Selection of soybean genotypes resistant to insects adapted to the cerrados

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ABSTRACT

This study aimed to select productive soybean genotypes, adapted to the conditions of the "Cerrado" and with insect resistance. The experimental material involved 170 soybeans lines $F_{7:2}$ obtained from partial diallel crosses (4 x 4), that is, four parents with insect resistance and four other parents with high agronomic performance and the other three lines obtained from the plant breeding program of the ESALQ/USP. The F_7, F_8 and F_9 generations were evaluated in Goiânia-GO, being the last one evaluated during three different sowing periods (October/21/98, November/09/98 and December/11/98). The following characters were evaluated: days to flowering; plant height at flowering; days to maturity; plant height at maturity; period of grain growth; spotted seeds; 100 seeds weight; foliar area sectioned; lodging; agronomic value; and grain yield. The augmented design was used for the F_7 generation while the complete randomized block design for the F_8 and F_9 generations. An analysis of variance was carried out for each generation and one joint analysis of variance was made for the three sowing periods with F_9 generation. Based on grain yield, through the different experiments, they were identified as to which were the most promising lines for the area, having the best combination of characteristics including insect resistance. The following results were obtained from the analysis: a) ten lines from the early cycle, with high yield, were considered favorable for the cultivation in the "cerrado", showing high resistance to sucker and defoliator insect, and they involve the genitor IAC-100; b) the line 81-9-13 (OCEPAR-04 x IAC-100) had the best agronomic performance, because it was classified above the mean of the check for all characters evaluated in the F_9 generation; c) the second sowing period (11/09/98) was considered the most favorable for the cultivation of soybean in the region; d) the parental IAC-100 (used as the check) showed good characteristics for grain yield and insect resistance. So, evaluation of this parental should occur in the region, in order to recommend it for cultivation.

KEY WORDS: *Glycine max*, long juvenile period, insect resistance.

INTRODUCTION

The introduction of the long juvenile period trait is very important in adapting soybean to low latitude regions (>15^o) and cropping outside the recommended period. This trait that results in late flowering is economically important because it allows an extension of soybean sowing in terms of date and latitudes (Ray et al. 1995; Destro et al., 2001).

The photoperiod influences the soybean vegetative and reproductive period, affecting the duration of the crop cycle. The sowing period is defined by a set of environmental factors that jointly act and interact with the plant, promoting variation in yield and affecting other agronomic traits. Cultivars sown in different periods express their potential in response to the environmental stimulus, which depends on the latitude, sowing period and the cultivars itself (Urben Filho and Souza, 1993).

The crop has been exposed to new challenges such as the outbreak of new pathogens and pests with the development of cultivars adapted to different agro-ecological regions and consequent expansion to new frontiers, increase in the planted area and monoculture. Soybean is attacked by various insect species, especially the pod sucking stink bugs (*Piezodorus guiildinii, Nezara viridula* and *Euschistus heros*) and leaf feeder insects (*Anticasia gemmatalis*, *Colaspis* sp., *Cerotoma arcuata, Diabrotica speciosa* and *Diphaulaca viridipennis*).

The use of resistant varieties has been recommended for pest control because the pest populations can be reduced to levels lower than that of economic damage without disturbing or polluting the ecosystem and without extra costs to the producer. Thus genetic resistance to insects is considered a complementary characteristic that, whenever possible, should be included as an objective of the breeding program (Vendramim, 1990).

The objective of the present study was to select high yielding and resistance to insects in soybean genotypes adapted to the Cerrados.

MATERIAL AND METHODS

The experimental material included initially 170 $F_{7:2}$ soybean lines derived from a partial diallel cross (4 x 4) involving eight parents, which were selected for their reaction to insects and high yield (Table 1), and three other lines from the soybean genetic breeding program at ESALQ/USP (USP1, USP2 and USP6). The Crockett, Lamar and IAC-100 cultivars and line D72-9601-1 were chosen as resistant parents. The BR-6 (Nova Bragg), IAS-5, Davis and OCEPAR-4 (Iguaçu) cultivars were chosen as high yielding, adapted but susceptible parents. The crosses were performed among the resistant and susceptible genotypes, in a total of 16 bi-parental combinations.

The F_2 generation was assessed and selected in São Paulo state based on the reaction to leaf feeder and pod sucking insects and yield (Pinheiro, 1993). The $F_{3:2}$, $F_{4:2}$ and $F_{5:2}$ were also assessed in São Paulo state for yield and long juvenile period (Pinheiro, 1998). The $F_{6:2}$ generation (270 lines) was assessed in Goiânia-GO in July 1996, to verify which among these genotypes could be selected as promising materials for cultivation in low latitude areas of the Cerrados. After carrying out this experiment, 170 lines with some potential for cultivation in the region were selected. It is important to emphasize that in all generations, selection was made only among progeny. Within progeny, selection was not performed. Therefore, the 170 $F_{7:2}$ lines considered promising for the region consisted of a mixture of lines, that is, each line was considered a family of inbred lines.

The 170 $F_{7:2}$ and the three USP1, USP2 and USP6 lines were sown on 21/05/97 for assessment at the experimental field of the Agronomic School of the Federal University of Goias (EA/UFG). A Federer augmented block design (1956) was used; each plot consisted of a 4.0m x 0.5m row and each block was formed by 29 plots of 25 lines and four common controls. The IAC-100, OCEPAR-4 (parents involved in the crosses), MTBR-45 (Paiaguás) and EMGOPA-313 (recommended materials for the region) cultivars were chosen as controls.

