Adaptability and Stability of Soybean Cultivars in Lowland Production System

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ABSTRACT

The objective was to study the adaptability and stability of soybean cultivars in the lowland production system under different conditions in a subtropical environment. Fourteen soybean cultivars were evaluated in five locations and three growing seasons in Rio Grande do Sul State, Brazil. Three sowing dates were evaluated in each location and growing season and named as: early, recommended for high yield and recommended to minimize the risk of water deficiency. The experiment was carried out in a randomized complete block design, with three replicates. Yield data was submitted to analysis of variance, and the Eberhart and Russel method was used to study its adaptability and stability. In general, the cultivars that showed adaptability and stability to the three sowing dates showed MG between 5.6 to 6.4 and the type of indeterminate growth. The cultivars A 6411 RG, TEC 5936 IPRO and TECIRGA 6070 RR combined wide adaptability and stability, the cultivars Fundacep 65 RR and 6869 RSF RR presented high yield and stability of production and are recommended for lowland environments.

Keywords: *Glycine max* L.; crop rotation; yield potential; sustainability.

INTRODUCTION

The monoculture of flooded rice favored the selection of weeds resistant to the main herbicide used in lowlands production system, significantly reducing yield and making it impossible to grow rice in many farms in the Southern of Brazil (Concenço *et al.*, 2017). Soybean is the main alternative for crop rotations in the lowland production system, supporting the integrated pest and disease management, and allowing the maintenance of rice farming technologies for high yield and farmers' profit (Zanon *et al.*, 2015; Sartori *et al.*, 2016a). The conditions of this environment, such as low hydraulic conductivity soils, physical restriction, low soil water storage capacity and the other restrictive characteristics that interfere in soybean growth and development (Sartori *et al.*, 2016a). The influence of these characteristics can be evaluated in terms of grain yield (GY), considering that the average yield of soybean in RS is approximately 2.9 Mg ha^{-1}, in lowland conditions the average yield in the last five years was 1.8 Mg ha^{-1} (CONAB, 2017).

The use of cultivars with high stability or specific cultivars to each environment minimize the interaction with the environment (Silva *et al.*, 2016; Marques *et al.*, 2011), and reduce the risk for yield. Adaptability is the ability of a cultivar to respond positively to environmental stimulus and stability is the ability of a cultivar to exhibit a performance as constant as possible, due to variations in the environmental conditions and interaction environmental exhibit optimal agronomic traits and yield potentials (Song *et al.*, 2019). Recently, studies have been carried out on soybean production system in lowland conditions, seeking to know the diversity of the response between cultivars at water stress (Da Rocha *et al.*, 2017; Henry *et al.*, 2018), adaptation of agricultural implements to this cropping system (Sartori *et al.*, 2016b), plant development and grain yield (Zanon *et al.*, 2015; Zanon *et*

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al., 2016). However, there is a knowledge gap regarding the characterization of the stability and adaptability of soybean cultivars according to location, year and interaction with the environment (GEI) in the soybean lowland production system (Romanato *et al.*, 2016).

Therefore, studies are necessary to evaluate the adaptability and stability of soybean cultivars in areas traditionally grown with flooded rice in the lowland production system. This study will shed light in the identification of cultivars with better adaptation and higher stability to improve yield and profitability of crop rotation in the lowland production system. Thus, the objective was to study the adaptability and stability of soybean cultivars in the lowland production system of subtropical environment.

MATERIAL AND METHODS

Field experiments were carried out in the 2014/2015, 2015/2016 and 2016/2017 growing seasons, in the areas of Instituto Rio grandense do Arroz (IRGA) in Cachoeira do Sul, Cachoeirinha, Uruguaiana, Santa Vitória do Palmar and Universidade Federal do Pampa in Itaqui, in the state of Rio Grande do Sul (RS), Brazil. These locations have soils traditionally cultivated with boundary layer flooded rice by conventional light grid preparation and others with a textural horizon of high levels of natural clay. The sand concentration varying from 8% to 45% and each of such locations represents the totality of soil conditions where soybean is grown in rotation with flooded rice in Southern Brazilian lowlands (Zanon *et al.*, 2016). It is noteworthy that during the 2014/2015, 2015/2016 and 2016/2017 growing seasons, the amount of rainfall was higher than the climatological average, and there was a regular distribution of rainfall during the development cycle in most sowing seasons and locations.

