Journal of Plant Sciences
2016; 4(2): 17-22
http://www.sciencepublishinggroup.com/j/jps
doi: 10.11648/j.jps.20160402.11
ISSN: 2331-0723 (Print); ISSN: 2331-0731 (Online)

Adaptability and Stability of Soybean Cultivars Under Different Times of Sowing in Southern Brazil

Augusto Tessele[1], Robson Fernando Missio[2], Juliano Boroluzzi Lorenzetti[2], Jean Carlos Bortoloto Trentini[2], Ruan Carlos Navarro Furtado[3], Giovane Moreno[2]

[1]Departament of Plant Science, Federal University of Viçosa, Viçosa, Brazil

[2]Department of Agronomy, Federal University of Paraná, Palotina, Brazil

[3]Department of Phytopathology, College of Agriculture Luiz de Queiroz (Esalq-USP), Piracibaca, Brazil

Email address:

augtessele@gmail.com (A. Tessele), rfmissio@gmail.com (R. F. Missio), lorenzettijb@gmail.com (J. B. Lorenzetti), jeantrentini@gmail.com (J. C. B. Trentini), ruannavarrofurtado@gmail.com (R. C. N. Furtado), moreno.giovane@gmail.com (G. Moreno)

To cite this article:

Augusto Tessele, Robson Fernando Missio, Juliano Boroluzzi Lorenzetti, Jean Carlos Bortoloto Trentini, Ruan Carlos Navarro Furtado, Giovane Moreno. Adaptability and Stability of Soybean Cultivars Under Different Times of Sowing in Southern Brazil. *Journal of Plant Sciences*. Vol. 4, No. 2, 2016, pp. 17-22. doi: 10.11648/j.jps.20160402.11

Received: March 7, 2016; **Accepted**: March 13, 2016; **Published**: March 29, 2016

Abstract: There is a large number of soybean cultivars recommended to the many regions that soybean is cultivated and, even though these cultivars hold a high potential yield, the environmental variation can alter the expected yield due to the genetic x environment interaction. So, the aim of this study was to evaluate the adaptability and stability of ten soybean cultivars in five environments, sowed in different times, in Palotina-PR. The randomized block design was used with three repetitions. The study was conducted in the 2013/14 and 2014/15 harvests. The Eberhart & Russel (1966) and MHPRVG (Resende 2004) methods were used to evaluate the yield adaptability and stability. Based on the results of either methods, the cultivars TMG 7060 RR, TMG 7062 IPRO and NA 5909 RG showed wide adaptability and high stability to this cultivation area.

Keywords: Genotype x Environment Interaction, *Glycine max* L., Yield

1. Introduction

The continuous release of soybean cultivars has led to a large number of different cultivars available and recommended for cultivation in many specific regions [6]. Even though these cultivars show good agronomic potential and yield, the environmental variation can led to an unexpected performance, as a result of the genotype x environment interaction. According to [17], the yield is a result of the genotype, the environment and the interaction of the genotype in each environment. As this interaction is a natural phenome, it is necessary to understand it well to optimize the selection gain [4].

In this scenario, studies of adaptability and stability are the most used practice to attenuate the effects of the interaction, because it can be performed in different situations [1, 5, 7, 13, 15, 16, 25]. This type of study allows identifying the most stable cultivars, which have a predictable response to the environmental variation [16]. The identification of genotypes adapted to a wide range of environments or just in some specific locations can be made as well.

According to [20], the most used method to evaluate the adaptability and stability of soybean genotypes are those based in linear regression, specifically the one proposed by Eberhart & Russel (1966). [22] added that this method should be preferably used when analyzing adaptability and stability because it considers simultaneously productivity, stability, and adaptability to unfavorable, favorable, and general environments.

In the method proposed by Eberhart & Russel (1966), it is computed a simple linear regression for the treat under evaluation, which is related to an environmental index, that can have positive or negative coefficients. The negative coefficients indicate unfavorable environments (these environments are considered negative because they present an average below the overall mean of all environments), representing areas with low technological level or adverse soil and weather conditions. Meanwhile, the positive coefficients indicate favorable environments. In this methodology, the ideal genotype is that with high yield (β_{0i}), coefficient of regression equal to one ($\hat{\beta}_{1i} = 1$) and the slightest possible regression deviation ($\hat{\sigma}^2_{di}$), which means, the genotype with the best response to the improvement of the environmental conditions ($\hat{\beta}_{1i} = 1$) and highly predictable performance ($\hat{\sigma}^2_{di} = 0$).

