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Correlation among adaptability and stability methodologies for soybean genotypes in regions of degraded areas

Correlação entre metodologias de adaptabilidade e estabilidade para genótipos de soja em regiões de áreas degradadas

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Abstract: Comparison of methods of adaptability and stability has raised interest, and there are SOME studies dealing on the subject; with that, this study aimed to estimate the correlation coefficient for adaptability and stability parameters in regions of degraded areas for grain yield, using competition experiments of soybean genotypes in the agricultural years of 2009-2010 and 2010-2011 in the municipalities of Gurupi and Palmas – State of Tocantins-TO, Brazil. The association among the mean and the methodologies of Plaisted and Peterson, Wricke, Annicchiarico, Finlay and Wilkinson, Eberhart and Russell, Tai Lin and Binns modified by Carneiro and Centroid was verified by Spearman's Correlation Coefficient. The methods of Plaisted, Peterson, and Wricke are associated with the highest stability and they are independent of adaptability to general, favorable, and unfavorable environment and should be used with restraint. Cultivars with high yield and adapted to favorable environments may be the best indicated alternative according to the method developed by Lin and Binns modified by Carneiro, Annicchiarico, and Centroid. The method of Eberhart and Russell may preferably be used for considering the productivity, stability, and adaptability simultaneously to general, favorable, and unfavorable environments The simultaneous use of Lin and Binns' methodologies modified by Carneiro, Annicchiarico, Centroid, and Eberhart and Russell can assist in selecting the promising genotypes for regions of degraded areas of the Amazonian "cerrado.

Key words: Coefficient. Multi-environments. *Glycine max*.

Resumo: A comparação entre metodologias de adaptabilidade e estabilidade tem levantado interesse, existindo diversos trabalhos tratando sobre o assunto, com isso, objetivou-se com este trabalho estimar o coeficiente de correlação para parâmetros de adaptabilidade e estabilidade em regiões de áreas degradadas para a produtividade de grãos, através de ensaios de competição de genótipos de soja nos anos agrícolas 2009/2010 e 2010/2011, nos municípios de Gurupi e Palmas – TO. Através do coeficiente de correlação de Spearman, foi verificada a associação entre a média e as metodologias de Plaisted e Peterson, Wricke, Annicchiarico, Finlay e Wilkinson, Eberhart e Russell, Tai, Lin e Binns modificado por Carneiro e Centróide. Os métodos de Plaisted e Peterson e Wricke, estão associados à maior estabilidade e independe da adaptabilidade a ambiente geral, favorável e desfavorável, devendo ser usados com restrição. Cultivares com alta produtividade e adaptados aos ambientes favoráveis podem ser os mais indicados pelo método de Lin e Binns modificado por Carneiro, Annicchiarico e Centróide. O método de Eberhart e Russell, por considerar simultaneamente a produtividade, a estabilidade e a adaptabilidade a ambientes geral, favorável e desfavorável, pode preferencialmente ser utilizado. A utilização simultâneas das metodologias de Lin e Binns modificado por Carneiro, Annicchiarico, Centroide e Eberhart e Russell podem auxiliar na escolha de genótipos promissores para regiões de áreas degradadas do cerrado amazônico.

Palavras-chave: Coeficiente. Multiambientes. *Glycine max*.

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INTRODUCTION

Cerrado is a Brazilian region with 196,776,853 ha, 2 million km^2, occupying 23.1% of the Brazilian territory; it is the second largest biome in the country, surpassed only by the Amazon Forest. It is situated mostly along the central Brazilian plateau, extending to the states of Goiás, Tocantins, Mato Grosso, Mato Grosso do Sul, Bahia, Minas Gerais, the Federal District, São Paulo, Maranhão, Piauí, Paraná, Pará, and Rondônia (*WORLD WILDLIFE FUND*, 2000).

Soybean is the third culture of Tocantins State regarding its participation in the gross value of production and it is cultivated off-season (May–June) under irrigated lowland conditions and a sub-irrigation system (water-table elevation) especially in the municipality of Formoso do Araguaia, and in the harvest period (November–December) under upland conditions (PELUZIO *et al*., 2006). Year after year, during the crop season, there is an increase of cultivated areas in soil of low production capacity, farmed by pastures, without performing practices to improve their physical, chemical, and biological features.

