

Genetic analysis of soybean resistance to stinkbug

Rogério Fernandes de Souza¹ and José Francisco Ferraz de Toledo²

ABSTRACT

Genetic mechanisms controlling the characters yield, healthy seed weight (HSW), percentage of healthy seeds (PHS) and leaf retention (LR) were studied in crosses involving the commercial cultivars Davis, BR-13 and Lancer and the breeding lines IAC 74-2832 and IAC 78-2318, that are reported to carry insect resistance genes. These materials and their segregating F_2 and F_4 generations were evaluated in the field, under insect (*Nezara viridula*, *Piezodorus guildinii* and *Euchistus heros* - Pentatomidae) pressure. Line IAC 74-2832 was the most resistant. The genetic models fitted to the means of the generations indicated the presence of additive, dominance and epistatic effects. The variance analyses indicated a predominance of additive effects, but also revealed the presence of linkage and genotype x microenvironmental interaction. The breeding potential analyses indicated that it is possible to obtain high yielding resistant lines from Lancer x IAC 74-2832 and Davis x IAC 74-2832 crosses.

INTRODUCTION

The pentatomid stinkbugs *Nezara viridula*, *Piezodorus guildinii* and *Euchistus heros* are the main soybean insect pests in Brazil. Since they prefer to feed on the reproductive part (pods) of the plant, a low population density of these insects can lead to a considerable decrease in yield and seed quality. Stinkbug control is usually done by spraying pesticides. More economical and environmentally safe control would be possible with resistant cultivars. Several breeding lines have been developed in Brazil by crossing resistant plant introductions (PI) with commercial (adapted) varieties of soybean (Rosseto *et al.*, 1984; Panizzi and Slansky Jr., 1985; Rosseto *et al.*, 1986; Lourenção *et al.*, 1989; Rosseto, 1989).

MATERIAL AND METHODS

Obtaining the segregant generations

Crosses were made using the cultivars Lancer, BR-13 and Davis with the breeding lines IAC 78-2318 and IAC 74-2832 (derived from PI 229.358 and PI 274.454, respectively), which are resistant to various insects, including phytophagous stinkbugs (Ferreira *et al.*, 1980; Panizzi *et al.*, 1981; Hinson and Hartwig, 1982; Lourenção *et al.*, 1985, 1987, 1989; Lourenção and Miranda, 1987). The segregant generations F_2 and F_4 of the crosses IAC 74-2832 x Davis, IAC 74-2832 x BR-13, IAC 74-2832 x Lancer and IAC 78-2318 x Lancer were obtained using the single seed descent method (SSD).

Field experiment

The experiment was carried out on an experimental field of the National Soybean Research Center (EMBRAPA-CNPSO) at Londrina, Paraná, located at latitude 23°22'S. A total of 2750 hill-plots,

¹ Universidade Estadual de Londrina, Caixa Postal 6001, 86051-970 Londrina, PR, Brasil.

² EMBRAPA-CNPSO, Caixa Postal 231, 86001-970 Londrina, PR, Brasil.
Send correspondence to J.F.F.T.

including the parents and the F_2 and F_4 generations of each cross, were sown in the field in a completely randomized design on November 11, 1988, using individual plant randomization (01 plant = 01 hill-plot). Plot spacing was 20 cm within and one meter between rows. Border rows were sown between hill-plot rows (at 50 cm spacing) and around the experiment, using a mixture of the remaining F_2 and F_4 seeds, to make stinkbug distribution uniform among plots during the reproductive period of the materials under assessment. Weekly samples of the stinkbug population, both adults and nymphs, were taken.

