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Adaptability and Stability of Wheat Genotypes by GGE Biplot Method

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Abstract **– The aim of this work were identify the adaptability and stability of 43 wheat lines (F_8) from UEPG breeding program and Safira® commercial cultivar by GGE biplot method. Plant height in cm, reproductive cycle in days and grain yield in kg ha^{-1}, were the characteristics evaluated for all genotypes in three field experiments. Through graphic analysis, was possible identify the ideal genotypes, characterized by great agronomic adaptation associated to phenotypic stability. For grain yield, the ideal genotypes were the lines L8, L15, L17, L31, L34, L38 and L40. These wheat lines presented better productive potential than the Safira® cultivar, making them strong candidates as new commercial cultivars for Ponta Grossa region. The GGE biplot methodology was efficient on estimated the adaptation and phenotypic stability of these genotypes, as well as on identify the wheat lines more promising for the region of this study.**

Keywords **– Genotype x environment, Grain yield, *Triticum aestivum*.**

I. Introduction

Wheat is the winter cereal more cultivated in the world. In this segment, Brazil produces annually around 5.9 million of tons of wheat grains. The Parana State, main national producer of this cereal, has an average yield of 2731 kg ha^{-1} in 2014 growing season, with yield increase of 21% in comparison to 2004 [1]. The increment of crop grain yield could be associated to technological advances on breeding programs, as release of new cultivars more adapted to the different growing regions, with high grain yield potential, more resistance to pests and diseases and with superior baking quality [2].

Despite Paraná State be the national leader on wheat production, the high variability for grain yield is still observed. Generally, the grain yield differences can be justified by climatic diversity in growth regions and by utilization of cultivars with lower adaptation to the growth environment at the State. Therefore, it is necessary more scientific efforts, in the sense of improve the artificial selection strategies at the wheat breeding programs, in order to identify at the segregating populations more promising genotypes for yield potential, with adaptation to environments as well with greater productive stability along growth seasons. In this context, the adaptability and stability analysis of important crop agronomic characters, could improve the efficiency on recommendation through adaptation broad or specific (regionalization) for the different edaphoclimatic regions at Paraná State [3].

Between the proposed methodologies to evaluate the genotypes adaptation and stability, has highlight the GGE biplot analysis (genotype main effects + genotype environment interaction), proposed by [4], in which is considered the genotype principal effect associated to interaction genotype x environment. The GGE biplot methodology is a technique that facilitates the visualization and interpretation of obtained data where in the genotypes could be evaluated as their performance in a determined environment, or in different evaluation environments, besides inform the genotypes broad or specific adaptation [5]. Frequently, different studies have used the GGE biplot on determination of genotypes adaptability and stability, as, for example, in wheat [5] – [8], maize [9], sugar cane [10] and lettuce [11].

The objectives of this study were evaluate the phenotypic adaptability and stability of 43 new improved wheat lines from Universidade Estadual de Ponta Grossa breeding program through GGE biplot methodology.

II. Materials and Methods

Plant Material and field Experiments

Were used 44 wheat genotypes, being 43 lines (F8) from Universidade Estadual de Ponta Grossa (UEPG) breeding program and the commercial cultivar Safira® as control (OR Melhoramento de Sementes LTDA and Biotrigo Genética LTDA) (Table 1). The development of experiments, installed at 2010, 2011 and 2012 growth seasons, were in the School Farm “Capão da Onça” experimental area from UEPG. The experimental design was a randomized blocks with three replications. Nine lines composed the plots with four meters of length and 0.17 m between lines, with a population of 350 viable plants per m^2. The characteristics evaluated for wheat genotypes were plant height in cm, total cycle (from emergence to maturity) in days and grain yield in kg ha^{-1} (corrected for 13% of humidity).

Statistical Analysis

Data from the phenotypic variables of three experiments were submitted to individual variance analysis in GENES program [12]. After verify the homocedasticity of residuals variances, by F maximum test, was realized the joint variance analysis of experiments, considering fixed effect for genotypes and random effect for environment. In the presence of significant interaction genotype x environment by the joint variance analysis, was proceeded the phenotypic adaptability and stability through GGE biplot methodology by the model:

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Table 1. Genealogy of wheat genotypes used on agronomic characterization experiments.

