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Adaptability and stability of transgenic soybean lines and cultivars in the Brazilian macroregion 3 assessed by using parametric and nonparametric methods

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This study aimed to evaluate the adaptability and stability of 20 soybean genotypes, ten of which were lines of Monsoy Ltd breeding program, whereas the other 10 genotypes were commercially used cultivars. The experiments were carried out in the agricultural years of 2005/2006 and 2006/2007, in Brazil, specifically in the soybean microregions 301, 302 and 303 (part of Minas Gerais, Goiás and São Paulo states). A randomized complete block design was used for all genotypes in each location, with three repetitions. Individual and joint analyses were done considering genotype yield in the different locations. Subsequently, genotypic adaptability and stability were evaluated by the methods of Eberhart and Russel (1966), Lin and Binns modified by Carneiro, Annicchiarico and Centroid. All methods presented partial coherence on classifying the best genotypes and allowed the identification of the transgenic lines L1 and L4, and the cultivars M-SOY 8199 RR, M-SOY 8045 RR, and Valiosa RR as the most promising ones to be grown in the microregion 3 because they have shown both stability and wide adaptation combined with outstanding grain yield. Lines L1 and L4, both with superior grain yield than the controls M-SOY 8199 RR and Valiosa RR, were classified as those with adaptability and stability to favorable environments. On the other hand, the lines L3, L10 and the cultivars M-SOY 8064, M-SOY 7908, and M-SOY 8045 RR were the most stable and productive genotypes for unfavorable environments.

Key words: *Glycine max*, adaptability, stability, GxE interaction.

INTRODUCTION

The soybean crop has been considerably developed in Brazil since the last three decades and in the last harvest season, it represents 49% of the total area aimed for grain production in the country. During the harvest season of 2014/2015, Brazil produced 95 million tons of soybean in an area of approximately 31 million hectares. Currently, the country is the second largest producer and exporter of the crop in the world (CONAB, 2015).

This expansion and the increasing grain yield are mainly due to technological developments and correct management of the crop (MAPA, 2014). The increasing soybean yield in the last years is essentially due to genetic breeding and development of new technologies of production (Freitas, 2011). The crop's expansion has been promoted towards new agricultural fields as a result of the large adaptability of the crop to different environmental conditions.

The term environment can be understood, in this context, as a series of conditions in which the plants grow and develop themselves involving aspects such as location, season, year, cultural practices or the combination of them (Rocha, 2002). Throughout the breeding process, genetic materials are tested in a wide range of croplands for posterior performance evaluation and genetic superiority proof. In this context, the occurrence of genotypic and environmental interactions (GxE) is common, for instance, those interactions affect crop behavior by reflex of environmental oscillations (Cruz et al., 2012). Therefore, knowing and evaluating the elements that compose this interaction are very important for genetic breeding programs because they allow further identification of genotypic responsiveness and predictability as a result of environmental variations.

The adaptability of a certain cultivar is related to its capacity of taking advantageously use of environmental stimulation; the stability is the ability to show a behavior that is highly predictable as a matter of environmental modification (Cruz et al., 2012).

Adaptability studies using parametric methodologies such as Eberhart and Russel (1966), Centroid (Rocha et al., 2005) and nonparametric methods such as that of Lin and Binns (1988) modified by Carneiro (1998) and Annicchiarico (1992), have been largely used in soybean crop in order to assess the stability and adaptability of genotypes (Vasconcelos et al., 2010; Barros et al., 2010; Marques et al., 2011; Oliveira et al., 2012; Carvalho et al., 2013; Polizel et al., 2013). Likewise, scientific researches, such as the one carried out by Silva Filho et al. (2008), reported that both nonparametric methods used in this study are concordant and identify lines of great performance and wide stability.

Thereby, this study aimed to evaluate the soybean performance, adaptability and stability of 20 genotypes of Monsoy Ltd breeding program by parametric and nonparametric methodologies in the soybean producing macroregion 3.

MATERIALS AND METHODS

The experiments were done in Brazil, in the soybean producing macroregion 3, which covers part of the states of Minas Gerais, Goiás and São Paulo, specifically in the microregions 301, 302 and303 (Table 1) during the agricultural years of 2005/2006 and 2006/2007, aiming to assess the performance of different soybean lines. In Figure 1, it is shown that Brazil is subdivided into 5 macroregions and 29 soybean producing microregions.

