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Adaptability and stability as selection criterion for wheat cultivars in Paraná State

Adaptabilidade e estabilidade como critério de seleção de cultivares de trigo no Estado do Paraná

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Abstract

The aim of this study was compare some techniques to assess the adaptability and stability seeking the selection of wheat genotypes in Paraná State. The grain yield data were obtained from trial experiments of the Value of Cultivation and Use, as assessed in 44 different locations in distributed environments and sowing date. The study of adaptability and stability were evaluated based on Eberhart and Russell (1966), Lin and Binns (1988) revised by Carneiro (1998), Porto, Carvalho and Pinto (2007) and Rocha et al. (2005). The methods of Eberhart and Russell (1966), Lin and Binns (1988) revised by Carneiro (1998), and the method of Porto, Carvalho and Pinto (2007) showed similar results. These methods were superior to the method of Rocha et al. (2005), which was sloppy in the selection process. The method of Porto, Carvalho and Pinto (2007) had the advantage of simplifying the analysis of adaptability and stability.

Key words: *Triticum aestivum*, Genotype x environment interaction, genetic improvement, recommending cultivars, grain yield

Resumo

O objetivo deste trabalho foi comparar métodos de adaptabilidade e a estabilidade como critérios de seleção para cultivares de trigo no Paraná. Os dados de rendimento de grãos foram obtidos de ensaios de Valor de Cultivo e Uso, avaliados em 44 ambientes distribuídos em diferentes locais e época de semeadura. O estudo de adaptabilidade e estabilidade foi realizado com base nos métodos de Eberhart e Russell (1966), de Lin e Binns (1988) modificado por Carneiro (1998), de Porto, Carvalho e Pinto (2007) e de Rocha et al. (2005). Os métodos de Eberhart e Russell (1966), Lin e Binns (1988) modificado por Carneiro (1998) e o método de Porto, Carvalho e Pinto (2007) apresentaram resultados similares. Estes métodos foram superiores ao método de Rocha et al. (2005), que foi pouco rigoroso no processo seletivo. O método de Porto, Carvalho e Pinto (2007) teve a vantagem de simplificar as análises de adaptabilidade e estabilidade.

Palavras-chave: *Triticum aestivum*, interação genótipos x ambientes, melhoramento genético, recomendação de cultivares, rendimento de grãos

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Introduction

Wheat (*Triticum aestivum* L.) is one of the most important agricultural foods and a source of protein worldwide. This cereal is very important, mainly, for the population with low purchasing power, justifying its essentiality in the food security of countries. Brazil harvested almost 5.9 million ton in 2014 crop season, in 2.7 million of hectare (CONAB, 2015). In Brazil, the Paraná State historically is the largest wheat producer. It maintained this position in the last crop season (2014), that amount production was almost 63% of total production in Brazil.

Release of new and more productive cultivars of wheat is imperative to keep and increase competitiveness in Paraná State, consequently increasing financial benefits when compared to other crops. This state shows a wide variability in terms of soil and climatic conditions as well as climatic risk. Because the climatic condition the selection and release of cultivars is accomplished in terms of grain yield mean in various environments (site, year and sowing date) (BRASIL, 1997). Besides, in Paraná State the genotype-environment interaction (GEI) was observed in wheat trials, that confirms the importance of this effect (SILVA et al., 2011; FRANCESCHI et al., 2010). In the presence of GEI, the selection of cultivars by the grain yield mean not identify superior genotypes for specific conditions (promising or unfavorable environments). Moreover, the GEI promotes significant differences in performance when these cultivars are grown in different locations.

The IGE effect can be decreased by using specific cultivars for each environment, or using cultivars with wide adaptability and good stability, or stratification of the region considered in sub-region with similar environmental characteristics within which the interaction becomes not significant (RAMALHO; SANTOS; ZIMMERMANN, 1993). The second alternative has been the most used.