Genotype	Genealogy	Genotype	Genealogy
L1	BRS220 / BH1146	L23	BRS210 / ALCOVER
L2	BRS220 / ÔNIX	L24	BRS210 / ALCOVER
L3	BRS220 / ÔNIX	L25	BRS210 / ALCOVER
L4	BRS220 / ÔNIX	L26	BRS210 / ALCOVER
L5	ÔNIX / BRS208	L27	BRS210 / OR1
L6	ÔNIX / BRS208	L28	BRS210 / OR1
L7	ÔNIX / BRS208	L29	ALCOVER / BRS220
L8	ÔNIX / BRS208	L30	ALCOVER / BRS220
L9	ALCOVER / BRS210	L31	ALCOVER / BRS220
L10	ALCOVER / BR18	L32	ALCOVER / BRS220
L11	ALCOVER / BR 18	L33	ALCOVER / BRS220
L12	ALCOVER / BR 18	L34	ALCOVER / ÔNIX
L13	BRS210 / ÔNIX	L35	ALCOVER / BH1146
L14	BRS210 / ÔNIX	L36	ALCOVER / BH1146
L15	BRS210 / ÔNIX	L37	ALCOVER / BH1146
L16	BRS210 / BRS208	L38	BRS208 / ALCOVER
L17	BRS210 / BRS208	L39	BRS208 / ALCOVER
L18	BRS210 / BRS208	L40	ALCOVER / OR1
L19	BRS210 / BRS208	L41	ALCOVER / OR1
L20	BRS210 / BRS208	L42	ALCOVER / OR1
L21	BRS210 / BRS208	L43	ALCOVER / OR1
L22	BRS210 / ALCOVER	Safira®	PF9099 / OR1 // GRANITO

$$\bar{Y}_{ij} - \mu_j = \lambda_1\gamma_{i1}\alpha_{j1} + \lambda_2\gamma_{i2}\alpha_{j2} + \bar{\varepsilon}_{ij}$$

Where: $\bar{Y}_{ij}$: is the average yield of genotype i in environment j; μ_j: is the average yield over all genotypes in environment j; $\lambda_1\gamma_{i1}\alpha_{j1}$: is the first principal component, effect of genotypes + interaction genotypes x environments; $\lambda_2\gamma_{i2}\alpha_{j2}$: is the second principal component, effect of genotypes + interaction genotypes x environments; $\bar{\varepsilon}_{ij}$: is the residual of the model associated with the genotype i in environment j [13].

The GGE biplot analysis (genotype main effects + genotype environment interaction) [13] was realized by GGEBiplot () function of R software version 3.1.3 [14]. To generate the biplot was used centering = 2 – corresponding to GGE model. It was decided by the decomposition with SVP = 1, that is, partitioning in a singular value was centered on genotype. The module "Which-won-where" was used for a possible identification of genotypes with the best performance in each mega-environment and the module "Mean vs. Stability" for evaluation of adaptability and stability of wheat genotypes.

III. Results and Discussion

From the results of individual variance analysis of the three experiments, was tested the homoscedasticity of residual variances for the three phenotypic variables evaluated. For all the characteristics evaluated the relation $\frac{>MSResidual}{<MSResidual}$ was lower than 7. How the statistical presupposition was attended, the experiments were considered with homogenies residual variances and then was performed the variance joint analysis of experiments [15].

Table 2 presents the results of joint variance analysis. The statistical analysis revealed significant effect ($p < 0.01$) for genotypes (G), environments (E) and the interaction (G x E), showing differences between wheat genotypes at the three growing seasons. The coefficients of variation (CV %) were low, with amplitude from 1.1 for cycle to 9.1% for grain yield indicating good experimental precision.

Table 3 indicates the average performance of wheat genotypes for the three evaluated variables on three environments (2010, 2011 and 2012). Independent of the growth season is possible to highlight some wheat lines from UEPG breeding program agronomically superior in relation to Safira® (commercial) (Table 3).

