Agronomic and chemical characterization of soybean genotypes for human consumption

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ABSTRACT

Soybean (*Glycine max* (L) Merrill) presents a high level of good quality protein and lipids that consist mainly of unsaturated fatty acids. It also has considerable amounts of B complex vitamins and minerals such as iron, potassium and magnesium (Carrão-Panizzi, 1987). In addition to these good nutritional characteristics, soybean for human consumption should have a sweet, nut-like flavor, pale colored seeds (tegument, hilum and cotyledon) and suitable seed size for use as food (Destro, 1991; Vello, 1992). This research was carried out to describe the agronomic and chemical characteristics of food-type soybean genotypes for later use as cultivars or in crosses. Seventy-two soybean genotypes were used in the study, and the agronomic quantitative, qualitative and chemical traits of the grains were assessed, including mineral composition, oil, protein, carbohydrates and ash contents. The results showed that there was great genetic diversity among the genotypes studied for all the agronomic characteristics assessed. The F 82-5782 genotype was outstanding, presenting yield compatible with commercial exploitation as well as large seeds. The Mikawashima genotype presented the highest carbohydrate contents, while the Toffumame II genotype showed the greatest P contents and was also among the six genotypes that presented the greatest K, Ca, Mg, S, Zn, Mn and protein values. These genotypes can be used as cultivars or in breeding programs to solve specific problems of nutrient shortage due to genetic traits.

KEY WORDS: Traits, soybean breeding, soybean consumption, food type soybean.

INTRODUCTION

Soybean arrived in Brazil in 1908 in the luggage of the first Japanese immigrants, who started to cultivate it in kitchen gardens for their own consumption (Hasse, 1996). This species presents a high level of good quality protein (around 40%) and lipids (around 20%), which consist mostly of polyunsaturated fatty acids. It also contains considerable quantities of B complex vitamins and minerals such as iron, potassium and magnesium. It consists of 5.4% ash (mineral), 2.3% fiber and 32.3% carbohydrates. It has proven medicinal properties, and is a technological challenge because, although it is a food of high nutritional value, it does not yet occupy a consistent place in the diet of western man (Antunes and Sgarbieri, 1981).

The current world situation indicates that the demand for food in the present is greater than in the past and this reality will be even more evident in the future, with a greater demand for calories, high quality protein and other nutrients such as riboflavin, vitamin A and iron, therefore, soybean is considered an excellent choice (Bressani, 1974).

In addition to the good nutritional characteristics already mentioned, soybean used directly as human food should have some special characteristics including a greater quantity of better quality protein, less but better quality oil content, a sweet nut-like flavor, pale colored seeds (seedcoat, hilum and cotyledon) and a suitable size for use as food (Destro, 1991; Vello, 1992). These characteristics compose the ideal germoplasm for human consumption. Therefore the development of cultivars adapted to each region is important because this adaptational factor may alter the quality of these characteristics.

The present study was carried out to describe the agronomic and chemical characteristics of the germplasm of food-type soybean genotypes for use as a source of variability in cultivars or in genetic breeding programs.

MATERIAL AND METHODS

Seventy-two food-type soybean genotypes were used, sown on FAZESC (School Farm) at the Londrina State University -UEL, (Londrina PR) on 29/11/99 and 07/11/00 in soil classified as 'structured eutrophic purple soil (Hapludult). A completely randomized block design with three replications was used. The plot consisted of one linear meter with 0.9m between-plot spacing. The seedlings were thinned after emergence leaving at most 10 plants per plot. The plots were hoed manually and insecticides applied according to technical recommendations. The plants were harvested and threshed individually and the seeds were placed in paper bags.

The following quantitative agronomic traits were measured: NDF (number of days to flowering), period in days between sowing and the anthesis of the first flower (R_1 stage (Fehr and Caviness, 1977), PHF (plant height at flowering: distance (cm) from the plant stem base to the insertion of the most distal inflorescence of the main stem (R_1); NDM (number of days to maturity) period between sowing and the day when approximately 95% of the pods were ripe (R_8); PHM (plant height at maturity) distance, in centimeters, from the plant stem base to the insertion of the most distal pod or node on the main stem, assessed at R_9; VWP (visual width of the pod): visual score scale of 1 (very narrow) to 5 (very broad) applied to the central portion of the distal pod locus; L (lodging) assessed visually on a score scale that varied from 1 (all the plants erect) to 5 (all the plants lodged) AV (agronomic value): visual assessment at maturity at harvest. The latter represents a visual index of global merit of the plant for a series of adaptive traits: pod quantity, plant vigor and health, resistance to lodging, resistance to premature pod threshing and less retention; IPY (individual plant yield): weight (in grams) of the grains of the individual plants; WHS (weight of one hundred seeds): weight (in grams) of one hundred seeds and NSP (number of seeds per plant: IPY/WHSx100. The following qualitative traits were analyzed: FC (flower color): W: white and P: purple; PC (pubescence color): B brown and G gray; TC (seed tegument color): Y: yellow, Gy: greenish yellow, G: green B: Black and B: brown; HC (hilum color): Y: yellow, B: brown, PB: pale brown, DB: dark brown, G: green and B: black.

The oil content was determined by nuclear magnetic resonance - RMN. Seed samples weighing 3.5 to 4.5 g were previously stored in a cold chamber at 18°C and 55% relative humidity for 20 days to homogenize the seed moisture. The protein content was quantified using 100mg of previously dried and ground seeds. The total nitrogen content was determined and multiplied by the 6.25 conversion factor according to the Kjeldahl micro method (N.A.I.A. 1985). The carbohydrate content was obtained by the difference: [100-(protein+lipids+ash+moisture)]. The ash content was obtained from the weight of 5g of previously dehydrated and ground seeds that were calcinated in an oven at 500°C for approximately seven hours, or until the ashes were completely white. The moisture was determined on scales equipped with an infra-red lamp (Ohaus, model MB45) where 1g of previously dehydrated and ground seeds was submitted to 125°C for one minute. The mineral composition was determined by the (ICP) method - Inductively Coupled Plasma in a Perkin Elmer apparatus, model Optma 3000 where the mineral analysis was performed simultaneously. The temperature in the emission zone where the readings were taken reached 6200°C to 6800°C.

