Performance of agronomic traits in a soybean F_1 diallel system

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ABSTRACT

The objectives of this research were: a) evaluate heterosis for agronomic traits; b) identify associations among the traits; c) estimate genetic divergence among parents and verify its predictive value of hybrid performance. A 10 x 10 diallel experiment was carried out at two localities. Number of days to flowering (NDF), plant height at flowering (APF), number of days to maturity (NDM), plant height at maturity (APM), oil content (%OL), one-hundred seed weight (PCS), agronomic value (VA) and seed yield (PG) were evaluated. Genotype x locality interaction influenced the analysis; varieties and heterosis effects were significant for most traits. Positive values of heterosis were found for most traits, especially PG. Heterosis for NDF was for earliness. %OL showed to be controlled essentially by additive genes. VA can be used for indirect selection for PG. Parental mean predicted hybrid performance better than Mahalanobis' distance (D^2); however, for some traits, this predicting ability was not sufficiently accurate.

KEY WORDS: Breeding, heterosis, genetic distance, correlations among traits, *glycine max*

INTRODUCTION

Recently, some research has been done with the objective of verifying heterosis occurrence in soybeans. The existence of highly heterotic crosses can serve as an incentive to make possible the use of soybean commercial hybrids. Specifically in soybeans, for the commercial hybrid to become a reality, two requirements are fundamental: the presence of heterosis for seed yield and an economical method of production of hybrid seeds in wide scale (Paschal and Wilcox, 1975).

The manifestation of the heterosis depends on the genetic divergence of the parents and on the type of gene action involved in the control of the trait. The genetic divergence among cultivars can be inferred through the heterotic pattern manifested in a series of crosses. If the heterosis manifested in the cross is high, it is concluded that the two parents are genetically more divergent than two genotypes that manifested small or no heterosis in the cross (Hallauer and Miranda Filho, 1988). Studies with molecular markers and coefficient of parentage have shown that the genetic variability alone is not a good indicative of heterosis (Manjarrez-Sandoval et al., 1997). However, heterosis has been mentioned as a good indication of the genetic diversity (Cerna et al., 1997), and it can be useful in the choice of parents in breeding programs.

Genetic diversity is an important factor for expression of heterosis. Low values of heterosis can result from an accentuated genetic similarity among the cultivated genotypes. In a research by Hiromoto and Vello (1986), it was observed that only 11 ancestors have collectively contributed to 89% of the gene pool of Brazilian soybean cultivars. Besides increasing the genetic variability in adapted genotypes, the establishment of heterotic gene pools is of great importance to increase the heterotic levels. The introduction of germplasm in a gradual and orderly way is equally necessary to increase the genetic variability (Vello et al., 1984).

The values of heterosis in soybeans are very variable for the different agronomic traits of interest, especially for seed yield. Several works have pointed positive heterosis for this trait. Nelson and Bernard (1984) evaluated 27 hybrids and they found five superiors for seed yield, with values between 13 and 19% of heterosis in relation to the superior parent. Positive values of 26.1% on the mean for a group of hybrids with values up to 68% superior to the best parent were obtained by Chaudary and Singh (1974). For plant height, estimates of heterosis are variable but are predominanthy positive (Raut et al., 1985; Freire Filho, 1988). A large number of crosses with heterosis for reduction of the number of days to flowering, or in other words, for earliness, were found (Campos, 1979; Freire Filho, 1988; Nass, 1989). Negative heterosis for number of days to maturity nas also found by Raut et al. (1985). Negative or non-significant heterosis for weight of one hundred seeds has been reported (Chaudary and Singh, 1974; Paschal and Wilcox, 1975; Nelson and Bernard, 1984; Gadag and Upadhyaya, 1995). Agronomic value presented positive (Nass, 1989) and negative (Freire Filho, 1988) values of heterosis. In the first case, probably due to the association of number of seeds and seed yield and, in the second case, due to the high occurrence of diseases, reducing the scores of agronomic value. In relation to oil content, there are few works developed in genotypes adapted to the Brazilian conditions. In cultivars, the oil content typically oscillates between 18 and 22%. Nelson and Bernard (1984) did not find significant values of heterosis in several soybean hybrids in different years. Gadag and Upadhyaya (1995) obtained, among 16 hybrids evaluated for oil percentage, only one with positive heterosis in relation to the parental mean.

Another important parameter in plant breeding is the correlation between traits. Different traits of agronomic importance can be correlated to each other in different magnitudes (Cruz and Regazzi, 1994). The knowledge of correlations allows the plant breeder to use this additional information to discard or to promote the genotypes of interest, mainly through the correlated response to the selection.

The objectives of this work were: a) to evaluate the heterosis for traits of agronomic importance; b) to identify associations among the most important adaptative and agronomic traits; c) to estimate the genetic divergence among the parents, and to verify if it is a good indication of the hybrid performance.

MATERIAL AND METHODS

In the present work, ten soybean genotypes were used as parents, including three cultivars [IAC 100 (1), Hartwig (2) and Conquista (3)], and seven inbred lines. Of these, five lines [USP 1-11 (4), USP 2-16 (5), USP 11-14 (8), USP 5-19 (9), and USP 6-6 (10)] were developed by the Section of Applied Genetics for Autogamous Species of the Department of Genetics of ESALQ/USP. The other two lines [MTBR-95-123800 (6) and MTBR-95-123247 (7)] were originated from the breeding program of EMBRAPA/Fundação Mato Grosso. Except for Hartwig, MTBR-95-123800 and MTBR-95-123247, the studied genotypes are adapted to the conditions of the State of São Paulo. The IAC 100 cultivar presents resistance to insects; the lines USPs and Hartwig have genes for multiple resistance to different races of soybean cyst nematode - NCS (*Heterodora glycines*); MTBR-95-123800, MTBR-95-123247, and Conquista carry genes for long juvenile period or tolerance to photoperiod, high yield and resistance to soybean stem canker (CHS; caused by the fungus *Diaphorthe phaseolorum* f. sp. *meridionalis*).

The experiments were developed at two localities: ESALQ and Anhembi Experimental Station, both located in State of São Paulo, Brazil, South 22°42’30’’ latitude, West 47°39’00’’ longitude and 543 meters above sea level. The area in ESALQ has a high fertile soil (kandiudalfic eutrudox, “terra roxa estruturada eutrófica”), with clay texture, and a hilly relief. In the Anhembi Experimental Station, located about 60 km from the ESALQ, the soil (typic udifluvent, a soil type commonly found in Brazilian savannahs or “cerrados”) is dystrophic alluvial, with acidity neutralized by lime application, and has flat relief.

The F_1 seeds were obtained in 1997/98 in a tropical greenhouse (thin net cover), according to a complete diallel mating system, without reciprocals. In 1998/99, 54 treatments were tested, ten parents and 44 F_1 hybrids, because the cross MTBR-95-123247 x USP6-6 did not produce sufficient seeds. The seeds were placed to germinate in controlled environmental conditions; seedlings were transplanted into plastic cups (200ml volume), containing soil as substratum, and transplanted to the field on the 10th of November 1998. The experiments were conducted in a completely randomized design. Each plot was represented by a hill with one individual plant, spaced by 0.80 m x 0.80 m. This procedure was carried out for all the treatments with the objective of avoiding any loss of hybrid seed. According to seed availability from 12 to 30 plants for each treatment were grown in each place.

Data were collected in individual plants, for the following traits: number of days to flowering (NDF), plant height at flowering (APF), number of days to maturity (NDM), plant height at maturity (APM), oil content (%OL), one-hundred seed weight (PCS), agronomic value (VA, notes from 1 to 5), and seed yield (PG, in g/plant). The exploratory analysis of the data was made in SAS LAB of the SAS program (SAS, 1996). Data transformation was made to correct deviations in relation to normality and homogeneity of variances.

The individual analysis of variance for each place and the joint analysis were developed considering the fixed effects of genotypes and localities. The analysis of the diallel followed the methodology proposed by Gardner and Eberhart (1966), with the following complete model: $Y_{ij} = m + (v_i+v_j) / 2 + q\,(\text{‘}h + h_i + h_j + s_{ij}) + \text{‘}e_{ij}$, where Y_{ij} is the observed mean of a parent or hybrid; $\text{‘}e_{ij}$ is the experimental error; m corresponds to the effect of the general mean of the trait in the diallel; v_i and v_j are effects of the varieties (parents); ‘h is the average heterosis of the trait in the diallel; h_i and h_j are effects of heterosis of the parental varieties i and j; and s_{ij} is the effect of specific heterosis of the cross ij. The variable q assumes the value zero for the parents and the value one for the hybrids. The sums of squares and the parameters of the model were calculated by least squares method, weighted by the number of observations of each treatment.

The comparison of the parental means was done through the test of Tukey at 5% probability and the means of the crosses were tested by the procedure of Scott and Knott (1974) at 5% probability. The genotypic, phenotypic and environmental correlations among traits were obtained through the variance and covariance components, as described by Vencovsky and Barriga (1992).

The estimates of genetic divergence among parents were based on all the eight traits, through Mahalanobis' generalized distance, using the program Genes (Cruz, 1997). The distance is defined by the expression: $D^2_{ij} = d' \, Y^{-1} \, d$, where D^2_{ij} is the distance of Mahalanobis between the parents i and j, d is the vector of the deviations or differences among the means of the parents for each trait, d' is the transposition of this vector and Y^{-1} is the inverse of the matrix of residual variances and covariances among the traits. The grouping analysis was carried out using the calculated distances by the method UPGMA, and was presented as a dendrogram, using the NTSYS program.

RESULTS AND DISCUSSION

In the individual analysis of variance, the mean squares of the genotype effect was significant ($p < 0,05$ or $p < 0,01$) for all traits, indicating presence of variability among the treatments that composed the diallel. In the combined analysis, the effect of localities was equally significant, except for the traits APF and PCS; however, the

Table 1 - Means of the parents for the traits number of days to flowering (NDF), plant height at flowering (APF), number of days to maturity (NDM), plant height at maturity (APM), oil content (%OL), one-hundred seed weight (PCS), agronomic value (VA) and seed yield (PG), 1998/99.