The study of adaptability and stability enables the identification of genotypes that shows grain yield predictable and responsive to wide or specific environmental conditions (CRUZ; CARNEIRO, 2006). The adaptability refers to the ability of genotypes respond positively to environmental conditions, whereas stability refers to the ability of genotypes perform a predictable behavior as a environmental conditions (CRUZ; REGAZZI, 2001).

A number of techniques have been used to estimate and interpret the adaptability and stability. These techniques differ about the statistic parameters used and the concept of adaptability and stability. Few studies in Brazil were performed to compare techniques to assess adaptability and stability of wheat genotypes (CAIERÃO et al., 2006; ALBRECHT et al., 2007; CARGNIN; SOUZA; FOGAÇA, 2008; FRANCESCHI et al., 2010). Franceschi et al. (2010) have compared wheat genotypes in field trials in Paraná State using techniques as Eberhart and Russell (1966) and Linn and Binns (1988) revised by Carneiro (1998).

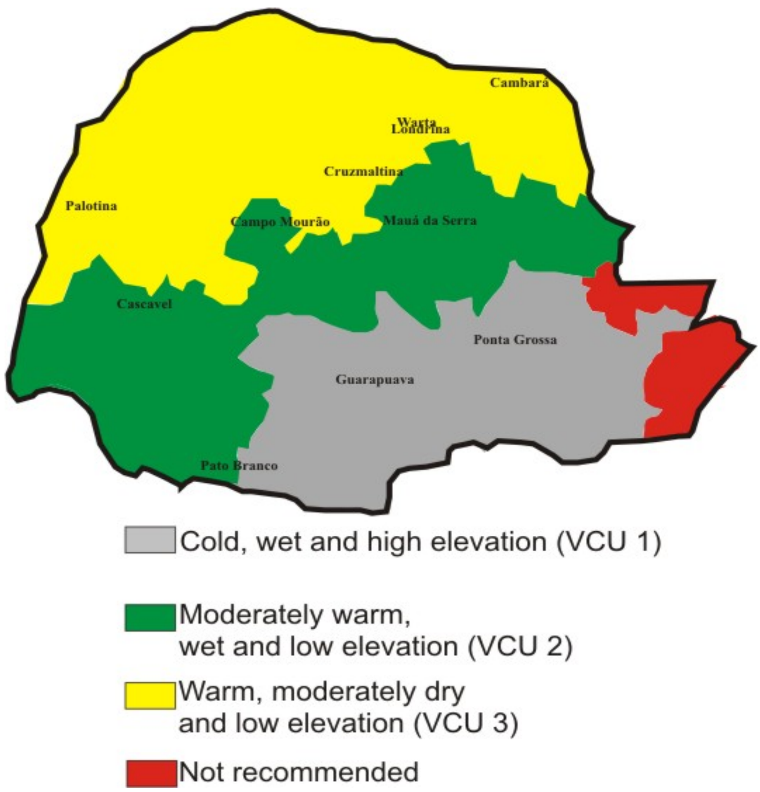
Moreover, currently other techniques have been proposed for many crops, e.g., eucalyptus (ROCHA et al., 2005) and sunflower (PORTO; CARVALHO; PINTO, 2007). Rocha et al. (2005) used principal components to compare the response of individual cultivars to the responses (maximal and minimal) of four ideal cultivars, in relation to the data set evaluated. This allows categorizing groups of genotypes with similar specific adaptability facilitating their recommendation. According to these authors, the non-subjectivity in the ranking provided by the centroid method, associated to graphical interpretation, gives an advantage of this method over the method of Lin and Binns (1988) – revised by Carneiro (1998). The stability and adaptability of cultivars according to Porto, Carvalho and Pinto (2007) is based on averages of favorable and unfavorable environments, and allows selecting genotypes that, despite having below average performances, generally stand out in specific environments, which is not shown by the method of Eberhart and Russell (1966).

Thus, the aim of this study was compare some techniques that assess the adaptability and stability seeking the selection of wheat genotypes in Paraná State, Brazil.