Analyses of variance and the Tukey test ($P<0.05$) were performed to compare the means using the Genes program (Cruz, 1997).

RESULTS AND DISCUSSION

Agronomic traits

The analysis of variance of the ten quantitative traits of agronomic importance indicated significant difference ($P<0.05$) among the treatments for all the traits analyzed (Table 1).

The coefficient of variation (CV) of these traits was low for NDF (5.2%) and NDM (3.4%), medium for PHF (17.6%), PHM (16.8%) VWP (12.7%), AV (17.8%) and WHS (12.6%) and high for L (24.9%), IPY (29.7%) and NSP (28.5%). Destro (1991) reported similar CV values for IPY and NSP in a study on food-type soybean genotypes. (Table 2) presents the means of the traits assessed and the Significant Minimum Difference (DMS - Tukey test 5%). Diversity was evident among the genotypes in all the treatments, especially for NDF (from 31 to 81 days), PHF (from 14.4 to 94.2cm), IPY (from 2.54 to 102.88 g/plant) and WHS (from 12.38 to 55.36 g/100 seeds). Guerra et al. (1999) studied the genetic behavior of 104 food-type soybean genotypes and also observed wide genetic diversity. High yielding genotypes adapted for the normal sowing season were also available.

There was considerable variation in the tegument and hilum pigmentation in both the color and tone and this is an important factor for genotype classification according to the type of soybean product required. Carrão-Panizzi and Meira (1989) characterized and analyzed 83 genotypes from the food-type soybean germplasm collection at Embrapa Soybean and suggested nine qualitative characteristics of agronomic importance, namely growth habit, flower color, pubescence color, pubescence type, pod color, tegument color, hilum color, cotyledon color and seed shine.

The general NDF mean was 53.5 days. The maximum NDF value was 81 days for the F 83-8012 genotype which, however, did not differ significantly from ten other genotypes. The lowest value was 31 days for the Kaoshiung and Prize genotypes, which, however, did not differ significantly from 15 other genotypes. This great variability among the genotypes studied can be exploited in plant selection programs. Toledo et al. (1993) reported in a genetic analysis of growth in soybean genotypes with determined growth habit, in three different photoperiods and concluded that selection for adaptation should be made in each sowing season, by direct selection according to height or number of days to flowering. Destro (2001) published a complete revision of the genetic control of the juvenile period, where the main determinant of the number of days to flowering and consequently, the number of days to maturity, was the plant height at this stage.

The general PHF mean was 48.7 cm. The maximum PHF was 94.2 cm for the F 83-8192 genotype, which, however, did not differ significantly from 15 other genotypes. These genotypes presented high NDF, showing positive correlation between PHF and NDF. Guerra et al. (1999) reported a similar result. The lowest PHF was 14.4 cm for the PI 205085 genotype, which, however, did not differ significantly from 28 other genotypes.

The NDM mean was 130.5 days. The maximum NDM was 163.5 days for the F 83-8192 genotype, which, however, did not differ significantly from 22 other genotypes. The lowest NDM was 84.2 days for the PI 205085 genotype, which, however, did not differ significantly from 8 other genotypes. The general PHM mean was 56.5cm. The maximum PHM was 118.3 cm for the Araçatuba genotype, which, however, did not differ significantly from another 12 genotypes. The lowest value was 13.5 cm for the PI 205085 genotype, which, however, did not differ significantly from 23 other genotypes.

The L mean was 2.1. The maximum L value was 4.7 for the Araçatuba genotype, which, however, did not differ significantly from 14 other genotypes, showing it susceptible to lodging. The greatest L values were observed in the genotypes with the greatest PHM, showing positive correlation between L and PHM. The lowest L value was 1.0 for the Tamba Kurodaisu genotype and for another 16 genotypes. This score, however, did not differ significantly from 35 other genotypes. The greatest PHM value among the L resistant genotypes was 52.3cm for the FT-Monsanto genotype. The VWP mean was 2.7 and the maximum VWP value was 3.9 for the Londrina V and Londrina I genotypes, which did not differ statistically from 37 other genotypes. The lowest value was 2.2 for the PR 205085, F 83-7843 and Londrina II genotypes, which, however, did not differ significantly from 4 other genotypes.

The general AV mean was 2.2. The maximum AV was 3.5 for the Embrapa 50 and BR-16 genotypes (commercial cultivars), which, however, did not differ significantly from 42 other genotypes. Only five of the best AV are commercial cultivars, showing the high performance of many food-type soybean genotypes for a series of adaptive traits. The BR-16 cultivar presented the highest value in this assessment and was among the best in IPY and PHM, results similar to those reported by Guerra et al. (1999) where the best AVs were in the genotypes with medium and

Table 1. Summary of the analysis of variance carried out on 10 agronomical characteristics, with their respective means and coefficients of variation (CV). Londrina, Paraná, Brazil.

Source of Variation	D.F.	Mean Square									
		NDF	PHF	NDM	PHM	VWP	L	AV	IPY	WHS	NSP
Treatments	71	1328.18[1/]	2963.91[1/]	3014.65[1/]	4256.89[1/]	4.30[1/]	5.50[1/]	3.15[1/]	2999.24[1/]	260.91[1/]	93700.24[1/]
Environment	1	1650.49	24650.76	19804.69	11375.47	21.02	85.96	64.10	173297.56	5558.62	1997377.61
Treat. x Environ.	71	15.81	340.73	146.66	280.17	0.37	1.05	0.49	1086.05	25.63	36185.60
Residue	288	7.90	73.37	19.76	89.95	0.12	0.27	0.15	149.60	8.08	6322.07
Mean		53.53	48.65	130.53	56.47	2.69	2.07	2.20	41.15	22.48	196.08
CV%		5.25	17.51	3.41	16.79	12.71	24.90	17.77	29.73	12.64	28.53

[1/] Significant at a 5% level.