Another method that can be used to evaluate the adaptability and stability is the MHPRVG Method, proposed by Resende (2004), which is based in the analysis of genetic values through mixed models and allows the simultaneous selection for adaptability, stability and yield (or trait under evaluation). Moreover, it is possible to consider correlated errors within the locals, as well as the adaptability and stability in the individual selection inside the progenies. Nevertheless, this method provides genetic values with the previous discount of instability, which can be applied to any number of environments. Finally, the result generated is in the same scale of the trait evaluated (for example: kg ha^{-1} when evaluating the yield or centimeters to height), allowing an interpretation like genetic values [21].

Therefore, the aim of this study was to evaluate the adaptability and stability of commercial soybean cultivars in five environments, during the 2013/2014 and 2014/2015 harvests, in Western Parana.

2. Material and Methods

The study was held in Palotina, PR, where the soil is classified as clayey oxisol soil [8]. Five cultivar assays were conducted during the 2013/2014 and 2014/2015 harvests.

The climate conditions during the experiments are shown in the Figure 1.

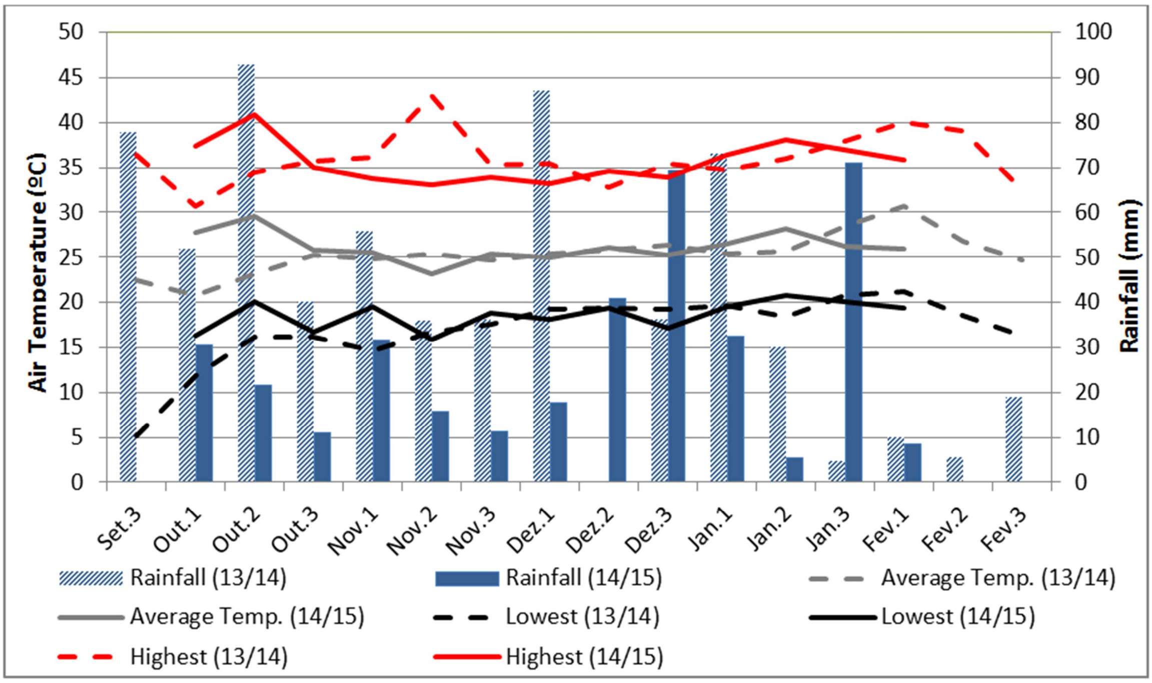

Figure 1. *Highest, average and lowest air temperature and accumulated rainfall in ten-day periods, during the soybean cycle of the 2013/2014 and 2014/1015 harvests.*

The randomized block design was used, with three replications and 10 treatments. The treatments were the cultivars TMG 7161 RR, TMG 7262 RR, TMG 7363 RR, TMG 1264 RR, TMG 1266 RR, TMG 2158 IPRO, TMG 7060 IPRO e TMG 7062 IPRO, which were selected for being recommended for the region, plus the cultivars BMX Potência RR and NA 5909 RG, used as control, because they have been widely cultivated in the state.