The change of natural environments such as Cerrado into agricultural systems has led to degradation of large areas due to their inappropriate operation. Searching for high productivity and improvements in physical, chemical, and biological soil properties requests studies for evaluating the various management systems as well as the interaction among different environments and genotypes (LAURINDO *et al*., 2009).

Under different environments, genotypes express their potential in relation to those occurring conditions, which change in space and time. As genotypes may respond differently to environments, studies on their behavior are required derived from regionalized trials, according to Schluchting and Teixeira (2002), Barros *et al.* (2003) and Peluzio *et al*. (2005).

The main study methods of adaptability and stability are based on analysis of variance, linear regression, non-linear regression, multivariate analysis, and non-parametric statistics (BASTOS *et al*., 2007). Aspects such as ease of analysis and interpretation of results must be considered when choosing methods to be used (BORGES *et al*., 2000).

The comparison among different methodologies applied for analyzing genotype/environment interaction aims to verify the similarity or divergence regarding the ordering of genotypes with environments. *Spearman* rank *correlation coefficient* can be used for comparing the methods of adaptability and stability (SILVA; DUARTE, 2006). *Spearman* rank *correlation coefficient* is a statistical method based on ranks and was introduced by Spearman in 1904; it requires that the *X* and *Y* variables be measured on an ordinal scale.

Thus, this study was carried out in agricultural years of 2009–2010 and 2010–2011 in the municipalities of Gurupi and Palmas, Tocantins, because of the scarcity of studies on the soybean genotypes' behavior in favorable and unfavorable environments in the state, as well as the association among parameters of adaptability and stability.

MATERIAL AND METHODS

Competition assays of soybean genotypes in the agricultural years of 2009–2010 and 2010–2011 were performed in a total of 8 (2 sites x 4 times); 4 competition assays were installed in the municipality of Gurupi (3 December 2009, 18 December 2009, 5 January 2010, and 29 November 2010) in the Universidade Federal do Tocantins (Federal University of Tocantins) at 280-m altitude (11° 43' S latitude, 49° 04' W longitude), and 4 competition assays were installed in the city of Palmas (30 November 2009, 16 December 2009, 4 December 2010, and 17 December 2010) in the Universidade Federal do Tocantins at 220-m altitude (10° 12' S latitude, 48° 21' W longitude). It is noteworthy that areas previously occupied by pastures were chosen. Each essay represented an environment, and fertilization was performed according to the crop requirements after previous soil chemical analysis.

The assays were installed in a randomized complete blocks design with four replicates. The treatments consisted of 11 soybean genotypes made available by public and private companies; from them, 4 genotypes are transgenic (RR) and the others are conventional (P98Y70, M-SOY8766RR, M-SOY9144RR, BR/EMGOPA314, P98R91, P98Y51, P99R01, M-SOY8867RR, M-SOY9056, M-and M-SOY8527RR, and M-SOY9350).

The experimental unit consisted of 4 rows of 5.0-m long, with 0.45-m spacing among rows, being the plot useful area represented by the 2 central rows, eliminating 0.50 m from the end of each row. Seeds were sowed in order to obtain density of 14 plants per linear meter. The seeds were inoculated with *Bradyrhizobium japonicum* strains in each test at sowing time. The plants from each experimental plot were harvested one week after they presented 95% of mature pods. After harvesting, the plants were threshed, and the dry (12% moisture) and clean seeds were weighed for determining the grain yield.

Individual variance analysis of the tests was performed, and subsequently the combined analysis was done. In the mathematical model used to perform the combined analysis, the cultivar effect was considered fixed and the other effects were considered randomized.

Adaptability and stability analyses were carried out based on the following methods: (a) variance analysis Plaisted and Peterson (1959) (PP), Wricke (1965) (WR), and Annicchiarico (1992) (AN); (b) linear regression — Finlay and Wilkinson (1963) (FW), Eberhart and Russell (1966) (ER), and Tai (1971) (TA); (c) non-parametric Statistics

— Lin and Binns (1988) — modified by Carneiro (1998) (LB); and (d) principal component — Centroid (ROCHA *et al*., 2005) (CT). Some of these methods respond well to evaluations for Tocantins, as observed by Peluzio *et al*. (2008), despite being traditional.