Table 2. Results from the 14 agronomical characteristics found in 72 soybean genotypes. Londrina, Paraná, Brazil.

Genotype	Quantitative characters										Qualitative characters			
	NDF	PHF	NDM	PHM	VWP	L	AV	IPY	WHS	NSP	TC	HC	PC	FC
BR 27-Cariri	80.3	81.4	156.7	92.0	2.1	2.3	2.8	44.89	17.17	261.4	A	P	M	B
F 82-5722 A	59.2	62.6	151.2	69.3	3.4	2.7	2.7	43.24	26.33	164.2	Av	P	M	B
F 82-5722 P	60.7	61.2	143.7	64.3	3.8	2.6	2.5	47.14	28.88	163.2	P	P	M	B
F 82-5769	56.9	47.7	148.5	54.5	3.7	2.2	2.6	56.25	27.50	204.5	P	P	M	B
F 82-5782	61.5	63.8	142.7	68.3	3.7	3.0	2.8	102.88	26.13	393.7	P	P	M	R
F 82-5807	54.0	51.8	143.0	59.2	2.8	1.8	2.6	60.68	23.76	255.4	Av	P	M	B
F 82-5813	51.3	49.3	138.8	51.7	2.5	2.4	2.7	63.58	20.06	316.9	A	P	M	B
Majos	67.7	81.8	153.5	91.5	1.6	3.4	2.9	51.28	15.15	338.5	A	M	C	R
Selection in Stwart	69.3	87.8	152.8	93.2	1.7	3.1	3.0	67.26	15.74	427.3	A	M	C	R
Fazenda Progresso	80.3	82.3	160.0	87.0	3.4	3.5	2.5	55.89	23.74	235.4	A	Mc	C	R
F 83-8012	81.0	84.0	156.5	95.3	2.2	3.4	2.5	46.40	13.70	338.7	M	M	C	B
F 83-8115	80.0	87.0	155.8	81.3	3.8	3.5	2.2	37.36	23.94	156.1	P	P	M	R
TMV	75.5	85.5	155.2	90.2	1.9	3.5	2.6	53.65	18.04	297.4	A	P	M	R
Ivaí	55.9	61.6	131.8	73.0	1.7	2.7	3.2	66.90	18.90	354.0	A	M	C	R
Delsta	59.8	47.2	140.8	54.3	2.3	1.7	2.4	41.06	20.95	196.0	A	Mc	C	R
F 83-8207 AB	57.4	52.8	143.8	58.3	3.0	1.7	2.5	65.95	28.69	229.9	A	M	C	B
Soja Feira 86-13	52.8	41.9	135.2	79.3	2.7	2.4	2.5	52.75	29.26	180.3	A	Me	C	R
EASY Cook	45.6	44.7	125.5	85.2	1.7	3.6	2.3	81.62	15.73	518.9	A	P	C	R
F 83-7977	56.6	48.0	144.7	49.7	2.8	1.4	2.4	45.82	25.48	179.8	A	M	C	B
Araçatuba	73.0	84.1	154.2	118.3	1.9	4.7	2.1	43.23	21.32	202.8	A	M	C	R
Soja Feira 86-14	72.2	74.6	152.3	81.8	3.0	2.9	3.0	49.60	22.90	216.6	A	M	C	R
PI 423.909	75.0	77.6	147.5	92.3	1.4	3.8	2.0	28.77	17.76	162.0	A	Me	M	R
Tamba Kurodaisu	52.0	25.7	152.7	27.3	3.8	1.0	1.2	16.63	55.36	30.0	P	P	M	R
BR 92-15.360	66.2	67.8	152.8	84.0	1.6	3.3	3.0	59.70	14.43	413.7	A	A	C	B
BR 92-22.106	77.5	89.3	161.5	98.8	1.9	2.9	3.0	52.73	16.88	312.4	A	P	M	B
91 K 208-3-1	74.8	85.0	159.7	96.5	1.6	3.0	2.6	64.76	16.40	394.9	A	P	M	R
Aoozora	33.5	22.8	97.7	21.0	3.4	1.0	1.1	4.74	21.02	22.5	A	Me	M	R
Kitamusumi	32.0	16.7	33.0	25.8	3.7	1.0	1.2	8.93	30.73	29.1	V	P	M	R
Late Giant	51.0	44.3	128.3	53.3	3.3	2.2	2.1	50.82	32.34	157.1	P	P	M	R
FT-monsanto	53.1	46.7	129.3	52.3	1.9	1.4	2.8	63.28	18.43	343.4	A	A	C	R
F 85-11.346	59.8	46.9	149.2	53.5	3.6	1.6	2.1	43.17	26.51	162.8	A	P	M	B
Mikamiashima	34.0	16.3	95.7	16.0	3.8	1.0	1.1	9.81	23.82	41.2	A	Mc	C	B
Tamahomare	43.3	24.4	118.8	23.7	3.0	1.0	1.3	18.6	25.27	74.0	A	A	M	R
Waseda	33.0	21.8	95.5	20.5	3.5	1.0	1.2	9.50	24.07	39.5	A	A	M	R
Wilami	34.3	21.5	99.7	28.8	3.4	1.0	1.1	11.14	25.36	43.9	A	A	M	R
PI 86023	33.7	21.9	96.2	21.3	3.7	1.0	1.2	9.99	20.97	47.6	V	P	M	R
PI 205085	31.3	14.4	84.2	13.5	2.2	1.0	1.1	2.54	13.21	19.2	A	Me	C	B
PI 408251	40.1	39.4	102.8	54.3	1.4	2.2	2.6	24.24	12.38	195.8	P	P	M	R
B6F4 (L-1 less)	36.3	20.7	100.7	18.7	3.2	1.0	1.2	9.80	23.44	41.8	A	Mc	M	R
B5F5 (L-2 less)	36.1	21.9	101.0	21.0	3.2	1.0	1.3	15.36	22.78	67.4	A	A	C	R
B6F4 (L-3 less)	34.0	18.5	100.7	17.2	3.4	1.0	1.1	6.81	23.11	29.5	A	Mc	M	R
Kunitz-1	33.0	35.2	105.7	51.2	2.5	1.8	2.2	50.23	19.49	257.7	A	P	M	B
Kunitz-2	33.3	30.3	106.3	49.5	2.4	1.6	2.5	45.78	20.11	227.7	A	P	M	B
Natto	37.7	24.6	108.8	25.0	1.5	1.1	1.3	8.44	15.05	56.1	A	A	C	R
Paranagoiana	69.5	77.9	155.7	89.3	1.4	2.7	2.7	46.36	12.82	361.6	A	Mc	C	B
F 83-7843	57.9	50.4	146.5	58.2	2.2	1.5	2.8	62.69	21.27	294.7	A	P	C	R
F 83-8017	57.3	59.5	143.3	68.5	2.8	2.8	2.9	57.38	27.33	210.0	P	P	M	R
F 83-8192	80.3	94.2	163.5	91.2	3.8	3.4	2.3	35.42	26.20	135.2	P	P	M	R
PL-1 marrom	71.0	64.3	154.7	66.2	3.2	2.8	2.4	79.20	20.27	390.7	M	M	M	R
Tadasha	42.8	28.3	105.3	28.2	3.6	1.1	1.2	10.97	29.00	37.8	M	P	M	B
Kaoshiung	31.0	22.4	96.2	21.8	3.8	1.0	1.1	9.52	36.04	26.4	A	A	C	R
Pérola	54.0	47.6	125.0	53.2	1.6	2.0	3.0	72.52	16.79	431.9	A	Mc	C	R
Prize	31.0	31.0	96.2	32.0	2.9	1.3	1.7	10.04	22.04	45.6	A	Mc	C	R
Toffumame I	41.9	28.1	108.8	28.0	3.3	1.1	1.6	20.65	23.41	88.2	A	A	C	R
BR-16	53.9	52.3	123.8	60.3	1.5	1.9	3.5	47.38	15.00	315.9	A	M	C	B
Stwart	66.0	67.1	157.2	102.8	1.8	3.7	2.5	56.49	17.39	324.8	A	Mc	C	B
PL-1 (marrom)	64.7	60.1	156.2	66.7	3.3	2.7	2.4	56.15	23.11	243.0	M	M	M	R
Toffumame II	31.3	20.3	94.7	19.3	3.7	1.0	1.2	8.38	25.42	33.0	A	A	M	B
Londrina I	43.2	24.8	116.3	26.5	3.9	1.0	1.3	10.71	27.46	39.0	V	V	M	R
Londrina II	52.3	44.7	126.0	82.2	2.8	3.4	2.8	44.29	20.76	213.3	V	P	M	R
Londrina III	51.8	39.0	126.8	70.7	2.2	2.8	2.5	95.07	19.69	482.8	V	P	M	R
Londrina IV	42.8	37.3	113.2	28.3	3.8	1.0	1.2	29.35	28.25	103.9	V	V	M	R
Londrina V	42.3	23.9	114.3	26.0	3.9	1.0	1.2	20.35	28.08	72.5	V	V	M	R
Londrina VI	48.3	40.6	128.5	41.8	3.3	1.2	1.8	47.94	27.98	171.3	A	Me	C	R
Londrina VII	47.8	35.8	128.3	42.3	2.9	1.3	1.7	32.93	28.68	114.8	A	Me	C	R
Londrina VIII	48.0	32.6	128.5	35.5	3.1	1.1	1.5	36.72	29.54	124.3	A	Me	M	R
Londrina IX	59.3	49.3	148.7	60.2	1.9	2.3	2.7	52.06	24.40	213.4	A	Mc	C	B
Londrina X	55.9	45.1	134.0	56.2	1.5	2.0	3.2	58.06	14.96	388.1	A	M	M	B
Londrina XI	60.0	54.0	148.7	60.7	1.8	2.5	2.9	53.91	20.23	266.5	A	M	C	B
Embrapa 48	53.0	56.0	126.2	66.2	1.4	1.9	3.4	60.22	14.13	426.2	A	Mc	C	B
Embrapa 59	57.5	47.3	126.8	64.2	1.5	1.7	3.5	65.46	16.80	389.6	A	Me	M	R
BR-36	53.4	53.7	130.5	55.7	1.9	2.1	2.9	69.27	19.35	358.0	A	M	C	B
Total average	53.5	48.7	130.5	56.5	2.7	2.1	2.2	41.15	22.48	196.0				
DMS[1/] (Tukey 5%)	9.54	29.08	15.09	32.19	1.16	1.75	1.33	41.52	9.65	269.93				