Data collection

The following characteristics were assessed: yield (total weight of seeds produced in grams per plant); healthy seed weight (HSW; total weight of healthy seeds, without apparent stinkbug damage, in grams per plant); percentage of healthy seeds [PHS; $100 \times (\text{healthy seed weight} \div \text{yield})$] and the index of leaf retention (LR), scored from 1 to 5 according to the percentage of leaf retention shown by the plants (0 to 20% = 1, 21 to 40% = 2, 41 to 60% = 3, 61 to 80% = 4 and 81 = 100% = 5). The LR index is considered an important component of soybean resistance to stinkbugs since plants that mature normally under insect pressure, when a few or several pods have been damaged, will allow mechanical harvesting. The means and variances of the parental populations and the segregating generations were obtained. For the F_4 , the between and within generation variances were calculated.

Analysis of genetic data

Genetic models were fitted to the means and variances (of parents and their segregant generations) of each characteristic. The mean genetic models involved the mean m , additives [d], dominance [h] and epistatic additive \times additive [i] and dominance \times dominance [l] effects. The genetic parameters were estimated by weighted least squares, following the method of Cavalli (1952) described by Mather and Jinks (1982). Models involving additive D , additive between linked loci $D1$, $D2$ or $D3$, dominance H , environmental E and genotype \times microenvironmental E_1 and E_2 effects were fitted to the variances of the generations using the method of Hayman (1960) and the models suggested by Toledo *et al.* (1991). In both cases a specific Fortran program (Toledo, 1991) was used. Predictions of the

genetic potential of the crosses to generate superior (high yielding and resistant) inbred lines were made according to Jinks and Pooni (1976) and Toledo (1987).

RESULTS AND DISCUSSION

The number of stinkbugs considered harmful to seed production (one stinkbug per linear meter of row) was surpassed in the March 3rd sample when all the materials were still forming the pods or beginning the pod filling stage. The gradual increase of the pentatomid population during the experiment was similar to that found by Ferreira and Panizzi (1981). All the plants in the experiment were exposed to insect damage during a significant part of their reproductive period (Figure 1).

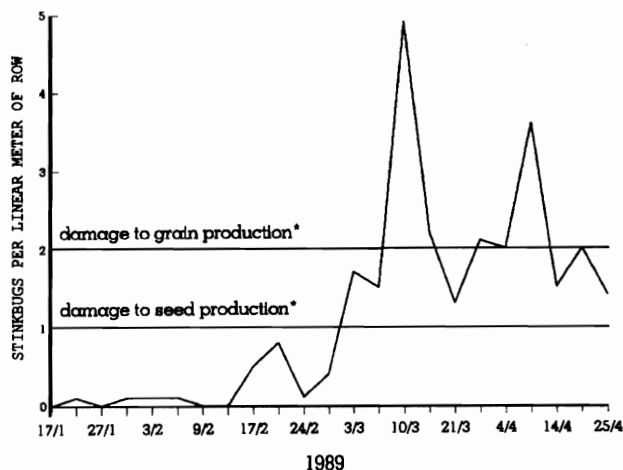


Figure 1 - Fluctuation in stinkbug population in the soybean field during the experiment. *Panizzi *et al.* (1978).

The means and variances of the generations are shown in Table I. The line IAC 74-2832 was the highest yielding, and presented the highest HSW and PHS, and the lowest LR. Line IAC 78-2318 was least resistant.

Significant levels of positive heterosis (desirable) were detected in the F_2 generation for some characteristics such as yield and HSW in the crossings among Davis and IAC 74-2832 and HSW in the crossings BR-13 and IAC 74-2832. Positive heterosis (undesirable) was also observed for LR in the crosses between BR-13 and IAC 74-2832, Lancer and IAC 74-2832 and Lancer and IAC 78-2318.

The genetic models fitted to the means and variances of yield, HSW, PHS, and LR are shown in Tables II and III, respectively. The mean effects, m , [d] and [h], were observed for yield in all crosses, except IAC 74-2832 \times Lancer. Dominance, whenever

Table I - Degrees of freedom, means and variances of soybean parents and their segregant F_2 and F_4 generations.