By this way, the average grain yield as well as adaptability and stability parameters were obtained for each cultivar for genotype recommendation in classes of unfavorable, favorable, and general environment methods as: (a) AN — stability parameters measured by the genotype superiority related to the average of each environment, obtaining an index of genotypes indication in general environments (ANWig), favorable environment group (ANWif), and unfavorable environment group (ANWid); (b) LB — estimates of stability parameters for genotypes indications in general environments (LBPig), favorable environment group (LBPif) and unfavorable environment group (LBPid); (c) CT — estimates of stability parameters for genotypes indication in general environments (CTI), favorable environment group (CTII), and unfavorable environment group (CTIII); (d) FW — regression coefficient (FWb) as a parameter of adaptability and stability; (e) ER — regression coefficient (ERb) as parameter of adaptability and determination coefficient (ERR2) as stability measure; (f) TA — TAb parameter evaluating adaptability, and TAy evaluating stability; (g) PP — stability parameter obtained by the arithmetic mean of the variance components of interaction of genotype pairs x environments (PPWi); and (h) WR — stability parameter estimated by the decomposition of the sum of genotype squares x environments in the parts due to isolates genotypes (WRwi).

To check the association intensity among the average and the adaptability and stability parameters, Spearman's correlation among the results was used by the described methods for the 153 estimate pairs (combination of 18 estimates) using the GENES software (CRUZ, 2001). Individual and combined analyzes and adaptability and/or stability ones were performed using the GENES software (CRUZ, 2001).

RESULTS AND DISCUSSION

In each test, the estimated mean squares of the residues ranged from 468,347.62 to 73,477.68, whereas the ratio of these values (max F-test) was 6.37 (Table 1), showing homogeneous residual variances according to Pimentel Gomes (1990); thereby, the combined analysis was viable, in which the lowest residual mean square did not differ from the highest more than seven times (CRUZ; REGAZZI, 2006).

The variance analysis for grain yield was significant ($p \leq 0.05$) by F-test for G x E interaction, indicating a differentiated behavior of genotypes in environments, making possible to justify the analysis of adaptability and stability (Table 1).

Table 2 shows data on Spearman's correlations among the average genotypes yield (kg/ha^{-1}) and the adaptability and stability parameters. Estimates of Spearman's correlation coefficients (r_s) from the genotype classifications for adaptability and stability parameters of the studied methods ranged from -0.99 to 1.00, showing different levels of agreement and/or disagreement in genotypes ranking.

The correlation estimate was significant and negative among the average and the stability parameters of LBg and LBd (average x LBg=-0.91; average x LBd=-0.82); and it was positive among the average and parameters of ANg and ANd (average x ANg=0.86; average x ANd=0.75). Thus, genotypes that may be recommended by the LB method (lower values) and by AN method (higher values) are those ones that achieved the highest yields, thus, showing the similarity between the two methods; similar results were found by Silva and Duarte (2006), and Cargnelutti Filho *et al*. (2007; 2009).

The average reached correlation with CT method for CTI parameter and obtained positive correlation in

Table 1 - Summary of combined variance analysis for mean grain yield (kg.ha^{-1}) of soybean genotypes, coefficient of variation and the ratio between the highest and lowest estimate of the mean square error among assays (QMR^+/QMR^-), in eight environments in the State of Tocantins, harvest of 2009–2010 and 2010–2011

Variation source	GL	Mean square	F
Block/environments	16	479,947.95*	2.79
Environments	7	23,461,185.08*	136.72
Genotypes	10	1,227,660.97*	7.15
G x E interaction	70	598,897.01*	3.49
Block	2	749,236,73*	4.36
Medium error	158	171,599.92	
CV (%)	14.37		
QMR^+/QMR^-	6.37		
Mean	2,881		

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

Table 2 - Estimates of Spearman's correlation coefficients among the means and the estimates of adaptability and stability parameters obtained by eight methods for grain yield in soybean genotypes in eight studied environments in the State of Tocantins