[1/] Minimal significant difference.

high IPY, while the lower AVs were for the genotypes that presented lower IPY and PHM. These results indicate a positive and significant correlation between the AV with IPY and PHM.

The general IPY mean was 41.15 g/plant. The maximum IPY was 102.88 g for the F 82-5782 genotype, and there was no significant difference with 14 additional genotypes. Of these genotypes, only three are commercially recommended cultivars for the soybean-based food industry, namely Embrapa 48, BR-16 and FT-Monsanto, suggesting that the others could be released as new food-type soybean cultivars with good adaptability.

The WHS mean of the 72 genotypes was 22.5 g. The maximum WHS value was 55.36 g/100 seeds for the Tamba Kurodaisu genotype. The lowest WHS was 12.38 g/100 seeds for the PI 408251 genotype, which, however, did not differ significantly from 34 other genotypes. Marega et al. (2001) assessed 25 food-type soybean genotypes in the field and 39 genotypes in a greenhouse for oil content (TO), protein content (PC) and weight of one hundred seeds (WHS) and showed that the relationship of the WHS to TO and TP was low and highly affected by years. The WHS reflects the seed size that is important in allocating each cultivar to a specific use in the soybean food industry, where, for example, small sized seeds are recommended for use in Natto production. The general NSP mean was 196.0 seeds/plant. The greatest value was 518.9 seeds/plant for the Easy Cook genotype, which, however, did not differ significantly from 26 other genotypes. The lowest value was 19.2 seeds/plant for the PI 205085 genotype, which, however, did not differ significantly from 48 other genotypes.