Fifty-six genotypes were selected after assessing the lines for yield and agronomic traits. Selection was made only among lines, but no selection was practiced within lines. The $F_{8:2}$ lines were sown in the Experimental field at EA/UFG in Goiania-GO, on 14/01/98. A randomized complete block design with three replications was used with the same controls as the previous experiment. The experimental plot consisted of two 4m x 0.5m rows. Twenty-five lines were selected for yield and resistance to sucking and leaf feeder insects.

The $F_{9:2}$ lines were sown at three dates - 21/10/98, 09/11/98 and 11/12/98 – for assessment in the experimental field at the Agronomy School/UFG in Goiânia-GO. A randomized complete block design with three replications per period was used. The experimental plot consisted of four 4m x 0.5m rows and the useful plot of two 4 x 0.5m lines. The same controls were used in these experiments. These lines were assessed for yield and resistance to insects.

A high natural infestation of pod sucking insects was observed in the field in all the experiments. The occurrence of leaf feeders although not high allowed genotype screening. It is important to point out that there was no chemical control of insects in the field in any of the experiments performed.

The following traits were assessed: number of days to flowering (NDF), plant height at flowering (APF),

Table 1. Identification of the 16 diallel crosses and the eight parents.

CR[1/]	Description	CR	Description	Parents
1	BR-6 x Crockett	9	Davis x Crockett	BR-6
2	BR-6 x Lamar	10	Davis x Lamar	IAS-5
3	BR-6 x IAC-100	11	Davis x IAC-100	Davis
4	BR-6 x D72-9601-1	12	Davis x D72-9601-1	OCEPAR-04
5	IAS-5 x Crockett	13	OCEPAR-4 x Crockett	Crockett
6	IAS-5 x Lamar	14	OCEPAR-4 x Lamar	Lamar
7	IAS-5 x IAC-100	15	OCEPAR-4 x IAC-100	IAC-100
8	IAS-5 x D72-9601-1	16	OCEPAR-4 x D72-9601-1	D72-9601-1

[1/] CR: crosses.

number of days to maturity (NDM), plant height at maturity (APM), pod filling period (PEG), cut leaf area (AF), lodging (AC) agronomic value (VA) and yield (PG). In the $F_{7:2}$ generation only the NDF, APF, NDM, AC, VA and PG traits were assessed, while the other traits and these traits were assessed in the $F_{8:2}$ and $F_{9:2}$ generations.

Individual analyses of variance were performed for the F_7, F_8 and F_9 generation, and a joint analysis of variance was also performed in the F_9 generation experiments.

The analyses of variance, in augmented block ($F_{7:2}$ generation) according to Scott and Milliken (1993) followed the following mathematical model:

$$\mathbf{Y_{ij} = m + b_j + c_i + X_i(c_i) + e_{ij}}, \quad \text{where:}$$

Yij = plot observed value in the j^{th} block that received the i^{th} common treatment or the regular i'^{th} treatment.;

m = fixed mean effect;

B_j = random effect of the j^{th} block; j = 1, 2, …, b;

C_i = fixed effect of the i^{th} common treatment, i = 1, 2, 3,…, v;

Xi(ci) = random effect of the i'^{th} regular treatment, i'of the j^{th} block;

i'^{th} = 1, 2, …, nj = number of plots in block j;

e_{ij} = random effect of experimental error associated with the plot in j^{th} block that received the i^{th} common treatment or i'^{th} regular treatment.

Table 2 shows the analysis of variance model of the augmented blocks, which used the intrablock error. The treatments sum of squares was partitioned into the sources controls and adjusted lines.

The $F_{8:2}$ and $F_{9:2}$ generation augmented block design analyses were carried out according to the following mathematical model:

$$\mathbf{Yij = m + t_i + b_j + e_{ij}}, \quad \text{where:}$$

Yij = observed value of the ith treatment with the jth block;

m = general mean;

ti = fixed effect of the ith treatment (i = 1, 2, ... , T);

bj = fixed effect of the jth block (j= 1, 2, ... , B);

eij = random experimental error effect.

Table 3 shows the analysis of variance model used. The treatment sum of squares was partitioned into the sources controls, lines and a contrast of lines vs controls.

The joint analysis of variance of the experiments of the F_9 generation in randomized blocks followed the mathematical model:

$$\mathbf{Y_{ijk} = m + t_i + a_k + (ta)_{ik} + b_{j(k)} + e_{ijk}}, \quad \text{where:}$$

Yijk = observed value of the i^{th} treatment, in the j^{th} period, within the k^{th} block;

m = general mean;

ti = fixed effect of i^{th} treatment (i = 1,2 …, T);

ak = fixed effect of k^{th} period (k =1, 2, …, A);

(ta)ik = effect of interaction of the i^{th} treatment with the k^{th} period;

bj(k) = effect of k^{th} block within the j^{th} period;

eijk = random effect of the experimental error.

Prior to this analysis a test of homogeneity of variances was made following the criteria of maximum relationship ≤ 7 for the ratio between the largest and smallest error variances (Pimentel Gomes, 1990).

Table 2. Analysis of variance model for the $F_{7:2}$ generation experiments with augmented blocks and intrablock error.

Source of variation	DF [1/]	MS	F test
Unadjusted block	b – 1	---	---
Adjusted treatments	$v_b + v_l - 1$	QM 4	QM_4/QM_1
Controls	v_b	QM 3	QM_3/QM_1
Lines aj. Xi(a)	$v_l - 1$	QM 2	QM_2/QM_1
Intrablock error	$(b - 1)(v_b - 1)$	QM 1	
Total	N – 1		

[1/] v_b: number of controls; v_l: number of lines; b: number of blocks and N: Total plot number.