The plots contained four five-meter lines, spaced 0.50 between rows. The useful area was of 4 m^2, consisting from the four central rows and eliminating 1 meter of each extremity (border). The seedling density was around 14-16 plants per meter. The plants caretaking, like phytosanity care and weed control, was made following the recommendations for the culture [9].

When plants exhibited over 95% of its pods with mature color and over 50% defoliation (R9) they were harvested [10, 11]. Succeeding, the plants were threshed with an experimental threshing machine and stored in paper-bags, which were later weighed in to obtain the yield.

The yield data was converted to kg ha^{-1} and submitted to individual and joint variation analysis. Observing significant variation in the genotype x environment interaction, the adaptability and stability analysis was made, following the Eberhart and Russel (1966) and MHPRVG (Resende, 2004) methods.

The Eberhart and Russel (1966) methodology uses the genotype average yield (μ_i), its regression coefficients (β_1) and the variance of the regression deviation (σ^2_{di}), as shown below:

$$Y_{ij}=\mu+\beta_i I_j+\sigma_{ij}+\varepsilon_{ij}$$

On the other hand, the MHPRVG (Resende, 2004) does not use the variance analysis (ANOVA) to analyze and statistically model, but uses the REML method, which allows handling with identical situation, however modeling with more flexibility and efficiency.

The MHPRVG statistical model is the following:

$$Y = Xr + Zg + Wi + e$$

where y is the data vector, r is the repetition effect (assumed as fixed) added to the general average, g is the vector of the genotypic effects (assumed as randomly), I is the vector of the genotype x environment interaction (random) and e is the error vector.

The analyses were made through the Sisvar software [12] to verify significant genotype x environmental interaction. Subsequently, the Eberhart and Russel adaptability and stability analysis was made with the software Estatistica [24]. Concurrently, the simultaneous adaptability, stability and yield (MHPRVG) was made through software Selegen Reml/Blup [19].

3. Results and Discussion

Significant differences were observed to the environment, genotype and the genotype x environment interaction, according to T test at 1% (Table 1). Consequently, the adaptability and stability analysis was made.

Table 1. *Yield (kg ha^{-1}) variance analyses of ten genotypes evaluated in five environments, in Palotina, PR, during the 2013/2014 and 2014/2015 harvests.*

VS	GL	SQ	MS	F
Blocks	2	614363.595	307181.798	2.917*
Environment (E)	4	168124293.119	42031073.280	399.080**
Genotype (G)	9	7039017.074	782113.008	7.426**
G*E Interaction	35	7912874.692	226082.134	2.147**
Average Error	96	10110723.290	105320.034	
CV %	12.56			

*Significant ($p<0.05$) by the F-test
**Significant ($p<0.01$) by the F-test.
CV: coefficient of variation.

Before discussing the result of the adaptability and stability of each cultivar, it is going to be shown the environmental conditions these genotypes were submitted, to understand their performance.

First, an environmental analysis is shown, according the Eberhart and Russel (1966) method, which allows a clear understanding of the overall performance.

The analysis of the environments, the average yield of each environment and the environmental index are in Table 2.

Table 2. *Average yield per environment and environmental index, according the Eberhart and Russel (1966) methodology.*

Environment	Harvest	Average	Index
1	2013/2014	4041.33	1510.10
2	2013/2014	3289.60	758.36
3	2014/2015	2746.83	215.60
4	2014/2015	1008.42	-1522.82
5	2014/2015	1570.00	-961.24

According to this methodology, the environments 1, 2 (harvest 13/14) and 3 (harvest 14/15) were considered favorable, because the average yield of these environments are higher than the overall mean of the environments, resulting in a positive index. Meanwhile the environments 4 and 5 are characterized as unfavorable (Table 2), with a negative index of 1522.82 and 961.24 kilos per hectare.

The high yield, calculated by the cultivars average, in the environments 1 and 2 are due to the good rainfall during late December and whole January, providing favorable conditions to an excellent vegetative growth and reproductive development, resulting in a high yield average (Figure 1). Besides, the accumulated rainfall during the soybean cycle (from October to February) in this harvest (2013/2014) was of 556 millimeters.

On the other hand, the environments 4 and 5 were considered unfavorable, basically, due to the reduced rainfall during the soybean cycle. Analyzing the Figure 1, can be observed that, during the vegetative growth phase, the total rainfall was lower than in the previous harvest (2013/2014). Even though the accumulated rainfall per ten-day period during November, December and January was acceptable, the distribution was extremely irregular. During each moth, there were 20, 16 and 20 days without rain, respectively. The accumulated rainfall during the soybean cycle, in this harvest (2014/2015), was of 367 millimeters.