Chemical characteristics

Table 3 shows the parameters of analysis of variance for the chemical traits. There was significant difference ($P<0.05$) among the genotypes for all the components studied except for iron and protein. The variation coefficient was considered satisfactory for the precision of this experiment. The means of the chemical parameters assessed and the Significant Minimum Difference (DMS - Tukey test 5%) are summarized in Table 4.

The general P content mean was 638 mg/100g. The maximum value was 771 mg/100g for the Toffumame II genotype and the minimum value was 506 mg/100g for the F82-5769 genotype. Mandarino et al. (1992) detected higher values (1030 mg/100) for the Kanrich cultivar. Slipcevic et al. (1992) explained that phosphorus accumulation and absorption can be affected by water shortage.

The general K mean was 1705 mg/100g and varied from 1438 mg/100g in the Araçatuba genotype to 2102 mg/100g in the Mikawashima genotype. The maximum value was similar to that reported by Mandarino et al. (1992) for the Kanrich cultivar, 2120 mg/100, where the K content was predominantly the highest of all the minerals.

The Ca mean was 256 mg/100g, and the maximum concentration was 366g/100g for the Stwart genotype. This value was greater than that reported by Mandarino et al. (1992) of 270 mg/100g in the Late Glant and Davies cultivars. The lowest contents were detected in the Delsta genotype (182 mg/100g). The Ca content in soybean is greater than that in other seeds, in spite of the presence of phytates and oxalates that interfere in the bioavailability of the mineral. For this, the ingestion of calcium rich foods, such as green leafy vegetables, cow milk and its derivatives and soybean help to prevent osteoporosis.

The general Mg mean was 249 mg/100g. The maximum value was 331 mg/100g for the Prize genotype and the minimum of 192 mg/100g for the F83-8192 genotype. Slipcevic et al. (1992) observed that Mg accumulation during seed development was greater at the end of the IV stage and at the beginning of the V stage.

Table 3. Summary of the analysis of variance carried out on 14 chemical characteristics, with their respective means and coefficients of variation (CV). Londrina, Paraná, Brazil.

Source of variation	D.F.	Mean Square (g/kg)					Mean Square (mg/kg)					Mean Square(%)			
		P	K	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Oil	Ashes	Proteín	Corbohydrates
Treatments	71	2.18 1/	10.81 1/	0.80 1/	0.40 1/	0.43 1/	138.06 1/	87.27 1/	1225.60	19.15 1/	118.62 1/	13.68 1/	1.08 1/	4.10	11.32 1/
Environments	1	1.27	637.32	52.07	1.67	6.23	8173.91	9898.73	19285.70	180.49	3475.31	94.02	2.01	13.28	368.08
Treat x Envir.	71	0.51	6.21	0.46	0.11	0.15	57.13	61.48	1227.12	8.17	82.55	2.41	0.63	3.22	5.60
Residue	288	0.35	4.07	0.10	0.06	0.24	22.87	16.82	848.93	5.60	28.95	0.91	0.49	3.07	4.80
Mean		6.38	17.05	2.56	2.49	3.66	46.30	32.48	111.81	16.96	37.82	20.16	6.03	40.06	28.33
CV(%)		9.22	11.83	12.13	9.54	13.47	10.33	12.63	26.06	13.95	14.23	4.74	11.58	4.37	7.73

1/ Significant at a 5% level.

Table 4. Mineral and centesimal composition of the 72 genotypes studied. Londrina, Paraná, Brazil.