Parents/ Generation	Yield (g/plant)			Weight of healthy seeds (g/plant)			Percentage of healthy seeds			Index of leaf retention		
	DF	Mean	Var	DF	Mean	Var	DF	Mean	Var	DF	Mean	Var
IAC 74-2832	28	37.54	364.76	28	19.74	161.85	28	52.17	508.00	29	1.40	0.59
Davis	29	24.60	61.84	29	9.13	55.65	29	34.63	567.07	29	3.60	2.25
F_2	46	48.09	188.96	46	25.94	112.73	46	54.02	239.46	46	2.77	1.84
F_4	281	39.66	261.48	281	18.84	112.81	281	48.35	417.14	289	2.18	1.80
Between ¹	29	-	727.11	29	-	246.67	29	-	1015.29	29	-	2.70
Within ²	252	-	205.72	252	-	96.78	252	-	345.51	260	-	1.70
IAC 74-2832												
BR-13	26	25.07	152.53	26	15.56	31.39	26	65.56	312.87	27	1.25	0.64
F_2	47	41.27	261.10	47	24.35	140.60	47	57.92	416.12	48	2.78	0.64
F_4	275	36.42	266.66	274	19.83	140.34	274	54.82	454.92	281	1.99	1.61
Between	29	-	505.51	29	-	307.44	29	-	1406.52	29	-	3.50
Within	246	-	236.92	245	-	119.45	245	-	355.97	252	-	1.38
IAC 74-2832												
Lancer	26	34.88	199.56	26	17.39	87.40	26	49.26	271.28	29	2.11	2.10
F_2	47	39.58	198.28	47	20.74	119.82	47	51.10	322.10	47	2.52	1.79
F_4	282	41.21	268.60	283	18.49	135.35	283	44.32	478.46	288	2.24	1.61
Between	29	-	769.24	29	-	410.59	29	-	1933.76	29	-	3.56
Within	253	-	208.94	253	-	102.55	253	-	305.02	259	-	1.38
Lancer												
IAC 78-2318	27	26.20	141.24	27	12.19	87.40	27	46.82	543.19	27	2.00	1.50
F_2	47	35.13	199.25	47	17.53	108.96	47	50.35	545.77	47	2.40	1.99
F_4	288	37.91	181.06	287	17.78	92.97	287	46.77	369.25	292	2.12	1.65
Between	29	-	339.84	29	-	168.65	29	-	781.83	29	-	4.19
Within	259	-	162.60	258	-	84.14	258	-	321.09	263	-	1.36

¹Between F_4 family variance.²Within F_4 family variance.

significant, was directional towards increasing yield as is usually observed for soybean yield in the absence of stink bug infestation. Negative values for $[i]$ and $[l]$ types of non-allelic interaction were observed in the crosses IAC 74-2832 x Davis and IAC 78-2318 x Lancer, respectively. The variance analyses indicated the presence of significant levels of D effects in crosses between IAC 74-2832 x BR-13 and IAC 78-2318 x Lancer. Genotype x microenvironment interaction was detected in the cross IAC 74-2832 x Davis. Linkage between loci showing additive effects D_2 was detected in the cross between IAC 74-2832 and Lancer. In spite of the complexity of the genetic model controlling yield it became evident that additive genetic effects predominated. The presence of ample additive genetic

variability indicated that it should be possible to derive high yielding lines from all crosses. This was confirmed by the inbreeding potential analyses (Table IV), which predicted large proportions of inbred lines yielding higher than IAC 74-2832 for crosses IAC 74-2832 x Davis and IAC 74-2832 x Lancer.

The genetic models adjusted to the means and variances of HSW showed significant levels of additive and dominance effects in the crosses between IAC 74-2832 x Davis and IAC 74-2832 x BR-13. Dominance was towards increased HSW. No genetic variation was observed in cross IAC 74-2832 x Lancer (only an m effect was detected). In the cross between IAC 78-2318 and Lancer, additive $[d]$ and negative $[i]$ type non-allelic interaction effects were significant. The variance

Table II - Genetic models adjusted to the means of the parents and their segregant generations in soybeans.