This contrast in the rainfall from one harvest to another is really harmful to agriculture and farmers, which cannot predict the soybean performance. However, as the aim of this study was to evaluate the adaptability and stability of soybean cultivars, this contrast is really advantageous, because it allows exploring the two faces of a cultivar: the response to a good environment and the capability to perform well in critical conditions, which turn this study trustful.

Regarding the adaptability and stability parameters evaluated, following the Eberhart and Russel (1966) method, the genotypes average yield, the regression coefficients (β_1), the variance of the regression deviation (σ^2_{di}) and the determination coefficient (R^2) were estimated (Table 3). It allows the characterization for each genotype related to the yield adaptability and stability.

Table 3. *Average yield, regression coefficients, variance of the regression deviation and determination coefficient of the soybean cultivars evaluated in Palotina, PR.*

Genotype	Average Yield (Kg ha^{-1})	β_1	σ^2_{di}	R^2 (%)
TMG 7161 RR	2531.84 ab	0.881375^{ns}	52150.09^{ns}	94.92
TMG 7262 RR	2523.29 ab	0.919398^{ns}	68466.94*	94.46
TMG 7363 RR	2386.11 b	0.974445^{ns}	45201.11^{ns}	96.13
TMG 1264 RR	2864.18 a	1.210722^{++}	156120.59**	94.15
TMG 1266 RR	2393.15 b	1.079992^{ns}	49409.40^{ns}	94.10
TMG 2158 IPRO	2337.15 b	0.934683^{ns}	193746.53**	88.75
TMG 7060 IPRO	2677.40 ab	0.956598^{ns}	$- 2336.72^{ns}$	98.39
TMG 7062 IPRO	2784.36 a	0.943073^{ns}	-13445.74^{ns}	98.94
NA 5909 RG	2665.67 ab	0.886493^{ns}	-11852.82^{ns}	98.70
BMX Potência RR	2149.22 ab	1.213223^{++}	153529.38**	96.66
Overall mean	2531.24			

* Averages followed by the same letter in the column do not differ according the Tukey test at 5%;
++= significantly different at 1%, according the T test;
*and**= significantly different of zero at 5 and 1%, respectively, according the T test;
ns = not significant.

The cultivars TMG 7060 IPRO, TMG 7062 IPRO and NA 5909 RG achieved high yield (higher than the average) and the regression coefficient equal to 1 (β_1 = 1), so, being classified to a wide range of environmental conditions according to this method. This cultivars had variance of the regression deviation not significant (σ^2_{di} = 0), indicating high stability or predictability. In the study conducted by [23], the two bean cultivars with the highest yield also showed general adaptability (β_1 = 1) and high stability (σ^2_{di} = 0).

The cultivar TMG 1264 RR had the highest yield, however, along the cultivar BMX Potência RR, showed a regression coefficient higher than 1 (β_1 > 1), which indicates adaptability to favorable environments and reduced predictability (σ^2_{di} > 0), though (Table 3). A similar result was found by [3] for the UFU-16, in which this line had the highest average yield, but low predictability. The recommendation of TMG 1264 RR ought to be prudent, because its cultivation in an unfavorable environment can cause a huge yield reduction. According to [2], this type of genotype is ideal in locations with controlled environmental condition, allowing the full expression of its high performance.

In a work conducted by [14], the genotype with the highest yield (JB93-54323) also showed regression coefficient higher than 1 and reduced predictability. However, the authors affirmed that this genotype should not be considered undesirable, because it had an excellent yield (high potential) and a good determination coefficient (R^2).

The values of the determination coefficient (R2) obtained was higher than 94% for all genotypes. It indicates that the genotypes had a satisfying performance depending on the environment [5]. [18] working with sugarcane, reported that values of the determination coefficient higher than 80% show low data dispersion, suggesting good reliability on the type of environmental response determined by the regressions.

The cultivars TMG 7262 RR and TMG 2158 IPRO showed wide adaptability (β_1 = 1), however, their regression deviation was significant ($\sigma^2_{di} \neq 0$), indicating reduced predictability. Studying the soybean adaptability and stability in different sowing dates in Northern Brazil, [15] found 6 lines with high yield, and wide adaptability, however with low stability. In conclusion, the authors did not recommend the cultivation of those lines due to their instability.