Parents	NDF[1/] days	APF cm	NDM days	APM cm	%OL **%**	PCS **g**	VA **scores 1-5**	PG **g/plant**
ESALQ								
1: IAC-100	64.20 c	47.10 bc	130.20 c	54.50 c	19.35 b	10.87 d	2.40 b	83.48 b
2: Hartwig	45.50 e	28.86 d	112.50 a	31.86 e	22.78 ab	15.81 bc	2.06 b	48.45 c
3: Conquista	65.00 bc	62.82 a	138.09 d	66.73 b	22.80 ab	19.61 a	2.64 ab	86.25 b
4: USP1-11	53.33 d	42.08 c	127.17 bc	85.25 a	23.78 a	17.43 ab	2.92 ab	123.03 ab
5: USP2-16	53.70 d	35.60 cd	123.30 b	74.10 ab	22.80 ab	14.73 c	2.65 ab	114.73 b
6: MTBR-95-123800	72.10 a	63.00 a	154.40 f	70.70 b	21.24 b	14.25 c	3.10 a	134.69 ab
7: MTBR-95-123247	67.82 b	63.11 a	145.82 e	72.55 ab	22.73 ab	17.35 ab	2.86 ab	174.32 a
8: USP11-14	54.25 d	36.00 cd	126.38 bc	41.88 d	23.22 ab	15.98 bc	2.13 b	76.68 bc
9: USP5-19	53.45 d	41.55 c	126.44 bc	75.67 ab	23.77 a	17.08 b	2.73 ab	81.23 b
10: USP6-6	65.44 bc	55.67 ab	134.67 cd	61.33 bc	22.93 ab	14.54 c	2.81 ab	139.41 ab
ANHEMBI								
1: IAC-100	63.80 b	45.20 c	129.90 b	54.20 bc	18.48 c	10.19 e	2.55 b	106.46 bc
2: Hartwig	45.50 d	29.43 d	123.00 a	34.43 d	21.02 b	16.73 bc	1.57 c	57.80 c
3: Conquista	63.56 b	58.11 b	138.56 c	62.00 bc	22.48 ab	20.07 a	2.94 ab	142.96 b
4: USP1-11	53.86 c	43.00 c	126.71 ab	91.50 a	22.62 ab	18.26 ab	2.43 b	115.98 bc
5: USP2-16	53.56 c	39.33 c	123.33 a	76.56 ab	22.16 ab	15.73 bc	2.89 ab	100.90 bc
6: MTBR-95-123800	68.60 a	57.73 b	149.64 e	77.00 ab	21.46 ab	14.80 c	3.50 a	189.20 ab
7: MTBR-95-123247	67.14 ab	70.00 a	143.88 d	82.67 a	23.12 a	17.53 b	3.50 ab	216.63 a
8: USP11-14	55.30 c	37.00 cd	129.00 b	52.00 c	21.60 ab	14.97 c	2.25 b	99.51 bc
9: USP5-19	53.43 c	41.86 c	123.29 a	88.57 a	23.39 a	18.45 ab	2.71 b	87.34 c
10: USP6-6	63.80 b	53.90 bc	129.22 b	65.11 b	21.07 b	12.97 d	2.50 b	107.55 bc

[1/] Means followed by the same letter do not differ by Tukey test at 5% probability.

Table 2 - Means of the hybrids for the traits number of days to flowering (NDF), plant height at flowering (APF), number of days to maturity (NDM), plant height at maturity (APM), oil content (%OL), one-hundred seed weight (PCS), agronomic value (VA) and seed yield (PG), 1998/99.

	ESALQ								ANHEMBI							
F_1	NDF[1/]	APF	NDM	APM	%OL	PCS	VA	PG	NDF	APF	NDM	APM	%OL	PCS	VA	PG
1X2	51.11 f	27.05 d	119.95 b	34.11 e	21.16 d	14.06 d	2.18 c	85.79 c	50.30 f	31.30 f	123.50 a	40.10 e	19.61 b	12.71 g	2.03 d	90.53 d
1X3	65.00 a	47.25 b	134.00 e	54.00 c	21.55 d	14.99 d	2.50 b	121.95 b	62.57 a	52.43 b	135.71 d	62.71 c	21.04 b	13.63 g	3.07 b	168.39 b
1X4	54.50 e	35.75 c	124.88 c	77.88 a	22.39 c	13.98 d	3.06 a	166.23 a	56.00 c	40.13 d	128.75 c	91.50 a	21.57 a	14.26 f	2.56 c	138.71 c
1X5	58.00 c	43.33 c	129.33 e	79.67 a	21.28 d	14.63 d	2.83 a	121.27 b	56.44 c	42.44 d	127.56 b	95.25 a	20.68 b	13.80 g	2.67 c	182.28 b
1X6	62.38 a	45.67 b	129.25 e	54.25 c	21.05 d	13.98 d	2.69 a	152.03 a	59.67 b	42.33 d	129.00 c	56.00 c	21.29 b	14.80 f	2.67 c	165.68 b
1X7	64.89 a	55.22 a	137.00 f	59.22 c	21.82 d	15.41 d	2.94 a	189.14 a	61.78 a	53.33 b	135.25 d	66.63 c	20.41 b	14.88 f	3.00 b	203.81 b
1X8	59.80 c	51.40 b	132.20 e	48.20 c	22.74 c	17.70 c	2.88 a	116.82 b	58.25 c	37.88 e	131.75 c	51.25 d	19.76 b	18.08 d	2.63 c	124.79 c
1X9	58.67 c	41.33 c	126.89 d	63.00 b	22.48 c	15.00 d	2.78 a	125.14 b	56.11 c	37.22 e	126.56 b	85.89 b	22.22 a	15.35 f	3.06 b	133.86 c
1X10	64.45 a	56.15 a	140.26 g	63.00 b	21.20 d	18.12 c	3.26 a	191.48 a	63.94 a	52.88 b	138.93 e	66.41 c	20.10 b	15.87 e	3.63 a	208.58 b
2X3	53.50 e	34.50 d	127.00 d	43.50 d	23.63 a	17.55 c	2.50 b	98.50 c	52.33 d	43.29 d	129.38 c	55.00 d	22.12 a	18.28 d	2.64 c	232.98 a
2X4	49.14 g	31.00 d	119.00 b	62.57 b	23.41 b	14.87 d	2.71 a	137.58 b	48.78 f	34.11 e	124.56 a	74.78 b	22.57 a	15.93 e	2.50 c	176.11 b
2X5	49.00 g	27.86 d	115.86 a	64.57 b	23.23 b	14.54 d	2.79 a	124.73 b	49.71 f	34.57 e	124.14 a	66.71 c	21.88 a	15.65 e	2.50 c	121.66 c
2X6	51.75 f	32.25 d	124.88 c	40.00 e	22.20 c	17.13 c	2.06 c	85.97 c	51.50 e	35.38 e	126.38 b	43.25 e	21.57 a	16.25 e	2.13 d	105.63 d
2X7	54.13 e	40.88 c	129.75 e	45.50 d	23.61 a	17.54 c	2.63 b	137.70 b	52.25 d	36.75 e	129.50 c	50.25 d	22.29 a	16.58 e	2.50 c	141.82 c
2X8	49.44 g	31.06 d	126.12 d	36.12 e	23.15 b	21.36 a	2.09 c	71.36 c	49.81 f	30.63 f	124.69 a	37.63 e	21.77 a	19.43 c	1.91 d	81.80 d
2X9	49.50 g	30.17 d	116.67 a	55.00 c	24.27 a	15.32 d	2.50 b	109.46 c	48.75 f	30.13 f	123.13 a	57.50 c	22.87 a	16.77 e	2.63 c	95.50 d
2X10	52.20 f	30.50 d	127.89 d	36.90 e	23.19 b	19.13 b	2.25 c	74.22 c	51.64 e	36.82 e	128.36 c	42.36 e	22.64 a	19.05 c	2.18 d	96.28 d
3X4	61.89 b	58.14 a	132.56 e	88.33 a	23.43 b	18.82 b	2.89 a	110.64 b	59.13 c	48.43 c	133.14 d	96.43 a	22.53 a	18.70 d	3.00 b	153.02 c
3X5	61.75 b	59.75 a	129.75 e	91.00 a	22.99 b	16.32 c	2.75 a	168.12 a	60.43 b	53.14 b	129.14 c	99.00 a	22.66 a	17.89 d	2.71 c	166.74 b
3X6	64.89 a	53.44 b	140.22 g	57.44 c	21.98 c	18.02 c	2.78 a	141.32 b	62.14 a	46.57 c	137.71 e	58.43 c	21.74 a	17.96 d	3.00 b	164.01 b
3X7	66.22 a	62.22 a	142.44 g	65.22 b	23.05 b	19.80 b	2.89 a	194.06 a	64.88 a	67.63 a	142.25 e	79.11 b	22.35 a	20.07 c	3.69 a	255.81 a
3X8	59.57 c	49.57 b	135.43 f	60.14 c	22.51 c	22.21 a	2.50 b	132.91 b	57.86 c	51.29 c	139.14 e	64.14 c	21.03 b	25.72 a	3.07 b	152.07 c
3X9	59.67 c	53.17 b	131.00 e	86.00 a	22.95 b	18.04 c	2.58 b	147.98 a	56.17 c	50.67 c	130.67 c	62.00 c	22.68 a	20.82 c	2.75 c	191.33 b
3X10	65.29 a	59.50 a	142.71 g	61.57 b	22.57 c	22.82 a	3.00 a	184.45 a	60.57 b	57.86 b	138.71 e	77.57 b	22.16 a	22.24 b	3.71 a	302.11 a
4X5	51.60 f	37.64 c	124.45 c	83.64 a	23.01 b	16.98 c	2.95 a	142.56 b	51.91 e	37.91 e	125.18 a	83.82 b	22.50 a	16.79 e	2.45 c	134.07 c
4X6	56.67 d	50.33 b	131.33 e	86.67 a	24.05 a	16.69 c	2.92 a	153.32 a	55.50 d	47.38 c	134.75 d	91.13 a	22.27 a	16.98 e	3.50 a	182.79 b
4X7	59.00 c	58.18 a	132.50 e	89.45 a	24.09 a	17.15 c	3.14 a	210.72 a	58.85 c	53.85 b	135.25 d	109.08 a	22.83 a	18.36 d	3.46 a	227.28 a
4X8	53.07 e	42.93 c	131.93 e	77.36 a	22.84 b	22.56 a	2.89 a	163.44 a	53.38 d	45.54 c	135.92 d	91.62 a	22.11 a	22.94 b	3.35 a	150.55 c
4X9	51.29 f	38.14 c	123.14 c	73.29 a	25.01 a	18.19 c	2.79 a	116.09 b	51.33 e	44.67 c	126.33 b	95.33 a	23.65 a	21.90 c	3.00 b	155.97 b
4X10	56.12 d	49.60 b	136.35 f	88.06 a	22.34 c	21.02 a	3.06 a	181.33 a	54.92 d	43.54 d	138.15 e	96.85 a	22.61 a	21.55 c	3.62 a	215.57 a
5X6	56.38 d	37.83 c	125.88 d	70.75 b	23.30 b	15.54 d	2.56 b	131.03 b	56.33 c	42.83 d	126.33 b	91.17 a	22.04 a	16.16 e	2.50 c	174.99 b
5X7	59.75 c	52.75 b	132.25 e	87.25 a	23.69 a	17.00 c	3.00 a	199.38 a	59.67 b	49.00 c	132.00 c	81.00 b	22.38 a	17.04 e	3.17 b	165.33 b
5X8	54.17 e	37.00 c	132.00 e	74.67 a	22.59 c	21.59 a	3.00 a	154.11 a	54.00 d	42.33 d	131.83 c	91.50 a	21.72 a	21.08 c	3.17 b	201.73 b
5X9	53.33 e	38.30 c	123.64 c	77.42 a	24.02 a	15.91 d	2.75 a	106.64 b	54.20 d	48.13 c	126.60 b	101.40 a	22.03 a	17.51 d	2.40 c	175.77 b
5X10	58.00 c	54.83 a	133.83 e	86.50 a	22.63 c	19.18 b	3.17 a	200.66 a	57.57 c	46.43 c	134.86 d	98.29 a	21.63 a	20.55 c	3.57 a	198.60 b
6X7	64.80 a	57.22 a	138.40 f	65.10 b	22.91 b	17.78 c	3.20 a	232.47 a	63.44 a	58.63 b	136.67 d	70.38 c	21.79 a	16.82 e	3.56 a	258.04 a
6X8	60.75 b	47.25 b	135.75 f	48.00 c	21.71 d	23.43 a	2.50 b	143.88 b	62.83 a	41.40 d	134.83 d	50.00 d	20.34 b	20.68 c	2.67 c	145.46 c
6X9	56.50 d	43.83 c	130.17 e	80.50 a	23.28 b	16.53 c	2.75 a	189.92 a	53.20 d	45.50 c	129.33 c	94.83 a	22.57 a	16.99 e	2.92 b	186.44 b
6X10	63.45 a	56.73 a	135.00 f	57.36 c	22.86 b	20.12 b	2.82 a	172.07 a	60.50 b	49.80 c	131.67 c	62.00 c	21.56 a	18.31 d	2.83 c	173.50 b
7X8	62.44 a	57.56 a	142.33 g	62.33 b	22.37 c	21.74 a	3.11 a	180.48 a	62.38 a	56.25 b	141.00 e	65.75 c	20.54 b	21.52 c	3.44 a	215.86 a
7X9	59.14 c	54.17 a	135.43 f	86.17 a	22.85 b	19.68 b	2.64 b	167.81 a	60.71 b	56.33 b	136.29 d	105.14 a	22.56 a	21.49 c	3.36 a	224.96 a
8X9	52.33 f	39.00 c	130.83 e	66.50 b	22.25 c	23.35 a	3.00 a	146.76 b	53.83 d	47.17 c	130.83 c	91.00 a	22.34 a	24.77 a	3.00 b	166.40 b
8X10	61.31 b	52.31 b	132.62 e	54.69 c	24.09 a	16.40 c	2.65 b	190.74 a	57.73 c	46.55 c	130.70 c	65.64 c	21.87 a	18.45 d	2.86 c	184.41 b
9X10	55.30 d	43.90 c	132.60 e	76.22 a	23.93 a	21.73 a	2.95 a	160.82 a	57.00 c	49.78 c	137.50 e	105.33 a	22.93 a	22.63 b	3.35 a	194.24 b