A total of 14 soybean cultivars (Table 1) were sowing from September to December and were classified in three sowing period, named: I) early (September 20th to October 20th, II) recommended to high yields from October 20th to November 20th (Zanon *et al.*, 2016) and III) recommended to minimize the risk of water deficiency November 20th to December 20th (Bortoluzzi *et al.*, 2020). These studies describe the sowing date (late of September and October) for high yields in a subtropical environment (Zanon *et al.*, 2016) and to reduce the probability of risks due to water stress in the lowland environment the recommended sowing date is from early of November (Bortoluzzi *et al.*, 2020).

The soybean cultivars maturity groups ranging from 4.8 to 8.2 and determinate and indeterminate growth type. Therefore, the evaluated cultivars represent all maturity groups and growth types grown in the lowland production system in the Southern Brazil. It should be noted that the cultivars TECIRGA 6070 RR and BSIRGA 1642 IPRO were developed specifically for the soybean production of lowland system.

The sowing was performed on corrected soil, according to technical recommendations, with fertilization aiming to reach 6.0 Mg ha^{-1}. The seeds were inoculated with *Bradyrhizobium japonicum* and treated with fungicide and insecticide. The control of weeds, insects and diseases was conducted in a way to keep the crop free from biotic stresses. Among the plots were built drains to minimize problems with water excess in the soil. The experiment was carried out under a randomized complete block design, with three replications. The row spacing was 0.5 m and the density was 30 plants m^{-2}. Each plot was composed of four rows of 5 m in length, seeded at a depth of 0.03 m. Grain yield evaluations were performed in the two central rows, discarded 0.5 m from the extremities and the moisture corrected to 13%.

The data was initially tested for the assumptions of randomness, homogeneity of variances and whether the residues follow a distribution of yield data or not. Then, data was submitted to joint analysis of variance and Tukey's test (1953) using the SAS software (SAS Institute, 2004). In the joint analysis, the coefficient of variation of the sources of variation was estimated by the expression:

$$R^2_f = SSv/SST$$

Where, (R^2) is the coefficient of variation, (SSv) square sum of variation source and (SST) total square sum. The adaptability and stability analysis used the Eberhart and

Table 1: Maturity group (MG), growth type and of soybean cultivars representative of the lowland production system and evaluated at five locations (Cachoeirinha, Cachoeira do Sul, Itaqui, Uruguaiana and Santa Vitoria do Palmar) in the 2014/2015, 2015/2016 and 2016/2017 growing seasons

Cultivar	MG	GrowthType
NS 4823 RR	4.8	Indeterminate
TEC 5936 IPRO	5.6	Indeterminate
58I60 RSF IPRO	5.8	Indeterminate
Fundacep 65 RR	5.9	Determinate
NS 6209 RR	6.2	Indeterminate
TECIRGA 6070 RR	6.3	Indeterminate
A 6411 RG	6.4	Determinate
BSIRGA 1642 IPRO	6.4	Indeterminate
6869 RSF RR	6.7	Indeterminate
CD 2694 IPRO	6.9	Determinate
CD 2737 RR	7.3	Indeterminate
SYN 1378C IPRO	8.0	Determinate
CD 219 RR	8.2	Determinate
IGRA 818 RR	8.2	Determinate