The other cultivars were not classified as ideal, even showing wide adaptability and good stability, because their average yield was below the overall mean.

The discussions about the results from the analysis of the MHPRVG method are shown below.

The stability analysis, according the MHPRVG method, is shown in Table 4.

Table 4. *Stability of the genotypic values (MHVG) from the cultivars studied, according the MHPRVG method.*

Genotype	MHVG
BMX Potência RR	2508.34
NA 5909 RG	2222.28
TMG 7060 IPRO	2166.03
TMG 7161 RR	2131.55
TMG 7062 IPRO	2120.85
TMG 1264 RR	2039.66
TMG 7363 RR	1948.10
TMG 7262 RR	1834.69
TMG 1266 RR	1817.58
TMG 2158 IPRO	1775.30
Overall mean	2056.44

According the MHPRVG (Resende 2004) methodology, the cultivar BMX Potência RR obtained the best stability (MHVG), because it had the lowest standard deviation, resulting in the biggest harmonic mean of the genotypic values (Table 4). However, this low standard deviation occurred because this cultivar could not be assessed in environment 4, which had the lowest average yield. The absence of BMX Potência RR in this environment caused the non-computation of a very reduced yield, resulting in a smaller yield range, which was read by the software as stability. Therefore, the use of the MHPRVG method for unbalanced experiments ought to be made carefully, because the genotypes can have advantages or disadvantages for not being tested in all environments [26].

Among the cultivars tested in all environments, the NA 5909 RG was the one with the best stability.

The adaptability data, following the MHPRVG method (Resende 2004), is contained in Table 5.

Table 5. *Adaptability according the MHPRVG method, proposed by Resende (2004).*

Genotype	PRVG	PRVG*MG
NA 5909 RG	1.0837	2753.76
TMG 7060 IPRO	1.0594	2692.06
TMG 7161 RR	1.0494	2666.72
TMG 1264 RR	1.0428	2650.04
TMG 7062 IPRO	1.0375	2636.37
TMG 7363 RR	0.9774	2483.83
BMX Potência RR	0.9686	2461.46
TMG 1266 RR	0.9449	2401.07
TMG 7262 RR	0.9433	2396.98
TMG 2158 IPRO	0.8928	2268.66
Overall mean	1	2542

Analyzing the adaptability results, it was observed that the cultivar NA 5909 RG was 1.0837 times more productive than the overall mean of all cultivars. It indicates that this cultivar has the ability to yield 8,37% over the overall mean, which in absolute values is 2753.76 kilos per hectare. The cultivars TMG 7060 IPRO, TMG 7161 RR, TMG 1264 RR e TMG 7062 IPRO also showed potential to yield over the mean.

The result of the simultaneous yield stability and adaptability (MHPRVG) of the cultivars evaluated, according the MHPRVG method, is in Table 6.

Table 6. *Stability and adaptability (MHPRVG*MG), according the MHPRVG, for ten cultivars with yield evaluated in Western Paraná.*

Genotype	MHPRVG	MHPRVG*MG
NA 5909 RG	1.0794	2742.82
TMG 7060 IPRO	1.0565	2684.73
TMG 7161 RR	1.0448	2654.95
TMG 1264 RR	1.0361	2632.90
TMG 7062 IPRO	1.0350	2630.00
TMG 7363 RR	0.9766	2481.61
BMX Potência RR	0.9670	2457.26
TMG 7262 RR	0.9399	2388.42
TMG 1266 RR	0.9383	2384.46
TMG 2158 IPRO	0.8881	2256.81
Overall mean	1	2531.40

The best genotypes, according the MHPRVG method, for simultaneous yield stability and adaptability are NA 5909 RG, TMG 7060 IPRO, TMG 7161 RR, TMG 1264 RR and TMG 7062 IPRO, which had the potential to yield 7,94%, 5,65%, 4,48%, 3,61% and 3,5% over the cultivars average, respectively. It is observed that this value (in percentage) is slightly reduced when compared to the adaptability result per se, basically because the instability is discounted.

Therefore, in absolute numbers (genotypic values), this cultivars could produce 2742.82, 2684.73, 2654.95, 2632.90 and 2630 kilos per hectare, respectively, while the overall mean yield is 2531.40 kilos per hectare. This value, in kg per hectare, allows an easy interpretation of the cultivars performance.