[1/] Means followed by the same letter do not differ by the test of Scott-Knott at 5% probability.

effect of the genotype x locality interaction was not significant for the trait %OL. The differential performance showed by most of the traits indicated the need to consider the specific locality when studying genetic parameters.

Study of the means

The parental means formed different groups for all the traits, by the Tukey test at 5% of probability (Table 1). The earliest genotype was Hartwig, for flowering and maturity, mainly in ESALQ. MTBR-95-123800 was the latest genotype in the two localities. Hartwig was also the genotype with smaller APF and APM, which can be explained by the lack of adaptation of this cultivar. On the other hand, USP 1-11 (ESALQ), MTBR-95-123247 (ESALQ and Anhembi) and Conquista (Anhembi) were the tallest genotypes. USP 1-11 has indeterminate growing habit, while MTBR-95-123247 and Conquista present genes for photoperiod tolerance, being adapted to areas of low latitude. These factors can explain their largest plant height.

For %OL, the means ranged from 18.48% (Anhembi) to 23.78% (ESALQ); the USP 1-11 and USP 5-19 parents exhibited the largest means, while IAC 100 had the smallest means in the two localities. It is interesting to observe that some parents have presented values for %OL superior to 22%, while in current cultivars the oil content has varied between 18 and 22%, with general mean around 20%. Restricted variability for oil content exists in the genus *Glycine*, which is pointed out as the main difficulty in obtaining genetic gains for this trait (Guangyu, 1993). Because of this, the use of induced mutations has been recommended to increase the variability for %OL (Mehetre, 1996).

PCS ranged from 10.19g to 20.07g; the cultivar Conquista presented the largest seed size in the two localities, while IAC 100 presented the lowest value for PCS. Low values of PCS and %OL are expected in cultivars with insect tolerance (Pinheiro, 1993). For VA, the means varied from 1.57 to 3.50, with the line MTBR-95-123800 being the best parent. For PG, there was wide variation among the parents from approximately 48 to 174g/plant in ESALQ, while this variation was from 58 to 217g/plant in Anhembi. The genotype MTBR-95-123247 showed superiority in relation to the other parents in both localities.

The parent Hartwig showed low values for most of the traits. This can be explained by the lack of adaptation of this cultivar to local conditions. It was chosen as parent because of its genes for multiple resistance to several races of soybean cyst nematodes (Anand, 1992).

The use of the Scott-Knott test for comparison of means among the F_1 hybrids (Table 2) allowed their partition in groups without overlapping to facilitate the understanding and the visualization of the best combinations. In earliness terms, the best crosses were IAC 100 x Hartwig (1 x 2), Hartwig x USP 2-16 (2 x 5), and Hartwig x USP 11-14 (2 x 8), in both localities. For APF and APM, the cross Conquista x USP 2-16 (2 x 5) presented the tallest plants in the two localities.

For %OL, four groups were formed in ESALQ and only two in Anhembi. The best cross was USP 1-11 x USP 5-19 (4 x 9), with 25.01% of oil in ESALQ and 23.65% in Anhembi. It is interesting to consider that the two parents of this cross have also showed the highest %OL among the parents.

The trait PCS presented wide variation, with the largest seed size occurring in the crosses Conquista x USP 11-14 (3 x 8) in Anhembi, USP 11-14 x USP 5-19 (8 x 9) in ESALQ and Anhembi, and MTBR-95-123800 x USP 11-14 (6 x 8) in ESALQ. For VA, the following crosses showed the best plants: Conquista x MTBR-95-123247 (3 x 7) and Conquista x USP 6-6 (3 x 10), in Anhembi; IAC 100 x USP 6-6 (1 x 10), USP 2-16 x USP 6-6 (5 x 10) and MTBR-95-123800 x MTBR-95-123247 (6 x 7), in both localities. It is interesting to notice that the crosses with the highest scores for agronomic value were also among the highest yielding, standing out Conquista x USP 6-6 (3 x 10) in Anhembi, USP 1-11 x MTBR-95-123247 (4 x 7) in ESALQ and MTBR-95-123800 x MTBR-95-123247 (6 x 7) in the two localities. Still observing Table 2, it can be verified that the locality Anhembi presented the highest values and the best discrimination of the hybrids, due to the formation of different groups for most of the traits. %OL was an exception whith values slightly inferior to those obtained in ESALQ. This last fact is evidence of positive specific interaction with ESALQ for oil content.

Heterosis

The heterosis of the hybrids in relation to the mean of the superior parent (HGS) and to the parental mean (HMG) are presented in Tables 4 and 5 respectively for ESALQ and Anhembi. For NDF, there was heterosis in the sense of reduction of the trait (earliness), and lower values were presented by hybrids 13 and 16 respectively than the parent mean, in ESALQ and in Anhembi. Even for the hybrids with significant values, the heterosis was of low magnitude, with the maximum of 12% in relation to the parental mean. In Brazil, selection of genotypes with determinate growth habit and tolerance to photoperiod has been accomplished in order to facilitate the adaptation of soybeans to low (< 15^0) latitudes (Kiihl and Almeida, 2000), thus reducing the variation for NDF. For the trait NDM, there were crosses significantly superior and inferior to the parental mean, however no one was later than the latest parent.

The presence of dominance in the sense of the reduction of vegetative and reproductive periods in soybeans has been reported by several authors, including works with Brazilian genotypes (Campos, 1979; Freire Filho, 1988; Nass, 1989; Bonato and Vello, 1999). Similar results were obtained for the traits APF and NDM. Seven hybrids with significantly lower values and 12 with higher values than the parental mean were detected for APM in ESALQ, while in Anhembi there were three inferior and 19 superior to the APM parental mean. In the two localities there was a small number of hybrids with positive heterosis in relation to the superior parent. Most of the parents presented means under 80 cm for APM. This result can be considered satisfactory if compared with the minimum limit of 60cm of APM for commercial crops, where density of plants is higher. Hence, crosses with APM similar to the parents can be considered adequate in the experimental conditions of this study.

For oil content, almost all the crosses did not differ statistically from the parental mean. This indicated that the trait is controlled predominantly

Table 3 - Percentage of heterosis in relation to the superior parent (HGS) and to parental mean (HMG) for the traits number of days to flowering (NDF), plant height at flowering (APF), number of days to maturity (NDM), plant height at maturity (APM), oil content (%OL), one-hundred seed weight (PCS), agronomic value (VA) and seed yield (PG), 1998/99.