For grain yield at the three growth seasons, was evidenced wheat lines with high grain yield potential. The yield amplitude at the three growth seasons range from2376.5 (L5 – 2011) a 5423.2 kg ha^{-1} (L41 – 2010). Some wheat lines have presented yield average superior in comparison to control Safira®. In 2010 the line L41 presented an increase of 68.3 kg ha^{-1} (+ 1.3%) in relation to control, in 2011 the line L36 was 1647 kg ha^{-1} (+ 44.4%) more productive and in 2012 the L21 showed an increase of 560.6 kg ha^{-1} (+ 14.8%) when were compared to control. For cycle, was possible to identify wheat lines 12 days more early maturing than the control. The phenotypic amplitude for this character between genotypes range from 95 to 142 days (Table 3). For plant height, were observed wheat lines with plant height varying from 58.2 (L1 – 2012) to 106.7 cm (L20 – 2011). Even so, wheat lines lower than the Safira® were found, with reduction of up to 15.7 cm on plant height (L43 – 2010) (Table 3).

GGE biplot Analysis

Based on average phenotypic data of studied characteristics the GGE biplot analysis was performed fromthe establishment of principal components (PC) which has better explain the obtained data.

Table 2.Summary of the analysis of variance for cycle, plant height and grain yield in function of the environment, genotype and interaction of genotype x environment (G x E) in the 2010, 2011 and 2012 growth seasons.

Source of Variation	Mean Square			
	DF	Grain Yield (kg ha^{-1})	Cycle (days)	Plant Height (cm)
Blocks (environment)	6	90522.66	3.150	186.239
Environment (E)	2	37092470.68 **	15732.410 **	10752.608 **
Genotypes (G)	43	1539880.28 **	119.795 **	336.462 **
G x E	86	594812,18 **	22.243 **	37.643 **
Residual	258	142277.77	1.640	11.367
Mean		4152.5	116.5	78.2
CV (%)		9.1	1.1	7.5

Table 3. Average performance of 44 wheat genotypes for cycle, plant height and grain yield in the 2010, 2011 and 2012 growth seasons.