This method also permits to calculate the cultivars estimated yield by cultivating only one cultivar. For example, if the cultivar NA 5909 RG is cultivated and it yields 3000 kilos per hectare, we are able to calculate what is supposed to be the overall mean of all cultivars, because NA 5909 RG perform 7,94% over the average. In this situation, the overall mean would be 2778,32 kilos per hectare. Using this value, we can predict the performance of all cultivars evaluated.

4. Conclusion

Converging the results from Eberhart and Russel (1966) and MHPRVG (Resende 2004) methods, the cultivars with wide adaptability and high stability are TMG 7060 IPRO, TMG 7062 IPRO e NA 5909 RG. These cultivars have the potential to respond well in favorable environments and maintain a good production in unfavorable environment, just like the conditions encountered in this study.

References

[1] ALLARD, R. W. (1961). Relationship between genetic diversity and consistency of performance in different environments. Crop Science, 1: 127-133.

[2] BORÉM, A.; MIRANDA, G. V. Plant Breeding. 4. ed. Viçosa: UFV, 2005. 525 p.

[3] CAVALCANTE, A. K., HAMAWAKI, O. T., HAMAWAKI, R. L., SOUSA, L. B., NOGUEIRA, A. P. O., & HAMAWAKI, C. D. L. Adaptabilidade e estabilidade fenotipica de genótipos de soja em porto alegre do norte, mt = Fentopic adaptability and stability in soybean genotypes in Porto Alegre do Norte, state of Mato Grosso. Bioscience Journal, 30(4). 2014.

[4] CHAVES, L. J. Interação de genótipos com ambientes. Interaction of genotypes with environments. In: NASS, L.L.; VALOIS, A.C. C.; MELO, I.S.; VALADARES-INGLIS, M.C. (ed.) Recursos genéticos e melhoramento de plantas. Rondonópolis: Fundação MT, 1183p. 2001.

[5] CRUZ, C. D. *et al*. Modelos biométricos aplicados ao melhoramento genético. Biometric models applied to plant breeding. 4. ed. Viçosa: UFV, 2006. 390 p.

[6] CULTIVARWEB. Gerenciamento de Informação. Registro Nacional de Cultivares – RNC. Information managment. National Cultivars Record. Disponível em: http://extranet.agricultura.gov.br/php/snpc/cultivarweb/cultivares_registradas.php. Acesso em: 01/04/2015.

[7] EBERHART, S. A.; RUSSELL, W. A. *Stability parameters for comparing varieties. Crop Science*, Madison, v.6, n.1, p. 36-40, 1966.

[8] EMBRAPA. Sistema brasileiro de classificação de solos. Brazilian system of soil classification. 2. ed. Rio de Janeiro, 240p. 2006.

[9] EMBRAPA. Tecnologias de produção de soja: região central do Brasil: 2012 e 2013. Soybean production Technologies: Brazilian's Central Region: 2012 and 2013. Londrina: Embrapa Soja; Embrapa Cerrados; Embrapa Agropecuária Oeste, 2011. 261p. (Sistemas de Produção, 15).

[10] FARIAS, J. R. B.; NEPOMUCENO, A. L.; NEUMAIER, N. Ecofisiologia da soja. Soybean ecophysiology. Circular Técnica 48. Londrina, PR, Setembro, 2007.

[11] FEHR, W. R. et al. Stage of development description for soybean, *Glycine max* (L.) Merrill. Crop Science, Madison, v.11, n.6, p.929-931, 1971.

[12] FERREIRA, D. F. Sisvar: a computer statistical analysis system. Ciência e Agrotecnologia (UFLA), Lavras, v. 35, n.6, p. 1039-1042, 2011.

[13] FINLAY, K. W.; WILKINSON, G. N. The analysis of adaptation in a plant-breeding programme. Australian Journal of Agricultural Research, Collingwood, v.14, n.5, p.742-754, 1963.

[14] GONÇALVES, E. C. P.; DI MAURO, A. O.; CARGNELUTTI FILHO, A.. Adaptabilidade e estabilidade de genótipos de soja conduzidos em duas épocas de semeadura, na região de Jaboticabal – SP. Adaptability and stability of soybean genotypes conducted in two sowing dates, in the region of Jaboticabal – SP. Científica, Jaboticabal, v.35, n.1, p. 61-70, 2007.

