soybean cultivars released by Embrapa-Soybean. The following characters were analyzed: texture after 60 and 90 minutes of cooking ,obtained by the compression of the grain by the TA-XT2i apparatus, weight of one hundred seeds; seed moisture content, water absorption and electric conductivity. Significant differences (P<0,01) were detected among treatments for the characters studied except seed moisture content and water absorption . Characters such as weight of one hundred seeds and electric conductivity presented significant differences (P<0,01) among environments. The cultivar x environment interaction was significant (P<0,01) for texture under 60 and 90 minutes of cooking , weight of one hundred seeds and electric conductivity. Significant phenotypic and genotypic correlations were found for texture under 60 and 90 minute of cooking (r_F = 0,86 and r_G = 0,97). Results from this study showed that the environment affected the behavior of the studied genotypes considerably. The correlation texture x cooking time revealed a high relationship for texture in the two cooking times indicating that both of the analyzed characters can be used for texture evaluation in breeding programs.

KEY-WORDS: *Glycine max*, genotype x environment, grain texture, technological characteristics.

INTRODUCTION

The Brazilian soybean consumer market is still restricted and most of the production is for oil extraction industries, margarine processing and animal feeding. As soybean is rich in proteins and oils (most cultivars contain 30 to 45% protein, 15 to 25% lipids and 20 to 35% carbohydrates), there has been great interest in using it in human nutrition (Moreira, 1999 and Yokomizo, 1999). In addition, the presence of essential amino acids in its proteins, except for metionin and cistine, has shown evidence that it can be used in the prevention of diseases such as cancer at a low cost (Vello and Tsutsumi, 2000).

Soybean derived foods are produced in the most diverse forms: “in natura”, semi-cooked, liquid or powdered milk (which may be flavored), textured vegetable protein, and processed with other products such as cold meats, biscuits, cookies, soups; cheese (tofu); sauces (soy sauce); fermented grains (natto); paste (misso) and sprouts. The use of soybean as food is traditional in oriental countries, mainly China, Japan, Korea and Taiwan (Carrão-Panizzi, 1987).

Although the advantages of using soybean in human nutrition are recognized, it is little accepted because of its flavor, aroma and texture characteristics. The disagreeable flavor and aroma are due mainly to the lipoxigenase isoenzymes. According to Sgarbieri et al. (1978) quoted by Dela-Modesta and Garrutti (1982), low soybean acceptance is also linked to its coarse texture after cooking. Soaking and cooking improve the texture and also give it a mild flavor.

According to Carrão-Panizzi (1989) and Vello (1992), soybean used for human consumption should have special characteristics such as higher quantity and quality protein, less quantity and better quality oil, a sweet nut-like flavor, high carbohydrate content, elimination or reduction of the unpleasant odor and anti-nutritional factors.

Soybean for “in natura” consumption in the form of sprouts, green beans and mature grains should have a better texture and quicker cooking time. According to Berra (1974), anti- nutritional factors can be de-activated by cooking.

Many of the technological processes in soybean industrialization begin with hydration followed later by cooking. With the growing use of soybean in human nutrition and the direct consumption of it and its derivatives, these characteristics need to be studied.

Some Brazilian researchers (Destro, 1991; Pacova, 1992; Guerra et al., 1999; Yokomizo 1999 and Tsutsumi, 2000) studied agronomic characteristics of grain and food type soybean genotypes in segregant generations, pure lines and their crosses to select more adaptable and adequate genotypes for human consumption, but without a parallel study of technological characteristics such as imbibition, cooking time or texture. In order to develope new cultivars for human nutrition, with good nutritional, organoleptic and technological characteristics favorable to consumption along with high grain yield, research has taken new directions, using food and grain type soybean as parents in breeding programs involving hybridization.

The objective of the present study was to estimate the effect of genotype, environment, genotype x environment interaction, and the correlation among technological characteristics in soybean cultivars.