	IAC 74-2832 x Davis	IAC 74-2832 x BR-13	IAC 74-2832 x Lancer	IAC 78-2318 x Lancer
<i>Yield (Y) - (grams/plant)</i>				
m	36.85 ± 1.45	33.62 ± 1.24	40.19 ± 0.81	30.54 ± 1.76
[d]	6.47 ± 1.91	7.12 ± 2.03	-	4.34 ± 1.76
[h]	22.48 ± 5.93	17.14 ± 5.97	-	75.55 ± 19.57
[i]	-5.78 ± 2.40	-	-	-
[l]	-	-	-	-132.75 ± 34.63
χ^2	-	1.78 ^{n.s.}	5.46 ^{n.s.}	-
df	0*	1	3	0*
<i>Healthy seed weight (HSW) - (grams/plant)</i>				
m	15.77 ± 0.80	18.04 ± 0.84	18.75 ± 0.58	17.75 ± 0.53
[d]	5.98 ± 1.25	2.34 ± 1.13	-	2.60 ± 1.22
[h]	21.49 ± 3.93	13.07 ± 4.22	-	-
[i]	-	-	-	-2.96 ± 1.33
χ^2	1.47 ^{n.s.}	0.16 ^{n.s.}	2.48 ^{n.s.}	0.02 ^{n.s.}
df	1	1	3	1
<i>Percentage healthy seed weight (PHS)</i>				
m	45.66 ± 1.53	55.89 ± 1.08	50.32 ± 2.53	47.32 ± 0.99
[d]	8.68 ± 3.02	7.30 ± 2.65	-	-
[h]	17.56 ± 6.24	-	-64.53 ± 28.87	-
[l]	-	-	132.17 ± 50.81	-
χ^2	0.76 ^{n.s.}	2.38 ^{n.s.}	0.31 ^{n.s.}	1.43 ^{n.s.}
df	1	2	1	3
<i>Leaf retention index trait (LR)</i>				
m	1.98 ± 0.12	1.33 ± 0.10	2.28 ± 0.07	2.14 ± 0.07
[d]	1.10 ± 0.15	-	0.36 ± 0.15	-
[h]	1.57 ± 0.57	6.07 ± 1.31	-	-
[i]	0.52 ± 0.18	-	-0.52 ± 0.17	-
[l]	-	-6.34 ± 2.50	-	-
χ^2	-	0.53 ^{n.s.}	1.83 ^{n.s.}	2.09 ^{n.s.}
df	0*	1	1	3

*Perfect fit; no degree of freedom left for testing the goodness of fit of the model.

n.s. = not significant.

m = mean.

[d] = additive effect.

[h] = dominance effect.

[i] = additive x additive epistatic effect.

[l] = dominance x dominance epistatic effect.

χ^2 = goodness of fit chi-square.

Table III - Genetic models adjusted to the variances of the parents and their segregant generations in soybeans.