Parameter	Mean	ERb	ERσ	ERr²	LBg	LBf	LBd	TAb	TAy
Mean	-	0.22	0.17	-0.04	-0.91*	-0.47	-0.82*	0.22	0.17
ERb		-	-0.28	0.65*	-0.09	-0.84*	0.28	1.00*	-0.28
ERσ			-	-0.85*	0.01	0.15	-0.28	-0.28	1.00*
ERr²				-	-0.03	-0.52	0.35	0.65*	-0.85*
LBg					-	0.44	0.84*	-0.09	0.00
LBf						-	0.01	-0.84*	0.15
LBd							-	0.28	-0.28
TAb								-	-0.28
	ANg	ANf	ANd	CTI	CTII	CTIII	FWb	PPwi	WRWi
Mean	0.86*	0.53	0.75*	0.87*	0.31	0.37	0.22	0.17	0.17
ERb	0.03	0.82*	-0.33	-0.18	0.71*	-0.66*	1.00*	-0.21	-0.21
ERσ	0.04	-0.12	0.31	0.22	-0.58	0.16	-0.28	0.94*	0.94*
ERr2	-0.06	0.50	0.01	-0.26	0.81*	-0.45	0.65*	-0.73*	-0.73*
LBg	-0.94*	-0.47	-0.78*	-0.90*	0.35	-0.41	-0.09	0.01	0.01
LBf	-0.35	-0.99*	0.05	-0.18	-0.49	0.56	-0.84*	0.13	0.13
LBd	-0.88*	-0.08	-0.99*	-0.97*	-0.67*	-0.78*	0.28	-0.25	-0.25
TAb	0.03	0.82*	-0.33	-0.18	0.71*	-0.66*	1.00*	-0.21	-0.21
TAy	0.04	-0.12	0.31	0.22	-0.58	0.16	-0.28	0.94*	0.94*
	CTI	CTII	CTIII	ANg	ANf	ANd	FWb	PPwi	WRWi
CT I	-	0.58	0.67*	0.94*	0.25	0.95*	-0.18	0.16	0.16
CT II		-	-0.68*	-0.42	0.77*	-0.70*	0.71*	-0.55	-0.55
CT III			-	0.53	-0.48	0.81*	-0.66*	0.09	0.09
ANg				-	0.38	0.85*	0.03	-0.04	-0.04
ANf					-	0.02	0.82*	-0.10	-0.10
ANd						-	-0.33	0.27	0.27
FWb							-	-0.21	-0.21
PPWi								-	1.00*

Mean (kg/ha^{-1}); ERb, ERσ, and ERr²: adaptability and stability (EBERHART; RUSSELL, 1966); LBg, LBf, and LBd: stability in unfavorable, favorable, and general environment, respectively (LIN; BINNS, 1988); ANg, ANf, and ANd: stability in the unfavorable, favorable, and general environment, respectively (ANNICCHIARICO, 1992); WRWi: stability (WRICKE, 1965); CT I, CT II, and CT III: general adaptabilities in unfavorable and favorable environments, respectively (Centroid; ROCHA *et al.*, 2005); FWb: adaptability (FINLAY; WILKINSON, 1963); PPWi: stability (PLAISTED; PETERSON, 1959); TAb and TAy: adaptability and stability (TAI, 1971).

*Significative ($p<0.05$) by t-test.

intensity and signal (average x CTI=0.87). Unlike, the other methods showed no significant correlation with the average, evidencing that not always the most productive genotypes provide better adaptability and stability and vice versa. As expected, the regression-based methods (FWb), (ERb), and (TAb) showed high correlation estimates (ERb x FWb, TAb=1.00; TAb x FWb=1.00), because they are based on similar mathematical concepts, making its concomitant use unnecessary for adaptability studies. Silva and Duarte (2006) and Cargnelutti Filho *et al*. (2009) also found positive and significant association among adaptability parameters proposed by ER and TA methods.