Table 4 shows the analysis of variance model. The treatment sum of the squares was partitioned in the sources lines, controls and in the lines vs controls contrast. The sum of squares of treatments x periods was also partitioned into the sources lines x periods, controls x periods and lines vs controls x periods.

Based on the yield means of the lines assessed in the different generations (F_7, F_8 and F_9) and sowing periods in the $F_{9:2}$ generation (21/10/98, 09/11/89 and 11/12/98), the 10 highest yielding lines in each case were identified. Those lines that were also among the best in the F_9 generation were selected (Table 5).

The PG promising selected lines were then characterized for their other traits already assessed in the F_8 and F_9 generations. The final characterization was made using the mean of the traits assessed in the F_9 generation (joint assessment) as this generation was evaluated in the period recommended for soybean cropping in the region, and because only the lines present in this generation were eventually selected (Table 6).

RESULTS AND DISCUSSION

The analysis of variance for the F_7 generation showed statistical differences (P<0.01 and P<0.05) among treatments and after partitioning this source of variation among lines, only for the APM, AC and NDM traits that indicated variability among them, enabling selection for these traits (Table 7).

Significant effects were not detected for the other traits (NDF, APF, VA and PG). These results were probably due to the non-detection by the design used, as highly variable values were reported among the lines and controls. For the PG trait, the non-detection of variation may further be explained by the sowing period (21/05/97) and because there was no insect control, that interfered in the experimental accuracy (CV=44.704%). In spite of the low experimental accuracy for PG this value is in line with results obtained by Freire-Filho (1988), Pinheiro (1993, 1998) and (Moura et al., 1998) where there was no insect control.

In the $F_{8:2}$ generation, significant differences (p<0.01) were detected among treatments and among lines for

Table 3. Randomized complete block analysis of variance of the $F_{8:2}$ and $F_{9:2}$ experiments.

Source of variation	DF [1/]	MS	F test
Blocks	(b –1)	---	---
Treatments	t – 1	QM_5	QM_5/QM_1
Lines	z – 1	QM_4	QM_4/QM_1
Controls	c – 1	QM_3	QM_3/QM_1
Lines vs Controls	1	QM_2	QM_2/QM_1
Error	(b – 1) (c – 1)	QM_1	

[1/] b: number of blocks; t: number of treatments; c: number of common treatments and z: number of lines.

Table 4. Joint analysis of variance model of the $F_{9:2}$ soybean lines experiments.

Source of variation	DF [1/]	MS	F test
Blocks/periods	a(b – 1)	---	---
Periods (a)	a – 1	QM_{10}	QM_{10}/QM_1
Treatments (t)	t – 1	QM_9	QM_9/QM_1
Lines (z)	z – 1	QM_8	QM_8/QM_1
Controls (c)	c – 1	QM_7	QM_7/QM_1
Lines vs Controls	1	QM_6	QM_6/QM_1
Treatments x Controls	(t – 1)(a –1)	QM_5	QM_5/QM_1
Lines x Periods	(z – 1)(a –1)	QM_4	QM_4/QM_1
Controls x Periods	(c – 1)(a –1)	QM_3	QM_3/QM_1
Lines vs Controls x Periods	1(a –1)	QM_2	QM_2/QM_1
Mean error	a(b – 1)(t – 1)	QM_1	
Total	atb – 1		

[1/] a: number of periods; b: number of replications per period; t: number of treatments; c: number of controls and z: number of lines.

all the traits (Table 8) indicating further possibility for selection because the design was able to detect the variability existing among the lines (Moura et al., 1999a).

When the contrast lines vs controls is observed, significant differences were observed for the NDF, APF, NDM, APM, AC, AFC, SM and PG traits. When the means between the lines and controls were compared, the lines were superior compared to the controls for the AC, AFC and SM traits, demonstrating superiority of the traits resistance to insects and for AC that influences the agronomic value of the plants. For NDF, APF, NDM, APM, and PG the controls were superior (on average) compared to the lines. These results may be explained by the use of two long cycle cultivars and recommended for the region as controls that probably increased the mean of the NDF and NDM traits and consequently, the APF and APM means, besides PG.

Analysis of variance of the different sowing periods (1st period =21/11/98, 2nd period = 09/011/98, 3rd period = 11/12/98) of the $F_{9:2}$ generation (Tables 9,

Table 5. Identification of the most productive lines (kg/ha) in the different generations. Cross (CR), lines, mean (absolute value (V.abs.), percentage compared to the mean of the controls (%T), mean control value (Testem.), number of generations in which the lines were selected (NS). Soybean EA/UFG – Goiânia, GO.