	IAC 74-2832 x Davis	IAC 74-2832 x BR-13	IAC 74-2832 x Lancer	IAC 78-2318 x Lancer
<i>Yield (Y) - (grams/plant)</i>				
D	69.48 ± 25.48	38.37 ± 19.56	-	24.87 ± 12.68
D ₂	-	-	229.20 ± 84.45	-
E	-	238.34 ± 19.16	219.16 ± 16.47	164.20 ± 12.93
E ₁	328.68 ± 35.77	-	-	-
E ₂	60.65 ± 15.71	-	-	-
χ^2	0.95 ^{n.s.}	5.71 ^{n.s.}	6.77 ^{n.s.}	1.36 ^{n.s.}
df	2	3	3	3
<i>Healthy seed weight (HSW) - (grams/plant)</i>				
D	20.96 ± 9.21	29.42 ± 12.26	40.96 ± 14.46	-
D ₂	-	-	-	19.17 ± 9.65
E	-	-	102.60 ± 8.57	85.25 ± 6.54
E ₁	141.50 ± 19.11	196.71 ± 20.81	-	-
E ₂	52.90 ± 13.18	32.41 ± 8.88	-	-
χ^2	0.50 ^{n.s.}	0.66 ^{n.s.}	5.28 ^{n.s.}	0.74 ^{n.s.}
df	2	2	3	3
<i>Percentage healthy seed weight (PHS)</i>				
D	-	147.45 ± 51.87	-	-
D ₂	-	-	203.32 ± 61.52	117.58 ± 49.25
E	-	351.75 ± 29.86	313.14 ± 24.44	-
E ₁	-	-	-	451.91 ± 72.50
E ₂	-	-	-	245.21 ± 60.22
χ^2	-*	3.13 ^{n.s.}	7.08 ^{n.s.}	4.44 ^{n.s.}
df	-	3	3	2
<i>Leaf retention index trait (LR)</i>				
D	-	-	0.32 ± 0.13	0.38 ± 0.15
H	-	4.93 ± 1.15	-	-
D ₃	-	3.73 ± 1.35	-	-
E	-	0.61 ± 0.11	-	1.44 ± 0.12
E ₁	2.91 ± 0.29	-	2.15 ± 0.26	-
E ₂	0.62 ± 0.16	-	0.59 ± 0.15	-
χ^2	5.07 ^{n.s.}	0.66 ^{n.s.}	0.77 ^{n.s.}	4.96 ^{n.s.}
df	3	2	2	3

*No adequate genetic model was found.

n.s. = not significant.

D = additive variance.

D₂ = additive variance between linked loci.

E = environment effect

E₁ and E₂ = microenvironment interaction effect.

χ^2 = goodness of fit chi-square.

Table IV - Expected proportions of randomly derived inbred soybean lines subjected to stinkbug infestation (in %).

	IAC 74-2832 x Davis		IAC 74-2832 x BR-13		IAC 74-2832 x Lancer		IAC 78-2318 x Lancer	
	≥ REF1	≤ REF2	≥ REF1	≤ REF2	≥ REF1	≤ REF2	≥ REF1	≤ REF2
	Yield*	46.5	7.0	26.7	7.2	57.2	15.3	7.9
HSW*	19.6	7.3	37.6	4.9	43.5	6.6	32.7	2.4
PHS*	-	-	62.1	3.9	44.6	13.6	33.0	12.1
LR**	-	-	51.5	12.0	5.9	1.0	11.5	0.9

*REF1: IAC 74-2832, REF2: Davis.

**REF1: Davis, REF2: IAC 74-2832.

analysis of the crosses IAC 74-2832 x Davis and IAC 74-2832 x BR-13 showed additive genetic effects and genotype x microenvironment interaction. The cross between IAC 78-2318 and Lancer showed a significant D_2 effect. Considering the predominance and magnitude of the additive genetic effects in the control of HSW, breeding inbred lines showing higher levels of HSW than IAC 74-2832 should be easy. Table IV shows that the expected proportions of inbred lines scoring higher than IAC 74-2832 for crosses IAC 78-2318 x Lancer, IAC 74-2832 x BR-13 and IAC 74-2832 x Lancer are large.

The genetic models fitted to the PHS means and variances also revealed the predominance of additive effects. Complicating factors such as epistasis, linkage and genotype x microenvironmental effects were also present indicating a complex control for the character. Dominance was towards increasing PHS in cross between IAC 74-2832 x Davis and towards decreasing PHS effects when coupled with positive [l] type non-allelic interaction effects in cross IAC 74-2832 x Lancer, indicating the presence of duplicate genes, but it was absent in the others. The genetic models adjusted to the variances of the cross between IAC 74-2832 and Davis had significant chi-square values, indicating the inadequacy of the fitted parameters to represent all the genetic variability observed. This confirmed the complexity of the genetic control of PHS.