	Minerals (Mg/100g)									Centesimal composition (%)				
Genotypes	**P**	**K**	**Ca**	**Mg**	**S**	**Zn**	**Mn**	**Fe**	**Cu**	**B**	**Oil**	**Ashes**	**Proteín**	**Carbohydrates**
BR27-Cariri	620	1741	290	223	341	5.32	4.33	12.38	1.89	4.27	18.70	5.84	39.80	30.17
F82-5722A	554	1722	308	248	353	4.40	4.45	10.99	1.70	4.65	19.26	6.01	38.60	30.94
F82-5722P	555	1939	253	239	376	4.58	3.66	11.63	1.70	4.51	20.27	6.13	39.99	28.62
F82-5769	506	1748	206	199	366	4.03	2.77	12.05	1.39	4.03	20.04	5.79	41.17	28.22
F82-5782	578	1800	258	232	398	4.30	3.34	11.44	1.49	4.69	19.98	5.66	40.02	28.92
F82-5807	560	1668	275	262	343	4.24	3.48	11.21	1.44	3.69	22.52	5.97	38.92	27.46
F82-5813	565	1822	295	267	372	4.35	3.60	11.62	1.66	4.37	22.08	6.16	38.76	27.93
Majos	597	1690	245	229	364	4.23	3.10	11.99	1.63	4.24	20.50	5.43	39.55	29.31
Selection in Stwart	620	1730	243	233	365	4.27	3.11	10.60	1.60	4.19	20.30	5.43	40.15	28.74
Fazenda Progresso	672	1682	248	247	406	4.96	3.33	11.29	1.92	4.52	19.91	5.62	40.62	28.69
F83-8012	608	1655	281	268	351	4.43	3.67	14.02	1.72	3.97	19.30	6.22	40.69	28.30
F83-8185	626	1724	232	210	328	4.75	3.25	11.52	1.74	4.63	17.88	5.69	40.11	30.76
TMV	622	1474	201	195	356	4.52	3.46	10.56	1.46	3.78	21.09	5.34	40.23	28.11
Ivaí	680	1689	249	286	373	4.90	3.29	10.82	1.79	3.90	20.96	6.11	40.83	27.22
Delsta	625	1686	182	224	328	4.46	3.14	8.46	1.52	3.39	20.46	6.15	40.52	27.57
F83-8207AB	627	1568	281	267	374	4.75	3.75	10.96	1.61	4.34	21.30	6.01	39.57	28.14
Soja Feira 86-13	711	1729	361	282	363	4.59	3.54	11.21	1.71	3.66	20.54	6.15	40.86	27.33
Easy Cook	714	1620	282	253	402	4.79	3.22	12.15	1.86	3.89	17.99	5.77	41.14	29.43
F83-7977	637	1563	250	254	363	4.44	2.93	14.15	1.66	4.06	22.29	5.95	40.83	25.53
Araçatuba	619	1438	260	246	344	4.21	3.05	10.65	1.68	3.27	19.95	5.62	39.67	29.25
Soja Feira 86-14	629	1593	243	233	390	4.15	3.24	10.76	1.83	4.32	19.99	5.56	39.38	30.90
PI 423.909	722	1614	290	234	412	5.04	3.58	11.92	1.97	3.77	20.52	6.02	40.87	27.26
Tamba Kurodaisu	681	1755	281	224	389	6.22	2.91	12.49	2.18	4.53	21.26	6.13	41.48	25.01
BR92-15.360	661	1856	284	240	371	4.68	3.33	11.93	2.05	4.07	20.64	6.38	39.73	27.92
BR92-22.106	599	1694	235	214	354	5.05	3.36	12.50	1.76	3.84	20.30	5.51	40.28	28.65
91k208-3-1	608	1498	269	232	331	4.53	3.55	15.52	1.68	4.14	20.85	5.54	39.99	28.25
Aoozora	660	1683	219	237	349	5.45	2.85	10.63	1.78	3.14	20.96	6.33	39.76	26.93
Kitamusume	703	1987	285	253	386	4.90	3.67	15.02	1.92	3.62	20.25	6.72	40.31	26.82
Late Giant	661	1919	283	255	336	4.93	3.50	8.60	1.97	3.94	20.59	6.44	40.54	27.14
FT-Monsanto	633	1796	302	247	354	4.19	3.32	10.89	1.62	3.74	22.94	6.25	38.88	26.49
F85-11.346	568	1631	235	239	351	5.05	2.95	10.81	1.48	3.88	19.80	6.35	39.74	28.61
Mikawashima	733	2102	227	281	422	5.03	2.83	14.34	2.03	3.87	14.68	6.47	41.42	33.73
Tamahomare	672	1833	254	271	352	4.54	3.00	10.66	1.71	3.40	20.22	6.73	40.15	27.03
Waseda	646	1691	230	267	345	4.49	3.12	12.33	1.62	3.26	18.27	6.77	40.18	29.78
Wilami	693	1721	272	283	375	5.20	3.44	12.33	1.97	3.50	17.63	6.02	41.16	28.92
PI 86023	735	1844	267	322	416	5.78	3.00	8.53	1.91	2.81	17.59	6.01	40.57	30.01
PI205085	682	1560	266	258	352	4.73	3.25	10.53	1.56	3.46	17.44	7.81	40.01	29.20
PI408251	724	1454	266	287	401	5.20	3.32	10.70	1.71	3.15	18.34	6.42	41.34	27.75
B6F4(L-1less)	713	1862	202	244	388	4.75	2.81	11.53	1.85	3.84	19.48	6.05	40.50	28.51
B5F5(L-2less)	672	1761	214	242	358	4.42	2.79	11.19	1.70	3.64	19.28	6.07	40.43	28.43
B6F4(L-3less)	696	1760	214	222	360	4.87	2.72	11.47	1.75	3.76	18.00	6.18	40.63	29.37
Kunitz-1	626	1677	269	253	379	4.46	3.13	12.11	1.61	3.56	21.21	5.96	40.77	26.71
Kunitz-2	658	1664	269	259	359	4.71	3.00	11.08	1.64	3.35	21.47	5.77	39.83	27.27
Natto	747	1633	300	271	380	5.26	2.89	10.08	1.81	2.96	18.50	6.21	40.31	29.19
Paranagoiana	639	1685	253	238	348	4.09	3.46	10.24	1.45	4.20	21.10	5.61	40.59	27.10
F83-7843	615	1656	296	304	394	4.41	3.62	10.20	1.59	4.36	22.08	6.36	39.27	26.85
F83-8017	537	1594	238	231	341	4.08	3.29	9.67	1.52	4.24	19.17	5.79	40.02	29.76
F83-8192	562	1499	190	192	311	4.39	2.64	8.87	1.46	3.74	17.85	5.35	40.70	30.66
PL-1 Manom	727	1847	295	234	434	5.02	3.50	11.82	1.75	4.12	19.08	5.48	41.15	27.71
Tadasha	751	1689	226	249	357	5.45	3.37	12.61	1.90	3.69	18.08	5.78	39.66	30.61
Kaoshiung	645	1810	208	262	397	3.81	2.32	8.30	1.54	3.05	19.25	6.22	41.16	28.36
Pérola	622	1810	221	265	327	3.88	3.08	9.47	1.58	3.79	22.79	5.79	39.27	26.74
Prize	739	1838	346	331	395	5.31	3.65	10.21	2.03	4.03	18.69	6.05	40.76	28.70
Toffumame I	691	1976	239	281	370	5.15	2.97	10.89	1.89	3.53	19.59	6.15	39.45	29.40
BR-16	547	1685	250	228	353	3.94	2.96	10.25	1.49	3.81	21.02	6.55	38.42	28.83
Stwart	615	1575	366	252	390	4.56	3.76	10.34	1.65	3.47	20.52	6.10	40.12	27.69
PL-1 (marrom)	624	1474	258	214	406	4.71	3.32	10.39	1.66	3.44	19.54	5.48	41.16	28.48
Toffumame II	771	1868	309	294	412	5.75	4.30	12.44	1.74	4.06	21.13	5.37	41.32	27.46
Londrina I	598	1605	229	237	320	4.28	3.14	11.77	1.58	3.69	20.14	5.83	39.89	28.77
Londrina II	640	1731	268	262	355	4.23	2.93	10.78	1.76	2.70	21.92	6.35	39.03	27.69
Londrina III	669	1786	279	262	359	4.48	3.34	11.46	1.85	2.99	21.82	5.69	39.31	27.97
Londrina IV	627	1765	238	244	337	4.47	3.09	1253	1.69	3.57	20.54	6.07	40.59	27.47
Londrina V	589	1566	228	229	315	4.31	2.95	1082	1.52	3.34	20.09	6.11	40.22	27.76
Londrina VI	605	1718	231	247	355	3.95	2.84	9.5	1.64	3.53	21.12	6.13	39.44	28.07
Londrina VII	652	1792	245	255	374	4.45	3.18	10.23	1.82	3.85	20.94	6.54	37.93	29.01
Londrina VIII	673	1832	242	256	381	4.58	2.95	9.42	1.87	3.57	20.88	6.54	38.74	28.37
Londrina IX	543	1447	265	228	340	4.45	3.81	10.69	1.58	3.85	21.02	5.71	39.35	28.36
Londrina X	583	1758	226	233	369	4.42	2.95	9.43	1.37	3.98	21.52	5.56	39.89	27.63
Londrina XI	563	1558	244	242	367	4.51	3.31	9.32	1.50	3.64	21.78	6.87	39.38	26.45
Embrapa 48	567	1581	211	249	337	3.69	2.90	11.04	1.45	3.50	21.87	5.86	38.33	28.58
Embrapa 59	557	1766	216	258	368	4.47	2.99	11.63	1.44	3.60	22.49	5.81	38.48	28.07
BR 36	580	1586	241	251	335	4.35	3.22	12.92	1.50	3.36	21.45	6.23	40.29	26.61
Average	638	1705	256	249	366	4.63	3.25	11.18	1.70	3.78	20.16	6.03	40.06	28.33
DMS[1/] (Tukey 5%)	199	684	105	80	167	1.62	1.39	9.89	0.80	1.83	3.24	2.37	5.94	7.43