Material and Methods

The data set used in this study were mean grain yield of wheat genotypes harvested in trial fields of Value for Cultivation and Use (VCU) in Paraná State, carried out by Embrapa Soja, IAPAR and Fundação Meridional (Figure 1). The field experiments at each site were designed in a completely randomized block design with four replicatons. The size of each plot was 5.10 m² (5m long x 1.02m). The grain yield was determined by harvesting each plot and estimated as kg ha^{-1} (13% moisture). The local management procedures were followed (CBPTT, 2010), and the grain yield was noted at each test location.

Figure 1. Value for Cultivation and Use: VCU 1 (wet, cold and high elevation), VCU 2 (wet, moderately warm and low elevation e VCU 3 (moderately dry, warm and low elevation).



Source: Elaboration of the authors.

The trial fields were conducted in 44 environments (various sites and sowing date) (Table 1). In 2009, the sites and sowing date were: Cambará (03/28, 04/15 and 04/27), Londrina (04/07, 07/22 and 05/03), Warta (04/05 and 04/21), Cruzmaltina (04/16 and 05/05), Palotina (03/30, 04/19 and 05/03), Cascavel (04/22 and 05/07), Campo Mourão (04/15 and 05/07), Pato Branco (06/09 and 06/30), Guarapuava (07/05), Ponta Grossa (07/10) and Mauá da Serra (05/21). In 2010, the sites and sowing date were: Cambará (03/30, 04/15 and 04/30), Londrina (04/07, 04/21 and 05/05), Warta (04/05 and 04/20), Cruzmaltina (04/22 and 05/11) Palotina (03/29, 04/19 and 05/03) Cascavel (05/01 and 05/15) Campo Mourão (04/20 and 05/07), Pato Branco (06/09 and 06/29), Guarapuava (07/16), Ponta Grossa (06/23) and Mauá da Serra (05/12).

Table 1. Characteristics of test locations that are conducted the trial experiments of VCU for wheat cultivars in Paraná State. Embrapa Soja, IAPAR e Fundação Meridional.

Site	VCU	Latitude (S)	Longitude (W)	Elevation (m)	Soil
Cambará	3	23°2’45”	50°4’26”	460	Eutroferric Red Latosol
Londrina	3	23°18’36”	51°9’46”	580	Eutroferric Red Latosol
Warta	3	23°11’37”	51°11’03”	630	Dystroferric Red Latosol
Cruzmaltina	2	24°0’46”	51°27’32”	680	Dystroferric Red Latosol
Palotina	3	24°17’2”	53°50’24”	320	Dystroferric Red Latosol
Cascavel	2	24°57’21”	53°27’18”	750	Dystroferric Red Latosol
Campo Mourão	2	24°2’45”	52°22’58”	620	Dystroferric Red Latosol
Pato Branco	2	26°13’44”	52°40’15”	775	Dystroferric Red Latosol
Guarapuava	1	25°23’42”	51°27’28”	1040	Dystrophic Bruno Latosol
Ponta Grossa	1	25°5’42”	50°9’43”	850	Dystroferric Red Latosol
Mauá da Serra	1	23°54’3”	51°13’44”	1040	Dystroferric Red Latosol

Source: Elaboration of the authors.

We evaluated the cultivars BR 18, BRS 220, IPR 85, IPR 110, IPR 118, BRS 208, IAPAR 53, IAPAR 78, Ônix, BRS 248, BRS 249, BRS Tangará, BRS Pardela, IPR 128, IPR 129, IPR 130, IPR 136 and BRS 229. The trial fields were conducted in accordance with the mandatory minimum set for VCU testing of wheat, established for the Ordinance 294, of October 14, 1998, of the Ministry of Agriculture, Livestock and Supply.

Before the joint analysis of variance (ANOVA) we realized the ANOVA at each site, sowing date and year to perform the homocedasticity test. In this test, variances were considered as homogeneous when the ratio between the larger and the smaller residual mean square was smaller than 7 (PIMENTEL-GOMES, 1990). Moreover, according the current laws for VCU, the trial field that showed a coefficient of variation over 20% we not perform the ANOVA.