The experiments were carried out in 8 municipalities of three different states: Goiás, Minas Gerais, and São Paulo, as shown in Table 1. It was evaluated 10 lines (L1 to L10) and developed by Monsanto Soybean Breeding Program – Monsoy Ltd, essentially from Morrinhos-GO research station, and 10 controls (commercial cultivars) (L11 to L20) of different maturity groups (Table 2).

All soybean lines assessed in the experiment were driven by the SPD method (single pod descendent), that is, starting from F2 to F5 generation, the procedure of picking one single pod per plant was performed. In the meantime, the seeds were sown from three to four rows of 5.0 m length, consisting of 12 to 15 seeds per linear meter, respectively.

With respect to field preparation, a burndown herbicide application for 14 days before sowing using the herbicide Roundup WG® was done with a dosage of 1.5 kg per hectare. Right before the sowing, complete soil analyses of all locations were done, as well as fertilizer applications according to the soil requirements and crop recommendations; the fertilizer formulation used was 2-28-20.

The sowing was done under no-till crop system using a plot seeder called Semeatos® SHP 249. During sowing process, an insecticide application was done at planting furrows with Cruizer® (300 g ha^{-1}), and also, an inoculation with Gelfix® (10 doses ha^{-1}) was done.

Roundup Ready® applications were performed 20 days after sowing on a dosage of 2.0 L ha^{-1} in order to control weeds. Meanwhile, insecticides and fungicides, registered for the crop, were sprayed as often as necessary.

The experimental design used was randomized complete blocks with three replications. Each experimental plot was formed by 4 soybean plant rows with 5 m length, spaced at 0.5 m within rows. The useful area was composed of 2 central lines, wherein the two external rows were discarded as borders, resulting in a useful area of 5 m^2.

It was determined that the grain (kg ha^{-1}) in the experimental plots were harvested through the use of a plot harvester Almaco® Company, model SPC-20. Whenever necessary, the soybean seeds were dried to a moisture content of 13% in a gas drier at Monsoy station, Morrinhos-GO. The seeds of each plot were kept in a cloth bag and weighed on a digital scale.

Data from grain yield were submitted to individual (each municipality separately) and joint variance analyses. The environmental variation source was composed of 3 soybean producing microregions with 9 municipalities and 2 agricultural years. Similar procedure was adopted by Oliveira et al. (2012). Before the joint analyses, the homogeneity of residual variance was checked by dividing the highest and smallest numbers of the mean square error. Since it was higher than 7, the degrees of freedom were adjusted.

After detecting the existence of GxE interaction, adaptability and stability analyses was conducted by using the methodology of Eberhart and Russel (1966), Lin and Binns (1988) modified by Carneiro (1998), Annicchiarico and Centroid. The statistical analyses were done using the Genes computer program (Cruz, 2013).

RESULTS AND DISCUSSION

The occurrence of GxE interaction (Table 3) was verified by F test (P>0.01) for the trait, grain yield of all 20

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Table 1. Regions and municipalities where the transgenic soybean genotypes were grown over two harvest seasons, in three different microregions.

Locality	Regions	Cities	State	Crop season
L1	Region 301	Edéia	GO	2005/2006
L2	Region 301	Santa Helena de Goiás	GO	2005/2006
L3	Region 302	Morrinhos 1	GO	2005/2006
L4	Region 302	Morrinhos 2	GO	2005/2006
L5	Region 303	Vianópolis	GO	2005/2006
L6	Region 302	Uberlândia	MG	2005/2006
L7	Region 301	Edéia	GO	2006/2007
L8	Region 301	Santa Helena de Goiás	GO	2006/2007
L9	Region 301	Tupaciguara 2	MG	2006/2007
L10	Region 301	Barretos	SP	2006/2007
L11	Region 301	Goiatuba	GO	2006/2007
L12	Region 302	Tupaciguara 1	MG	2006/2007
L13	Region 302	Morrinhos 1	GO	2006/2007
L14	Region 302	Morrinhos 2	GO	2006/2007
L15	Region 303	Vianópolis	GO	2006/2007
L16	Region 302	Uberlândia	MG	2006/2007