	NDfF(Days)		APF (cm)		NDM (days)		APM (cm)		%OL (%)		PCS (g)		VA (scores 1 a5)		PG (g/plant)	
F_1	HGS	HMG	HGS	HMG	HGS	HMG	HGS	HMG	HGS	HMG	HGS	HMG	HGS	HMG	HGS	HMG
1X2	-20.40 *	-6.83 *	-42.56 *	-28.77 *	-7.87 *	-1.16	-37.42 *	-21.01 *	-7.13 *	0.45	-11.04	5.44 *	-8.99	-2.11	2.76	30.05 *
1X3	0.00	0.62	-24.78 *	-14.03	-2.96	-0.11	-19.07 *	-10.91	-5.48	2.27	-23.57 *	-1.64	-5.17	-0.72	41.38 *	43.69 *
1X4	-15.11 *	-7.26 *	-24.10 *	-19.83 *	-4.09 *	-2.96 *	-8.65 *	11.45 *	-5.86 *	3.83	-19.80 *	-1.20	5.00	15.20 *	35.12 *	61.00 *
1X5	-9.66 *	-1.61	-8.00	4.80	-0.67	2.04	7.51 *	23.90 *	-6.68	0.97	-0.65	14.34	6.92	12.21	5.70	22.37
1X6	-13.49 *	-8.47 *	-27.51 *	-17.05 *	-16.29 *	-9.17	-23.27 *	-13.34 *	-0.92	3.71	-1.91	11.31 *	-13.31 *	-2.27	12.87	39.36 *
1X7	-4.32 *	-1.70	-12.50 *	0.21	-6.05 *	-0.73 *	-18.37 *	-6.77	-4.02	3.71	-11.19 *	9.22 *	2.82	11.88	8.50	46.73 *
1X8	-6.85 *	0.97	9.13	23.71 *	1.54	3.05	-11.56	0.03	-2.06	6.85 *	10.75	31.85 *	19.79 *	27.07 *	39.94 *	45.88 *
1X9	-8.62 *	-0.27	-12.24	-6.74	-2.54	-1.12	-16.74 *	-3.20	-5.45	4.26	-12.16 *	7.37	1.85	8.35	49.90 *	51.95 *
1X10	-1.52	-0.57	0.87	9.28	4.16 *	5.91 *	2.72	8.78	-7.54 *	0.29	24.61 *	42.64 *	16.02	25.21 *	37.35 *	71.81 *
2X3	17.58 *	-3.17	-45.08 *	-24.73 *	-8.03 *	1.36	-34.81 *	-11.75	3.66	3.70	-10.46 *	-0.87	-5.17	6.41	14.20	46.25 *
2X4	-7.86 *	-0.55	-26.34 *	-12.60	-6.42 *	-0.70	-26.60 *	6.86 *	-1.59	0.53	-14.70 *	-10.55 *	-6.94	9.03	11.83	60.46 *
2X5	7.69 *	-1.21	-21.75 *	-13.56	-6.04 *	-1.73	-12.86 *	21.88 *	1.91	1.95	-8.01	-4.74	5.12	18.23	8.72	52.88 *
2X6	-28.22 *	-11.99 *	-48.81 *	-29.78 *	-19.12 *	-6.43 *	-43.42 *	-21.99 *	-2.54	0.87	8.33	13.94 *	-33.47 *	-20.10 *	-36.17 *	-6.12
2X7	-20.19 *	-4.47	-35.23 *	-11.11	-11.02 *	0.46	-37.28 *	-12.84	3.61	3.72	1.11	5.81	-8.33	6.57	-21.01 *	23.62 *
2X8	-8.87 *	-0.88	-13.73 *	-4.22	-0.20	5.59 *	-13.75 *	-2.03	-0.29	0.66	33.64 *	34.36 *	-1.73	-0.26	-6.95	14.05
2X9	-7.40 *	0.05	-27.39 *	-14.30	-7.73 *	-2.35	-27.31 *	2.30	2.09	4.26	-10.34 *	-6.87	-8.33	4.39	34.75 *	68.81 *
2X10	-20.24 *	-5.90	-45.21 *	-27.83 *	-5.03 *	3.48 *	-39.84 *	-20.81 *	1.17	1.48	20.99 *	26.05 *	-20.00 *	-7.69	-46.76 *	-20.98
3X4	-4.79 *	4.60 *	-7.44	10.85 *	-4.01 *	-0.06	3.62	16.25	-1.47	0.61	-3.98	1.67	-0.95	4.05	-10.06	5.74
3X5	-5.00 *	4.04	-4.88	21.42 *	-6.04 *	-0.72	22.81 *	29.24 *	0.83	0.83	-16.78 *	-4.94 *	3.77	4.04	46.54 *	67.30 *
3X6	-10.00 *	-5.34 *	-15.17 *	-15.04 *	-9.18 *	-4.12 *	-18.75 *	-16.40 *	-3.61	-0.20	-8.08 *	6.46	-10.39	-3.15	4.92	27.93 *
3X7	-2.35	-0.28	-1.41	-1.18	-2.31	0.35	-10.09	-6.34	1.07	1.22	0.98	7.13	0.88	5.05	11.32	48.95 *
3X8	-8.35 *	-0.09	-21.09 *	0.33	-1.93	2.42	-9.87	10.76	-3.05	-2.17	13.31 *	24.84 *	-5.17	5.01	54.09 *	63.14 *
3X9	-8.21 *	0.74	-15.36	1.89	-5.13 *	-0.96	13.66	20.79 *	-3.46	-1.44	-8.00 *	-1.67	-5.28	-3.67	71.57 *	76.71 *
3X10	-0.24	0.10	-5.28	0.43	3.35	4.65	-7.73	-3.84	-1.53	-1.26	16.41 *	33.67 *	6.67	10.11	32.31 *	63.48 *
4X5	-3.91 *	-3.58 *	-10.57	-3.10	-2.13	-0.62	-1.89	4.97	-3.24	-1.20	-2.57	5.62	1.30	6.15	15.88	19.92
4X6	-21.41 *	-9.65 *	-20.11 *	-4.20	-14.94 *	-6.71 *	1.66	11.15	1.12	6.83 *	-4.25	5.35 *	-5.91	-3.05	13.83	18.98
4X7	-13.00 *	-2.60	-7.81	10.62 *	-9.13 *	-2.93 *	4.93	13.38	1.28	3.56	-1.60	-1.38	7.53	8.52	20.88	41.73 *
4X8	-2.17	-1.34	2.01	9.96 *	3.74 *	4.07 *	-9.26 *	21.70 *	-3.99	-2.83	29.47 *	35.06 *	-0.82	14.76 *	32.8 *	63.68 *
4X9	-4.06 *	-3.95	-9.36	-8.78	-3.16 *	-2.89 *	-14.03 *	-8.91	5.13 *	5.15 *	4.37	5.41	-4.49	-1.28	-5.64	13.67
4X10	-14.25 *	-5.51 *	-10.90 *	1.48	1.25	4.15 *	3.29	20.15 *	-6.08 *	-4.36	20.62 *	31.51 *	4.87	6.78	30.07 *	38.19 *
5X6	-21.81 *	-10.37 *	-39.95 *	-23.26 *	-18.47 *	-9.34 *	-4.52	-2.28	2.19	5.80 *	5.53	7.26	-17.34 *	-10.87	-2.71	5.07
5X7	-11.90 *	-1.66	-16.42 *	6.88	-9.30 *	-1.72	17.75 *	18.99 *	3.91	4.06	-2.04	5.98	4.76	8.82	14.37	37.95 *
5X8	-0.15	0.36	2.78	3.35	4.45 *	5.74 *	0.76	28.76 *	-2.72	-1.83	35.11 *	40.64 *	13.21	25.65 *	34.32 *	61.02 *
5X9	-0.68	-0.46	-7.81	-0.71	-2.22	-0.99	2.31	3.38	1.05	3.17	-6.83	0.07	0.83	2.28	-7.05	8.84
5X10	-11.38 *	-2.64	-1.50	20.16 *	-0.62	3.76 *	16.73 *	27.74 *	-1.30	-1.03	30.24 *	31.06 *	12.59	15.94 *	43.93 *	57.91 *
6X7	-10.12 *	-7.37 *	-9.33	-9.25	-10.36 *	-7.80 *	-10.2	-9.11	0.79	4.21	2.45	12.50 *	3.23	7.32	33.35 *	50.46 *
6X8	-15.74 *	-3.84	-25.00 *	-4.55	-12.08 *	-3.30	-32.11 *	-14.72 *	-6.49	-2.34	46.57 *	54.96 *	-19.35 *	-4.31	6.82	36.13 *
6X9	-21.64 *	-10.00 *	-30.42 *	-16.14	-15.70 *	-7.30	6.39	10.00	-2.06	3.45	-3.20	5.54	-11.29	-5.62	41.00 *	75.91 *
6X10	-11.99 *	-7.73 *	-9.96 *	-4.39	-12.56 *	-6.60	-18.86 *	-13.11 *	-0.31	3.49	38.37 *	39.76 *	-9.09 *	-4.67	23.43	25.55
7X8	-7.92 *	2.31	-8.80 *	16.14	-2.39	4.58	-14.08 *	8.95 *	-3.67	-2.66	25.28 *	30.42 *	8.64	24.73	3.53	43.81 *
7X9	-12.79 *	-2.46	-14.17 *	3.51	-7.13 *	-0.52	13.88 *	16.27	-3.87	-1.72	15.22 *	14.31 *	-7.71	-5.46	-3.74	31.33 *
8X9	-3.53	-2.82	-6.13	0.59	3.47	3.50	-12.11	13.15	-6.43	-5.32	36.69 *	41.23 *	10.00	23.65	80.67 *	85.87 *
8X10	-6.32 *	2.44	-6.03	14.13 *	-1.52	1.60	-10.83	5.98	3.77	4.42	2.64	7.49	-5.64	7.50	36.82 *	76.53 *
9X10	-15.50 *	-6.98 *	-21.14 *	-9.68	-1.53	1.57	0.73	11.27	0.67	2.50	27.21 *	37.43 *	4.89	6.50	15.36	45.77 *

* significant at 5% probability by the t test.

by genes with additive effect. Similar results have been obtained by other authors (Nelson and Bernard, 1984; Gadag and Upadhyaya, 1995). PCS presented about half of the crosses with positive heterosis in relation to the parental mean. The cross MTBR-95-123800 x USP 11-14 (6 x 8) stood out in both localities, with heterosis of 46.57% in ESALQ and 38.09% in Anhembi, in relation to the superior parent. For VA, eight and fifteen hybrids showed positive heterosis in relation to the parental mean, respectively in ESALQ and Anhembi. Only the cross IAC 100 x USP 6-6 (1 x 10) was superior to the best parent in the two localities.

For PG, most of the crosses (33 in ESALQ and 26 in Anhembi) were superior to the parental mean. There were 18 hybrids in ESALQ and 17 in Anhembi with positive heterosis in relation to the superior parent. The trait PG presented the most expressive values of heterosis among the studied traits, with positive values in relation to the superior parent of up to 111.33% (Table 3).

In general, there was heterosis for almost all traits in different magnitudes, with positive or negative values, indicating the contribution of genes with non-additive effects. Heterosis for seed yield was positive and the most expressive values. This fact together with the positive values previously obtained by other authors (Kunta et al., 1985; Raut et al. 1985; Nass, 1989; Moro, 1990) can justify the future use of commercial hybrids in soybeans.