For evaluate the adaptability and stability we used the techniques proposed by Eberhart and Russell (1966), Lin and Binns (1988) revised by Carneiro (1998), Porto, Carvalho and Pinto (2007) and Rocha et al. (2005). These techniques show different statistical procedures: regression analysis, comparison of grain yield performance in various environments and the principal components.

In the Eberhart and Russel technique an ideal genotype must show high grain yield (GY) with wide adaptability (β_{li} = 1) and high stability ($\sigma^2_{\delta i}$ = 0). The genotypes adapted to favorable and unfavorable environments have $\beta_{li} > 1$ and $\beta_{li} < 1$, respectively. When the $\sigma^2_{\delta i}$= 0, mean that genotype shows high stability. When the $\sigma^2_{\delta i} > 0$, mean that genotype shows low stability. The difference between the mean of grain yield in a given environment and the mean of grain yield of the field experiments is used to rate the environments as a favorable environment (environment ratio>0) or an unfavorable environment (environment ratio<0).

The method proposed by Lin and Binns (1988) revised by Carneiro (1998), recommends the decomposition of measure Pi, in terms of favorable environments (P_{if}) and unfavorable environments (P_{id}), while genotypes with wide adaptability shows high P_i. The P_{if} parameter is used to identificate genotypes for favorable environments, and the P_{id} parameter to identify genotypes adapted to unfavorable environments.

Porto, Carvalho and Pinto (2007) recommends the decomposition of the mean of grain yield (GY) each genotype in terms of grain yield in favorable environments (GYF) and unfavorable environments (GYU). Genotypes with wide adaptability when shows high GYF e GYU in favorable and unfavorable environments, respectively; an ideal genotype for favorable environments if the GYF is high in favorable environments and low GYU in unfavorable environments and; an ideal genotype for unfavorable environments is one that shows high GYU in unfavorable environments and low GYF in favorable environments. The Pearson's correlations between GY and P_i, GYU and P_{id}, and GYF and P_{if} were estimated to verify if grain yield of cultivars show tendency of demonstrate their adaptability and stability as related by Carneiro (1998).

According Rocha et al. (2005), an ideal genotype with wide adaptability is one that perform high GY in all environments tested (ideal genotype I); an ideal genotype adapted to favorable environments must perform maximum response to favorable environments and minimum response to unfavorable environments (ideal genotype II); an ideal genotype with adaptation to unfavorable environments is one that perform maximum response in unfavorable environments and minimum response in favorable environments (ideal genotype III) and; an ideal genotype with low adaptability is that shows the poorest grain yield in all environments tested (ideal genotype IV).

The means GY, GYF and GYU were compared using the clustering test at 5 % probability (SCOTT; KNOTT, 1974). The GENES software was used to perform the statistical analysis (CRUZ, 2006). The GYF and GYU (PORTO; CARVALHO; PINTO, 2007) was obtained with the same software.

Results and Discussion

Genotype x environment interaction (GEI) was highly significant (P<0.01) (Table 2), showing there was a change in the genotypes production performance in the several environments evaluated and justifying the study of adaptability and stability (CRUZ; CARNEIRO, 2006). Moreover, the coefficient of variation was 5.81, thus below the recommended by the Ordinance 294 (Law of Plant Variety Protection); which implies in a good experimental accuracy and is ranked as low/usual in trial experiments with wheat (LÚCIO; STORCK; BANZATTO, 1999).

Table 2. Joint analysis of variance for grain yield obtained in trial experiments of Value for Cultivation and Use (VCU) for wheat in Paraná State.

Source	DF	Mean square
Blocks/environments	88	97630.19
Genotypes	17	2780973.18**
Environments	43	47847715.61**
GxE	731	680565.67**
Error	1.496	51633.40
Mean (kg ha^{-1})	3907	
CV (%)	5.81	

** Meaningful to 1% of probability (P<0.01).
Source: Elaboration of the authors.

The wide variability in terms of soil and climatic conditions as well as climatic risk is the major cause of presence of GEI in this study (Table 2). Thus, the GEI implies that the release of wheat cultivars occurs in each VCU region (VCU 1, 2 and 3) based on grain yield performance observed in trial VCU (Figure 1); BRASIL, 1997). However, the adaptability and stability were assessed for the State rather than each VCU region that implies the selection of cultivars was performed for all regions (Paraná State) which the wheat is cultivated (Tables 3 and 4).