		$\bar{x}$												
		$F_{7:2}$		$F_{8:2}$		$F_{9:2}$		$F_{9:2}$ (ep 1)		$F_{9:2}$ (ep 2)		$F_{9:2}$ (ep 3)		NS
CR [1/]	Lines	V. abs.	% T	V. abs.	% T	V. abs.	% T	V. abs.	% T	V. abs.	% T	V. abs.	% T	
3	81-2-02	-	-	1983.3	101.9	-	-	-	-	3050.0	122.4	-	-	2
3	81-1-23	2339.3	169.9	-	-	2675.0	120.4	2220.0	115.7	3591.8	144.1	2233.3	99.2	4
3	81-1-24	-	-	2083.3	107.1	2836.1	127.7	2658.2	138.5	3550.0	142.5	2300.0	102.1	4
3	81-1-25	-	-	-	-	-	-	-	-	3291.8	132.1	2325.0	103.2	2
3	81-1-26	-	-	2018.3	108.3	-	-	-	-	-	-	-	-	1
3	81-1-28	-	-	2033.3	104.5	2552.8	114.9	2150.0	112.0	3083.3	123.7	2425.0	107.7	4
6	81-3-25	-	-	2233.3	114.8	-	-	-	-	-	-	-	-	1
6	81-4-02	-	-	2108.3	108.3	-	-	-	-	-	-	-	-	1
7	81-4-13	-	-	-	-	2622.2	118.1	2225.0	116.0	3141.8	126.1	2500.0	111.0	3
7	81-4-27	3076.8	223.5	2008.3	103.2	-	-	2058.3	107.3	-	-	-	-	2
11	81-7-01	-	-	-	-	2652.8	119.5	2150.0	112.0	3208.2	128.8	2600.0	115.5	3
11	81-7-12	-	-	-	-	-	-	-	-	-	-	2125.0	94.4	1
11	81-7-18	2339.3	169.9	2233.3	114.8	2483.3	111.8	1990.0	103.7	-	-	2916.8	129.5	4
12	81-8-20	-	-	1983.3	101.9	-	-	-	-	-	-	-	-	1
13	81-9-04	-	-	2300.0	118.2	-	-	-	-	-	-	2116.7	94.0	2
15	81-9-13	2801.8	203.5	-	-	2583.3	116.3	2591.8	135.1	3066.7	123.1	-	-	3
15	81-9-18	2551.8	185.3	-	-	2569.5	115.7	2616.7	136.4	3083.3	123.7	-	-	3
15	81-10-08	-	-	-	-	2683.3	120.8	2391.8	124.6	3216.7	129.1	2441.8	108.4	3
15	81-10-09	-	-	2283.3	117.4	2597.2	116.9	2525.0	131.6	2275.0	91.3	-	-	3
	Testem.	1376.8	100.0	1945.8	100.0	2220.8	100.0	1918.8	100.0	2491.7	100.0	2252.1	100.0	-
N	4	5		11		10		11		11		10		

[1/] Crosses identified in Table 1.

Table 6. Characterization of lines considered promising for the grain yield trait. Values (mean) of the traits NDF, APF, NDM, APM, PEG and PCS. Soybean, F_9 generation (set). EA/UFG – Goiânia, GO.

		$\bar{x}$										
Lines	CR	NDF (days)	APF (cm)	NDM (days)	APM (cm)	PEG (days)	PCS (g)	SM (note 1-5)	AFC (note 1-5)	AC (note 1-5)	VA (note 1-5)	PG (kg/ha)
81-1-23	3	46.33	47.11	119.11	55.22	32.44	14.70	1.33	1.39	1.33	4.17	2675.0
81-1-24	3	45.67	44.78	117.67	46.89	34.56	10.68	1.56	1.50	1.11	3.83	2836.1
81-1-28	3	43.56	42.22	113.33	49.89	32.67	13.78	1.33	1.22	1.00	3.78	2552.8
81-4-13	7	45.56	48.11	128.22	59.56	38.00	14.09	1.78	1.61	1.11	3.56	2622.2
81-7-01	11	38.89	34.22	114.00	35.89	37.22	12.94	1.22	1.39	1.00	3.00	2652.8
81-7-18	11	46.78	44.44	125.22	55.67	33.44	12.97	1.61	1.56	1.00	4.06	2483.3
81-9-13	15	50.22	57.00	130.56	69.22	35.78	14.13	1.33	1.72	1.00	3.44	2583.3
81-9-18	15	47.22	46.44	126.11	56.00	37.89	14.57	1.89	1.67	1.22	3.72	2569.5
81-10-08	15	43.78	44.44	114.89	45.89	35.78	12.75	1.33	1.22	1.00	3.78	2683.3
81-10-09	15	40.44	37.78	113.67	46.33	36.44	13.51	1.33	1.50	1.00	3.50	2597.2
$\bar{x}$ Controls		49.08	52.31	129.89	56.89	39.61	16.50	2.09	1.73	1.06	3.10	2220.8

10 and 11) showed that significant differences could be detected among treatments for all the traits, except for AC in the 1st and 2nd periods and SM in the 3rd period, in line with the results for the source of variation lines, after treatment partitioning (Moura et al., 1999b).

When the lines vs controls contrast was analyzed, statistical differences were detected for the NDF, APF, NDM, APM and AFC traits in all the periods of the $F_{9:2}$ generation where the means of the controls for the traits for the late flowering genes (NDF and NDM) were greater than the means of the lines,

Table 7. Summary of the analysis of variance, in augmented blocks, with values and significance of the mean squares of seven traits. Soybean, $F_{7:2}$ generation. EA/UFG – Goiânia, sown in 21/05/97.

		QM						
Source of variation	DF	NDF (days)	APF (cm)	NDM (days)	APM (cm)	AC (note)	VA (nota)	PG (Kg/ha)
Unadjusted block	6	766.781	537.288	1521.320	1.594.046	3.672	2.664	1.297.279.34
Adjusted treatments	176	50.429 $^{n.s}$	125.786 $^{n.s}$	391.601$^{2/}$	264.989$^{1/}$	0.953$^{1/}$	0.389 $^{n.s}$	365.444.52 $^{n.s}$
Controls	4	410.429$^{2/}$	1.101.287$^{2/}$	3.424.291$^{2/}$	806.681$^{2/}$	3.212$^{2/}$	0.774 $^{n.s}$	956.372.95 $^{n.s}$
Lines aj. Xi(a)	172	42.057 $^{n.s}$	103.100 $^{n.s.}$	321.074$^{1/}$	252.392$^{1/}$	0.900$^{1/}$	0.380 $^{n.s}$	351.702.00 $^{n.s}$
Intrablock error	18	47.302	145.274	137.056	107.917	0.468	0318	355.674.603
Total	200							
General mean		52.960	46.995	128.965	61.308	2.405	2.381	1.334.08
Lines mean		50.944	64.621	126.228	60.214	2.613	2.368	1.322.73
Controls mean		55.893	54.285	139.928	68.215	2.536	2.447	1.376.80
CV%		12.986	25.647	9.078	16.944	28.447	23.705	44.704

$^{1/, 2/}$ significant at the 0.05 and 0.01probability level, by F test, respectively; $^{n.s.}$ not significant at the 0.05 probability.