MATERIAL AND METHODS

This research was carried out in the Food and Drug Technology Laboratory and the Seed Laboratory at the Agricultural Sciences Center at Londrina State University. Six grain type soybean cultivars with medium sized grains and a mean weight of 100 seeds between 10 and 20 grams were used. The grains came from seed production fields in the counties of Toledo and Mariópolis, in the state of Paraná, from the BR-48, BR-58, BR-59, BR-61, BRS-133 and BRS-134 cultivars. These cultivars were supplied by Embrapa-Soybean and chosen according to their greater adaptation to the soil and better grain yield and availability in these two counties. The extreme localizations of these counties in the State (Mariópolis is in the south of the state at 26.5° latitude south, 53.5° longitude, 726 m altitude and a mean annual rainfall of 1600mm while Toledo is in the west of the a state at 25.5° latitude south, 54.4° longitude, 367 m altitude and with mean annual rainfall of 1900mm) were also considered.

The laboratory experiment was carried out in a complete randomized block design with four replications. The experimental unit contained 50 seed samples for the characteristics assessed except for seed weight which was represented by units with 100 seed samples. Each cultivar represented one treatment.

The following characteristics were assessed:

Seed texture (T60 and T90)

Seed texture was assessed by the strength required to squash and extrude a cooked soybean grain, measured in Newtons/second ($N.seg^{-1}$). The results of a replication consisted of a mean unit ten individual grains. The experimental unit consisted of 50 cooked soybean grains, from which ten grains were removed and assessed individually. To determine the texture of an individual grain, a P25mm probe (Cylinder Aluminium) was used attached to the Texture Analyser TA-XT2i apparatus, with the squashing speed calibrated at $2mm.seg^{-1}$. Samples were prepared by immersing 50 seeds in 75ml distilled water for 18 hours at a mean temperature of 20°C; the water was replaced whenever necessary. The seeds selected for the analyses were intact without any damage or split seed coat. After an 18 hours imbibition, the water was drained from the samples, boiling (90 to 100°C) distilled water was added , and they were cooked for 60 or 90 minutes. The result of the texture was obtained by the strength value ($N.seg^{-1}$) which was used to squash the cooked soybean grain.

Weight of one hundred seeds (WHS)

The weight of one hundred seeds was obtained by weighing a sample of one hundred seeds with standardized moisture on precision scales for each replication. The seeds were obtained from undamaged samples.

Seed Moisture Content (SMC)

Soybean seed moisture content was obtained according to methodology proposed by Brasil (1992). Each experimental unit was formed by a sample of 50 seeds.

Determination of the seed water imbibition percentage (IP)

The percentage of water absorption by the seeds was determined by adapting the methodology proposed by Jackson and Varriano-Marston (1981) described for beans. The technique consists of first determining the dry weight of 50 soybean grains and later soaking the grains in 75ml distilled water for 18 hours. After 18 hours imbibition the water is drained off and the grains are immediately weighed. The experimental unit consisted of a 50 soybean grain sample, which was weighed before and after being soaked in water. The imbibition percentage was determined by the following formula:

$$IP = \frac{WWAI - DWBI}{DWBI} \quad x \ 100$$

where,
IP: imbibition percentage
DWBI: dry weight before imbibition
WWAI: wet weight after imbibition

Electric conductivity of the bulk mass (EC)

Electric conductivity was determined according to the methodology described by the Association of Official Seed Analysts (1992). In this test, the grain quality is assessed by immersing 50 grains in 75ml deionized water kept for 24 hours at 25°C. The reading is performed by the DM31 Conductivimeter apparatus where its conductivity cell is immersed in the grain imbibition solution and the result obtained in nomS. cm^{-1}. g^{-1}.