Genotypes	Grain Yield (kg ha^{-1})			Cycle (days)			Plant Height (cm)		
	2010	2011	2012	2010	2011	2012	2010	2011	2012
L1	3643.4	3900.0	2821.7	127	119	105	63.7	82.6	58.2
L2	3481.3	3168.6	2463.2	133	125	109	74.0	84.6	64.6
L3	4197.1	4411.8	3164.8	126	120	109	76.7	92,5	71.9
L4	4053.5	4405.9	3575.4	118	121	98	71.0	93.3	71.3
L5	4038.9	2376.5	2965.7	133	125	106	82.2	91.7	76.2
L6	4265.8	4003.9	3336.4	129	121	105	75.0	87.5	74.2
L7	4195.9	4119.6	3296.6	121	120	105	73.7	83.2	65.7
L8	4476.9	4564.7	3694.8	120	120	99	74.5	81.1	67.5
L9	4575.3	4976.5	3829.6	120	117	104	63.5	79.9	67.2
L10	4852.1	4147.0	3832.7	129	121	106	68.2	77.9	65.3
L11	4541.1	2927.4	3401.3	122	121	106	74.5	81.9	68.6
L12	4153.1	4552.9	3581.5	122	117	104	74.0	89.2	67.6
L13	2531.0	4460.8	3762.2	142	120	104	82.5	103.1	78.4
L14	3649.1	4911.8	3428.3	128	121	107	81.7	96.6	78.2
L15	5095.8	5337.2	3376.2	126	121	106	74.7	93.3	74.9
L16	4464.7	4966.7	3550.8	127	122	104	70.5	91.7	67.5
L17	4825.1	4998.0	3548.4	124	121	106	81.7	99.3	73.7
L18	5035.3	4390.2	3860.3	129	121	109	72.2	86.9	67.4
L19	4341.6	5098.0	3431.4	123	120	103	73.2	89.4	71.2
L20	4762.7	5235.3	3578.4	131	123	108	87.0	106.7	77.4
L21	4638.2	5018.1	4347.4	130	121	105	83.2	98.7	77.0
L22	4863.5	4296.1	3553.9	124	121	105	78.0	84.5	67.7
L23	4724.9	5149.0	3826.6	126	118	103	76.7	93.5	78.6
L24	3893.4	4531.4	3180.1	118	115	98	64.0	81.3	68.2
L25	4917.2	4233.3	4197.3	126	121	106	76.0	85.3	68.6
L26	4493.5	5356.9	3835.8	129	122	107	84.0	98.7	75.8
L27	5203.2	4278.4	3918.5	131	126	109	82.2	98.5	75.7
L28	3912.5	5251.0	3275.1	125	116	98	71.7	83.5	71.9
L29	4363.1	5129.4	3281.2	121	117	103	79.7	92.0	78.5
L30	4192.5	4009.8	3348.6	116	113	96	71.5	75.1	65.5
L31	5007.4	4809.8	3370.1	127	121	108	84.0	95.5	76.2
L32	4080.9	4011.8	3265.9	121	116	104	73.7	80.0	68.7
L33	4169.2	3737.2	2901.3	142	121	106	62.5	69.0	60.9
L34	5119.0	4866.7	3673.4	123	119	108	80.2	89.0	72.9
L35	4879.1	4561.8	3547.8	118	115	98	72.5	82.0	73.8
L36	4842.7	5358.8	4010.4	126	121	103	78.7	95.8	78.5
L37	4152.6	3590.2	3391.5	115	112	95	89.0	93.4	86.0
L38	5069.9	4988.2	3946.1	125	120	105	81.0	99.5	72.6
L39	3892.7	4262.7	3816.2	126	117	101	66.5	83.5	71.9
L40	5227.3	5052.9	4102.3	131	123	109	78.0	86.3	70.2
L41	5423.2	4521.6	3805.1	123	116	105	74.0	81.6	66.1
L42	4076.7	4892.1	4031.9	125	118	105	66.7	80,9	64.2
L43	3573.1	4511.8	3569.2	122	116	102	63.0	84.7	69.2
Safira®	5354.9	3711.8	3786.8	128	122	107	78.7	83.9	66.2
Mean	4437.5	4479.2	3556.4	126	120	104	75.2	88.4	71.2
Difference*	+ 68.3	+ 1647.0	+ 560.6	- 12.0	- 9.0	- 12.0	- 15.7	- 14.9	- 8.0

* Difference of the best wheat line in relation to commercial cultivar Safira®

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For plant yield, two first PC explained the most part of total variation G + GE, with 91.6% of accumulate variation. Cycle presented the accumulate variation of PC1 and PC2 of 95.2% and plant height of 93.7% (Fig. 1, 2 and 3, respectively). Thus, is evident by high-accumulated variation percentage for two first components that the utilization of PC1 and PC2 for interpret graphically the data by GGE biplot is the most indicated. According[16], is the first principal components that have the major percent of total correct variation. As increase the number of principal components selected, the error percentage is incremented, reducing the reliability on obtained results.

Fig. 1A, 2A and 3A represent the graphic option of methodology of GGE biplot analysis named "Which-won-where". This is an important tool for genetic breeding programs, it provides the better way to visualize the patterns of interactions between genotypes and environments, as well as the facility to interpret the results by graphic form [17]. To grain yield data, the irregular polygon is formed by connecting the genotypes that are more distant of biplot origin, being, in this case, the lines L26, L36, L40, L41, cultivar Safira®, L5, L2 and L13 (Fig. 1A). Posteriorly, the perpendicularly lines to polygon with origin on biplot center, were drawn, sharing the graphic in sectors. These sectors, also called of mega-environments [13], include a set of environments that are correlated positively.