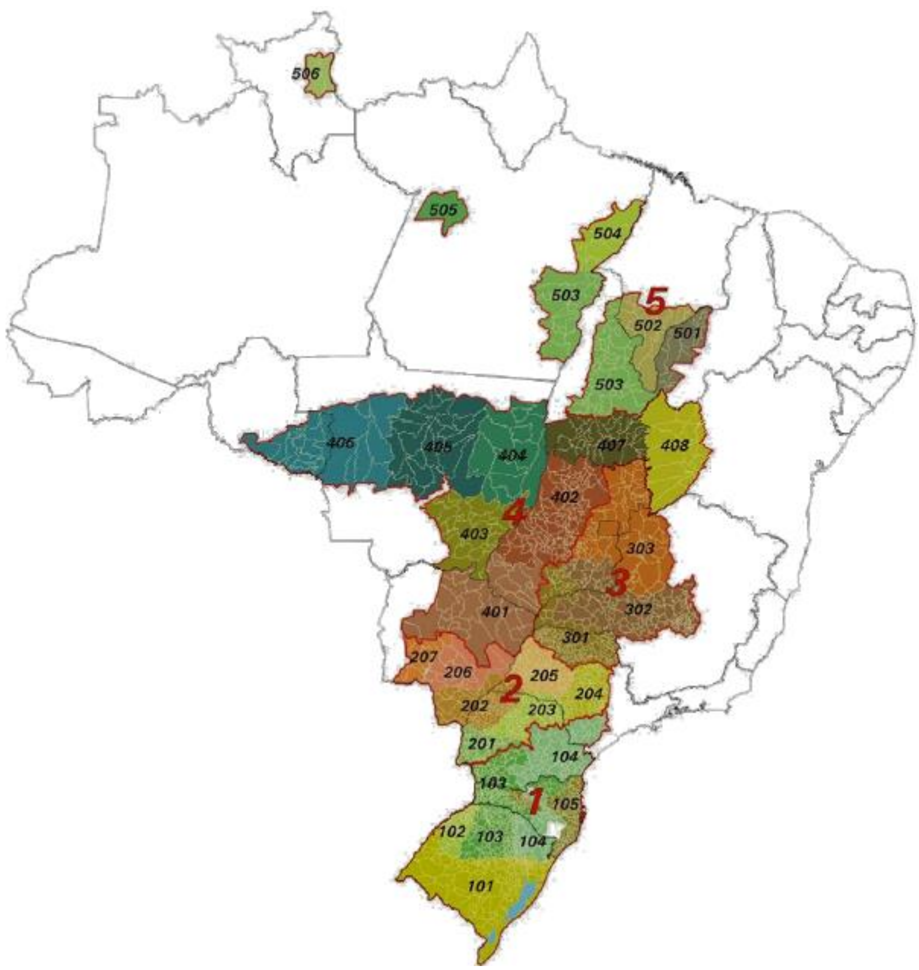

Figure 1. Brazil's map subdivided into macro and micro soybean producing regions (Source: Kaster and Farias, 2002).

Table 2. Cultivars and lines evaluated during two consecutive harvest seasons, 2005/2006 and 2006/2007, in the soybean producing macro region 3.

Genotypes (L)	Cultivars and lines	Maturity group (MG)
1	Line1	8.2
2	Line 2	8.1
3	Line 3	7.5
4	Line 4	8.1
5	Line 5	7.5
6	Line 6	7.5
7	Line 7	7.6
8	Line 8	7.9
9	Line 9	8.0
10	Line 10	8.0
11	M-SOY 8064 RR	8.0
12	M-SOY 8000 RR	8.0
13	M-SOY 8248 RR	8.2
14	M-SOY 8008 RR	8.0
15	M-SOY 8360 RR	8.3
16	M-SOY 7908 RR	7.9
17	M-SOY 8199 RR	8.1
18	M-SOY 8287 RR	8.2
19	M-SOY 8045 RR	8.0
20	VALIOSA RR	8.1

Table 3. Summary of joint variance analyses of grain yield (kg ha^{-1}) of 20 soybean genotypes grown in sixteen environments, soybean producing region 3, during the harvest years of 2005/2006 and 2006/2007.

Source of variation	Degrees of freedom	Mean squares
Blocks/environment	32	3265.10
Genotype	19	1653444.38**
Environment	15	5113196.45**
Genotype x environment	223	442284.41**
Residue	468	29987.43
Coeficient of variation (CV %): 4.5%		

**Significant at 0.01 of probability by F test.

genotypes in the sixteen studied environments, which represent the three soybean producing microregions. Due to the fact that the interaction genotype x cultivation area is significant, grain yield was influenced by either the genotype or the environment. Similar results were observed by Rocha and Velho (1999) while studying the same interaction (genotype x environment) for grain yield of soybean lines with different maturity groups.