Genetic and statistical analysis

The analyses of variance were performed by the Statistical Analysis System (SAS). An individual analysis of variance was performed to verify the effect of the treatments on the traits assessed for each environment . Later, a ratio was established between the greatest and the smallest residual mean squares. According to Gomes (2000), this ratio should be at most 7:1 to guarantee adequate experimental accuracy among the environments and thus allow the unification of the different experiments in the joint analysis without restrictions. The mixed model consisted of a fixed environmental effect and a random genotype effect plus genotype x environment effects.

The data in percentile $\sqrt{x/100}$ (%) obtained for moisture content and imbibition were transformed in arc sen for the analyses of variance. The original data, without the transformation, are shown in the tables.

Heritability

Heritability was determined by the mean of the treatments based on the formula proposed by Cruz and Regazzi (1997):
$h^2 = s^2_G / s^2_F$, where s^2_G is genetic variance and s^2_F the phenotypic variance.

Phenotypic, genotypic and environmental correlations

The assessed traits were matched pairwise to estimate the phenotypic (r_F), genotypic (r_G) and environmental (r_E) correlation for each group of genotypes, using the formula proposed by Vencovsky and Barriga (1992):

$$r_F\ (x, y) = COV_F\ (x, y) / (s^2_{Fx} \cdot s^2_{Fy})^{0.5}$$
$$r_G\ (x, y) = COV_G\ (x, y) / (s^2_{Gx} \cdot s^2_{Gy})^{0.5}$$
$$r_E\ (x, y) = COV_E\ (x, y) / (s^2_{Ex} \cdot s^2_{Ey})^{0.5}$$

Where:
r_F (x, y), r_G (x, y) and r_E (x, y): phenotypic, genotypic and environmental correlations among the traits x and y; COV_F (x, y), COV_G (x, y) and COV_E (x, y): mean product of treatments or covariance for the traits x and y involved; s^2_F(x, y), s^2_G (x, y) and s^2_E (x, y): phenotypic, genotypic and environmental variance of treatments for the x and y traits, respectively.

Tukey test and Scott-Knott test

Due to the presence of significant differences among the variation sources detected by the F test (P<0.05), the Scott-Knott test was applied to compare texture means at 60 and 90 minutes of cooking, for each treatment (Table 2), and the Tukey test to compare the means of each treatment for each characteristic assessed, in each locality (Table 3).

RESULTS AND DISCUSSION

In the joint analysis of variance (Table 1) for the Cultivar (C) source of variation, the results showed significant values (P<0.01) for T60, T90 and EC and a significant value (P<0.05) for WHS, indicating the existence of variability among the genotypes tested. No significant difference was found for the SMC and IP traits, indicating similarity in the genotypes tested. Moisture content for seed storage remained similar, reflecting the uniformity and standardization of the tested samples. The lack of uniformity in this characteristic can affect and hide real results of other assessed characteristics. According to Vieira and Krzyzanowski (1996), the standardization of seed moisture content gives more uniform results in the IP and EC tests.

The two environments (Mariópolis and Toledo) affected WHS and EC (P<0.01) significantly. The T60, T90, SMC and IP did not show significant differences, indicating similarities among the cultivars tested in the two environments (Table 1).

A highly significant cultivar x environment interaction was observed for the T60, T90, WHS and EC traits, but not for the SMC or IP. The significance of the interaction indicates that the studied cultivars showed different behavior for the traits assessed in each environment. Significant cultivar x environment interaction differences for texture characteristic in soybean cultivar grains were also found by Della-Modesta and Garrutti (1982). Hosfield et al. (1984); Stanley et al. (1990); Michael and Stanley (1991) found these significant interactions in bean cultivar grains.

Table 1 - Joint analysis of variance, variation coefficient and heredity of six traits[1/] in the counties of Toledo and Mariópolis.