[15] PELUZIO, J. M. Interação cultivar x ambiente e correlações fenotípicas, genotípicas e ambientais entre cultivares de soja no Estado do Tocantins. Cultivar x environment interaction and phenotypic, genotypic and environmental interactions among soybean cultivars in Tocatins State. 86 f. Tese (Doutorado em Genética e Melhoramento de Plantas) - Universidade Federal de Viçosa, Viçosa. 1996.

[16] PELÚZIO, J. M.; FIDELIS, R. R.; GIONGO, P.; Da SILVA, J. C.; CAPPELLARI, D.; BARROS, H. B. Adaptabilidade e estabilidade de cultivares de soja em quatro épocas de semeadura no sul do Estado do Tocantins. Adaptability and stability of soybean cultivars in four sowing dates in Southern Tocatins State. Revista Ceres, v. 55, n. 1, p. 034, 2008.

[17] PRADO, E. E.; HIROMOTO, D. E.; GODINHO, V. de P. C.; UTUMI, M. M.; RAMALHO, A. R. Adaptabilidade e estabilidade de cultivares de soja em cinco épocas de plantio no cerrado de Rondônia. Adaptability and stability of soybean cultivars in five sowing dates in Rondonia’s Cerrado. Pesquisa Agropecuária Brasileira, Brasília, v. 36, n. 4, p. 625-635, 2001.

[18] RAIZER, A. J.; VENCOVSKY, R. Estabilidade fenotípica de novas variedades de cana-de-açúcar para o estado de São Paulo. Phenotypic stability of new sugar-cane cultivars recommended to São Paulo State. Pesquisa Agropecuária Brasileira, Brasília, v. 34, n. 12, p. 2241-2246, 1999.

[19] RESENDE, M. D. V. Métodos estatísticos ótimos na análise de experimentos de campo. Colombo. Great statistical methods to analyze field experiments. Embrapa Florestas. 65p. (Documentos, 100). 2004.

[20] ROCHA, M. M. Seleção de linhagens experimentais de soja para adaptabilidade e estabilidade fenotípica. Selection of experimental soybean lines for phenotypic adaptability and stability. Piracicaba, 165f. Tese (Doutorado em Genética e Melhoramento de Plantas) Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo, Piracicaba, 2002.

[21] ROSADO, A. M.; ROSADO, T. B.; ALVES, A. A.; LAVIOLA, B. G.; BHERING, L. L. Seleção simultânea de clones de eucalipto de acordo com produtividade, estabilidade e adaptabilidade. Eucalyptus clones simultaneous selection according to yield, stability and adaptability. Pesquisa Agropecuária Brasileira, Brasília, v. 47, n. 7, p. 966-973, 2012.

[22] TEIXEIRA JÚNIOR, T., PELUZIO, J. M., DE MELO, A. V., ARCHANGELO, E. R., & AFFERRI, F. S. Correlation among adaptability and stability methodologies for soybean genotypes in regions of degraded areas. Revista Agro@ mbiente On-line, 9(1), 35-41. 2015.

[23] TEODORO, P. E., BARROSO, L. M. A., NASCIMENTO, M., TORRES, F. E., SAGRILO, E., SANTOS, A. D., & RIBEIRO, L. P. Artificial neural networks to identify semi-prostrate cowpea genotypes with high phenotypic adaptability and stability. Pesquisa Agropecuária Brasileira, 50(11), 1054-1060. 2015.

[24] UNIVERSIDADE FEDERAL DE LAVRAS. Estabilidade (software): versão 3.0. Lavras: Ufla-DEX, 2000.

[25] VERNETTI, F. de J.; GASTAL, M. F. da C.; ZONTA, E. P. Estabilidade fenotípica de cultivares de soja no sudeste do Rio Grande do Sul. Phenotypic stability of soybean cultivars in Southeastern Rio Grande do Sul State. Pesquisa Agropecuária Brasileira, Brasília, V. 25, n.11, p. 1593-1602, nov. 1990.

[26] ZENI-NETO, H.; OLIVEIRA, R.A. de; DAROS, E.; BESPALHOK FILHO, J. C.; ZAMBON, J. L. C.; IDO, O. T.; WEBER, H. Seleção para produtividade, estabilidade e adaptabilidade de clones de cana-de-açúcar em três ambientes no Estado do Paraná via modelos mistos. Selection to yield, stability and adaptability of sugar-cane clones in three environments in Parana State through mixed models. Scientia Agraria, Curitiba, v.9, p.425-430, 2008.