The PHS data, as indicated in Material and Methods, were obtained from the ratio $HSW \div \text{yield}$ and are, therefore, subjected to larger sampling errors. This fact became evident from the mean standard errors (Table I) and from the adjusted models (Tables II and III). Considering these larger errors, the genetic information obtained from the PHS analyses should be seen only as an auxiliary tool for the breeder. In this work, it provided useful information for the cross IAC

74-2832 x Lancer, and confirmed that it should be possible to derive inbred lines outperforming the references from crosses IAC 74-2832 x BR-13, IAC 74-2832 x Lancer and IAC 78-2318 x Lancer, in terms of insect resistance.

The genetic models fitted to the means and variances of LR for all crosses indicated that additive effects were predominant in the control of this character, but again indicated the presence of other genetic and environmental effects. Breeding pure lines with less LR than the references (Table IV) requires large populations since the expected percentage of lines falling below the smaller parent was relatively small in at least two cases.

CONCLUSIONS

All analyzed traits were shown to be controlled by a fairly complex polygenic system with a predominance of additive genetic effects. The predictions of the breeding potential of the crosses indicated that it should be relatively easy to obtain inbred lines outperforming the parent highest in yield, HSW or PHS. Among the tested material, the line IAC 74-2832 was the most resistant to phytophagous stinkbugs and easily transferred this characteristic to its descendants. Thus, it would be useful in a breeding program for stinkbug resistance.

ACKNOWLEDGMENTS

The authors are grateful to Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the research grants received during the period this work was carried out.

RESUMO

Os mecanismos genéticos controlando os caracteres produtividade, peso de sementes sadias, porcentagem de sementes sadias e índice de retenção foliar foram avaliados através de cruzamentos envolvendo os cultivares Davis, BR-13 e Lancer com as linhagens IAC 74-2832 e IAC 78-2318, indicadas como sendo portadoras de genes de resistência a insetos. Estes materiais e seus descendentes F_2 e F_4 foram avaliados em um experimento a campo, sob a infestação dos percevejos *Nezara viridula*, *Piezodorus guildinii* e *Euchistus heros*. A linhagem IAC 74-2832 foi o melhor material deste experimento, mostrando bons resultados com relação aos caracteres analisados. Os modelos genéticos adaptados às médias destas gerações indicaram a presença de efeitos aditivos, de dominância e epistáticos. A análise de variâncias indicou a predominância de efeitos aditivos, mas também revelou a presença de ligação e de interação genótipo x microambiente. Dispersão gênica também foi detectada na maioria dos cruzamentos. Os cruzamentos entre Lancer e IAC 74-2832 e Davis e IAC 74-2832 mostraram boas possibilidades de obtenção de descendentes superiores para o caráter produtividade e resistência a insetos, como indicado pela previsão do potencial genético.

