COMPARISON BETWEEN HILL AND ROW PLOTS METHODS ON SELECTION OF SOYBEANS FOR ALUMINIUM TOLERANCEIN A BRAZILIAN SAVANNAH (CERRADO) ACID SOIL[1]

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ABSTRACT - The objective of this work was to compare two different methods concerning their efficiency in a selection of soybean genotypes for Al tolerance. Selection for aluminium tolerance is necessary to the full adaptation of the soybean crop in the acid soils of the Brazilian Savannahs (Cerrados). Field techniques, however, are laborious and time consuming. The present results indicate that hill plot method is as efficient as row plot method in the identification of Al-tolerant genotypes. Similar efficiency observed in low Al environment. Hill plot method can be applied in genetic studies and in breeding programmes for crop improvement, using less effort and time than the row plots.

Index terms: *Glycine max,* soybean adaptation, tolerant genotype, breeding method, genetic study.

COMPARAÇÃO DE PARCELAS EM COVAS E EM SULCOS NA SELEÇÃO DE SOJA TOLERANTEAO ALUMÍNIO EM UM SOLO ÁCIDO DE CERRADO

RESUMO - O objetivo do presente trabalho foi comparar dois diferentes métodos quanto a sua eficiência na seleção de genótipos de soja tolerantes ao alumínio. A seleção de soja com vistas a tolerância ao alumínio é necessária para a completa adaptação da cultura aos solos ácidos dos Cerrados. Entretanto, as técnicas de campo são laboriosas e damandam tempo. Os resultados indicam que o método de parcelas em covas é tão eficiente quanto o método de parcelas em sulcos na identificação de genótipos tolerantes. Similar eficiência foi observada no ambiente com baixo alumínio. Assim, o método de parcelas em covas pode ser empregado em estudos genéticos e em programas de melhoramento, com maior economia de recursos e de tempo.

Termos para indexação: *Glycine max,* adaptação da soja, genótipo tolerante, método de melhoramento, estudo genético.

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INTRODUCTION

Soil acidity constraints are the major components of environment, in large proportion of the Brazilian Savannahs (Cerrados) soils. Identifying and selecting desirable genotypes under these conditions is not a simple task due to the mineral element interactions (Wilkinson & Duncan, 1993; Spehar, 1994a, 1995a, 1995b; Spehar & Galwey, 1995).

A logical approach is to test in these problem-soils, as many cultivars as possible from a range of environments with similar soil characteristics. It has been shown (Bilski & Foy, 1987; Spehar, 1994b, 1994c) that aluminium (Al) tolerance and the origin of germplasm are closely associated. There are two applications for this procedure: one is to be able to recommend the selected cultivar, if its performance for agronomic characteristics suits the farming systems; the other is to be able to choose cultivars from distinct classes of tolerance for hybridization in genetic and breeding programmes (Spehar, 1994d).

Field experiments have been the final test for characteristics very interactive with the environment like grain yield. To achieve progress in breeding, the selected genotypes should yield economically. Grain yield, *per se,* is the result of many physiological paths in the plant. If each one is controlled by at least one gene, it is not difficult to admit that grain yield is quantitatively inherited (Allard, 1960). There are cases, however, in which strategic genes play a major role in the success of selection (Spehar, 1995c). If a selected cultivar for high yield does not have Al tolerance, its whole genome, although being superior, will be inhibited of expressing this characteristic in a Al-stress environment.

When seed supply and land and labour are limited and, a large number of genotypes must be tested in replicated trials, the hill plot method could be used (Baker & Leisle, 1970; Smith et al., 1970). This method was first suggested by Torrie (1962), for soybeans, and studies have been carried out on the effects of plant population in hills (Shannon et al., 1971a), the distance between hills (Shannon et al., 1971b), and on the performance of soybean cultivars in row and hill plot experiments (Torrie, 1962). The plants, however, are far apart from those in neighbouring plots, in contrast with row plot testing, where plants grow in a community simulating a farmer's field.