The results of Eberhart and Russel (1966) method none cultivar was identified as an ideal genotype, because the cultivars showed low stability ($\sigma^2_{\delta i}$ major than 0), i.e., low predictability in mean of grain yield performance (Table 3). However the BRS Tangará, BRS Pardela, BRS 299, BRS 220 and Onix cultivars showed high GY and wide adaptability (β_{li}=1). Although the regression deviation ($\sigma^2_{\delta i}$) were no null, the coefficients of determination (R^2) of BRS Tangará and BRS Pardela cultivars were above 80%; that implies in cultivars with reasonable stability (CRUZ; REGAZZI, 2001). The same authors explained that when $\sigma^2_{\delta i}$ is meaningful the R^2 is an important support measure. Despite the results for BRS 229, BRS 220 and Onix cultivars, their observed stability are tolerated because the R^2 was closely to 80%.

Table 3. Estimates of mean of grain yield (β_{li}), regression coefficients ($\sigma^2_{\delta i}$) and the determination (R^2), by he method of Eberhart and Russel (1966).

Cultivars	GY (kg ha^{-1})	Eberhart and Russel (1966)		
		β_{li}	$\sigma^2_{\delta i}$	R^2
BRS Tangará	4121.07 a[1]	1,01^{ns}	20985,19**	80,86
BRS Pardela	4051.88 b	1,01^{ns}	174571,93**	82,55
BRS 229	4036.20 b	1,04^{ns}	254168,02*	78,49
IAPAR 53	4035.80 b	0,91**	152707,18**	81,57
IAPAR 78	4025.93 b	1,21**	170938,03**	87,63
BRS 220	4022.57 b	1,05^{ns}	250816,84*	77,71
Ônix	4008.34 b	1,02^{ns}	234550,18**	79,22
BRS 208	3968.76 c	1,21^{ns}	141531,67**	86,32
BRS 249	3926.23 c	1,02^{ns}	271368,89**	75,69
IPR 110	3926.07 c	0,99^{ns}	212965,74**	79,42
BR 18	3885.70 d	0,99**	147107,05**	81,09
IPR 136	3884.14 d	1,01^{ns}	66019,36**	91,55
BRS 248	3850.09 e	1,00^{ns}	269020,59**	75,66
IPR 128	3821.15 e	1,13**	218075,22**	83,13
IPR 129	3766.91 f	0,92*	241078,70**	74,95
IPR 130	3757.24 f	1,04^{ns}	120151,11**	87,87
IPR 118	3676.19 g	0,99**	152889,66**	79,39
IPR 85	3577.09 h	1,04*	240358,38**	79,39
MGY	3907.85			

[1] Means followed by the same letter in the column do not differ by the Scott-Knott test (1974) at 5 % probability, *,** Meaningful to 1% and 5% of probability, respectively; ^{ns} not meaningful (P>0.05).
Source: Elaboration of the authors.

The IAPAR 53 and IAPAR 78 cultivars showed high GY, but these results were observed in specific environment. These cultivars showed adaptability to unfavorable (β_{li} < 1) and favorable (β_{li} > 1) environments, respectively; moreover, the R^2 was above 80%, implying in reasonable stability.

Using the method of Lin and Binns (1988) revised by Carneiro (1998) the BRS Tangará, BRS Pardela, BRS 229 and Onix we identified that these cultivars showed wide adaptability, because the lowest value of P_i, P_{if}, P_{id} (Table 4). The IAPAR 78 and BRS 208 cultivars are closely to ideal genotype for favorable environments, i.e., it were responsive with the improve environmental conditions (low value of P_{if}).