Table 8. Summary of the analysis of variance, in complete randomized block, with values and significance of the mean squares of eleven traits. Soybean, $F_{8:2}$ generation. EA/UFG – Goiânia, sown in 14/01/98.

		QM										
Source of variation	DF	NDF (days)	APF (cm)	NDM (days)	APM (cm)	AC (note)	VA (note)	PCS (g)	AFC (note)	PEG (days)	SM (note)	PG (kg/ha)
Blocks	2	0.689	998.155	16.550	52.017	1.579	1.572	0.299	0.126	68.467	1.217	1.079.920.14
Treatments	59	19.371$^{2/}$	206.626$^{2/}$	58.303$^{2/}$	240.324$^{2/}$	1.987$^{2/}$	0.911$^{2/}$	13.891$^{2/}$	0.901$^{2/}$	14.156$^{2/}$	0.697$^{2/}$	490.975.22$^{2/}$
Lines	55	10.591$^{2/}$	146.132$^{2/}$	30.933$^{2/}$	205.903$^{2/}$	1.997$^{2/}$	0.936$^{2/}$	13.728$^{2/}$	0.710$^{2/}$	12.809$^{2/}$	0.473$^{2/}$	503.385.76$^{2/}$
Controls	3	89.194$^{2/}$	265.194$^{1/}$	289.000$^{2/}$	421.861$^{2/}$	0.833 $^{n.s}$	0.667 $^{n.s}$	21.169$^{2/}$	2.722$^{2/}$	25.861$^{1/}$	3.417$^{2/}$	148.125.00 $^{n.s}$
Lines vs Controls	1	292.810$^{2/}$	3.358.048$^{2/}$	871.557$^{2/}$	1.588.889$^{2/}$	4.889$^{2/}$	0.268 $^{n.s}$	1.038 $^{n.s}$	5.906$^{2/}$	53.157 $^{n.s}$	4.889$^{2/}$	836.946.67$^{2/}$
Error	118	1.655	32.579	6.392	21.107	0.561	0.304	0.515	0.147	4.986	0.188	40.139.06
Total	179											
General mean		36.811	49.589	96.267	59.967	1.717	3.644	16.401	1.820	39.450	1.300	1.690.70
Lines mean		36.470	48.434	95.679	59.173	1.672	3.655	16.421	1.774	39.595	1.256	1.672.47
Controls mean		41.583	65.750	104.500	71.083	2.333	3.500	16.117	2.500	37.417	1.917	1.945.83
CV %		3.495	11.510	2.626	7.661	43.623	15.125	4.375	21.082	5.660	33.390	11.850

$^{1/, 2/}$ significant at the 0.05 and 0.01probability level, by F test, respectively; $^{n.s.}$ not significant at the 0.05 probability.

Table 9. Summary of the analysis of variance, in complete randomized blocks, with values and significance of the mean squares of eleven traits. Soybean, $F_{9:2}$ generation. EA/UFG – Goiânia, sown in 21/10/98.

		QM										
Source of variation	DF	NDF (days)	APF (cm)	NDM (days)	APM (cm)	AC (note)	VA (note)	PCS (g)	AFC (note)	PEG (days)	SM (note)	PG (kg/ha)
Blocks	2	1.345	65.598	65.207	157.460	-	0.382	0.360	0.124	1.184	2.977	26343.39
Treatments	28	89.109$^{2/}$	224.509$^{2/}$	236.252$^{2/}$	559.274$^{2/}$	-	3.493$^{2/}$	14.525$^{2/}$	0.284$^{2/}$	53.441$^{2/}$	5.621$^{2/}$	1.966.279.76$^{2/}$
Lines	24	53.028$^{2/}$	161.036$^{2/}$	98.889$^{2/}$	449.641$^{2/}$	-	3.462$^{2/}$	14.110$^{2/}$	0.194$^{1/}$	40.719$^{2/}$	5.606$^{2/}$	1.943.923.61$^{2/}$
Controls	3	244.083$^{2/}$	408.889$^{2/}$	978.778$^{2/}$	904.083$^{1/}$	-	4.910$^{2/}$	21.958$^{2/}$	0.799$^{2/}$	172.000 $^{n.s}$	7.576$^{2/}$	2.377.135.42$^{2/}$
Lines vs controls	1	490.141$^{2/}$	1.194.733$^{2/}$	1.305.394$^{2/}$	2.156.041$^{2/}$	-	0.000 $^{n.s}$	2.180 $^{n.s}$	0.879$^{2/}$	3.092 $^{n.s}$	0.115 $^{n.s}$	1.270.260.41 $^{n.s}$
Error	56	0.928	31.705	34.362	57.269	-	0.174	1.091	0.097	11.874	0.623	205.911.84
Total	86											
General mean		42.483	39.402	127.493	40.805	1.000	2.454	16.355	1.540	38.530	3.201	1.616.67
Lines mean		41.533	37.920	125.933	38.813	1.000	2.453	16.292	1.500	38.453	3.187	1.568.33
Controls mean		48.417	48.667	137.167	53.250	1.000	2.458	16.751	1.792	39.000	3.292	1.918.81
CV %		2.268	14.290	4.598	18.546	-	16.990	6.386	20.198	8.944	24.653	28.067

$^{1/, 2/}$ significant at the 0.05 and 0.01probability level, by F test, respectively; $^{n.s.}$ not significant at the 0.05 probability.

maintaining the results obtained in the $F_{8:2}$ generation. For AFC, the result obtained in the $F_{8:2}$ generation was also maintained that indicated superiority (on average) of the lines compared to the controls (Tables 9, 10 and 11).