Considering grain yield is possible to verify formation of nine sectors, being each environment allocated on a different sector (Fig. 1A). Lines L18, L35 and L41 more adapted to 2010 growing season represent the sector 2. Third sector include lines L15, L17, L31, L34, L38 and L40 positively related to 2012. Lines L8, L9, L16, L20, L21, L23, L26 and L36 were more adapted at 2011 growing season representing the sector four. The other lines and the commercial cultivar Safira®, were not included on anyone of this environments, being considering disadvantaged by these tested environments (Fig. 1A). This shows that are genotypes with lower productive performance in some or the most of environments indicating the lack of adaptation of this genotypes to the different environment conditions that were submitted. At the Fig. 1B, is presented the graphic "Mean vs. Stability"where is possible evaluate simultaneouslythe productive potential of genotypesas well as your stability through average environment coordinate (AEC). Initially, the ideal environment is defined through average scores of all environments for the first and second principal components, which is represented by a little circle. The AEC line passes through the biplot origin and by ideal environment calling AEC abscissa. AEC ordered is the axis that passes by the biplot origin and is perpendicular to AEC abscissa, related to genotypes x environments interaction. Thus how bigger the genotype vector, major is the interaction with the respective environment, being, consequently less stable [10]. In this context, the first principal component (PC1) indicate the adaptability of genotypes, highly correlated with yield, in which genotypes more distant toy axis in direction to the arrow are more productive [13]. The graphic analysis showed that wheat lines L40, L36, L15, L38, L41, L34, L21, L23, L20, L26 in decreasing order, were the ten lines that more highlight to grain yield at the three season's growth. In contrast, the less productive genotypes were the lines L2, L5, L13, L1, L11, L33, L37, L32, L30 and L43, by be more distant in opposite direction to arrow.

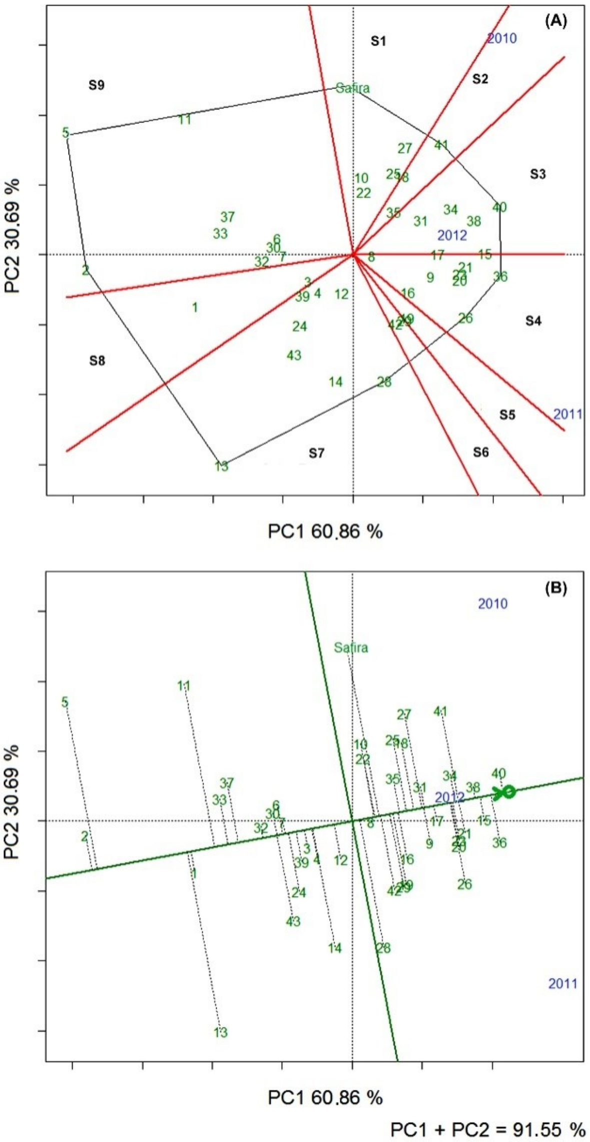

Fig. 1. Characterization of wheat lines according principal components (PC1 and PC2). (A) Visualization of polygon formed by GGE biplot analysis "Which-won-were". (B) AEC (Average Environment Coordination) showing the average performance and stability of 44 wheat genotypes in function of grain yield in kg ha^{-1}. *S: sector.

The second principal component (PC2) is correlated with phenotypic stability. This way, genotypes with low vector, that is, more next to zero are those with higher stability. Analysis results shown that lines L1, L3, L6, L7, L8, L15, L17, L31, L32, L34, L38 and L40 are the that present greater phenotypic stability at the three growth seasons. On the other hand, commercial cultivar Safira® along with lines L5, L11, L13 and L28, obtained the highest vectors, indicating the lowest stability at different growing environments.