[1/] Minimal significant difference.

The general S mean was 366 mg/100g and its contents varied from 311 mg/100g in the F83-8192 genotypes to 434 mg/100g in the PL-1 genotype (brown).

The general Zn mean was 4.63 mg/100g. There was great variation among the genotypes for this mineral, from 3.69 mg/100g in the Embrapa 48 genotype to 6.22 mg/100g in the Tamba Kurodaisu genotype. Mandarino et al. (1992) obtained similar results of from 2.8 to 6.8 mg/100g for Zn contents.

The general Mn mean was 3.25 mg/100g. The highest value was 4.45 mg/100g for the F82-5722A genotype and the lowest was 2.32 mg/100g for the Kaoshiung genotype. Laszlo (1990) reported that the maximum accumulation of this mineral was at the end of the R_8 stage.

The general Fe mean was 11.18 mg/100g. Considering the DMS of 9.89, the maximum concentration of 15.52 mg/100g for the 91k208-3-1 genotype and the lowest of 8.30 mg/100g for Kaoshiung, this characteristic did not show significant difference among the genotypes. Araújo et al. (2001) studied the effect of the genotype x environment interaction on the iron concentration in the common bean in 25 genotypes and three locations and reported that the effects of the genotypes x location interactions were significant, indicating the presence of genetic differences among the 25 genotypes. The Iapar-57 and Pérola genotypes were recommended for crosses based on their adaptation and stability and they also presented superior iron concentrations. The mean of 11.2 mg/100g is considered good according to Carrão-Panizzi and Mandarino (1998) who stated that soybean grains contain 8.8 mg/100g iron.

The Cu mean was 1.70 mg/100g and varied from 1.37 mg/100g in the Londrina X genotype to 2.18 mg/100g in the Tamba Kurodaisu genotype. Based on a DMS of 0.80, only this genotype showed this low level, none of the others that showed a high level displayed significant differences.

The B presented a general mean of 3.78 mg/100g and varied from 2.70 mg/100g in the Londrina II genotype to 4.69 mg/100g in the F82-5782 genotype.

The minerals underwent small variation in P (506-771 mg/100g), Ca (182-366mg/100g), Mg (192-331mg/100g), Zn (3.69-6.22mg/100g), Mn (2.32-4.45mg/100g), Cu (1.37-2.18mg/100g) e B (2.70-4.69mg-100g), a similar result was reported by Mandarino et al. (1992) when they studied the mineral composition of 14 soybean genotypes and attributed these variations to the soil chemical composition. Laszlo (1990) examined the distribution of Mg, Ca, Cu, Fe and Mn in the tegument and embryo of five soybean cultivars during their development and detected that the Mg and Fe levels in the tegument and embryo varied with the stage of reproductive development. The Ca and Zn levels decreased at first, then increased in the final cultivation stage. These elements decreased in the embryo in some genotypes but remained constant in others. The author reported that there were increases at first in the Cu and Mn contents in the tegument, but they decreased as these minerals increased in the embryo. The authors suggested that cationic metals are not assimilated together with the accumulation of dry matter. Slipcevic et al. (1992) conducted a similar study, observing the accumulation of macronutrients (P, K Ca and Mg) during the seed maturing period. It was found that there was an intense accumulation of these minerals during stages II and IV of the seed development and that this accumulation was favored by increased rainfall in moderate temperatures.

The oil mean was 20.16%. The maximum value was 22.94% for the FT-Monsanto genotype. Considering the DMS (3.24) this did not differ significantly from 49 other genotypes. The minimum value was 14.689% for the Mikawashima genotype. Marega et al. (2001) obtained a higher mean for the F83-8207AB genotypes with 21.79% oil, which did not differ from the F82-7843, Delsta, Sel. Stwart and F82-5813 genotypes. Mandarino et al. (1993) tested twelve soybean genotypes in three different edaphoclimatic regions in Paraná (Londrina, Campo Mourão and Palotina) and observed that the oil content percentage was greater in Campo Mourão (19.82%). According to the author, this was probably due to the higher temperatures in this location. Similar research by Pipper and Boote (1999) tested 20 soybean cultivars for temperature effect on oil composition. The oil concentration increased with higher temperatures and reached a maximum of 22% at 28°C and this factor may be affected by photoperiod and water stress.