Further considering the lines vs controls contrast, statistical differences were found for PCS in the 2nd and 3rd periods and for VA and PG in the 3rd period (Tables 10 and 11). The lines were superior (on

Table 10. Summary of the analysis of variance, in complete randomized blocks, with values and significance of the mean squares of eleven traits. Soybean, $F_{9:2}$ generation. EA/UFG – Goiânia, sown in 09/11/98.

Source of variation	GL	NDF (days)	APF (cm)	NDM (days)	APM (cm)	AC (note)	VA (note)	PCS (g)	AFC (note)	PEG (days)	SM (note)	PG (kg/ha)
Blocks	2	1.483	79.896	10.425	35.874	0.103	0.606	3.644	0.103	3.080	0.181	241903.74
Treatments	28	85.140$^{2/}$	319.443$^{2/}$	444.855$^{2/}$	597.633$^{2/}$	0.032$^{n.s}$	1.527$^{2/}$	29.057$^{2/}$	0.141$^{2/}$	104.255$^{2/}$	0.696$^{2/}$	1.475.772.27$^{2/}$
Lines	24	40.487$^{2/}$	219.219$^{2/}$	158.491$^{2/}$	531.552$^{2/}$	0.000$^{n.s}$	1.605$^{2/}$	30.028$^{2/}$	0.083$^{n.s}$	25.624$^{2/}$	0.517$^{1/}$	1.407.428.47$^{2/}$
Controls	3	290.000$^{2/}$	755.417$^{1/}$	2049.889$^{2/}$	839.639$^{2/}$	0.000$^{n.s}$	1.417$^{n.s}$	24.747$^{2/}$	0.521$^{1/}$	461.417$^{2/}$	1.965$^{1/}$	2.394.722.22$^{2/}$
Lines vs controls	1	542.250$^{2/}$	1.416.911$^{2/}$	2.502.477$^{2/}$	1.457.554$^{2/}$	0.896$^{n.s}$	0.001$^{n.s}$	18.680$^{2/}$	0.381$^{1/}$	919.912$^{2/}$	1.184$^{n.s}$	359.173.563$^{n.s}$
Error	56	1.661	28.682	8.830	33.993	0.032	0.228	1.126	0.065	7.830	0.270	210.832.31
Total	86											
General mean		41.759	43.828	117.092	46.184	1.034	3.408	15.156	1.293	35.287	1.500	2.652.30
Lines mean		40.760	42.213	114.947	44.547	1.027	3.407	14.970	1.267	33.987	1.453	2.678.00
Controls mean		48.000	53.917	130.500	56.417	1.083	3.417	16.314	1.458	43.417	1.792	2.491.67
CV %		3.087	12.220	2.538	12.624	17.298	14.021	7.002	19.679	7.930	34.661	17.312

$^{1/,\ 2/}$ significant at the 0.05 and 0.01probability level, by F test, respectively; $^{n.s.}$ not significant at the 0.05 probability.

Table 11. Summary of the analysis of variance, in complete randomized blocks, with values and significance of the mean squares of eleven traits. Soybean, $F_{9:2}$ generation. EA/UFG – Goiânia, sown in 11/12/98.

Source of variation	DF	NDF (days)	APF (cm)	NDM (days)	APM (cm)	AC (note)	VA (note)	PCS (note)	AFC (note)	PEG (days)	SM (note)	PG (kg/ha)
Blocks	2	6.770	39.552	1.529	62.942	0.034	0.164	0.340	0.744	0.563	0.218	38.045.97
Treatments	28	90.512$^{2/}$	372.545$^{2/}$	128.935$^{2/}$	383.128$^{2/}$	0.104$^{2/}$	1.099$^{2/}$	27.530$^{2/}$	0.284$^{1/}$	18.607$^{2/}$	0.129$^{n.s}$	752.846.37$^{2/}$
Lines	24	41.083$^{2/}$	156.292$^{2/}$	82.750$^{2/}$	251.626$^{2/}$	0.111$^{2/}$	1.180$^{2/}$	27.622$^{2/}$	0.126$^{n.s}$	19.174$^{2/}$	0.136$^{n.s}$	822.938.89$^{2/}$
Controls	3	311.667$^{2/}$	1.241.111$^{2/}$	420.000$^{2/}$	555.333$^{2/}$	0.083$^{n.s}$	0.583$^{n.s}$	30.148$^{2/}$	1.132$^{1/}$	18.75$^{1/}$	0.111$^{n.s}$	141.440.97$^{1/}$
Lines vs controls	1	613.345$^{2/}$	2.956.918$^{2/}$	364.184$^{2/}$	3.022.573$^{2/}$	0.002$^{n.s}$	0.717$^{1/}$	17.464$^{2/}$	1.534$^{2/}$	4.551$^{n.s}$	0.023$^{n.s}$	904.842.02$^{1/}$
Error	56	2.211	20.171	8.100	37.097	0.046	0.143	0.683	0.155	3.444	0.099	168.633.77
Total	86											
General mean		44.195	39.759	116.885	46.264	1.069	3.190	15.316	1.626	36.988	1.126	1.997.127
Lines mean		43.133	37.427	116.067	43.907	1.067	3.153	15.136	1.573	37.080	1.120	1.956.33
Controls mean		50.833	54.333	122.000	61.000	1.083	3.417	16.435	1.958	36.417	1.167	2.252.02
CV %		3.364	11.296	2.435	13.165	20.148	11.854	5.395	24.204	5.017	27.98	20.562

$^{1/,\ 2/}$ significant at the 0.05 and 0.01probability level, by F test, respectively; $^{n.s.}$ not significant at the 0.05 probability.