		Means Square					
Variation Source	**df**	**T60**	**T90**	**WHS**	**SMC**	**Il**	**EC**
Cultivar (C)	5	2948.26**	4725.42**	1.22*	0.60^{ns}	48.05^{ns}	1962.35**
Environment (E)	1	950.86^{ns}	112.32^{ns}	3.57**	0.80^{ns}	0.12^{ns}	25676.31**
C x E	5	2370.37**	1836.89**	4.70**	0.44^{ns}	48.88^{ns}	3742.32**
Error	36	599.55	417.94	0.47	0.57	23.50	2433.76
h^2		0.87	0.91	0.61	-	0.51	0.24
Means		202.88	185.69	15.51	10.56	135.24	123.57
VC (%)		12.07	11.01	4.41	7.15	3.58	6.65

[1/]T60 = texture in the 60 minute cooking time (N.seg^{-1}); T90 = texture in the 90 minute cooking time (N.seg^{-1}); WHS = weight of one hundred seeds (g); SMC = seed moisture content (%); IP = inbibition percentage (%) e EC = seed eletric condutivity (µomS.cm^{-1}.g^{-1}).

*,**5% and 1% by the F test, respectively.

^{ns}, not significant.

The significance for cultivar (C) confirms the expected genetic variability among the grain type cultivars tested, which are normally not standardized for technological characteristics. The cultivar x environment interaction significance indicates that the mean of the grouped localities and the behavior of the derived cultivars varied between these environments. The coefficients of variation (VC) varied from 3.5 to 12% for the traits assessed, indicating good experimental accuracy in their measuring. The VC in T60 and T90 were 12.7 and 11.01%. These values are slightly superior to those found by Tróia et al. (1996) who obtained a VC of 6.94% in the first experiment and of 4.24% in the second experiment, using the adapted Mattson Machine.

Means comparison

Variability was found among the genotypes when the mean and the behavior of each cultivar for each characteristic were assessed, in each environment separately (Table 2). As for the Mariópolis T60 trait, cultivars varied from 180.5 to 256.6 ($N.seg^{-1}$) whereas for Toledo they varied from 170.3 to 229.7 ($N.seg^{-1}$). In Mariópolis, the BR-58, BR-59 and BRS-134 presented the highest means, different statistically from the BR-48, BR-61 and BRS-133 cultivars which presented the lowest means. Cultivars with higher means for texture showed greater resistance to squashing, consequently, they required greater strength from the probe apparatus (Texturometer TA-XT2i) during compression.

Cultivars with lower texture means for grains cooked for 60 minutes, presented less resistance to squashing and a softer texture, making them more suitable for human nutrition, as grains with softer seed coat are more palatable and better accepted. As for the T90 trait, the mean of the cultivar varied from 144.3 to 234.3($N.seg^{-1}$). The highest means were found in the BRS-134 (234.3 $N.seg^{-1}$), BR-59 (208.7 $N.seg^{-1}$), BR-61 (184.2 $N.seg^{-1}$) and BR-58 (183.7 $N.seg^{-1}$) cultivars. They represent the coarser textured cultivars which differed statistically from the soft textured BR-48 (149.8 $N.seg^{-1}$) and BRS-133 (144.3 $N.seg^{-1}$) .

In Toledo, the lowest means for the T60 trait were obtained for the BR-48 and BR-58 cultivars (176.8 and 170.3 N.seg-1, respectively) which differed statistically from the BR-59, BR-61 BRS-133 and BRS-134 cultivars. Table 2 shows that cultivars with harder and softer grains behaved similarly regarding the T60 and T90 traits, in the two

Table 2 - Trait means in six grain type cultivars tested in two different environments.