The experimental coefficient of variation was of low magnitude (4.5%), indicating good experimental precision. Furthermore, the CV was lower than 16%, which is considered the maximum coefficient accepted for soybean grain yield according to Carvalho et al. (2003), and lower than what it was found in other studies (Barros et al., 2009, 2010, 2012; Vasconcelos et al., 2010; Marques et al., 2011; Carvalho et al., 2013).

The existence of GxE interaction highlights differences on the behavior of genotypes in responsiveness to environmental fluctuations (Cruz et al., 2012), and therefore, justifies the study of adaptability and stability, allowing a better understanding regarding each genotype and future cultivar recommendations.

According to Barros et al. (2010), the GxE interaction event represents one of the main difficulties found by breeding programs, whether in cultivar selection or recommendation stages. In this context, it is undeniably important to know the adaptability and stability of genotypes to different growing regions in order to identify

Table 4. Grain yield of 20 soybean genotypes in each locality and environmental index by the method of Annicchiarico (1992).

Locality	Mean	Index	Class
1	4170.50	353.22	Favorable
2	3962.49	145.21	Favorable
3	4110.73	293.45	Favorable
4	4011.66	194.38	Favorable
5	3503.59	-313.69	Unfavorable
6	3456.99	-360.29	Unfavorable
7	4246.96	429.68	Favorable
8	3776.21	-41.06	Unfavorable
9	3788.58	-28.69	Unfavorable
10	3749.46	-67.82	Unfavorable
11	3374.46	-442.82	Unfavorable
12	3438.42	-378.86	Unfavorable
13	4234.06	416.79	Favorable
14	3842.66	25.39	Favorable
15	3861.89	44.61	Favorable
16	3547.77	-269.51	Unfavorable

lines of predictable behaviors that perform well against environment oscillations.

Adopting adaptability and stability analyses by using the methods of Annicchiarico (1992) (Table 4) and Eberhart and Russel (1966) (Table 5), it was possible to classify the localities according to classes, as shown in Table 4. It is noticed that from the sixteen classified environments, 50% were classified as favorable and the other 50% as unfavorable environments.

As stated in Eberhart and Russel (1966), the ideal genotype is the one that reveals B1 equal to a non-significant unit and regression deviation, and as a result, it is a genotype of wide adaptation and high predictability. Still, this method also facilitates the identification of genotypes adapted to unfavorable environments, B1<1, and to favorable ones B1>1.

In Table 5, according to Eberhart and Russel (1966) methodology, it was observed that the lines L6 and L9 and the cultivars M-SOY 8008 RR and M-SOY 8199 RR have shown wide adaptation. However, it has a low predictability for all deviation variances which were significant and R^2 had low magnitude, with the exception of M-SOY 8008 RR showing R^2 equals to 72%.

The lines L1, L2, L4, L8, L10 and the cultivars M-SOY 8248 RR, M-SOY 8360 RR, M-SOY 8287 RR, Valiosa RR have shown adaptation to favorable environments although these adaptations were of a low predictability, as detected by the significant deviations. In contrast, only the genotypes L1, M-SOY 8360 RR, and Valiosa RR showed R^2 that is higher 70%. Meanwhile, the lines L3, L5, L7, L10 and the cultivars M-SOY 8064, M-SOY 8000 RR, M-SOY 7908 RR, and M-SOY 8045 RR demonstrated adaptation to unfavorable environments, once again, with low predictability and R^2 of low magnitude (Table 5). Previous studies on soybean lines and cultivars in the same microregion using similar cultivars such as M-SOY 8000 RR, M-SOY 8045 RR, M-SOY 8199 RR, and Valiosa RR have also shown that all sixteen genotypes evaluated presented significant regression deviations and predominance of low values for R^2 (Oliveira et al., 2012).

With respect to the methodology of Eberhart and Russel (1966), which is based on regression analyses and consideration of the values of R^2, whether it is low, there is indication that the regression by itself does not explain properly the genotypic behavior against the environmental oscillations. Analyses on soybean lines and cultivars by Polizel et at. (2013) also suggest the predominance of low values for R^2, similar to what was found in the current study. Additionally, having studied transgenic cultivars, Carvalho et al. (2013) has found that 63% of all genotypes analysed in their experiments were classified as having low predictability which is similar to the results achieved in this study, and accordingly, they classified the cultivars as having wide or specific adaptation to favorable and unfavorable environments.