Table 12. Summary of the analysis of variance with values and significance of the mean squares of six traits[1]. Soybean, $F_{9:2}$ generation. EA/UFG – Goiânia.

Source of variation	DF	NDF (days)	APF (cm)	NDM (days)	APM (cm)	AC (note)	VA (note)
Periods (a)	2	136.234$^{2/}$	525.866$^{2/}$	3.194.682$^{2/}$	851.912$^{2/}$	0.103$^{1/}$	21.736$^{2/}$
Blocks/periods	6	3.199	61.682	25.720	85.425	0.046	0.384
Treatments (t)	28	254.874$^{2/}$	832.678$^{2/}$	674.543$^{2/}$	1.421.934$^{2/}$	0.056$^{2/}$	5.089$^{2/}$
Lines (z)	24	124.301$^{2/}$	253.117$^{2/}$	253.117$^{2/}$	1.106.046$^{2/}$	0.060$^{2/}$	5.284$^{2/}$
Controls (c)	3	836.991$^{2/}$	2.273.435$^{2/}$	3.040.222$^{2/}$	2.258.000$^{2/}$	0.037$^{n.s}$	5.137$^{2/}$
Lines vs Controls	1	1.642.268$^{2/}$	10.419.872$^{2/}$	3.691.718$^{2/}$	6.495.035$^{2/}$	0.018$^{n.s}$	0.267$^{n.s}$
Treatments x Controls	56	4.944$^{2/}$	41.909$^{1/}$	67.749$^{2/}$	59.051$^{n.s}$	0.040$^{1/}$	0.515$^{2/}$
Lines x Periods	48	5.148$^{2/}$	35.909$^{1/}$	43.506$^{2/}$	63.386$^{1/}$	0.038$^{2/}$	0.481$^{2/}$
Controls x Periods	6	4.380$^{2/}$	65.991$^{n.s}$	204.222$^{2/}$	20.528$^{n.s}$	0.065$^{n.s}$	0.887$^{1/}$
Lines vs Controls x Periods	2	1.734$^{n.s}$	113.682$^{1/}$	240.167$^{2/}$	70.567$^{n.s}$	0.008$^{n.s}$	0.226$^{n.s}$
Mean error	168	1.600	26.853	17.097	42.786	0.026	0.182
Total	260						
General mean		42.812	40.996	120.487	44.418	1.034	3.017
Lines mean		41.809	39.187	118.982	42.422	1.031	3.004
Controls mean		49.083	52.306	129.889	56.889	1.056	3.097
CV%		2.955	12.640	3.432	14.726	15.628	14.128

$^{1/,\ 2/}$ significant at the 0.05 and 0.01probability level, by F test, respectively; $^{n.s.}$ not significant at the 0.05 probability.

average) for the PCS trait compared to the controls that presented lower means, indicating the possibility of effective selection for the trait of resistance to pod sucking insects. This trait is very important in genetic resistance because it has genetic correlation with a low index of damage in the pods by the dilution effect (Link and Estefanel, 1982; Panizzi et al., 1986; Rossetto, 1989; Rossetto and Lara, 1991; Rossetto et al., 1995; Pinheiro et al., 1997).

The controls were superior (on average) for the VA and PG traits compared to the lines, that can be explained because cultivars recommended for the region are among the controls.

For the joint analysis of the $F_{9:2}$ generation, the sources of variation treatments and lines were statistically different for all the traits, indicating further the presence of variability among them for future selection (Tables 12 and 13).

Statistical differences were observed in the sources of variation treatments x periods and lines x periods (after partitioning for the NDF, NDM, VA, PCS, SM, PEG and PG traits (p<0.01) and for APF, APM and AC (P<0.05) indicating a change of behavior in the materials in function of the sowing period.

Better means were observed in the lines for the traits in the second sowing period, that indicated that this period (09/11/98) is the most promising for cropping in the region (Table 10).

Lines were considered promising for the PG trait that were present in the three generations (F_7, F_8 and F_9) or at least those that were present in one of the initial generations (F_7 and, or F_8) and in two periods of the F_9 generation, as this generation was assessed in the period recommended for cropping in the region (Table 5).

Thus the lines 81-1-23, 81-1-24, 81-1-28, 81-4-13, 81-7-01, 81-7-18, 81-9-13, 81-9-18, 81-10-08 e 81-10-09 were selected. The line 81-7-18 was considered the most promising line for the PG trait, because it was among the ten greatest yields in the F_7, F_8 and F_9 generations (set) and in the 1st and 3rd periods of the F_9 generation, indicating its good yield and stability (Table 5).

Once the lines (ten) considered promising for the grain yield trait had been selected, they were differentiated by the various traits assessed in the F_8 and F_9 generations (Table 6).

It was observed that for the traits related to the late flowering genes (NDF and NDM), only the line 81-9-13 presented a greater mean compared to the general mean of the controls. This may be explained because the lines were derived from crosses with early cycle parents and so these are also early cycle.

For the traits related to resistance to insects (PEG, SM, PCS, AFC) all the lines considered promising for PG were superior to the general mean of the controls, that is, presented shorter pod filling period, lower percentage of marked seeds, lower weight of one hundred seeds and lower cut leaf area, indicating a good behavior for characteristics of resistance to

Table 13. Summary of the analysis of variance with values and significance of the mean squares of six traits[1]. Soybean, $F_{9:2}$ generation. EA/UFG – Goiânia.