Traits	Cultivar	Environment: Mariópolis	Environment: Toledo
Texture in 60 minutes cooking ($N.seg^{-1}$)	**BR-48**	180.5[1]a	176.8a
	BR-58	214.1b	170.3a
	BR-59	219.3b	229.7b
	BR-61	191.9a	208.7b
	BRS-133	181.7a	207.1b
	BRS-134	256.6b	197.9b
Texture in 90 minutes cooking ($N.seg^{-1}$)	**BR-48**	149.8a	194.5b
	BR-58	183.7b	153.6a
	BR-59	208.7b	206.1b
	BR-61	184.2b	199.1b
	BRS-133	144.3a	167.3a
	BRS-134	234.3b	202.8b
Weight of one hundred seeds (g)	**BR-48**	17.1c	14.1a
	BR-58	14.5a	15.9b
	BR-59	15.6b	16.0b
	BR-61	15.7b	14.4a
	BRS-133	16.5c	15.6b
	BRS-134	15.3b	15.4b
Seed moisture content (%)	**BR-48**	10.4a	10.8a
	BR-58	11.3a	10.5a
	BR-59	10.5a	10.1a
	BR-61	10.2a	10.4a
	BRS-133	11.1a	10.5a
	BRS-134	10.7a	10.2a
Inbibition percentage (%)	**BR-48**	131.9a	137.6a
	BR-58	136.4a	128.5a
	BR-59	133.9a	134.9a
	BR-61	140.4a	138.7a
	BRS-133	135.1a	132.9a
	BRS-134	134.1a	138.5a
Seed electric condutivity (µomS.$cm^{-1}.g^{-1}$).	**BR-48**	84.7a	127.2a
	BR-58	148.4c	129.8a
	BR-59	97.2b	152.7b
	BR-61	91.9b	137.6a
	BRS-133	86.7a	203.2c
	BRS-134	93.6b	127.9a

[1/]Means followed by the same letter in the same column do not differ by the Scott-Knott test.

localities. Softer grain type cultivars are of greater interest to human nutrition and as parents in crosses with food type soybean.

A comparison of means among the different textures, for the two environments studied ,is shown in table 3. The means for the T60 trait are higher than those found for the T90 trait. The trait means that differ for T60 and T90 show that a softer texture was found in the 90 minute cooking time.

Means for the BRS-134, BR-59 and BR-61 at Mariópolis did not differ in texture in both cooking times. Differences among the T90 means were found with the BR-58, BRS-133 and BR-48 cultivars. In Toledo, the only difference obseved was for BR-133 at T90.

The lack of significance among these assessed traits lead to the choice of the texture determined by the 60- minute cooking time in the BR-134, BR-59 and BR-61 at Mariópolis and in the BRS-134, BR-59, BR-58, BR-61 and BR-48 at Toledo, respectively. The T60 trait may be considered better than T90 because is spends less energy and it is less time consuming.

Texture assessment at different cooking times (60 and 90 minutes) may be considered destructive and degrading characteristics in grains. These traits present high heritability (Table 1) varying from 0,82 to 0.91, respectively. These values indicate that these traits can be assessed and selected in early generations in breeding programs, as the greater variation will represent genetic variation among the genotypes.

Table 3 –Means of the six grain type cultivars for the texture trait in 60 and 90 minutes cooking time for the Toledo and Marioípolis environments.

Cultivars	Environment				Means
	Mariópolis		Toledo		
	T60[1/]	T90[1/]	T60	T90	
BR-134	256.6A[2/]	234.3A	197.9A	202.8A	222.9018
BR-59	219.3A	207.6A	229.3A	206.2A	180.4342
BR-58	214.1A	183.7B	170.3A	153.7A	216.1516
BR-61	191.9A	184.2A	208.7A	199.0A	195.9503
BR-133	181.7A	144.3B	207.1A	167.0B	175.0735
BR-48	180.5A	149.8B	176.8A	194.5A	175.4103
Means	207.7	184.0	198.4	187.2	194.3203

[1/]T60 = texture in 60 minute cooking time (N.seg^{-1}); T90 = texture in 90 minute cooking time.

[2/] Means followed by the same letter, for each locality,did not differ by the Tukey test at 5%.