By the Lin and Binns (1988) methodology, modified by Carneiro (1998), the genotypic performance is estimated through the parameter (*Pi*), which is related to the distance between the genotype in analysis from the best genotype, so that the lower the value of *Pi* is, the higher the genotypic adaptability and stability will be. In Table 5, the lowest values of general *Pi* and high grain yield for the lines L1, L2, L3, L4, L10 and cultivar M-SOY 8199 RR were verified.

The lines L1, L2, L4, and L10 showed lower values of

Table 5. Estimation of adaptability and stability parameters according to the methodology of Eberhart and Russel (1966) and Lin and Binns (1988) modified by Carneiro (1998) in 20 soybean genotypes, during the harvest years of 2005/2006 and 2006/2007.

Genotype	Mean	Eberhart and Russel (1966)			Lin and Binns (1988) modified by Carneiro (1998)		
		β_1	S^2d	R^2 (%)	Pi general	Pi favorable	Pi unfavorable
L1	4108.4	1.67**	56146.3**	79.9	59378276.7	11967040.3	26192280.3
L2	4086.7	1.67**	102619.3**	69.7	64086454.1	16105207.9	45164406.6
L3	3896.6	0.42**	129059.2**	10.5	67748359.9	23526529.4	45723718.6
L4	4060.8	1.36**	81025.4**	65.5	68640906.5	24561198.9	45875317.7
L5	3670.7	0.20**	185683.6**	1.9	99324700.8	41503842.2	58203433.5
L6	3687.8	0.86^{ns}	100646.0**	38.4	96383070.1	36559256.0	52535698.6
L7	3630.9	0.39**	146558.5**	8.2	116301577.1	45574957.6	70344852.5
L8	3836.7	1.25**	79758.9**	61.8	98207496.3	40492635.6	52719103.1
L9	3800.1	1.10^{ns}	50288.2**	65.7	101556428.9	41556079.6	58560354.5
L10	4042.2	0.85*	115111.2**	34.7	63656608.9	12369469.5	336168877
M-SOY 8064 RR	3843.8	0.80*	132812.2**	29.4	91725339.6	35175873.4	52119413.8
M-SOY 8000 RR	3537.8	0.23**	79482.5**	5.4	129857489.4	51675722.9	93803861.8
M-SOY 8248 RR	3520.5	1.52**	158967.5**	56.0	155381739.3	71654055.9	114889103.7
M-SOY 8008 RR	3682.8	1.04^{ns}	30441.2**	72.0	111848694.6	43663967.0	66380555.6
M-SOY 8360 RR	3600.5	1.16*	36467.0**	73.4	139378819.4	57741222.7	103347165.
M-SOY 7908 RR	3796.6	0.76*	67493.36**	41.1	82282974.7	30039721.3	47648977.9
M-SOY 8199 RR	3968.8	1.02^{ns}	57539.2**	59.4	69725605.5	25422865.6	47008807.2
M-SOY 8287 RR	3683.9	1.72**	126341.1**	66.7	128770030.6	45850021.9	72310317.7
M-SOY 8045 RR	3916.1	0.65**	51859.3**	39.5	82302721.9	34758692.9	50074431.4
VALIOSA RR	3973.6	1.35**	20672.4**	85.3	73600960.8	25897178.6	47544029.1

*Significant at 5% of probability by the t test; **significant at 1% of probability by the F test; ns: not significant.

favorable *Pi*, and thus, specific adaptation to favorable environments and superior grain yield than the controls M-SOY 8199 RR and Valiosa RR, which also reached lower values for favorable *Pi* among the other cultivars. Besides, with regard to unfavorable environments, the best lines were L1 and L10 and the controls M-SOY 8064 RR, M-SOY 7908, M-SOY 8199 RR and Valiosa RR (Table 5).

According to Annicchiarico (1992), the stability is measured by the genotypic superiority as compared to the average value in each environment. It is based on what it is called confidence index (or recommendation index (ω*i*)). By this method, the lines L1, L2, L3 and L4 accomplished higher values of ω*i,* and consequently, they are strongly recommended for wide environmental conditions. Those lines also had higher averages with regards to grain yield than the cultivars M-SOY 8199 RR, M-SOY 8045 RR and Valiosa RR that reached ω*i* values higher than 100% (Table 6). Carvalho et al. (2013), studying sixteen transgenic cultivars of soybean and classifying them using Annicchiarico's method also found similar results (values above 100% for the parameter ω*i).*

Under favorable environments, the most stable genotypes were the lines L1, L3, L4 and 10 and the controls M-SOY 8199 RR, MSOY-8045 RR, and Valiosa RR wherein all lines outperformed the controls with regards to the grain yield aspect (Table 6).