Diallel analysis

The mean squares of the analysis of variance of the diallel, model 4 of Gardner and Eberhart (Table 4), obtained individually by locality, were significant for the effects of varieties and heterosis, except for the heterosis effect of %OL in Anhembi. However, for %OL in ESALQ only the average heterosis was not significant, while in Anhembi, the average and specific heterosis were significant. The average heterosis was not significant for APF, NDM, APM and VA in

Table 4 - Percentage of heterosis in relation to the superior parent (HGS) and to parental mean (HMG) for the traits number of days to flowering (NDF), plant height at flowering (APF), number of days to maturity (NDM), plant height at maturity (APM), oil content (%OL), one-hundred seed weight (PCS), agronomic value (VA) and seed yield (PG), 1998/99.

	NDF (days)		APF (cm)		NDM (days)		APM (cm)		%OL (%)		PCS (g)		VA (scores 1 to 5)		PG (g/plant)	
F_1	HGS	HMG	HGS	HMG	HGS	HMG	HGS	HMG	HGS	HMG	HGS	HMG	HGS	HMG	HGS	HMG
1X2	-21.16 *	-7.96 *	-30.75 *	-16.12 *	-4.93 *	-2.33	-26.01 *	-9.51	-6.71 *	-0.71	-24.06 *	-5.59	-20.59 *	-1.73	-14.96	10.22
1X3	-1.93	-1.74	-9.78	1.50	-2.05	1.11	1.15	7.94	-6.42	2.72	-32.07 *	-9.89	4.31	11.80	17.79	35.03 *
1X4	-12.23 *	-4.81 *	-11.23	-9.01	-0.89	0.35	0.00	25.60 *	-4.68	4.92	-21.90 *	0.27	0.49	2.94	19.60	24.72
1X5	-11.53 *	-3.81	-6.10	0.42	-1.80	0.74	24.42 *	45.69 *	-6.65 *	1.79	-12.28 *	6.50 *	-7.69	-1.94	71.23 *	75.82 *
1X6	-13.02 *	-9.87 *	-26.67 *	-17.74 *	-13.79 *	-7.70 *	-27.27 *	-14.63 *	-0.77	6.63 *	0.02	18.48 *	-23.81 *	-11.85	-12.43	12.08
1X7	-7.99 *	-5.64 *	-23.81 *	-7.41	-5.99 *	-1.20	-19.41 *	-2.64	-11.74 *	-1.90	-15.09 *	7.41 *	-14.29 *	-0.83	-5.92	26.16 *
1X8	-8.70 *	-2.18	-16.21 *	-7.85	1.42	1.78 *	-5.44	-3.48	-8.51	-1.40	20.76 *	43.74 *	2.94	9.38	17.23	21.18
1X9	-12.05 *	-4.27 *	-17.65 *	-14.49 *	-2.57	-0.03	-3.03	20.32 *	-5.03	6.11	-16.83 *	7.18 *	12.57	16.09	25.74 *	38.14
1X10	0.22	0.22	-1.89	6.73	6.95 *	7.23 *	2.00	11.33 *	-4.59	1.65	22.38 *	37.09 *	42.16 *	43.56 *	93.95 *	94.94 *
2X3	-17.66 *	-4.02	-25.51 *	-1.11	-6.63 *	-1.07	-11.29	14.07	-1.61	1.69	-8.91	-0.66	-10.24	17.05	62.98 *	132.10 *
2X4	-9.43 *	-1.81	-20.67*	-5.81	-1.70	-0.24	-18.28 *	18.76 *	-0.23	3.44	-12.74 *	-8.93 *	2.94	25.00 *	51.85 *	102.68 *
2X5	-7.17 *	0.38	-12.11	0.55	0.66	0.79	-12.86	20.22 *	-1.24	1.36	-6.47 *	-3.60	-13.46 *	12.10	20.58 *	53.32 *
2X6	-24.93 *	-9.73 *	-38.72 *	-18.82 *	-15.55 *	-7.29 *	-43.83 *	-22.37 *	0.51	1.54	-2.87	3.10	-39.29 *	-16.20 *	-44.17 *	-14.47
2X7	-22.18 *	-7.23 *	-47.50 *	-26.08 *	-9.99 *	-2.95 *	-39.21 *	-14.17	-3.59	1.00	-5.43	-3.23	-28.57 *	-1.41	-34.54 *	3.35
2X8	-9.92 *	-1.17	-17.23 *	-7.80	-3.34 *	-1.04	-27.64 *	-12.93	0.78	2.15	16.14 *	22.58 *	-15.28	-0.23	-17.79	4.00
2X9	-8.76 *	-1.44	-28.03 *	-15.48 *	-0.13	-0.01	-35.08 *	-6.50	-2.23	2.99	-9.11 *	-4.67	-3.29	22.50 *	9.34	31.59 *
2X10	-19.07 *	-5.51	-31.69 *	-11.63	-0.66	1.79	-34.94 *	-14.88	7.49 *	7.60	13.85 *	28.28 *	-12.73	7.18	-10.47	16.46
3X4	9.78 *	0.71	-16.66	-4.21	-3.91 *	0.38	5.39	25.64 *	-0.40	-0.08	-6.81	-2.42	1.89	11.67	7.04	18.19
3X5	-4.92 *	3.20	-8.55	9.07	-6.79 *	-1.38	29.32 *	42.90 *	0.81	1.55	-10.82	-0.03	-7.82	-6.94	16.64	36.76 *
3X6	-9.41 *	-5.95 *	-19.86 *	-19.59 *	-7.97 *	-4.43 *	-24.12 *	-15.93	-3.32	-1.07	-10.49 *	3.04	-14.29 *	-6.90	-13.31	-1.25
3X7	-3.38	-0.73	-3.39	5.57	-1.13	0.73	-4.30	9.37	-3.35	-1.99	0.02	6.76	5.36	14.44	18.08	42.28 *
3X8	-8.97 *	-2.64	-11.75	7.84	0.42	4.01 *	3.46	12.53	-6.45	-4.57	28.20 *	46.83 *	4.31	18.26 *	6.38	25.44
3X9	-11.63 *	-3.98	-12.81	1.37	-5.69 *	-0.19	-30.00 *	-17.65	-3.05	-1.13	3.76	8.11 *	-6.60	-2.81	33.84 *	66.16 *
3X10	-5.06	-4.88	-0.44	3.31	0.11	3.60 *	19.14 *	22.05	-1.43	1.77	10.85 *	34.66 *	26.15 *	36.44 *	111.33 *	141.21 *
4X5	-3.62	-3.35 *	-11.84	-7.91	-1.21	0.13	-8.40	-0.25	-0.55	0.49	-8.04	-1.21	-15.03	-7.68	15.60	23.63
4X6	-19.10 *	-9.36 *	-17.93 *	-5.93	-9.95 *	-2.48	-0.41	8.16	-1.55	1.06	-7.00	2.74	0.00	18.07 *	-3.39	19.79 *
4X7	-12.36 *	-2.73	-23.08 *	-4.70	-5.99 *	-0.03	19.22 *	25.26 *	-1.27	-0.19	0.54	2.60	-1.10	16.77 *	4.91	36.66 *
4X8	-3.46	-2.19	5.90	13.85 *	5.37 *	6.31 *	0.13	27.69 *	-2.27	0.00	25.61 *	38.03 *	37.78 *	43.04 *	29.81 *	39.73 *
4X9	-4.69 *	-4.31 *	3.88	5.27	-0.30	1.07	4.19	5.88	1.10	2.79	18.70 *	19.32 *	10.53	16.67	34.48 *	53.43 *
4X10	-13.91 *	-6.64 *	-19.22 *	-10.14	6.91 *	7.96 *	5.84	23.68 *	-0.05	3.52	18.02 *	38.02 *	44.62 *	46.71 *	85.87 *	92.88 *
5X6	-17.88 *	-7.77 *	-25.80 *	-11.74	-15.57 *	-7.44 *	18.40 *	18.74 *	-0.55	1.04	2.67	5.82 *	-28.57 *	-21.74 *	-7.51	20.64
5X7	-11.13 *	-1.13	-30.00 *	-10.37	-8.25 *	-1.20	-2.02	1.74	-3.22	-1.16	-2.81	2.43	-9.52	-0.87	-23.68 *	4.14
5X8	-2.35	-0.79	7.63	10.92	2.20	4.49 *	19.52 *	42.35 *	-1.96	-0.71	33.99 *	37.31 *	9.62	23.24 *	99.93 *	101.32 *
5X9	1.20	1.32	14.97	18.55 *	2.65	2.67 *	14.48	22.81 *	-5.84	-3.29	-5.12	2.43	-16.92	-14.33	74.20 *	86.75 *
5X10	-9.76 *	-1.89	-13.86 *	-0.40	4.36 *	6.79 *	28.38 *	38.76 *	-2.38	0.08	30.58 *	43.16 *	23.63 *	32.55 *	84.66 *	90.55 *
6X7	-7.52 *	-6.52 *	-16.25 *	-8.20	-8.67 *	-6.87 *	-14.87 *	-11.85	-5.77 *	-2.25	-4.07	4.03	1.79	1.79	19.11	27.16
6X8	-8.41 *	1.43	-28.28 *	-12.59	-9.89 *	-3.22 *	-35.06 *	-22.48 *	-5.83	-5.53	38.09 *	38.91 *	-23.81 *	-7.25	-23.12 *	0.77
6X9	-22.45 *	-12.81*	-21.18 *	-8.62	-13.57 *	-5.22 *	7.07	14.55 *	-3.50	0.66	-7.93 *	2.19	-16.67 *	-6.13	-1.46	34.84 *
6X10	-11.81 *	-8.61 *	-13.73 *	-10.77	-12.01 *	-5.57 *	-19.48 *	-12.74	0.49	1.41	23.75 *	31.90 *	-19.05 *	-5.56	-8.30	16.94
7X8	-7.10 *	1.88	-19.64 *	5.14	-2.00	3.34 *	-20.46 *	-2.35	-11.18 *	-8.15 *	22.76 *	32.40 *	-1.79	19.57 *	-0.36	36.56 *
7X9	-9.57 *	0.71	-19.52 *	0.72	-5.27 *	2.03	18.71 *	22.80 *	-3.54	-2.98	16.46 *	19.44 *	-4.08	8.05	3.84	48.01 *
8X9	-2.65	-0.98	12.68	19.63 *	1.42	3.72 *	2.74	29.47 *	-4.51	-0.70	34.22 *	48.18 *	10.53	20.86 *	67.22 *	78.11 *
8X10	-9.52 *	-3.06	-13.64	2.41	1.14	1.23	0.81	12.09	1.28	2.55	23.24 *	32.09 *	14.55	20.57 *	71.47 *	78.12 *
9X10	-10.66 *	-2.75	-7.65	3.97	6.41 *	8.91 *	18.92 *	37.08 *	-1.96	3.17	22.67*	44.07 *	23.42 *	28.49 *	80.61 *	99.33 *

*Significant at 5% probability by the t test.