Tróia et al. (1996) assessed two experiments with the Adapted Mattson Machine which was composed of 25 vertical sticks placed on the soybean grain during the test, with a 90 gram weight on each grain. The sample was considered cooked when 13 of the 25 sticks were displaced. Cooking time goes from boiling until displacement occurs. Thirty pure lines of food type soybean were assessed in the first experiment. The cooking time varied from 26 to 169.5 minutes. In the second experiment, 24 pure lines were assessed derived from crosses among food and grain type soybean genotypes. Cooking time varied from 67.6 to 124.3 minutes. These results indicated that the food type genotypes from Japan present greater variability for cooking time opening the possibility of developing genotypes with fast grain cooking.

Guerra et al. (1999) assessed 96 lines of food type soybean and eight grain type cultivars. The authors concluded that soybean breeding programs for direct human consumption, at low latitudes, are viable for both direct use of pure Asiatic lines and for allele incorporation for late flowering in short days . Destro et al. (2001) presented a revision of the long juvenile period in soybean to help breeding programs involved with soybean adaptation.

In Mariópolis, the BR-48 and BR-133 cultivars present the highest means for weight of one hundred seeds with 17.1 and 16.5g, respectively (Table 2). The BR-59, BR-61 and BRS-134 cultivars presented intermediate means and the BR-58 cultivar presented the lowest mean (14.5g). The cultivars behaved differently in Toledo and in Mariópolis, and the highest means were found for the BR-58 (15.9g), BR-59 (16.0g), BRS-133 (15.6g) and BRS-134 (15.4g). These cultivars differed statistically from the BR-48 (14.1g) and BR-61 cultivars (14.4g) which presented the lowest means.

The seed electric conductivity means (EC) (Table 2) were higher at Toledo than at Mariópolis. In the Mariópolis environment, the highest value was obtained for the BR-58 cultivar (148.4 uomS.com^{-1}.g^{-1}) while in the Toledo environment, the highest mean was found for the BR-133 (203.2 uomS.cm^{-1}.g^{-1}) and the lowest for the BR-48, BR-58, BR-61 e BRS-134 cultivars, respectively, with 127.2; 129.8; 137.6 and 127.9 uomS.cm^{-1}.g^{-1}. According to Marcos Filho et al. (1987), Vieira (1994) and Vieira and Krzyzanowski (1996), electric conductivity assesses the physiological quality of the seeds and the higher values obtained in its measuring imply a greater quantity of lixiviates in the seed imbibition solutions. The presence of greater quantity of lixiviates, in turn ,is directly related to the integrity of the cell membranes. The results obtained show that there was greater solute lixiviation in the imbibition solution in the at BR-48 cultivar at Mariópolis, indicating that the seed samples from this cultivar showed less vigor. Greater solute lixiviation was observed in the seed imbibition solution of the at BRS-133 cultivar Toledo as well (Table 2).

Correlations among traits

Knowledge of the association between two traits and their high correlation enables earlier indirect selection of a trait by selection made on another trait with known high heritability. Table 4 shows the estimates for the phenotypic, genotypic and environmental correlation coefficients among the pairs of traits studied.

The positive and significant phenotypic and genotypic correlations among T60 and T90 (r_F = 0.86 and r_G = 0.97) showed a high ratio for texture in these two cooking times. These data indicate that either one of the two cooking times may be used to assess texture in breeding programs. Therefore what is selected for the T60 trait will be indirectly selected for the T90 trait and is efficient and viable in time energy and money saved in selection for T60 because the cooking time is shorter.

The phenotypic and genotypic correlations between T60 and the WHS, SMC, IP and EC traits were of low magnitude. Non-significant correlations of average magnitude were found between T90 and IP (r_F = 0.45 and r_G = 0.59) and EC (r_F = 0.55 and r_G = -0.57).