The genotypes of soybean dapted to unfavorable environments were the lines L1, L3, L4, L10 and the controls M-SOY 8064 RR, M-SOY 8199 RR, M-SOY 8045 RR, and Valiosa RR as they highly performed in those environments with the highest values of ω*i* (Table 6).

With respect to wide adaptation by the Centroid method, the lines L1, L2, L4, L10 and the controls M-SOY 8199 RR, M-SOY 8045 RR, and Valiosa RR were identified as the best adapted genotypes (Table 7).

No genotypes showed specific adaptation to favorable environments by the Centroid method; on the other hand, the genotypes L3, L5, L8, L9, M-SOY 8064 RR, M-SOY 7908 RR and M-SOY 8287 RR were classified as having specific adaptation to unfavorable environments (Table 7).

The lines L6 and L7 and the cultivars M-SOY 8000 RR, M-SOY 8248 RR, M-SOY 8008 RR and M-SOY 8360RR were allocated in the group IV, which means that the genotypes are slightly adapted to these environments (Table 7). Those genotypes represent 30% of the whole genotypes analysed in the study. In addition, Cavalcante et al. (2014), analysing 25 lines and 4 cultivars of soybean by the Centroid method, obtained a number of 62% of all genotypes belonging to the group IV.

Among all genotypes analysed, the superiority of the transgenic lines was evidently noticed in both grain yield

Table 6. Adaptability and stability parameters of soybean genotypes during the harvest years of 2005/2006 and 2006/2007 in the soybean producing region 3, based on the methodology of Annicchiarico (1992).

Genotypes	General analysis		Favorable environment		Unfavorable environment	
	Mean	Wi (%)	Mean	Wi (%)	Mean	Wi (%)
L1	4108.36	105.13	4518.02	109.55	3698.70	101.26
L2	4086.69	104.00	4519.60	109.78	3653.78	98.95
L3	3896.59	99.47	3965.56	95.98	3827.61	103.50
L4	4060.79	104.05	4418.55	106.85	3703.03	101.41
L5	3670.74	93.06	3792.31	90.88	3549.18	95.32
L6	3687.78	94.33	3883.73	93.80	3491.83	94.77
L7	3630.86	92.45	3746.57	89.53	3515.15	95.39
L8	3836.66	98.27	4137.33	99.91	3536.00	96.59
L9	3800.14	97.77	4036.17	98.28	3564.12	97.33
L10	4042.25	103.57	4171.13	100.51	3913.37	106.80
M-SOY 8064 RR	3843.86	98.21	3964.72	94.95	3723.01	101.62
M-SOY 8000 RR	3537.86	90.57	3580.95	86.14	3494.76	95.61
M-SOY 8248 RR	3520.52	88.79	3863.93	92.36	3177.11	85.32
M-SOY 8008 RR	3682.78	95.01	3931.51	96.05	3434.05	94.06
M-SOY 8360RR	3600.51	92.68	3862.68	93.99	3338.34	91.39
M-SOY 7908 RR	3796.62	97.60	3947.50	95.52	3645.75	99.75
M-SOY 8199 RR	3968.81	102.22	4220.33	102.18	3717.29	102.14
M-SOY 8287 RR	3683.93	93.06	4162.63	100.44	3205.23	86.80
M-SOY 8045 RR	3916.14	100.97	4102.51	99.39	3729.76	102.53
VALIOSA RR	3973.64	102.60	4276.65	104.08	3670.63	101.17

*Mean: kg ha^{-1}.

Table 7. Adaptability and stability parameters of soybean genotypes during the harvest years of 2005/2006 and 2006/2007 in the soybean producing region 3, according to the Centroid methodology.