ESALQ nor for NDM and APM in Anhembi. For PG, in Anhembi, the specific heterosis was not significant.

The significance of the mean squares associated to the effects of varieties and of heterosis (Table 4) evidenced that the varieties did not constitute a homogeneous group and that there is manifestation of the heterosis in the crosses. The results showed that additive and dominance effects were important in the manifestation of the traits. For the trait %OL (Anhembi), the heterosis effects were not significant, indicating that in this locality the additive effects were the most important. This is in agreement with the non significant estimates of HMG for most of the crosses (Table 3).

Significance for heterosis of varieties and specific heterosis indicated that the heterosis was not the same to all the varieties and that each cross had a different heterotic effect, as in the previous report of Vencovsky and Barriga (1992). When the average heterosis is not significant and heterosis of varieties and specific heterosis are, as observed for several traits (Table 4), the occurrence of non directional dominance, i - e, positive in some loci and negative in others, and the existence of non directional epistatic effects are suggested (Vencovsky, 1970).

The trait %OL showed significance for average and specific heterosis in ESALQ (Table 4), while the variety heterosis was non significant, indicating existence of variation among crosses. On the other hand in Anhembi, significance was detected only for heterosis of varieties, indicating tendency of each parent to have a particular heterotic value for %OL. The interaction of these effects with localities is certainly responsible for the differences observed between ESALQ and Anhembi, for oil content.

Table 5 shows the estimates of parameters for each trait. The effect of varieties (v_i) that indicates the potential of each parent for use *per se* showed the most favorable parents, in the two localities: MTBR-95-123800 (v_6) and MTBR-95-123247 (v_7) with larger values of NDF, APF, VA and PG;

Hartwig (v_2) and USP 2-16 (v_5) with the earliest cycle; USP 1-11 (v_4) and USP 5-19 (v_9) with the highest values of APM and %OL.

The average heterosis (‘h) attributed to the group of crosses of the diallel, indicated the presence of differences in gene frequencies among parents, at least in part of the loci showing dominance. Most of the estimates of average heterosis occurred in the favorable sense of expression of the traits, in the two localities; the only exception was for APF, with negative values in the two localities (Table 5). The variety

Table 5 - Estimates of the parameters mean (m), variety effect (v_i), average heterosis ($\bar{h}$) and variety heterosis (h_i) for the traits number of days to flowering (NDF), plant height at flowering (APF), number of days to maturity (NDM), plant height at maturity (APM), oil content (%OL), one-hundred seed weight (PCS), agronomic value (VA) and seed yield (PG), 1998/99.

Effects	NDF days	APF cm	NDM days	APM cm	%OL %	PCS g	VA scores 1-5	PG g/plant
ESALQ								
m	59.480	47.578	131.896	63.455	22.443	15.764	2.629	106.228
v_1	4.720	-0.478	-1.696	-8.955	-3.098	-4.898	-0.229	-22.748
v_2	-13.980	-18.721	-19.396	-31.598	0.339	0.046	-0.567	-57.779
v_3	5.520	15.240	6.195	3.272	0.357	3.841	0.007	-19.977
v_4	-6.147	-5.495	-4.730	21.795	1.341	1.663	0.287	16.799
v_5	-5.780	-11.978	-8.596	10.645	0.355	-1.039	0.021	8.499
v_6	12.620	15.422	22.504	7.245	-1.200	-1.513	0.471	28.462
v_7	8.338	15.533	13.922	9.090	0.291	1.587	0.234	68.097
v_8	-5.230	-11.578	-5.521	-21.580	-0.198	0.218	-0.504	-29.543
v_9	-6.026	-6.033	-5.452	12.211	1.331	1.317	0.098	-24.997
v_{10}	5.964	8.088	2.770	-2.122	0.482	-1.222	0.183	33.186
$\bar{h}$	-2.919	-3.461	-2.408	6.194	0.397	2.152	0.047	32.063
h_1	1.357	1.001	1.894	-7.213	0.311	-0.473	0.244	14.527
h_2	0.948	-5.274	2.756	-11.741	0.134	-1.418	-0.016	-12.601
h_3	3.331	2.441	3.118	-4.090	-0.290	-1.004	0.034	16.903
h_4	1.102	3.330	1.208	1.652	-0.045	-0.955	0.146	8.763
h_5	2.006	5.018	1.998	5.755	-0.031	-0.674	0.204	8.736
h_6	-2.746	-4.273	-8.067	-11.968	0.322	0.503	-0.212	5.441
h_7	-4.982	-4.637	-7.778	15.486	-0.161	-0.973	-0.363	-37.827
h_8	3.095	7.166	6.987	-1.564	0.055	3.529	0.319	21.756
h_9	-4.524	-7.648	-7.488	16.135	-0.083	-1.090	-0.476	-42.401
h_{10}	0.413	2.875	5.372	-2.453	-0.212	2.555	0.121	16.704
Anhembi								
m	58.854	47.556	131.652	68.403	21.814	15.970	2.685	122.432
v_1	4.946	-2.356	-1.752	-14.203	-3.332	-5.784	-0.135	-15.976
v_2	-13.354	-18.127	-8.652	-33.975	-0.794	0.763	-1.113	-64.628
v_3	4.702	10.555	6.903	-6.403	0.667	4.096	0.260	20.523
v_4	-4.997	-4.556	-4.938	23.097	0.810	2.290	-0.256	-6.452
v_5	-5.298	-8.222	-8.319	8.152	0.343	-0.236	0.204	-21.533
v_6	9.746	10.172	17.984	8.597	-0.356	-1.173	0.815	66.765
v_7	8.289	22.444	12.223	14.263	1.308	1.559	0.815	94.200
v_8	-3.554	-10.556	-2.652	-16.403	0.523	-0.996	-0.435	-22.923
v_9	-5.425	-5.699	-8.367	20.168	1.579	2.481	0.030	-35.091
v_{10}	4.946	6.344	-2.430	-3.292	-0.748	-3.001	-0.185	-14.886
$\bar{h}$	-2.640	-2.439	-0.771	12.036	0.139	2.666	0.171	45.967
h_1	-0.081	-0.836	0.761	-6.425	0.303	-1.400	0.017	-4.381
h_2	0.367	-2.941	-1.386	-17.210	0.417	-2.874	-0.035	-16.394
h_3	1.418	2.877	1.290	-5.493	-0.243	-1.098	0.114	23.598
h_4	0.483	0.963	2.982	1.774	0.229	-1.183	0.345	5.536
h_5	1.942	2.953	1.624	6.447	-0.179	-1.289	-0.172	11.465
h_6	-2.473	-4.616	-7.900	-17.645	-0.124	-1.011	-0.399	-28.265
h_7	-2.022	-3.879	-5.189	20.268	-0.158	0.879	-0.328	-23.826
h_8	2.296	4.399	4.172	-6.227	-1.117	3.617	0.265	-0.104
h_9	-1.834	0.378	-2.051	25.560	0.382	1.666	-0.320	-8.355
h_{10}	-0.095	0.701	5.697	-1.050	0.489	2.695	0.514	40.726

Table 6 - Estimates of specific heterosis (s_{ij}) for the traits number of days to flowering (NDF), plant height at flowering (APF), number of days to maturity (NDM), plant height at maturity (APM), oil content (%OL), one-hundred seed weight (PCS), agronomic value (VA) and seed yield (PG), at ESALQ, 1998/99.

Effects	NDF	APF	NDM	APM	%OL	PCS	VA	PG
	days	cm	days	cm	%	g	scores 1 - 5	g/plant
s_{1x2}	-3.131	-3.193	-3.644	3.686	-0.747	0.465	-0.323	-14.167
s_{1x3}	-1.369	-7.691	-2.749	-1.505	0.060	-0.925	-0.344	-26.414
s_{1x4}	-3.806	-9.712	-4.502	7.367	0.164	-0.893	-0.034	7.628
s_{1x5}	-1.394	-0.576	1.100	10.631	-0.474	0.829	-0.187	-33.160
s_{1x6}	-1.467	-2.651	-4.468	4.637	-0.277	-0.761	-0.142	-9.091
s_{1x7}	5.424	7.212	7.283	-18.768	0.234	0.594	0.384	51.479
s_{1x8}	-0.958	5.143	-2.560	2.595	1.182	-0.932	0.002	-31.605
s_{1x9}	5.925	7.117	6.569	-17.199	0.293	0.441	0.399	38.590
s_{1x10}	0.777	4.351	2.972	8.555	-0.436	1.183	0.245	16.739
s_{2x3}	-3.109	-5.045	-1.761	3.844	0.602	0.117	0.085	-5.215
s_{2x4}	0.596	0.934	-2.390	7.912	-0.362	-1.532	0.047	23.614
s_{2x5}	-0.635	-0.656	-4.389	11.385	-0.056	-0.783	0.194	14.946
s_{2x6}	-2.333	-0.671	-0.856	6.237	-0.663	0.859	-0.338	-30.505
s_{2x7}	4.419	8.261	8.021	-16.641	0.476	1.202	0.494	44.675
s_{2x8}	-1.560	0.199	-0.655	6.362	0.052	1.200	-0.355	-32.428
s_{2x9}	6.518	11.347	4.334	-9.350	0.544	-0.774	0.550	67.557
s_{2x10}	-0.766	-11.176	1.341	-13.436	0.154	-0.753	-0.355	-68.478
s_{3x4}	1.209	3.382	-1.991	8.588	0.081	0.116	-0.115	-51.723
s_{3x5}	-0.018	6.542	-3.653	12.728	0.114	-1.322	-0.178	9.930
s_{3x6}	-1.327	-4.172	1.334	-1.405	-0.473	-0.557	0.041	-23.557
s_{3x7}	4.383	4.914	7.558	-22.004	0.332	1.144	0.421	52.635
s_{3x8}	-3.560	-5.984	-4.501	5.301	-0.174	-0.256	-0.280	-19.284
s_{3x9}	4.551	9.652	5.510	-3.436	-0.359	-0.364	0.297	57.676
s_{3x10}	-0.761	-1.598	0.254	-2.111	-0.183	2.047	0.074	5.952
s_{4x5}	-2.105	-6.093	-1.577	-9.639	-0.599	0.380	-0.226	-25.878
s_{4x6}	-1.487	2.196	-0.183	12.814	0.864	-0.852	-0.073	-21.807
s_{4x7}	5.224	10.352	4.985	-12.775	0.638	-0.464	0.416	59.045
s_{4x8}	-1.997	-3.148	-0.630	7.513	-0.585	1.132	-0.140	1.004
s_{4x9}	4.233	4.107	5.024	-31.153	0.957	0.828	0.246	15.533
s_{4x10}	-1.866	-2.019	1.264	9.374	-1.157	1.285	-0.120	-7.417
s_{5x6}	-2.866	-8.751	-4.497	-1.630	0.589	-0.928	-0.351	-39.915
s_{5x7}	4.886	6.473	5.879	-13.507	0.718	0.454	0.355	51.883
s_{5x8}	-1.990	-7.524	0.586	6.295	-0.356	1.233	0.043	-4.154
s_{5x9}	5.193	5.817	6.662	-25.550	0.454	-0.376	0.287	10.260
s_{5x10}	-1.072	4.767	-0.112	9.288	-0.390	0.513	0.064	16.087
s_{6x7}	5.488	6.537	6.544	-16.234	0.366	0.293	0.746	78.281
s_{6x8}	0.146	-1.682	-1.150	-0.949	-0.809	2.125	-0.266	-21.072
s_{6x9}	3.911	6.942	7.707	-3.044	0.139	-0.696	0.478	86.854
s_{6x10}	-0.065	2.253	-4.430	-0.426	0.263	0.516	-0.094	-19.188
s_{7x8}	6.217	8.931	9.436	-14.993	-0.416	0.363	0.614	38.987
s_{7x9}	-36.041	-52.681	-49.706	114.922	-2.349	-3.586	-3.430	-376.985
s_{8x9}	2.829	4.170	7.332	-13.036	-0.161	2.226	0.684	56.381
s_{8x10}	0.873	-0.106	-7.857	0.911	1.267	-7.092	-0.301	12.171
s_{9x10}	2.881	3.527	6.568	-12.154	0.481	2.301	0.489	44.133