The positive association between T90 and IP implies that genotypes with higher texture values presented harder and coarser textures and consequently higher percentages of seed imbibition. The presence of negative values in the T90 and EC associations implied in gains by lixiviation when the seeds are harder. Negative estimates and average magnitudes were found between WHS and IP (r_F = -0.45 and r_G = -0.70), and the greater the grain size, the lower the percentage of imbibition. Positive phenotypic and genotypic correlations among WHS and EC (r_F = 0.55 and r_G = 0.71) of average magnitude were estimated, implying that larger seeds can lixiviate more solids. Highly significant genetic correlation was detected between IP and EC (r_F = -0.62 and r_G = -0.85). This implies that seeds that imbibe more lixiviate fewer solids.

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CONCLUSIONS

1. There is genetic variation among soybean cultivars for grain technological characteristics such as texture, WHS and EC.
2. WHS and EC were affected differently by the Toledo and Mariópolis environments as opposed to the T60, T90 and SMC and IP traits.
3. Cultivar performance for the T60, T90, WHS and EC traits depends on the environment. This dependence is shown by the significant cultivar x environment interaction.
4. The high correlation between T60 and T90 makes possible the use of the first trait for texture assessment in breeding programs.

RESUMO

Interação genótipo x ambiente e correlações entre características tecnológicas de grãos de soja

Muitos dos processos tecnológicos de industrialização da soja possuem como ponto inicial a hidratação e posterior cozimento da soja. Com o crescente uso da soja e seus derivados na alimentação humana, há

Table 4 - Estimate of the phenotypic (r_F), genotypic (r_G) and environment (r_E) correlations in the trait pairs in soybean

Trait Pairs	r_F	r_G	r_E
T60 x T90	0.86*	0.97**	-0.06
T60 x WHS	0.02	-0.02	0.17
T60 x IP	0.21	0.42	-0.31
T60 x EC	-0.07	-0.07	-0.10
T90 x WHS	-0.29	-0.38	-0.01
T90 x IP	0.45	0.59	0.22
T90 x EC	-0.55	-0.57	-0.29
WHS x IP	-0.45	-0.70	-0.11
WHS x EC	0.55	0.71	-0.32
IP x EC	-0.62	-0.85*	-0.05

[1/]T60 = texture in the 60 minute cooking time ($N.seg^{-1}$); T90 = texture in the 90 minute cooking time ($N.seg^{-1}$); WHS = weight of one hundred seeds (g); IP = imbibition percentage (%); EC = seed electric condutivity ($uomS.cm^{-1}.g^{-1}$).
*By the t test, the values required for significance in the phenotypic and genotypic correlations at 5% and 1% should be superior or equal to 0.81 and 0.92, respectively.

necessidade de se estudar a genética de características físicas e químicas e suas correlações. O objetivo deste trabalho foi avaliar características tecnológicas de grãos, assim como a interação entre genótipos x ambiente de seis cultivares de soja lançados pela Embrapa-Soja. Foram avaliados os seguintes caracteres: textura em 60 e 90 minutos de cozimento; peso de cem sementes; grau de umidade das sementes; porcentagem de embebição e condutividade elétrica. Diferenças significativas (P<0,01) foram detectadas entre cultivares para os caracteres em estudo, com exceção do grau de umidade e porcentagem de embebição. Os caracteres peso de cem sementes e condutividade elétrica, apresentaram diferenças significativas (P<0,01) entre ambientes. A interação cultivar x ambiente, foi significativa (P<0,01) para os caracteres textura em 60 minutos de cozimento, textura em 90 minutos de cozimento, peso de cem sementes e condutividade elétrica. Correlações fenotípicas e genotípicas significativas foram encontradas para textura em 60 e 90 minutos de cozimento (r_F = 0,86 e r_G = 0,97). Conclui-se que o ambiente afeta consideravelmente o comportamento das características tecnológicas para os genótipos estudados. As correlações entre os caracteres textura aos 60 e 90 minutos de cozimento revelam uma alta relação entre eles, fato que possibilita a utilização de avaliações de apenas 60 minutos em programas de melhoramento.

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