Genotype	Mean	Classification	Prob (I)[1]	Prob (II)[1]	Prob (III)[1]	Prob (VI)[1]
L1	4108.36	I	0.34	0.30	0.18	0.18
L2	4086.69	I	0.33	0.31	0.18	0.18
L3	3896.59	III	0.28	0.20	0.31	0.21
L4	4060.79	I	0.33	0.29	0.20	0.18
L5	3670.74	III	0.23	0.22	0.29	0.27
L6	3687.78	IV	0.23	0.23	0.27	0.27
L7	3630.86	IV	0.21	0.22	0.28	0.29
L8	3836.66	III	0.25	0.28	0.22	0.24
L9	3800.14	III	0.25	0.25	0.25	0.25
L10	4042.25	I	0.32	0.22	0.26	0.20
M-SOY 8064 RR	3843.86	III	0.25	0.22	0.28	0.25
M-SOY 8000 RR	3537.86	IV	0.18	0.19	0.30	0.34
M-SOY 8248 RR	3520.52	IV	0.18	0.28	0.20	0.34
M-SOY 8008 RR	3682.78	IV	0.21	0.25	0.24	0.30
M-SOY 8360RR	3600.51	IV	0.20	0.26	0.22	0.33
M-SOY 7908 RR	3796.62	III	0.25	0.23	0.27	0.25
M-SOY 8199 RR	3968.81	I	0.31	0.26	0.22	0.20
M-SOY 8287 RR	3683.93	III	0.20	0.35	0.18	0.27
M-SOY 8045 RR	3916.14	I	0.28	0.24	0.26	0.23
VALIOSA RR	3973.64	I	0.31	0.28	0.21	0.20

Classification: 1– Probability of belonging to the indicated class; Class I: general adaptability; Class II: specific adaptability to favorable environments; Class III: specific adaptability to unfavorable environments; Class IV: poorly adapted.

and stability rather than the controls, which in turn, emphasizes the high potential of these lines to be commercially accepted as new cultivars in the future, as well as being indeed important for breeding programs.

Although, the methods used for determining the adaptability and stability vary according to their statistical principle, whenever used together, they can enhance the understanding of the stability and adaptability capacity of a specific genotype. To this end, they allow breeders to have more reliance in both recommendation process of cultivar and selection of an excellent line that can be released into the market in the end of a breeding process.

The genotypic classification related to wide adaptation had evidently coherence in between the methods of Lin and Binns (1988) modified by Carneiro (1998) Annicchiarico (1992) and Centroid allowing, therefore, the joint identification of the lines L1, L2, and L4 as having a higher potential yield than the controls M-SOY 8199, M-SOY 8045 and Valiosa RR. Studies on adaptability and stability of soybean genotypes in the state of Mato Grosso have also shown, according to Polizel et al. (2013), the occurrence of a positive and significant association among both methodologies: Lins and Binns and Annicchiarico, as well as being concordant and complementary throughout the genotypic classification process.

Since the classification of genotypes to favorable environments allows the identification of genotypes that show a better capacity of response to better environmental conditions, the genotypes were successfully classified, indicating homogeneity along all three methods used. As a result, the most promising genotypes for grain yield were the lines L1 and L4, both with higher averages than the most productive controls, M-SOY 8199 and Valiosa RR.

For the genotypic classification to unfavorable environments, the methods of Eberhart and Russel (1966), Lin and Binns (1988) modified by Carneiro (1998), Annicchiarico (1992), and Centroid identified the lines L3 and L10 as the most productive and stable ones; conjointly, they have shown higher averages than the best controls M-SOY 8064, M-SOY 7908 and M-SOY 8045 RR. Analysing seven soybean cultivars in different planting seasons, Marques et al. (2011) stated a marked concordance among the methods of Lin and Binns (1988) modified by Carneiro (1998) and Centroid on classifying genotypes adapted to unfavorable conditions.

Conclusion

There was more overall coherence among the methods of Lin and Binns (1988) modified by Carneiro (1998), Annicchiarico (1992) and Centroid for the classification of transgenic soybean genotypes regarding yield stability and adaptability.

The transgenic lines L1 and L4 and the cultivars M-SOY 8199 RR, M-SOY 8045 RR and Valiosa RR are the most promising ones for soybean cultivation in the microregion 3 because they combine either stability and wide adaptation with high patterns of soybean yield.

Under favorable environmental conditions, the transgenic lines L1 and L4, which are both more productive than the most productive controls, M-SOY 8199 RR and Valiosa RR, were the most adapted genotypes to this condition.

Overall, under unfavorable environmental conditions, attaining high soybean yield and stability, the lines L3 and L10 and the cultivars M-SOY 8064, M-SOY 7908 and M-SOY 8045 RR were considered the best adapted ones.

Conflict of Interests

The author(s) have not declare any conflict of interests.

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