heterosis attributed to a parent (h_i) is a constant value that is expressed in the crosses that involve the parent expressed as a deviation from the average heterosis of the diallel. Its significance depends on the value of the mean gene frequency and on the dispersion of these frequencies around the mean (Gardner and Eberhart, 1966). The parents USP 11-14 (h_8) in ESALQ and USP 6-6 (h_{10}) in Anhembi, with positive and relatively high values of h_i for the traits %OL, PCS, VA and PG, were the most promising in terms of variety heterosis.

Knowledge of the specific heterosis is of great importance for the development of hybrid seeds, and can also be useful in the development of homozygous lines, if there is significant contribution of the epistatic additive x additive interaction (Pimentel, 1991). Also, the knowledge of its magnitude can help the plant breeder to choose the selection method and to identify the predominant genetic effect in the combinations studied. In general, the values for specific heterosis (s_{ij}) were not consistent between localities (Tables 6 and 7). Considering just PG initially, some crosses expressed relatively high s_{ij} values in the two localities: IAC-100 x MTBR-95-123247 (1 x 7), Conquista x MTBR-95-123247 (3 x 7) and MTBR-95-123800 x MTBR-95-123247 (6 x 7). When all the traits are considered, the results were different in each locality. In ESALQ, the best crosses were the same three previously mentioned, and the cross USP 2-16 x MTBR-95-123247 (5 x 7). On the other hand, the crosses with favorable s_{ij} for several traits in Anhembi were Hartwig x Conquista (2 x 3), Conquista x USP 6-6 (3 x 10), and USP 2-16 x USP 11-14 (5 x 8).

Association among traits

The genotypic, phenotypic and environmental correlations were calculated for all studied traits (Table 8). In general, high values of genotypic and phenotypic correlations of VA with the other traits were observed in the two localities. The correlations among VA and NDM were high and

Table 7 - Estimates of specific heterosis (s_{ij}) for the traits number of days to flowering (NDF), plant height at flowering (APF), number of days to maturity (NDM), plant height at maturity (APM), oil content (%OL), one-hundred seed weight (PCS), agronomic value (VA) and seed yield (PG), at Anhembi, 1998/99.

Effects	NDF	APF	NDM	APM	%OL	PCS	VA	PG
	days	cm	days	cm	%	g	scores 1-5	g/plant
s_{1x2}	-1.995	0.201	-1.554	7.385	-1.000	0.856	-0.189	-16.795
s_{1x3}	0.197	1.170	0.207	4.496	0.358	-1.663	0.023	-21.501
s_{1x4}	-0.590	-1.664	-2.529	11.265	0.341	-0.044	-0.460	-19.630
s_{1x5}	-1.454	0.499	-0.675	17.814	0.101	0.866	-0.068	25.557
s_{1x6}	-1.339	-1.240	-2.858	2.434	1.005	2.054	-0.147	4.536
s_{1x7}	1.050	2.887	3.562	-27.688	-0.680	-1.117	0.115	24.505
s_{1x8}	-0.874	-4.349	-1.862	-1.234	0.025	0.620	-0.228	-19.670
s_{1x9}	2.052	-3.410	2.024	-16.668	0.455	-1.904	0.555	3.728
s_{1x10}	2.954	5.906	3.685	2.195	-0.605	0.333	0.398	19.270
s_{2x3}	-1.339	2.018	-0.536	17.453	0.054	1.186	0.135	79.432
s_{2x4}	0.890	2.313	-1.128	15.214	-0.035	-0.171	0.019	54.111
s_{2x5}	0.518	2.617	1.509	9.950	-0.083	0.914	0.306	1.273
s_{2x6}	-0.803	1.792	0.113	10.355	-0.105	1.708	-0.148	-19.174
s_{2x7}	0.224	-3.706	3.408	-23.392	-0.178	-1.224	0.156	-1.147
s_{2x8}	-0.610	-1.609	-3.328	5.812	0.648	0.172	-0.406	-26.324
s_{2x9}	3.393	-0.517	4.190	-24.385	-0.274	-2.280	0.666	1.707
s_{2x10}	-0.278	-3.109	-2.674	-18.392	0.972	-1.161	-0.539	-73.084
s_{3x4}	1.158	-3.529	-2.993	11.362	-0.144	-0.848	-0.317	-51.550
s_{3x5}	1.153	1.029	-3.944	16.732	0.628	-0.284	-0.315	-36.212
s_{3x6}	-0.239	-7.170	0.999	0.030	-0.008	-0.027	-0.108	-43.369
s_{3x7}	2.770	7.010	5.705	-20.034	-0.193	-1.175	0.509	30.277
s_{3x8}	-2.644	-1.107	0.674	6.827	-0.157	3.020	-0.076	-38.621
s_{3x9}	0.731	-0.134	1.279	-45.389	-0.538	-1.672	-0.045	14.974
s_{3x10}	-1.789	0.712	-1.390	8.523	0.001	1.463	0.193	66.571
s_{4x5}	-1.582	-4.735	-3.677	-20.466	-0.079	-0.399	-0.548	-37.338
s_{4x6}	-1.098	3.102	2.263	10.710	-0.011	-0.019	0.419	6.964
s_{4x7}	2.525	2.701	2.933	-12.078	-0.255	-1.896	0.309	33.292
s_{4x8}	-1.332	2.615	1.682	12.283	0.379	1.219	0.226	-8.594
s_{4x9}	1.682	3.335	1.173	-34.072	-0.109	0.399	0.232	11.164
s_{4x10}	-1.653	-4.138	2.277	5.781	-0.088	1.759	0.121	11.580
s_{5x6}	-1.573	-1.595	-3.105	13.551	0.391	0.523	-0.294	0.772
s_{5x7}	2.037	-2.302	2.732	-37.362	-0.065	-1.851	0.302	-27.037
s_{5x8}	-2.026	-0.746	0.641	14.967	0.631	0.735	0.334	44.199
s_{5x9}	3.240	6.637	4.489	-25.206	-1.092	-2.628	-0.081	32.568
s_{5x10}	-0.313	-1.404	2.029	10.020	-0.432	2.123	0.364	-3.783
s_{6x7}	2.709	5.695	3.770	-24.118	-0.359	-1.882	0.619	61.244
s_{6x8}	3.701	-3.308	0.013	-2.664	-0.459	0.520	-0.245	-16.493
s_{6x9}	-0.866	2.384	3.594	-7.903	-0.250	-2.957	0.357	38.820
s_{6x10}	-0.491	0.340	-4.789	-2.396	-0.204	0.079	-0.453	-33.301
s_{7x8}	3.520	4.669	6.350	-27.660	-1.056	-1.895	0.455	35.749
s_{7x9}	-14.836	-16.955	-28.460	172.331	2.786	11.040	-2.464	-156.883
s_{8x9}	1.648	5.400	3.340	-10.654	-0.673	0.104	0.402	35.463
s_{8x10}	-1.383	-1.566	-7.510	2.322	0.662	-4.495	-0.461	-5.709
s_{9x10}	2.955	3.259	8.371	-8.053	-0.306	-0.103	0.377	18.456

negative in the two localities. Exceptions occurred for the correlations between VA and the traits expressed in the seeds (%OL and PCS), with low values in the two localities. Therefore, VA can be considered a trait of great importance for use in indirect selection in breeding programs for the traits NDF, APF, APM and, mainly, seed yield (correlation of 0.81 in ESALQ and 0.94 in Anhembi). These correlation values, coupled with the previous knowledge of the germplasm, allow the search of genotypic combinations for the development of a highly desirable soybean ideotype. It is possible and advisable to include in the evaluation of VA undesirable traits such as lodging, leaf retention, shattering of pods, and plants not well developed or poorly adapted. Another aspect to be considered is the resistance to the main diseases and insects. Low VA scores could be attributed to the genotypes with susceptibility to the most important diseases. High and positive

Table 8 - Phenotypic (r_F), genotypic (r_G) and environmental (r_E) correlations among traits, at the localities ESALQ (above diagonal) and Anhembi (below diagonal) 1998/99

		NDF	APF	NDM	APM	%OL	PCS	VA	PG
NDF	r_F		0.71	-0.92	0.25	-0.94	-0.24	0.63	0.23
	r_G		0.71	-0.93	0.26	-0.99	-0.24	0.70	0.24
	r_E		0.30	-0.23	0.10	-0.22	-0.35	-0.29	-0.43
APF	r_F	-0.29		-0.94	0.40	-0.26	-0.46	0.66	0.60
	r_G	-0.28		-0.95	0.40	-0.27	-0.49	0.71	0.62
	r_E	-0.69		-0.03	0.59	-0.08	0.29	0.20	0.06
NDM	r_F	-1.02	-0.85		-0.44	0.10	-0.50	-0.76	-0.68
	r_G	-1.03	-0.88		-0.45	0.12	-0.51	-0.84	-0.71
	r_E	-0.74	0.15		-0.18	-0.23	-0.287	0.26	0.00
APM	r_F	0.32	0.42	-0.32		-0.07	0.23	0.99	0.71
	r_G	0.33	0.43	-0.33		-0.06	0.24	1.07	0.74
	r_E	-0.40	0.08	-0.10		-0.26	-0.19	0.02	0.06
%OL	r_F	-0.38	0.19	-0.08	0.59		0.35	-0.14	0.00
	r_G	-0.39	0.19	-0.09	0.64		0.39	-0.17	-0.01
	r_E	-0.39	0.18	0.14	-0.33		-0.28	0.09	0.05
PCG	r_F	-0.33	-0.18	-0.11	0.29	1.08		0.17	-0.07
	r_G	-0.33	-0.16	-0.11	0.30	1.17		0.17	-0.06
	r_E	-0.04	-1.06	-0.43	-0.16	-0.66		0.19	-0.15
VA	r_F	0.67	0.66	-0.76	0.75	0.19	0.08		0.75
	r_G	0.70	0.69	-0.80	0.79	0.22	0.09		0.81
	r_E	-0.13	0.29	-0.14	0.21	-0.04	-0.07		0.29
PG	r_F	0.31	0.87	-0.92	0.61	0.18	0.09	0.90	
	r_G	0.32	0.90	-0.94	0.62	0.20	0.09	0.94	
	r_E	0.02	0.25	-0.23	0.30	0.03	0.03	0.31	

correlations between VA and PG were also obtained by other authors (Unêda-Trevisoli, 1999; Yokomizo et al., 2000).