Russell method (1966), is based on regression analysis linear test, which measures the response of each genotype to environmental variations (Eberhart & Russell, 1966). The choice was made considering that it is easy to interpret and it is widely used in agricultural crops, as in soybean to identify the best sowing season (Marques *et al.*, 2011; Romanato *et al.*, 2016), location (Silveira *et al.*, 2016), regions (Oliveira *et al.*, 2012; Carvalho *et al.*, 2013), grain yield and oil quality (Silva *et al.*, 2016). In addition, this method is used by breeders of IRGA to select irrigated rice cultivars for the lowland production system in the southern of Brazil. This is a simple linear regression analysis, where the environment is the independent variable and the average yield is the dependent one. The cited linear regression was used in the evaluation, the mean yield of the genotype ($\bar{Y}_i$), the regression coefficient ($\hat{\beta}_i$), (where (I_j)is the environment index), and the variance of the regression deviations ($\hat{\sigma}^2_{di}$), estimated according to the following expressions:

$$\bar{Y}_i = \sum_j Y_{ij}/a$$

$$\hat{\beta}_i = \sum_j Y_{ij} I_j \Big/ \sum_j I_j^2 I_j$$

$$\textit{Environmental Index} = I_j = \left(\sum_j Y_{ij}\right)/g - \left(\sum_i \sum_j Y_{ij}\right)/ag$$

$$\hat{\sigma}^2_{di} = \left\{\left[\sum_j Y_{ij}^2 - (\sum_j Y_{ij})^2/a\right] - (\sum_j Y_{ij}\, I_j)^2 \Big/ \sum_j I_j^2\right\}/a - 2$$

The analysis of adaptability and stability allows the identification of the most responsive cultivars to the environment with greater yield predictability. Thus, when the regression coefficient is equal to the unity (β = 1), it is considered that the cultivars show general or wide adaptability; when the regression coefficient is higher than the unity (β > 1), the cultivars show adaptability to favorable environments, and when lower to the unity (β < 1), it is adaptability to unfavorable environments. The coefficient of the variance of the regression deviations ($\hat{\sigma}^2_{di}$), when lower ($\hat{\sigma}^2_{di}$=0) indicates stability of the cultivars with high predictability and, higher ($\hat{\sigma}^2_{di}$>0) refers to stability cultivars with low predictability.

RESULTS AND DISCUSSIONS

The analysis of variance indicated significant effects of year, location, growing season and cultivar (Table 2). It is worth mentioning the source of variation of the interaction year* location, which was significant in the F test ($p < 0.05$) and corresponded to 30.9% of the total square sum of the sources of variation involved. The typification of each environment as favorable or unfavorable was determined in comparison with the general average (Table 3), which includes all evaluated cultivars, locations, years and growing seasons, presenting yield of 3.3 Mg ha^{-1}. Thus, it was considered a favorable environment that presented yield average higher than the general average (Carvalho *et al.*, 2013). The locations Cachoeira do Sul and Uruguaiana were considered as favorable environments, and Itaqui and Santa Vitória do Palmar as unfavorable. Cachoeirinha

Table 2: Summary of variance analysis for grain yield (Mg ha^{-1}) of 14 soybean cultivars representative of the lowland production system and evaluated at five locations (Cachoeirinha, Cachoeira do Sul, Itaqui, Uruguaiana and Santa Vitoria do Palmar), in the 2014/2015, 2015/2016 and 2016/2017 growing seasons

Source of Variation	DF	SS	MS	R^2_f (%)
Year	2	124.8736	62.4368*	16.13
Location	4	10.0627	2.5157*	1.30
Season	2	38.5380	19.2690*	4.98
Cultivars	13	35.3041	2.7157*	4.56
Year*Location	5	239.8135	47.9626*	30.98
Year*Season	4	58.1813	14.5453*	7.51
Year*Cultivars	7	2.6401	0.3772^{ns}	0.34
Location*Season	8	31.6018	3.9502*	4.08
Location*Cultivars	29	32.7896	1.1307*	4.24
Season*Cultivars	26	16.7743	0.6452^{ns}	2.17
Year*Location*Season	2	0.3562	0.1781^{ns}	0.05
Year*Location*Cultivars	10	9.0719	0.9072*	1.17
Year*Season*Cultivars	12	6.4150	0.5346^{ns}	0.83
Location*Season*Cultivars	37	28.6331	0.7739*	3.70
Year*Location*Season*Cultivars	3	1.3858	0.4619^{ns}	0.18
Residue	311	137.7672	0.4433	17.79
CV (%)	**21.52**			
Mean (Mg ha^{-1})	**3,092**			

ns, * = not significant and significant, respectively, at 5% of probability with F test. DF = degrees of freedom. SS = Square Sum. MS = Mean Square. R^2f (%) = total square sum of the variation source.