The phenotypic stability is advantageous only when associated to high productive potential. [17]Reported that the ideal genotype is one that shows high performance to grain yield combined to high stability in all evaluated environments. In this way, genotypes more productive and stable should have PC1 high scores, however, scores next to zero for PC2. In this work, when were analyzed two parameters simultaneously (PC1 and PC2) was found that genotypes with major yield and better adapted to Ponta Grossa region were the lines L40, L15, L38, L34, L17, L31 and L8. It is important highlight good agronomic performance forthe most of wheat lines from UEPG breeding program when compared with commercial cultivar Safira®, which showed lower grain yield average associated to low stability. Similarly,[18] evaluated adaptation and stability of wheat lines and commercial cultivars for grain yield in different environments. Of seven lines evaluated, two stood out in relation to productive potential being superior to the two commercial cultivars analyzed, despite presented stability to several tested environments. The authors highlighted that new wheat lines come presented high agronomic performance in relation to the cultivars in market. In this way, stay clear that the breeding programs must intensify efforts in the sense of to seek through artificial selection of improved genotypes with better adaptation to Brazil growing regions. The high productive potential, presented by wheat lines from UEPG breeding program, associated to stability of grain yield make these lines strong candidates to the new cultivars to Ponta Grossa region on Paraná State.

Besides grain yield, others adaptive characteristics are important in wheat crop like plant height and cycle. The technique "Wich-won-where" was used to analyze these characteristics. However, the graphic obtained was constructed on inverse scale, once the most promising wheat genotypes to these variables presented reduction on value of these characteristics. To reproductive cycle the graphic "Wich-won-where" showed that extreme genotypes, responsible for polygon formation were the lines L11, L37, L13, L33, L2 and L27, sharing the figure in seven sectors. At the sector 3, were allocated the three evaluated environments (2010, 2011 and 2012), indicating, however, no environmental influence on cycle, being the different evaluations growth seasons considered as a mega-environment. At this same sector 18 lines (L4, L7, L8, L9, L12, L19, L23, L24, L28, L29, L30, L32, L35, L37, L39, L41, L42 and L43) were grouped with the best performance, that is, higher precocity at the three growth seasons(Fig. 2A).

On graphic "Mean vs. Stability" (Fig. 2B), is possible observe that genotypes more early maturing in relation to average, were allocated in the arrow AEC abscissa, highlighting, in decrease order, the lines L37, L30, L35, L24, L4, L8, L28, L43, L29, L9, L32, L12, L39, L41, L7, L19, L42, L23 and L38. On the other hand, as more late maturing, were identified the lines L33, L13, L2, L27, L5, L40 and L20. Safira® cultivar was allocated between longer-cycle genotypes. In relation to AEC ordered axis, referring to interaction of genotypes x environments, can be noted that genotypes more stables were the lines L1, L14, L15, L16, L18, L23, L25, L26, L27, L31, L36, L40, L41, L42, L43 and Safira®. On the other hand, the lines L7, L9, L11, L13, L28, L33 and L34 showed larger interaction withenvironment. Genotypes considered ideals, that is, with lowest cycle and high stability were lines L23, L37, L41, L42 and L43, because obtained higher scores at PC1 and next to zero for PC2.