Garland & Fehr (1981) compared the effectiveness of hill and row plots methods in a selection for seed yield and other agronomic characteristics among soybean lines. They found that the two types of plot were effective for phenotypic selection of agronomically desirable genotypes. Equally important for the achievement of consistent results in hill plots is the standardization of seed size and vigour as suggested by Tekrony et al. (1987).

Al tolerance has been mainly evaluated on the basis of shoot and root dry matter productions and nutrient composition, in controlled environment experiments (Foy et al., 1993). It has been reported that Al interacts with P (Camargo, 1985), Ca (Wilkinson & Duncan, 1993; Spehar, 1994a) and Mg (Spehar, 1994a). Only in a few cases grain yield has been used in the screening for Al tolerance (Lafever et al., 1977; Spehar et al., 1982).

The objective of this work was to compare the hill plot method with the row plot method concerning their efficiency in a selection of soybean genotypes for Al tolerance.

MATERIAL AND METHODS

Twelve cultivars previously screened for Al tolerance, namely 'IAC-7', 'Cristalina', 'Vx5-281.5', 'IAC-5','IAC-8', 'IAC-2', 'UFV-1', '(BR-9) Savana', 'Santa Rosa', 'Doko', 'Biloxi' and 'IAC-9' (Spehar, 1994a) were included in an experiment to test the relative efficiency of row and hill plots in high and in low Al areas. These cultivars belong to different maturity groups to represent a range of soybean cultivars.

The row plots consisted of four rows equally spaced at 50 cm, 2.5 m long, with a density of 25 plants/m after emergence. The harvest area, which consisted of the two central rows 2 m long, was divided into subplots of 0.5 m each, to be used in the statistical analysis to evaluate within plot soil variation. Three replications of the randomized complete block were used.

The hill plots consisted of 15 cm rows, sown to produce ten seedlings at emergence and were equally spaced by1.0 m in width and 0.7 m in length. Distances between hills and the number of plants per hill were chosen based on previous work (Shannon et al., l971a, 1971b). Three sets of four replications in randomised complete block design were used.

The row and hill experiments were repeated at two levels of lime on a cerrado oxisol, classified as Dark Red Latosol (Typic Haplustox, fine, kaolinitic, isohyperthermic in the U.S. soil taxonomy), at the Centro de Pesquisa Agropecuária dos Cerrados (CPAC), Planaltina, DF, Brazil, which is located on 15^{o} 36' S and 47^{o} 12' W at an elevation of 1,000 m a.s.l. The physico-chemical characteristics of the virgin soil are: sand 340 g/kg, silt 190 g/kg and clay 460 g/kg; pH (H_20) 4.7, Al 1.9 $cmol_c$/kg, Ca+Mg 0.4 $cmol_c$/kg,P 0.9 mg/kg and K 0,041 $cmol_c$/kg.

The two areas were fertilized, at the end of the rainy season and prior to these experiments, in the following manner: 1) 500 kg/ha dolomitic lime (100% $CaCO_3$ equivalent), 150 kg/ha P, 75 kg/ha K and 40 kg/ha of slow release micronutrients source, FTE-BR-12; 2) 4,000 kg/ha dolomitic lime (100% $CaCO_3$ equivalent) and the other sources of nutrients in the same amounts as in the first case. All the amendments were incorporated previous to the planting of the experiments, by the use of a rotovator, to approximately 20 cm depth. The two areas were classified for experimental purposes as high and low Al environments, respectively.

All the seeds utilized in the row and hill experiments were produced in an experimental field of CPAC, in the previous crop season. Germination tests were carried out before starting the experiment to standardize for vigour (Tekrony et al., 1987) . Only the homogeneous seed lots which had higher than 80% germination were used in these experiments. In both experiments all the seeds of the twelve soybean cultivars were inoculated with *Bradyrhizobium japonicum*/peat inoculant at sowing time. At harvest time, data on grain yield, days to maturity (number of days from emergence to the date when 95% of the pods reached the mature colour), plant and first pod heights and number of plants per hill were collected.