location behaved as an environment of general conditions and with yield similar to the general average, being considered intermediate. The locations were well representative of their regions, corresponding to all the soybeans grown in the lowland production system of the Southern of Brazil.

To address the differences between the environments, an analysis to identify the most suitable cultivars that increased stability and yield was obtained at each location separately (Table 4). In Cachoeira do Sul, the whole set of evaluated cultivars presented adaptability. Stability were found in cultivars NS 4823 RR, TEC 5936 IPRO and TECIRGA 6070 RR, all with approximate mean yields of 3.5 Mg ha^{-1}. This is associated with the I and II sowing dates, that is, from September 20th to November 20th (Table 5). All cultivars evaluated in Uruguaiana presented a wide adaptability to the sowing dates, having the I and II presented higher yield potential. The cultivars 6869 RSF RR, NS 4823 RR and TECIRGA 6070 RR presented the highest GY, with 3.7 Mg ha^{-1}, 3.6 Mg ha^{-1}, and 3.5 Mg ha^{-1}, respectively. In Cachoeirinha, the cultivars Fundacep 65 RR and 6869 RSF RR showed high average yield and adaptability to more favorable environmental conditions, while the cultivars TEC 5936 IPRO and A 6411 RG adapted to unfavorable environmental conditions, being that the set of cultivars showed yield higher than 4.2 Mg ha^{-1} and stability with high predictability. The cultivars TECIRGA 6070 RR, NS 6209 RR and BS IRGA 1642 IPRO, with average yield of 3.2 Mg ha^{-1}, 2.6 Mg ha^{-1} and 1.5 Mg ha^{-1} respectively, presented adaptability and stability. The most recommended season was the II sowing date (Table 5). In Itaqui, the cultivars NS 4823 RR, 6869 RSF RR and TECIRGA 6070 RR presented adaptability and stability, with yields of 3.4 Mg ha^{-1}, 2.6 Mg ha^{-1} and 2.5 Mg ha^{-1}, respectively. However, the cultivar 58I60 RSF IPRO can also be considered interesting, since it presented stability and higher yield in comparison with the other ones. The most appropriate sowing date in Itaqui was the third one, which minimized the risks of water deficiency, according to the Soybean Climate Risk Zoning. In Santa Vitória do Palmar, neither of the cultivars presented adaptability and stability. The cultivar TECIRGA 6070 RR with yield of 3.3 Mg ha^{-1} showed, however, adaptability to the environment. 6869 RSF RR, with yields of 3.2 Mg ha^{-1} showed adaptability to a more favorable environmental condition. The most recommended sowing date were the second and the third, because of more favorable temperature for plant establishment in the field (Table 5).

The general averages of sowing date for favorable environments (Cachoeira do Sul and Uruguaina), indicated the I and II sowing date to reach the highest yields. The unfavorable (Santa Vitória do Palmar and Itaqui) and intermediate (Cachoeirinha) environments presented preferably the II and III sowing date, in which it is sought to reduce the impact water stress deficits (Table 5). In Table 6 are presented the general analysis of the cultivars in all the studied environments. The cultivars A 6411 RG, TEC 5936 IPRO and TECIRGA 6070 RR combined wide adaptability, high yield predictability presented yield average higher than the mean of the trials (4.9 Mg ha^{-1}, 3.3 Mg ha^{-1} and 3.1 Mg ha^{-1}, respectively).