The parameter estimates of (FWb), (ERb), and (TAb), when compared with the estimates obtained using the other methods, showed significant correlation with the stability parameters of favorable environment group of the (LBPif) (LBPif x FWb, ERb, TAb=-0.84), (ANWif) (ANWif x FWb, ERb, TAb=0.82), (CTII) (CTII x FWb, ERb, TAb=0.71) methodology; and unfavorable environment group of the (CTIII) (CTIII x FWb, ERb, TAb=-0.66) methodology. By these results, it is observed that the more indicated genotypes by the method proposed by (ANWif) and (CTII) (higher scores in both methodologies) and (LBPif) (lower scores) are strongly associated with the highest values of regression coefficient (FWb, ERb and TAb), *i.e.* genotypes adapted to favorable environments. Cargnelutti Filho *et al.* (2007) also found a significant association between ANWif and LBPif (ANWif x ERb, TAb=0.62 and LBPif x ERb and TAb=-0.72). Moreover, Silva and Duarte (2006), Melo *et al*. (2007), and Pereira *et al.* (2009) found no significant correlation between ERb x ANWif and ERb x LBPif parameters.

In methods involving variance analysis, *i.e*. PPwi and WRwi, there was perfect association among the stability parameters (r_s=1.00), resulting in genotype similar indication. This result confirms those ones obtained by Oliveira (1976), cited by Cruz and Regazzi (2006), Silva and Duarte (2006), and Cargnelutti Filho *et al*. (2007; 2009). Thus, it can be concluded that it becomes unnecessary using simultaneously these methods.

The parameter estimates of PPwi and WRwi, when compared with the estimates obtained by other methods, showed significant correlation only between the determination coefficient (ERR^2) (ERR^2 x PPwi, WRwi=-0.73) and the stability parameter of the (TAy) (TAy x PPwi, WRwi=0.94) method, since they provide the same information (Table 2). Thus, it is concluded that more stable genotypes, *i.e.* that show lower scores in relation to PPwi and WRwi parameters, are associated with the highest scores of ERR^2 (more stable) and the smallest scores of TAy (more stable). These results in magnitude and sign (ERR^2 x PP_{Wi}, WRwi=-0.86 and TAy x PP_{Wi}, WRwi=0.93) are in agreement with those obtained by Cargnelutti Filho *et al*. (2007).

Genotypes with higher ERR^2 values would be the most indicated by the PPwi, WRwi, and TA methods. The other methods showed poor agreement in indication of cultivars and can be indicated simultaneously because they aggregate information for adaptability and stability studies.

The estimates by stability methods proposed by AN for unfavorable (ANWid), favorable (ANWif), and general environments (ANWig) showed negative Spearman's correlation and high magnitude when compared with the stability estimates of the LB method, modified by Carneiro (1998), respectively, for unfavorable (LBid) (LBid x ANWid=-0.99), favorable (LBif) (LBif x ANWif=-0.99), and general environments (LBig) (LBig x ANWig=-0.94). These results showed concordances among these methods in terms of genotype ranking for these environments, *i.e.* the most indicated genotypes (higher scores) by the AN method would be the most indicated (lower scores) by the Lin and Binns (1988) method, modified by Carneiro (1998). These results are similar to those ones found by Borges *et al*. (2000), Machado *et al*. (2003), Silva and Duarte (2006), Cargnelutti Filho *et al*. (2007; 2009), Mora *et al*. (2007), Silva Filho *et al*. (2008), and Pereira *et al*. (2009).

Stability parameters of the Centroid method (ROCHA *et al*., 2005) for unfavorable (CTIII) and general environments (CTI) showed negative correlation of high magnitude with stability estimates of Lin and Binns (1988) method modified by Carneiro (1998), respectively, for unfavorable (LBid) (LBid CTIII=-0.78) and general environments (LBig) (CTI LBig=-0.90); and positive and significant correlations when compared with stability estimates of the method proposed by Annicchiarico (1992) for unfavorable (ANWid) (ANWid x CTIII=0.81) and general environments (ANWig) (ANWig x CTI=0.94). These results show accordance among methods as the similarity of genotypes' behavior in the studied environments, *i.e.* the most indicated genotypes (higher scores) by the Annicchiarico (1992). Centroid (ROCHA *et al*., 2005) method would be the most indicated (lower scores) by the Lin and Binns (1988) method, modified by Carneiro (1998).

CONCLUSIONS

The methods of Plaisted and Peterson and Wricke, based on analysis of variance, are associated with greater stability and do not depend on adaptability to the unfavorable, favorable, and general environment, but they should be used with restraint.