Source of variation	DF	PCS (g)	AFC (note)	SM (note)	PEG (days)	PG (kg/ha)
Periods (a)	2	36.897[2/]	2.604[2/]	36.897[2/]	228.705[2/]	23.874.750.94[2/]
Blocks/periods	6	1.448	0.324	1.448	1.609	102.097.69
Treatments (t)	28	64.446[2/]	0.535[2/]	64.446[2/]	98.639[2/]	3.287.812.19[1/]
Lines (z)	24	64.648[2/]	0.228[2/]	64.648[2/]	49.825[2/]	3.459.188.19[2/]
Controls (c)	3	73.248[2/]	2.303[2/]	73.248[2/]	422.333[2/]	2.769.699.07[2/]
Lines vs Controls	1	33.181 [n.s]	2.600[2/]	33.181 [n.s]	638.262[2/]	729.126.525 [n.s]
Treatments x Controls	56	3.333[2/]	0.086 [n.s]	3.333[2/]	38.832[2/]	453.543.12[2/]
Lines x Periods	48	3.556[2/]	0.088 [n.s]	3.556[2/]	17.846[2/]	357.551.375[2/]
Controls x Periods	6	1.802 [n.s]	0.074 [n.s]	1.802 [n.s]	114.917[2/]	1.071.799.77[2/]
Lines vs Controls x Periods	2	2.571 [n.s]	0.097 [n.s]	2.571 [n.s]	314.229[2/]	902.574.725 [n.s]
Mean error	168	0.967	0.105	0.967	7.716	195126.00
Total	260					
General mean		15.609	1.486	1.942	36.935	2.088.70
Lines mean		15.466	1.447	1.920	36.507	2.067.56
Controls mean		16.500	1.736	2.083	39.611	2.220.83
CV%		6.299	21.849	29.610	7.521	21.148

[1/, 2/] significant at the 0.05 and 0.01probability level, by F test, respectively; [n.s.] not significant at the 0.05 probability.

leaf eater and sucking insects.

The lines behaved well for the other agronomic traits (AC and VA) compared to the general mean of the controls, confirming the good performance observed for the other traits assessed.

Line 81-9-13 (OCEPAR-04 x IAC-100) was superior to the mean of the controls for all the traits, and the other lines could also be considered promising for the region. Thus the importance is understood of carrying out assessment experiments of the agronomic characteristics in different agro-ecological regions to assess their performance and possible recommendation for cultivation in the region.

The IAC-100 cultivar (used as a control) “per se” presented good agronomic characteristics and insect resistance, in line with previous experimental results obtained by Rossetto (1989), Rossetto et al. (1995) Pinheiro et al. (1997) and Veiga et al. (1999). Furthermore, it presented high yields that suggest that this cultivar should be assessed in experiments in the region for recommendation.

CONCLUSIONS

– Ten early cycle lines were selected and considered promising for cultivation in the Cerrado regions, mainly for grain yield and insect resistance, whose parent was the IAC-100 cultivar;

– Line 81-9-13 (OCEPAR04 x IAC-100) was the most outstanding because it was superior to the mean of the controls for all the traits assessed in the F9 generation;

– Sowing in November is recommended for soybean cultivation in the region;

– The IAC-100 cultivar (used as control) “per se” presented good agronomic and insect resistance characteristics as well as high yield, and it is recommended that this cultivar be assessed in experiments in the region for future recommendation.

RESUMO

Seleção de Genótipos de Soja Adaptados às Condições de Cerrado e Resistentes a Insetos

Este trabalho teve por objetivo a seleção de genótipos produtivos de soja, adaptados às condições de cerrado e com resistência a insetos. O material experimental incluiu 170 linhagens $F_{7:2}$ de soja obtidas de cruzamentos dialélicos parciais (4 x 4) envolvendo oito parentais com base na reação a insetos e produtividade de grãos e mais três linhagens provenientes do programa de melhoramento genético de soja da ESALQ/USP. Foram avaliadas em Goiânia – GO, as gerações F_7, F_8 e F_9, sendo esta última avaliada em três épocas de semeadura (21/10/98, 09/11/98 e 11/12/98). Os seguintes caracteres foram avaliados: número de dias para o florescimento, altura da planta no florescimento, número de dias para a maturidade, altura da planta na maturidade, período de granação, sementes manchadas, peso de cem sementes, área foliar cortada, acamamento, valor agronômico e produtividade de grãos. Foram utilizados os delineamentos de blocos aumentados na geração F_7 e de blocos completos casualizados nas gerações F_8 e F_9. As análises de variância foram realizadas para cada geração individualmente; uma análise de variância conjunta foi feita para as três épocas de semeadura da geração F_9. Com base na produtividade de grãos, dos diferentes experimentos, foram identificadas as linhagens mais promissoras para a região, sendo discriminadas em relação aos caracteres de resistência a insetos. A partir deste trabalho pode-se extrair as seguintes conclusões: a) dez linhagens do ciclo precoce foram consideradas promissoras para o cultivo nas regiões de cerrado, principalmente em termos de produtividade de grãos e de resistência a insetos, e estas envolvem o genitor IAC-100; b) a linhagem 81-9-13 (OCEPAR-04 x IAC100) foi superior a média das testemunhas para todos os caracteres avaliados na geração F_9, destacando-se das demais; c) a semeadura realizada em novembro é a mais indicada para o cultivo de soja na região; f) o cultivar IAC-100 (utilizado como testemunha) ‘per se’ apresentou boas características e de resistência a insetos, bem como produtividades altas, recomendando-se a avaliação deste cultivar em ensaios na região, visando sua recomendação.

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