In addition, we can consider the cultivars Fundacep 65 RR and 6869 RSF RR for lowland cultivation due to high yields (3.98 Mg ha^{-1} and 3.51Mg ha^{-1}, respectively) and significant stability (Table 6). However, these cultivars depend on favorable conditions of the environments and present higher risks because these cultivars do not have wide adaptability. Therefore, these cultivars were the most suitable for cultivation in lowland environment, having presented high yield potential.

Considering the diversity of environmental conditions for soybean cultivation in a lowland production system and the GEI, cultivars with broad adaptability and high predictability are indicated to mitigate the environmental effects (Silveira *et al.*, 2016). In general, the cultivars that showed adaptability and stability to the three sowing dates showed MG between 5.6 to 6.4 and the type of indeterminate growth (Table 6).

Table 3: Summary of the variance analysis for grain yield (Mg ha-1) of 14 soybean cultivars in the average of five locations (Cachoeirinha, Cachoeira do Sul, Itaqui, Uruguaiana and Santa Vitoria do Palmar) representative of the lowland system production, in the 2014/2015, 2015/2016 and 2016/2017, growing season

Locations	MeanYield (Mg ha^{-1})	DFr	MSr	CV (%)
Cachoeirinha	3.27	120	0.3067462	16.95
Cachoeira do Sul	3.53	30	0.07850571	7.94
Itaqui	3.05	65	0.6484241	26.37
Santa Vitória do Palmar	3.14	50	0.36490507	19.22
Uruguaiana	3.48	46	0.83064501	26.22
Mean	**3.29**			

DFr = Residue's Degrees of Freedom. MSr = Residue's Mean Square. CV (%) = coefficient of variation.

These results are similar to Zdziarski *et al.* (2018) who defined MG between 5.3 and 5.9 the most suitable for southern Brazil, however in lowland areas there are high risks in cultivate MG lower than 5.6 and determined growth type, due to shorter cycle duration and non-overlapping the vegetative and reproductive phases (Zanon *et al.*, 2015; Zanon *et al.*, 2016), which result in lower capacity to recover of hydric (excess and deficiency) and heat stress that is common to occur in soybean-rice rotation in lowland areas. Moreover, it is important to highlight that it is worth mentioning in the three growing seasons, the rainfall distribution occurred favored the growth and development of maturity group cultivars lower than 5.5, although in years with water availability close to normal climatic conditions, these maturity groups presented a high risk of loss of yield

Table 4: Adaptability and stability analysis (Eberhart & Russell, 1966) for grain yield (Mg ha^{-1}) of 14 soybean cultivars within each evaluated location (Cachoeirinha, Cachoeira do Sul, Itaqui, Uruguaiana and Santa Vitoria do Palmar), in the 2014/2015, 2015/2016 and 2016/2017 growing seasons