Genotypes with high yield and adapted to favorable environments may be the most indicated by Lin and Binns method, modified by Carneiro (1998), Annicchiarico (1992), and Centroid (ROCHA *et al*., 2005).

The method of Eberhart and Russell should preferably be used, by considering simultaneously the productivity, stability, and adaptability to unfavorable, favorable, and general environments of the Amazonian Cerrado.

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LITERATURA CIENTÍFICA CITADA

ANNICCHIARICO, P. Cultivar adaptation and recommendation from alfafa trialsin Northern Italy. **Journal of Genetics and Plant Breeding**, v.4, p.269-278, 1992.

BARROS, H. B.; PELUZIO, J. M.; SANTOS, M. M.; BRITO, E. L.; ALMEIDA, R. D. Efeito das épocas de semeadura no comportamento de cultivares de soja, no sul do estado de Tocantins. **Revista Ceres**, v.50, n.291, p.565-572, 2003.

BASTOS, I. T.; BARBOSA, M. H. P.; RESENDE, M. D. V.; PETERNELLI, L. A.; SILVEIRA, L. C. I.; DONDA, L. R.; FORTUNATO, A. A.; COSTA, P. M. A.; FIGUEIREDO, I. C. R. Avaliação da interação genótipo x ambiente em cana-de-açúcar via modelos mistos. **Pesquisa Agropecuária Tropical**, v.37, n.4, p.195-203, 2007.

BORGES, L. C.; FERREIRA, D. F.; ABREU, A. F. B.; RAMALHO, M. A. P. Emprego de metodologias de avaliação da estabilidade fenotípica na cultura do feijoeiro comum (*Phaseolus vulgaris* L.). **Revista Ceres,** v.47, n.269, p.89−102, 2000.

CARGNELUTTI FILHO, A.; PERECIN, D.; MALHEIROS, E. B.; GUADAGNIN, J. P. Comparação de métodos de adaptabilidade e estabilidade relacionados à produtividade de grãos de cultivares de milho. **Bragantia,** Campinas, v.66, n.4, p.571-578, 2007.

CARGNELUTTI FILHO, A.; STORCK, L.; RIBOLDI, J.; GUADAGNIN, J. P. Associação entre métodos de adaptabilidade e estabilidade em milho. **Ciência Rural**, v.39, p.340-347, 2009.

CARNEIRO, P. C. S. **Novas metodologias de análise da adaptabilidade e estabilidade de comportamento**. 1998. 155 f. Tese (Doutorado em Genética e Melhoramento) – Universidade Federal de Viçosa, Viçosa.

CRUZ, C. D. **Programa GENES**: aplicativo computacional em genética e estatística. Viçosa: UFV, 2001. 542 p.

CRUZ, C. D.; REGAZZI, A. J. **Modelos biométricos aplicados ao melhoramento genético**. Viçosa: UFV; Imprensa Universitária, 2006. 390 p.

EBERHART, S. A.; RUSSELL, W. A. Stability parameters for comparing varieties. **Crop Science**, v.6, p.36-40, 1966.

FINLAY, K. W.; WILKINSON, G. N. The analysis of adaptation in a plant breeding programme. **Australian Journal of Agriculture Research**, v.14, p.742-754, 1963.

LAURINDO, M.C.O.; NÓBREGA, L.H.P.; PEREIRA, J.O.; DIRCEU, D.; LAURINDO, É.L.Atributos físicos do solo e teor de carbono orgânico em sistemas de plantio direto e cultivo mínimo. **Engenharia na Agricultura**, v.17, n.5, p.367-374, 2009.

LIN, C. S.; BINNS, M. R. A superiority measure of cultivar performance for cultivars x location data. **Canadian Journal of Plant Science**, v.68, n.1, p.193-198, 1988.

MACHADO, J. R. A.; PENNA, J. C. V.; FALLIERI, J.; SANTOS, P. G.; LANZA, M. A. Adaptabilidade e estabilidade de genótipos de algodoeiro para características tecnológicas de fibra. **Revista Brasileira de Oleaginosas Fibrosas**, v.7, p.673-683, 2003.