Besides VA, the traits APF and APM also presented high correlations with PG. NDM presented a negative correlation of high magnitude with APF and PG. Similarly, but with higher values, negative correlation occurred between NDF and NDM. This indicated the tendency of early flowering genotypes to show a long reproductive period. It is probable that these correlations are dependent of the genotypes involved.

The correlations between PCS and PG were not significant, as previously reported in the literature (Gilioli, 1979; Bravo et al., 1981). However, the farmers have preference for large-seeded cultivars because of appearance and the possibility of correlation with seed yield, that they believe to be significant. This has induced the plant breeders to select a large seed size and for this reason, some cultivars present PCS of 20g or more, in years of normal development, with sowing at recommended time. As expected, the selection for large or small size seeds, withim certain limits, did not affect seed yield (Hartwig and Eduards, 1970; Tinius et al., 1992).

Genetic distance and prediction of hybrid performance

The estimates of Mahalanobis' generalized distance (D^2) were obtained for ESALQ and Anhembi. In general, they were similar between localities, with the correlation of the distance matrices of 0.94. The oil content trait explained, in both localities, more than 80% of the existing genetic diversity among the parents. The traits APF and PCS explained about 5% of the diversity in each one. The largest distances, in the two localities, occurred among Hartwig (2) and the two lines MTBR (6 and 7).

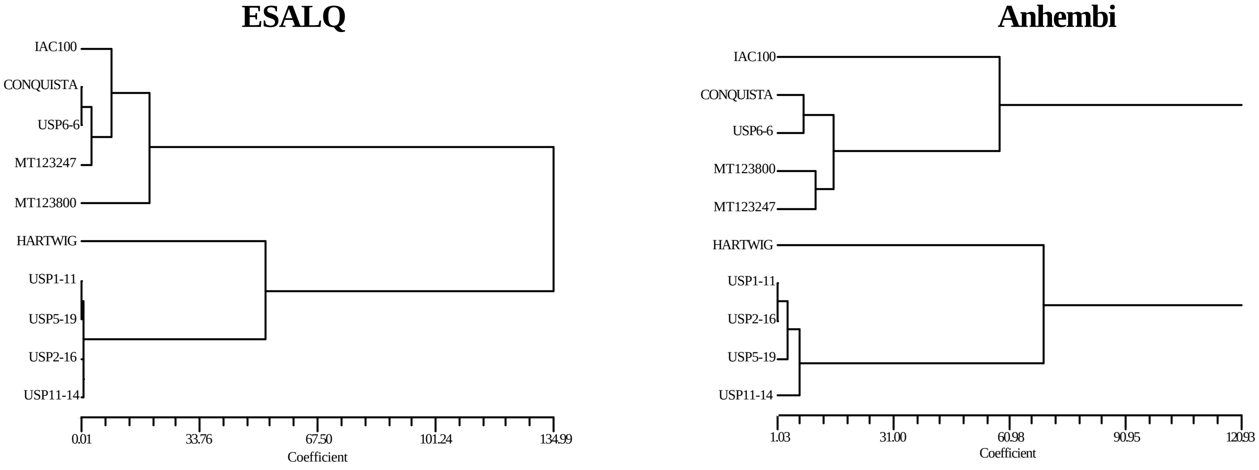

Figure 1 - Clustering of the parents by Mahalanobis' generalized distance (D^2) and cophenetic correlations (r). Localities: ESALQ and Anhembi, 1998/99.

Table 9 - Correlations of the means of the hybrids for eight traits with Mahalanobis' distance (D^2) between the parents, parental mean (MG) and heterosis in relation to parental mean (HMG). Correlations between heterosis in relation to parental mean and Mahalanobis' distance (HMG x D^2). Localities: ESALQ and Anhembi, 1998/99

	NDF	APF	NDM	APM	%OL	PCG	VA	PG
ESALQ								
D^2	-0.30*	-0.34**	0.23	-0.43**	0.06	-0.13	-0.55**	-0.40**
MG	0.90**	0.80**	0.75**	0.85**	0.71**	0.46**	0.51**	0.78**
HMG	0.21	0.67**	-0.22	0.78**	0.41**	0.78**	0.66**	0.54**
HMG x D^2	-0.47**	-0.47**	-0.23	-0.35**	0.16	-0.12	-0.48**	-0.43**
Anhembi								
D^2	-0.34*	-0.44**	0.32*	-0.46**	-0.09	-0.34*	-0.47**	-0.37*
MG	0.90**	0.82**	0.56**	0.81**	0.74**	0.47**	0.52**	0.59**
HMG	0.18	0.49**	-0.37*	0.80**	0.34**	0.71**	0.62**	0.57**
HMG x D^2	-0.39**	-0.57**	-0.34*	-0.31*	-0.12	-0.33*	-0.30	-0.31*

*, ** significant at 5% and 1% probability, respectively

Three main groups were identified: the first group was formed by four lines USP (USP 1-11, USP 5-19, USP 2-16, and USP 11-14); the second group included the parents USP 6-6, MTBR-95-123247, MTBR-95-123800, Conquista, and IAC100; and Hartwig was in an isolated group (Figure 1). Hartwig is a North American cultivar introduced recently as a source of resistance to soybean cyst nematode and presents very low values for some traits, especially APM and PG, probably because of the lack of adaptation to the Brazilian environmental conditions.

In order to identify the ability of D^2 estimates to predict hybrid performance, simple correlations among these values were obtained. The same was made to verify the influence of the parental mean (MG) and of the heterosis (HMG) in this performance (Table 8). The correlations between D^2 and the mean of the hybrids were negative and significant, with two exceptions: the trait NDM, which presented positive and significant correlation in Anhembi, and the oil content, with non significant correlations in the two localities (Table 8). The occurrence of negative correlations, suggests at first, that the best hybrid may result from crosses among more similar parents. However, the very low values of these correlations indicated this kind of prediction is not possible. Even for the trait %OL, that has explained more than 80% of the genetic diversity among the parents, these correlations were not significant. In the same way, D^2 was not able to explain a significant portion of the heterosis in relation to the parental mean (HMG). Barroso (2000) found negative correlation between Euclidian parental distance and hybrid performance for seed yield in soybeans.

The parental mean was positively correlated with hybrid performance for all the traits, in the two localities, while the heterosis in relation to the parental mean (HMG) was positively correlated in most of the traits, except from NDF and NDM (Table 9). The predictability of the parental mean (MG), inferred from the values of correlations, was larger than from D^2 for all the traits, except VA in ESALQ. Besides, MG showed better predictability than HMG for NDF, APF, NDM, %OL and PG. This is probably due to the fact that the means of the hybrids for these traits are influenced mainly by additive effects. Other works have presented high values of correlation between parental mean and hybrid performance (Barroso, 2000). However, for the trait APM, the correlations with MG and HMG had similar magnitude. On the other hand, among the traits PCS and VA, the largest correlations were with HMG, indicating predominance of dominance and epistatic effects. The use of predictions based on the parental mean presents, as well as D^2, the advantage of being done previously to the accomplishment of the crosses. The higher the value of correlation with hybrid performance, the better the predictive ability of the studied parameter. For some traits as NDF, APF, and NDM the correlations obtained with the parental mean were above 0.80. However, for PG, which is the most important trait in soybean breeding programs, the correlations were 0.78 in ESALQ and 0.59 in Anhembi, and could be considered to have intermediate predictive value in choosing the crosses to be done.

CONCLUSIONS

Positive values of heterosis were found for most of the studied traits, and the largest frequency and most expressive values were obtained for seed yield. The heterosis for the number of days to flowering was negative, indicating presence of dominance effects for earliness. The oil content trait showed to be determined essentially by genes of additive effect. The scores of agronomic value were a good criterion of indirect selection for seed yield. The parental mean was able to predict with greater efficiency the hybrid performance than the Mahalanobis' generalized distance. However, for some traits, this predictability was not sufficiently high.

ACKNOWLEDGEMENTS

Thanks to CNPq for the scholarships; to EMBRAPA and Fundação Mato Grosso for seeds of two experimental lines; to the technicians M. C. Nekatschalow, C. A. Didoné, and A. R. Cogo, for help during the field experiments. To Prof. Dr. Antônio Augusto Franco Garcia for the discussion on the statistical analysis.

RESUMO

Desempenho de caracteres agronômicos em um sistema dialélico F_1 em soja

Os objetivos desta pesquisa foram: a) avaliar a heterose para caracteres de importância agronômica; b) identificar associações entre os caracteres; c) estimar a divergência genética entre os parentais e verificar sua eficiência na predição do desempenho dos híbridos. Um dialelo 10 x 10 foi estudado em dois locais. Foram avaliados número de dias para o florescimento (NDF), altura da planta no florescimento (APF), número de dias para maturidade (NDM), altura da planta na maturidade (APM), teor de óleo (%OL), peso de cem sementes (PCS), valor agronômico (VA) e produtividade de grãos (PG). A interação genótipos x locais e os efeitos de variedades e da heterose foram significativos para a maioria dos caracteres. Valores positivos de heterose foram encontrados para a maioria dos caracteres, especialmente PG. A heterose para NDF foi para precocidade. A %OL mostrou ser determinada essencialmente por genes de efeito

aditivo. O VA demonstrou ter potencial para a seleção indireta de genótipos mais produtivos. A média dos genitores foi capaz de predizer com maior eficiência o desempenho dos híbridos do que a distância de Mahalanobis (D^2); porém, para alguns caracteres, esta capacidade preditiva não foi suficientemente alta.

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Received: February 08, 2001;
Accepted: June 01, 2001.