The row and hill plot experiments were analyzed independently and genotypic correlation was computed for cultivars in the two plot arrangements at each environment by a joint analysis of the twelve cultivars for grain yield, days to maturity, plant height, and first pod height.

RESULTS AND DISCUSSION

The analysis of variance for the hill plot experiment in the high and in the low Al environments indicated statistic differences for plant height, first pod height and grain yield. The magnitude of Al effect relative to error was greatest for seed yield.

Strong effect of Al on plant height and grain yield, and a minor effect on first pod height are shown. It is possible that, even though these two traits are closely associated, the plants in the high Al environment tended to abort the lower pods, resulting in higher first pod height, which was not followed by increased plant heights. The Al x cultivar interaction, which measures the genotypic response to stress, was highly significant for grain yield, which is of immediate interest in selection.

The comparisons of means for the twelve cultivars employed in the hill plot experiment (Table 1 and 2) indicate that at high Al, 'UFV-1' and 'Biloxi' produced the lowest grain yield, in contrast with '(BR-9) Savana', 'IAC-2', 'IAC-8', and 'IAC-9', which produced the highest grain yields. In the absence of stress, these cultivars showed different degrees of responsiveness and this suggests that comparisons for grain yield should be made on their performance in high Al. The other six cultivars fell in between these two groupings. These results confirmed the response of cultivars IAC-2 and UFV-1 in field experiments and in hydroponics experiments, with the exception of Biloxi and IAC-8 (Mascarenhas et al., 1984; Spehar, 1994a). A possible explanation is that in the field other uncontrolled factors affect the results, like dry spells; they are erratic and affect cultivars of different maturity groups, which is the case in the present experiment.

TABLE 1. Plant height (cm), first pod height (cm) and grain yield (g/plot) of twelve soybean cultivars, from hill plots in high and in low Al levels. Planaltina, DF, 1989.

Variable	Al	Cultivar												Mean
		IAC-9	IAC-5	IAC-8	BR-9	Cristalina	Biloxi	UFV-1	S. Rosa	Vx5-281	IAC-7	Doko	IAC-2	
Plant	High	38.5	50.9	48.8	46.0	44.7	35.5	22.9	29.7	49.5	51.2	51.7	61.1	44.2
height	Low	55.9	68.3	63.9	63.7	65.8	49.9	35.3	46.1	65.0	73.7	69.7	75.3	61.1
	Mean	47.2	59.6	56.4	54.9	55.2	42.7	29.1	37.9	57.2	62.5	60.7	68.2	52.6
First pod	High	6.3	10.3	9.8	7.7	7.3	8.9	5.0	5.7	11.2	11.1	13.7	11.2	9.0
height	Low	8.4	11.1	11.2	9.7	8.4	11.4	6.2	9.8	12.4	12.2	15.4	12.4	10.7
	Mean	7.4	10.7	10.5	8.7	7.9	10.2	5.6	7.8	11.8	11.6	14.5	11.8	9.9
Grain	High	80.4	57.7	81.7	91.9	68.4	34.3	47.7	64.2	75.0	63.1	74.9	86.9	68.9
yield	Low	175.7	148.5	180.7	222.0	216.7	93.0	140.8	154.3	127.5	167.7	166.1	157.3	162.5
	Mean	128.1	103.1	131.2	157.0	142.5	63.7	94.2	109.3	101.2	115.4	120.5	122.1	115.7

TABLE 2. Standard errors of differences of means for hill plots.

Variable	Aluminium (Al)	Cultivar (C)	Al x C[1]	
Plant height	2.29	1.61	3.16	(2.28)
First pod height	0.63	0.51	0.93	(0.72)
Grain yield	71.9	65.9	114.6	(93.2)

[1] Numbers between brackets to compare means within the same level of aluminium.