MELO, L. C.; MELO, P. G.; FARIA, L. C. de; DIAZ, J. L. C; DEL PELOSO, M. J.; RAVA, C. A.; COSTA, J. G. C. da. Interação com ambientes e estabilidade de genótipos de feijoeiro-comum na Região Centro-Sul do Brasil. **Pesquisa Agropecuária Brasileira**, v.42, n.5, p.715−723, 2007.

MORA, F.; PUPIM-JUNIOR, O.; SCAPIM, C. A. Prediction of cultivar effects on cotton yield in the presence of genotype environment interaction. **Ciencia e Investigación Agraria**, v.34, n.1, p.7-16, 2007.

PELUZIO, J. M.; ALMEIDA JUNIOR, D.; FRANCISCO, E. R.; FIDELIS, R. R.; RICHTER, L. H.; BARBOSA, V. S. Comportamento de cultivares de soja no sul do estado do Tocantins. **Bioscience Journal,** v.21, p.113-118, 2005.

PELUZIO, J. M.; FIDELIS, R. R.; ALMEIDA JUNIOR, D.; RICHTER, L. H.; SILVA, R. R.; AFFERRI, F. S. Desempenho de cultivares de soja, em duas épocas de semeadura, no sul do Estado do Tocantins. **Bioscience Journal**, v.22, p.69/22-74, 2006.

PELUZIO, J. M.; FIDELIS, R. R.; BARROS, H. B.; CAPELLAR, D. Adaptabilidade e estabilidade de cultivares de soja em diferentes épocas de semeadura em Gurupi, TO. **Revista Ceres**, v.55, p.34-40, 2008.

PEREIRA, H. S.; MELO, L. C.; FARIA, L. C.; DEL PELOSO, M. J.; COSTA, J. G. C.; RAVA, C. A.; WENDLAND, A. Adaptabilidade e estabilidade de genótipos de feijoeiro-comum com grãos tipo carioca na Região Central do Brasil. **Pesquisa Agropecuária Brasileira**, v.44, n.1, p.29-37, 2009.

PIMENTEL GOMES, F. **Curso de estatística experimental**. 13. ed. Piracicaba: Nobel, 1990.

PLAISTED, R. L.; PETERSON, L. C. A technique for evaluating the ability of selections to yield consistently in different locations and seasons. **American Potato Journal**, v.36, p.381-385, 1959.

ROCHA, R. B.; MURO-ABAD, J. I.; ARAUJO, E. F.; CRUZ, C. D. Avaliação do método centróide para estudo de adaptabilidade ao ambiente de clones de *Eucalyptus grandis*. **Ciência Florestal**, v.15, n.3, p.255-66, 2005.

SCHLUCHTING, D.; TEIXEIRA, M. R. O. Influência de três épocas de semeadura na região de Dourados – MS, sobre os aspectos fenológicos de cinco cultivares de soja (*Glycine max* (L.) Merrill). In: CONGRESSO BRASILEIRO DE SOJA, 2., 2002, Foz do Iguaçu. **Resumos:** EMBRAPA/CNPSo, 2002. 117 p.

SILVA, W. C. J.; DUARTE, J. B. Métodos estatísticos para estudo de adaptabilidade e estabilidade fenotípica em soja. **Pesquisa Agropecuária Brasileira,** v.41, p.23-30, 2006.

SILVA FILHO, J. L. da; MORELLO, C. de L.; FARIAS, F. J. C.; LAMAS, F. M.; PEDROSA, M. B.; RIBEIRO, J. L. Comparação de métodos para avaliar a adaptabilidade e estabilidade produtiva em algodoeiro. **Pesquisa Agropecuária Brasileira**, v.43, p.349–355, 2008.

TAI, G. C. C. Genotype stability analysis and its application to potato regional trials. **Crop Science**, v.11, n.2, p.184-190, 1971.

WORLD WILDLIFE FUND. **Expansão agrícola e perda da diversidade no cerrado: origens históricas e o papel do comércio internacional**. Brasília: WWF Brasil, 2000.

WRICKE, G. Zur Berechning der okovalenz bei sommerweizen und hafer. **Zeitschrift fur Pflanzenzuchtung,** v.52, p.127-138, 1965.