Location	Cultivars	MeanYield (Mg ha^{-1})	Adaptability	Stability	
			$\beta = 1$	$\sigma^2_{di} = 0$	R^2 (%)
Cachoeira do Sul	CD 219 RR	3.69	1.206 NS	0.194 *	83.06
Cachoeira do Sul	TEC 5936 IPRO	3.53	0.903 NS	0.078 NS	85.25
Cachoeira do Sul	A 6411RG	3.50	1.129 NS	0.180 *	82.11
Cachoeira do Sul	TECIRGA 6070 RR	3.48	0.981 NS	-0.008 NS	97.47
Cachoeira do Sul	NS 4823 RR	3.45	0.780 NS	0.003 NS	93.92
	Mean	**3.53**	**1.000**	**0.090**	**88.4**
Uruguaiana	6968 RSF RR	3.73	0.859 NS	0.520 NS	44.17
Uruguaiana	NS 4823 RR	3.64	0.532 NS	0.255 NS	31.26
Uruguaiana	TECIRGA 6070 RR	3.54	1.191 NS	-0.170 NS	91.88
Uruguaiana	Fundacep 65 RR	3.43	0.998 NS	-0.180 NS	91.87
Uruguaiana	TEC 5936 IPRO	3.40	1.611 NS	0.224 NS	85.01
Uruguaiana	CD 219 RR	3.40	0.464 NS	-0.254 NS	91.15
Uruguaiana	A 6411RG	3.20	0.878 NS	-0.107 NS	83.24
	Mean	**3.48**	**0.933**	**0.041**	**74.1**
Cachoeirinha	Fundacep 65 RR	4.53	1.184 *	-0.102 NS	99.98
Cachoeirinha	A 6411RG	4.41	0.845 *	-0.101 NS	99.70
Cachoeirinha	6968 RSF RR	4.30	1.209 *	-0.093 NS	99.25
Cachoeirinha	TEC 5936 IPRO	4.22	0.212 *	-0.084 NS	51.20
Cachoeirinha	CD 2694 IPRO	4.02	0.796 *	0.078 NS	87.52
Cachoeirinha	CD 219 RR	3.47	1.165 *	-0.030 NS	88.90
Cachoeirinha	Igra 818 RR	3.44	-0.179 *	-0.095 NS	90.34
Cachoeirinha	NS 4823 RR	3.02	1.105 NS	0.234 *	90.38
Cachoeirinha	TECIRGA 6070 RR	3.02	1.061 NS	0.025 NS	95.80
Cachoeirinha	58I60 RSF IPRO	2.72	1.221 *	0.025 NS	96.84
Cachoeirinha	NS 6209 RR	2.63	1.035 NS	-0.071 NS	98.89
Cachoeirinha	CD 2737 RR	1.19	0.785 *	0.047 NS	71.68
Cachoeirinha	BS IRGA 1642 IPRO	1.51	1.000 NS	0.190 NS	67.69
	Mean	**3.27**	**0.880**	**0.002**	**87.6**
Santa Vitória do Palmar	TECIRGA 6070 RR	3.29	0.920 NS	0.418 *	30.87
Santa Vitória do Palmar	6968 RSF RR	3.24	2.057 *	0.002 NS	92.95
Santa Vitória do Palmar	58I60 RSF IPRO	3.06	2.143 *	0.012 NS	87.02
Santa Vitória do Palmar	NS 4823 RR	2.90	1.039 NS	0.506 *	32.91
	Mean	**3.14**	**1.540**	**0.235**	**60.9**
Itaqui	58I60 RSF IPRO	3.81	1.768 *	-0.137 NS	96.05
Itaqui	NS 4823 RR	3.36	1.088 NS	-0.155 NS	96.00
Itaqui	CD 2737 RR	3.03	0.132 *	-0.160 NS	33.29
Itaqui	6968 RSF RR	2.60	1.117 NS	-0.108 NS	94.67
Itaqui	TECIRGA 6070 RR	2.47	0.840 NS	-0.078 NS	87.70
	Mean	**3.05**	**0.989**	**-0.13**	**81.5**

NS, *: not significant and significant, respectively, at 5% of probability. Adaptability: $\beta = 1$ (NS), it is attributed to the cultivars general or wide adaptability, $\beta > 1$ (*), when the regression coefficient is higher to the unity, it is adaptability to favorable environments, $\beta < 1$, (*) when lower to the unity, it is adaptability to unfavorable environments. Stability: $\hat{\sigma}^2_{di} = 0$ (NS), indicates stability of the genotype with high predictability, $\hat{\sigma}^2_{di} > 0$ (*), higher refers to stability genotypes with low predictability.