REFERENCES

- Cavalli, L.L.** (1952). An analysis of linkage in quantitative inheritance. In: *Quantitative Inheritance* (Reeve, C.R., Waddington, C.D., eds.). HMSO, London, pp. 135-144.
- Ferreira, B.S.C. and Panizzi, A.R.** (1981). Percevejos-pragas da soja no norte do Paraná: abundância em relação a fenologia da planta e hospedeiros intermediários. *Anais: II Seminário Nacional de Pesquisa de Soja* (EMBRAPA-CNPSo). Londrina 2: 140-151.
- Ferreira, B.S.C., Kiihl, R.A.S. and Almeida, L.A.** (1980). Avaliação de genótipo resistente a percevejos. In: *Resultados de Pesquisa de Soja 1979/80* (EMBRAPA-CNPSo). Londrina, pp. 126-129.
- Hayman, B.I.** (1960). Maximum likelihood estimation of genetic components of variation. *Biometrics* 16: 369-381.
- Hinson, K. and Hartwig, E.E.** (1982). Soybean production in the tropics. *FAO Plant Production and Protection Papers* 4: 155-170.
- Jinks, J.L. and Pooni, H.S.** (1976). Predicting the properties of recombinant inbred lines derived by single seed descent. *Heredity* 36: 253-266.
- Lourenção, A.L. and Miranda, M.A.C.** (1987). Resistência de soja a insetos: VIII. IAC 78-2318, linhagem com resistência múltipla. *Bragantia* 46: 65-72.
- Lourenção, A.L., Rosseto, C.J. and Miranda, M.A.C.** (1985). Resistência de soja a insetos: IV. Comportamento de cultivares e linhagens em relação a *Hedilepta indicata* (Fabr.). *Bragantia* 44: 149-157.
- Lourenção, A.L., Miranda, M.A.C. and Nagai, V.** (1987). Resistência de soja a insetos: VII. Avaliação de danos de percevejos em cultivares e linhagens. *Bragantia* 46: 45-57.
- Lourenção, A.L., Costa, A.S. and Miranda, M.A.C.** (1989). Sources of resistance to insects pests and virus vectors in the soybean germplasm tested at the Instituto Agronômico, S.P., Brazil. In: *IV Conferencia Mundial e Investigacion en soja*. Argentina, 3: 1578-1581.
- Mather, K. and Jinks, J.L.** (1982). *Biometrical Genetics*. Chapman and Hall, London, pp. 396.
- Panizzi, A.R. and Slansky Jr., F.** (1985). Review of phytophagous pentatomids (Hemiptera: Pentatomidae) associated with soybean in the Americas. *Florida Entomologist* 68: 184-214.
- Panizzi, A.R., Smith, J.G., Pereira, L.A.G. and Yamashita, J.** (1978). Efeitos dos danos de *Piezodorus guildinii* no rendimento e qualidade da soja. *Anais do 1º Seminário Nacional de Pesquisa de Soja* (vol. II), EMBRAPA-CNPSo, Londrina, 1979, pp. 59-78.
- Panizzi, M.C.C., Bays, I.A., Kiihl, R.A.S. and Porto, M.P.** (1981). Identificação de genótipos fontes de resistência a percevejos-pragas da soja. *Pesq. Agrop. Bras.* 16: 33-37.
- Rosseto, C.J.** (1989). Breeding for resistance to stink bugs. In: *IV Conferencia Mundial de Investigacion en Soja*. Argentina, 4: 2046-2060.
- Rosseto, C.J., Lourenção, A.L., Miranda, M.A.C. and Igue, T.** (1984). Resistência de soja a insetos: II. Teste de livre escolha entre a linhagem IAC 73-228 e o cultivar Paraná, infestados por *Nezara viridula* (L.) em telado. *Bragantia* 43: 141-153.
- Rosseto, C.J., Igue, T., Miranda, M.A.C. and Lourenção, A.L.** (1986). Resistência de soja a insetos: VI. Comportamento de genótipos em relação a percevejos. *Bragantia* 45: 323-335.
- Toledo, J.F.F.** (1987). Predicting the inbreeding and the outcrossing potential of soybean (*Glycine max* (L.) Merrill) varieties. *Rev. Brasil. Genet.* 10: 543-558.
- Toledo, J.F.F.** (1991). Programa de computador para estimar parâmetros genéticos, componentes de médias e variâncias, pelo método dos quadrados mínimos ponderados. *Pesq. Agrop. Bras.* 26: 1023-1039.
- Toledo, J.F.F., Rossini, M.C., Souza, R.F. and Leão, F.F.** (1991). Genetical analysis of a soybean biparental cross and comparative model fitting to means and variances of two sets of generations. *Pesq. Agrop. Bras.* 14: 1041-1064.

(Received November 8, 1994)