In other hand, the IAPAR 53 and BRS 220 cultivars are closely an ideal genotype for unfavorable environment, because the P_{id} was low. In general, except for the BRS 220 and BRS 208 cultivars, the results found by regression analysis and the decomposition of P_i were similar (Tables 3 and 4). Franceschi et al. (2010) in trial experiments in Paraná State observed these methods have little similarity. However, we emphasize that the Lin and Binns (1988) revised by Carneiro (1998) method was suitable to select cultivars, e.g., BRS 208, which showed adaptability to specific environment, in spite that showed medium GY. Despite the similarities in our study, Carneiro (1998) method showed had the advantageous because include the ideas of adaptability and stability in only a measure.

The technique of Porto, Carvalho and Pinto (2007) revealed that the BRS Tangará, BRS Pardela, BRS 229, BRS 220 and Onix cultivars are adapted in favorable and unfavorable environments, because showed high GYF and GYU (Table 4). For favorable environments this method identified as adapted the IAPAR 78, BRS 208 and IPR 110 cultivars (high GYF and low GYU); whereas for unfavorable environments the better cultivars are IAPAR 53, BRS 249 and BR 18 because showed high GYU and low GYF.

The estimative of adaptability of the five wheat cultivars with superior GY in trial experiments of VCU region, obtained by Porto, Carvalho and Pinto (2007) does not differ of the indication observed in Lin and Binns (1988) revised by Carneiro (1998), Eberhart and Russell (1966) methods. We observed that the some cultivars recommended for specific environments by Porto, Carvalho and Pinto (2007) are cultivars with medium GY, e.g., the BRS 208, BRS 249, BR 18 and IPR 110 cultivars.

The Pearson's correlations between GY and P_i, GYU and P_{id}, and GYF and P_{if} were –0,92, –0,94 e –0,93, respectively. These results implies that the mean of grain yield of cultivars showed tendency of demonstrate their adaptability and stability as related by Carneiro (1998). Moreover, the results obtained based in the mean of grain yield were similar to observed on P_i. However, the use of Porto, Carvalho and Pinto (2007) had advantageous when compared with P_i, because simplified the adaptability and stability analysis. Negative correlation between GY and P_i, GYU and P_{id}, GYF and P_{if} was observed by various authors (CARVALHO et al., 2002, 2003; GRUNVALD et al., 2008).

In the method of Rocha et al. (2005), the BRS Tangará, BRS Pardela, BRS 229, IAPAR 53, IAPAR 78, BRS 220, Onix, BRS 208, BRS 249 and IPR 136 cultivars were considered an ideal genotype for maximum adaptability (ideal genotype I), because presented values closer to the maximum related for all environments studied (Table 4). Our study demonstrated that these cultivars showed GY above average of trial experiments. Thus, the method showed to be somewhat strict in selection, due to large number of cultivars shown as ideotype for wide adaptability. The IPR 136 cultivar was ranked as ideal genotype I, but not showed a high GY, moreover this cultivars had a medium values for P_i, P_{id}, P_{if}, MGY, MF and MU.

The IPR 128 cultivar was ranked as ideal genotype to favorable environments adaptability (ideal genotype II). However, this cultivar showed P_{if} above the mean of all P_{if}. In the same way, BRS 248 cultivar was ranked as ideal genotype to unfavorable environments adaptability (ideal genotype III). This cultivar had a superior P_{id} than mean of all P_{id}. So, we observed that this method is some severe in genotypes selection.

Although in Paraná State the genotypes selection and recommendation performed are based on mean of grain yield in different environments, our results enable to identify predictable wheat cultivars and adapted to specific environmental conditions. Various authors have been related same results in Paraná (FRANCESCHI et al., 2010) and others States (CAIERÃO et al., 2006; ALBRECHT et al., 2007; CARGNIN; SOUZA; FOGAÇA, 2008). Moreover, our study showed that is possible selection of cultivars with medium GY for specific environmental conditions.