Table 5: Analysis by the Tukey Test (1953) at 5% probability of the mean grain yield (Mg ha^{-1}), for each sowing date and evaluated location (Cachoeirinha, Cachoeira do Sul, Itaqui, Uruguaiana and Santa Vitoria do Palmar) in the 2014/2015, 2015/2016 and 2016/2017 growing seasons

Location	Growing Season I	Growing Season II	Growing Season II	Mean
Cachoeira do Sul	4.00 a	3.74 b	2.84 c	**3.53** A
Uruguaiana	3.52 a	3.44 ab	2.80 b	**3.37** AB
Cachoeirinha	2.95 b	3.67 a	2.87 b	**3.17** BC
Santa Vitória do Palmar	2.53 b	3.12 a	3.38 a	**3.06** C
Itaqui	2.10 c	3.03 b	3.61 a	**2.90** C
Mean	**2.92** b	**3.37** a	**3.07** b	**3.21**

Averages with the same lowercase letter on the line and uppercase letter in the column do not differ by Tukey's test at 5% probability.

Table 6: Adaptability and stability analysis (Eberhart & Russell, 1966) for grain yield (Mg ha^{-1}) of 14 soybean cultivars averaging five locations (Cachoeirinha, Cachoeira do Sul, Itaqui, Uruguaiana and Santa Vitoria do Palmar) in the 2014/2015, 2015/2016 and 2016/2017 growing season, RS, Brazil

Genotype	Mean (Mg ha^{-1})	Adaptability	Stability	
		$\beta = 1$	$\sigma^2_{di} = 0$	R^2 (%)
Fundacep 65 RR	3.98	1.150 *	-0.112 NS	96.06
A 6411RG	3.81	1.095 NS	-0.059 NS	89.87
6869 RSF RR	3.51	1.182 *	0.036 NS	86.28
CD 2694 IPRO	3.48	1.121 NS	0.274 *	73.73
TEC 5936 IPRO	3.29	0.986 NS	-0.024 NS	89.52
NS 4823 RR	3.23	1.039 NS	0.153 *	79.74
CD 219 RR	3.20	0.684 *	0.071 NS	70.03
58I60 RSF IPRO	3.15	1.285 *	-0.012 NS	93.37
Igra 818 RR	3.06	0.008 *	0.324 *	0.01
TECIRGA 6070 RR	3.07	1.039 NS	0.044 NS	86.40
NS 6209 RR	2.73	1.041 NS	-0.075 NS	96.87
BS IRGA 1642 IPRO	2.58	0.980 NS	0.022 NS	91.35
SYN 1378C IPRO	2.19	0.518 *	-0.051 NS	80.00
CD 2737 RR	2.00	0.736 *	0.236 *	68.79
Mean	**3.09**	**0.919**	**0.059**	**78.72**

NS, *: not significant and significant, respectively, at 5% of probability. Adaptability: $\beta = 1$ (NS), it is attributed to the cultivars general or wide adaptability, $\beta > 1$ (*), when the regression coefficient is higher to the unity, it is adaptability to favorable environments, $\beta < 1$, (*) when lower to the unity, it is adaptability to unfavorable environments. Stability: $\hat{\sigma}^2_{di} = 0$ (NS), indicates stability of the genotype with high predictability, $\hat{\sigma}^2_{di} > 0$ (*), higher refers to stability genotypes with low predictability.

(Zanon *et al.*, 2018). Thus, future studies should identify adaptability and stability for MG, being a broader and more lasting recommendation, mainly because cultivars are replaced by others with higher potential and new technologies.

Lowland production system in southern Brazil present different soybean yield potentials and climate risk when associated with sowing dates, which modulate the adaptability and stability responses of cultivars, which can be attributed by soil, climatic variability and maturity group. Our believes the characterization of lowland environments and cultivars could help producers and technician to improve management practices, aiming at reaching the maximum potential with sustainability.

CONCLUSIONS

The cultivars A 6411 RG, TEC 5936 IPRO and TECIRGA 6070 RR combined wide adaptability, high yield predictability and performed high yield as expected. Therefore, these cultivars were the most suitable for cultivation in lowland environment with high yield potential.

The cultivars Fundacep 65 RR and 6869 RSF RR presented high yield and stability of production and are recommended for lowland environments with lower yield potential.

CONFLICT OF INTERESTS

The authors declare that there isn't any conflict of interests.

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