The analysis of variance for the row plot experiment indicated that the samples-within-plots term identified soil heterogeneity within plot, which was high for grain yield and low for first pod height and plant height. The variability within plot in row plot should be taken into consideration and plot size seemed to limit the comparison of the genotypes for grain yield. This acts in favour of the use of hill plots. They occupy only a small strip of land and the variability in the terrain detected by the row plots would be eliminated from the hills by blocking them. The block effect will remove the error, which in the row plot is confounded with main effects.

The means for row plots and the standard errors of differences of means are presented in Table 3 and 4, respectively. The effect of Al stress was more evident on plant height and first pod height than on grain yield. This could be explained as the stress levelling off yield differences. These results confirmed part of the ones for the hill plots. For the ratio high Al/low Al the trend keeps the same relationship in both hill and row plot experiments.

The results on the correlation analysis are presented in Table 5. The correlation coefficients are highly significant for all the characters. It becomes evident that hill plots are as efficient as row plots in both high and low Al environments, to evaluate soybean germplasm of different maturity groups. Similar results were obtained by Garland & Fehr (1981) in a different environment and with a narrow range of maturity among cultivars. This opens the way for more efficient testing, as hill plots are easier to handle and require less labour. The use of hills can be important to identify the best hybrid combinations at an early generation test in a breeding programme (Spehar, 1994b). In selection for Al tolerance, such field testing of hybrid populations to identify the superior genotypes will certainly play an important role in the improvement of soybean cultivars for cultivation in the Brazilian Savannah soils. It is expected that this method might be useful in breeding other self-pollinating grain crops.

TABLE 3.Plant height (cm), first pod height (cm) and grain yield (g/plot) of twelve soybean cultivars, from row plots in high and in low Al levels. Planaltina, DF, 1989.

Variable	Al	Cultivar												Mean
		IAC-9	IAC-5	IAC-8	BR-9	Cristalina	Biloxi	UFV-1	S. Rosa	Vx5-281	IAC-7	Doko	IAC-2	
Plant	High	44.9	44.1	54.3	49.4	51.8	30.7	21.8	30.0	52.3	45.6	55.9	61.0	45.1
height	Low	76.1	78.2	98.9	94.6	89.9	57.6	52.8	60.5	96.7	96.0	98.8	99.2	83.3
	Mean	60.5	61.2	76.6	72.0	70.8	44.1	37.3	45.3	74.5	70.8	77.3	80.1	64.2
First pod	High	13.7	13.7	16.0	14.0	12.7	10.9	5.0	10.0	15.1	14.0	21.5	13.8	13.4
height	Low	14.6	21.4	17.2	13.3	13.3	14.3	14.2	13.6	15.7	15.0	28.3	16.8	16.5
	Mean	14.1	17.6	16.6	13.6	13.0	12.6	9.6	11.8	15.4	14.5	24.9	15.3	14.9
Grain	High	256.6	208.7	330.5	291.9	252.1	117.7	196.2	307.0	258.8	244.0	231.1	395.0	257.5
yield	Low	596.1	507.1	701.6	789.3	678.9	420.6	652.3	635.8	655.5	683.7	598.6	652.9	631.0
	Mean	426.4	357.9	516.1	540.6	465.5	269.1	424.3	471.4	457.1	463.9	414.9	524.0	444.3

TABLE 4.Standard errors of differences of means for row plots.

Variable	Aluminium (Al)	Cultivar (C)	Al x C[1]
Plant height	2.16	3.07	4.69 (4.35)
First pod height	0.86	1.24	1.88 (1.75)
Grain yield	26.7	39.1	59.3 (55.4)

[1] Numbers between brackets to compare means within the same level of aluminium.

TABLE 5.Correlation coefficients between hill and row plot methods for the performance of soybean cultivars in high and in low Al levels (n=12 observations).

Variable	High Al	Probability	Low Al	Probability
Grain yield	0.82	0.01	0.75	0.01
Maturity	0.96	0.01	0.95	0.01
Plant height	0.91	0.01	0.90	0.01
First pod height	0.81	0.01	0.71	0.01

CONCLUSION

Hill plots are as efficient as row plots for genetic studies and breeding programmes in both high and low Al environments.

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