Table 4. Estimates of adaptability and stability parameters[1] using methods of Lin and Binns (1988) revised by Carneiro (1998), Porto, Carvalho and Pinto (2007) and Rocha et al. (2005).

Cultivars	GY	Lin and Binns (1988)						Porto, Carvalho and Pinto (2007)				Rocha et al. (2005)
		P_{ig}	C	P_{if}	C	P_{iu}	C	GYF	C	GYU	C	Ideal genotype
BRS Tangará	4121.07	269840.09	1	275903.16	1	263777.03	3	4914.42 a[2]	2	3327.72 b	2	I
BRS Pardela	4051.88	356611.34	3	459711.02	6	253511.67	2	4801.39 b	4	3302.37 b	3	I
BRS 229	4036.20	344873.98	2	370515.03	4	319232.94	6	4815.39 b	3	3257.01 c	6	I
IAPAR 53	4035.80	389736.73	7	573177.98	12	206295.49	1	4671.63 d	10	3399.96 a	1	I
IAPAR 78	4025.93	406104.26	8	328911.36	2	483297.15	14	4941.27 a	1	3110.59 d	13	I
BRS 220	4022.57	364633.50	4	464960.53	7	264306.47	4	4787.21 b	6	3257.93 c	5	I
Ônix	4008.34	372234.18	6	433561.37	5	310907.00	5	4746.03 c	7	3270.65 c	4	I
BRS 208	3968.76	371116.53	5	370379.33	3	371853.73	9	4788.22 b	5	3149.30 d	10	I
BRS 249	3926.23	439681.36	9	523852.68	10	355510.03	7	4632.37 d	12	3220.09 c	7	I
IPR 110	3926.07	452639.59	11	467350.21	8	437928.96	12	4739.48 c	8	3112.63 d	12	II
BR 18	3885.70	501168.53	12	608557.12	13	393779.93	10	4583.83 e	13	3187.57 c	8	III
IPR 136	3884.14	441434.49	10	520413.95	9	362455.03	8	4640.22 d	11	3128.06 d	11	I
BRS 248	3850.09	525150.84	13	625630.82	14	424670.86	11	4546.63 e	14	3153.56 d	9	III
IPR 128	3821.15	585550.50	14	549219.69	11	615881.32	17	4673.31 d	9	2968.99 f	17	II
IPR 129	3766.91	653037.57	16	758000.00	16	548075.15	15	4490.95 e	16	3042.87 e	14	IV
IPR 130	3757.24	600299.02	15	645116.53	15	555481.50	16	4535.51 e	15	2978.96 f	16	IV
IPR 118	3676.19	694804.80	17	919115.61	18	460493.99	13	4318.80 f	17	3033.59 e	15	IV
IPR 85	3577.09	831047.92	18	912463.41	17	749632.44	18	4316.89 f	18	2837.28 g	18	IV
Mean	3907.85	477608.72		544824.43		409867.78		4663.53		3152.17		

[1] GY= mean of grain yield, Pig= Parameter of stabilitiy of general response, Pif= Parameter of stability to favorable environments, Piu= Parameter of stability to unfavorable environments, C= Cultivars ranking about adaptability and stability each method, GYF= mean of grain yield in favorable environments, GYU= mean of grain yield in unfavorable environments, Ideal genotype I= genotype widely adapted, Ideal genotype II= genotype adapted to favorable environments, Ideal genotype III= genotype adapted to unfavorable environments, Ideal genotype IV= genotype with low adaptability, [2] Means followed by the same letter in the column do not differ by the Scott-Knott test (1974) at 5 % probability.
Source: Elaboration of the authors.

Conclusion

1. Statistics procedures proposed by Eberhart and Russell (1966), Lin and Binns (1988) revised by Carneiro (1998) and Porto, Carvalho and Pinto (2007) are efficient for selecting wheat cultivars in State of Paraná.

2. The method of Porto, Carvalho and Pinto (2007) simplifies the adaptability and stability analysis of wheat in Paraná State.

3. The method of Rocha et al. (2005) was sloppy in wheat genotype selection.

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