Soybean oil also presents high digestibility and does not contain cholesterol as do animal fats. The unsaturated fatty acids represent 86% of the total soybean lipids and 60% of these consist of essential fatty acids, such as linoleic and linoleico (Carrão-Panizzi and Mandarino, 1998).

The general ash mean was 6.03% and the maximum value was in the PI205085 genotype, which, however, did not differ significantly from 68 other genotypes (DMS = 2.37). The minimum value was 5.34% for the TMV genotype. Mandarino et al. (1992) reported uniform concentrations for all the samples, with a small variation from 4.56% to 6.44%.

The mean protein content was 40.06%. The content remained stable in all the genotypes, considering the DMS of 5.94. The maximum was 41.48% for the Tamba Kurodaisu genotype and the minimum was 37.93% for the Londrina VII genotype. Even though there was no statistical difference among the treatments, it was observed that the Mikawashima genotype showed the second highest protein value, but this same genotype presented the lowest value for oil. The FT-Monsanto genotype showed higher oil value but it ranked among the eight lowest values for protein. Thus the negative correlation between oil and protein was confirmed. Mandarino et al. (1996) studied eight national soybean cultivars and eight improved lines with high protein content and observed that the protein content varied from 34.92% to 40.16% while the oil content varied from 21.50% to 24.20% in the cultivars. The protein content varied 43% to 47.14% and the oil content varied from 16.40% to 19.90% in the bred lines. The increase in protein content reduced the oil content in soybean seeds, confirming the negative correlation between oil and protein. Similar results were also obtained by Marega et al. (2001), Piper and Boote (1999) and Stombaugh et al. (2000). Soybean protein is well balanced in amino acids that determine its quality when compared with other plants. The quality of soybean protein corresponds to 80% of the biological values of cow milk (Carrão-Panizzi and Mandarino, 1998). Considering these factors, it is evident that the soybean protein becomes much more accessible in terms of cost than protein of animal origin.

The general carbohydrate mean was 28.33%. The maximum contents was 33.73% for the Mikawashima genotype that was only statistically different from the Tamba Kurodaisu and F83-7977 genotypes that presented minimum values of 25.01% and 25.53%, respectively. Negative correlation was also observed between carbohydrates and protein, except in the Mikawashima genotype that presented high values for both characteristics. Mandarino et al. (1996) obtained similar results in soybean where the cultivars that presented higher protein values also presented lower carbohydrate values. Similar results were reported by Stombaugh et al. (2000), who studied the carbohydrate variation in seeds of 14 soybean genotypes, considering the genotype and environment. The increase in protein and oil, associated with the reduction in the carbohydrate concentration, showed that the correlation between the carbohydrate, protein and oil concentrations was negative for the genotypes studied. The soybean grain tegument is rich in carbohydrates that constitute fibers that help in the digestion of foods and help prevent colon cancer.

The F 82-5782, Mikawashima and Toffumame II genotypes can be used as cultivars and also in breeding programs to solve, with genetic traits, specific nutritional shortage problems. According to Guerra et al. (1999), genetic breeding programs of soybean for human consumption in Brazil are viable both by introduction of Asiatic lines and by incorporating genes for late flowering in short days in these lines.

CONCLUSIONS

There was genetic diversity among the genotypes studied for all the agronomic characteristics assessed.

The F 82-5782 genotype presented yield with large seeds that makes it viable as a cultivar for commercial exploitation.

The Mikawashima genotype presented the highest carbohydrate content, the second highest protein content and the third highest iron content.

The Toffumame II genotype showed the highest P concentration and also was among the six genotypes that presented the highest K, Ca, Mg, S, Zn, Mn and protein contents.

The F 82-5782, Mikawashima and Toffumame II genotypes can be used as cultivars for human consumption or in genetic breeding programs for soybean cultivation as a source of variability.

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RESUMO

Caracterização Agronômica e Química de Genótipos de Soja para Consumo Humano

A soja (*Glycine max* (L) Merrill) apresenta elevado teor de proteínas de alta qualidade, e de lipídios que são constituídos em sua grande maioria por ácidos graxos insaturados. Possui ainda, teores consideráveis de vitaminas do complexo B e minerais como ferro, potássio e magnésio (Carrão-Panizzi, 1987). Além destas boas características nutricionais, a soja para consumo humano deve apresentar sabor adocicado lembrando nozes, sementes (tegumento, hilo e cotilédones) de cor clara e tamanho da semente apropriado ao tipo de alimento (Destro, 1991; Vello, 1992). Esta pesquisa objetivou caracterizar agronômica e quimicamente, genótipos de soja tipo alimento, para posterior uso como cultivar ou em cruzamentos. No estudo foram utilizados 72 genótipos de soja, onde foram avaliados os caracteres agronômicos quantitativos, qualitativos e a análise química dos grãos, que incluiu a composição mineral, o óleo, a proteína, os carboidratos e as cinzas. Os resultados mostraram que houve grande diversidade genética entre os genótipos estudados para todas as características agronômicas avaliadas. Destaque especial deve ser dado para o genótipo F 82-5782, que apresentou produtividade compatível para a sua exploração comercial e tamanho da semente caracterizada como graúda. O genótipo Mikawashima apresentou o maior em carboidratos, enquanto que o genótipo Toffumame II mostrou maior concentração de P e também esteve entre os seis genótipos que apresentaram os maiores valores em K, Ca, Mg, S, Zn, Mn e proteína. Estes genótipos podem ser utilizados como cultivares ou em programas de melhoramento para suprir, com caracteres genéticos, problemas específicos de carência alimentar.

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