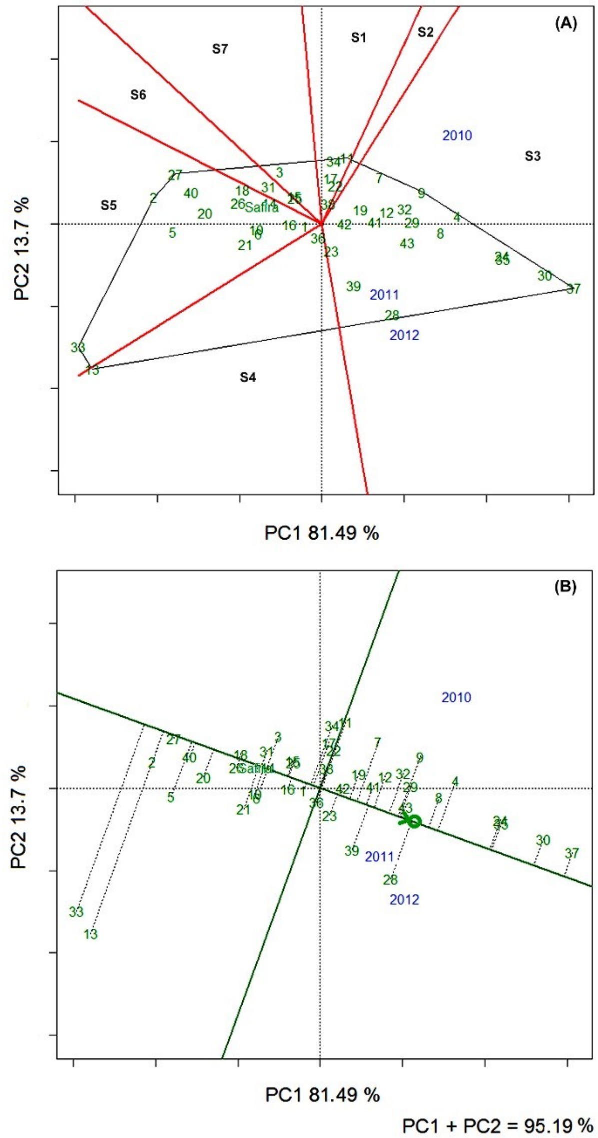

Fig. 2. Characterization of wheat lines according principal components (PC1 and PC2). (A) Visualization of polygon formed by GGE biplot analysis "Which-won-were". (B) AEC (Average Environment Coordination) showing the average performance and stability for 44 wheat genotypes in function of cycle (emergence to maturity) in days. *S: sector.

On "Which-won-where" GGE biplot graphic for plant height (Fig. 3A), the polygon was formed by lines L37, L20, L4, L16, L1, L33 and L30, resulting in seven sections. Growth season of 2010 was allocated on sector 5, on which the lines L12, L16 and L19 were grouped. Sector

6, grouped the most of genotypes (47.7%), together with 2011 and 2012 growth seasons, indicating low variation on performance of these lines depending on the evaluation environment. For genotypes that not were allocated in none agricultural growth seasons, indicate the worst wheat genotypes in relation to the plant height in some or all environments. On graphic "Mean vs. Stability" (Fig. 3B), can be observed that wheat genotypes with highest PC1 scores, were those with lower height, highlighting the lines L33, L1, L9, L42, L10, L24, L30, L43, L39 and L41, being considered the ten best wheat genotypes in decrease order. The genotypes L14, L27, L20, L21, L13, L37 and L20, were that who presents greater plant height. In relation to genotype x environment interaction, was observed that more stable genotypes were the lines L2, L6, L9, L14, L18, L24, L28, L29, L31, L39 and L42. Genotypes considered ideals, that is, that who presents low height associated to high stability were wheat lines L2, L9, L18, L24, L28, L39 and L42. Similarly, is possible stand out the wheat lines from UEPG breeding program in relation to commercial cultivar Safira®.

Through of obtained results with the methodology of GGE biplot analysis was possible confirm the adaptation and stability of wheat genotypes from UEPG breeding program for the three characteristics considered important to adaptation of this cereal. [5]Emphasized that estimates of genotypes adaptation and stability are extremely useful to breeders, by the fact of allow identify the most of promising genotypes for recommendation as new cultivars, or even to be used as parental in crossing blocks. On grain yield analysis, were identified seven ideal genotypes (L8, L15, L17, L31, L34, L38 and L40) with productive potential to be recommended as new commercial cultivars. These lines showed superior performance in relation to control (Safira®), although, not still in the group of ideal genotypes for plant height and cycle.

The methodology of data analysis by GGE biplot was considered efficient on identification of wheat genotypes more suitable due to higher adaptability and stability. This perspective, the analysis enabled increase the information in relation to new wheat lines set from UEPG breeding program, as well as establish criteria for selection of newgenotypes adapted to Campos Gerais of Paraná. On work of [8], the GGE biplot methodology was used to evaluate 12wheat lines in relation to hectoliter weight in six locations in two growth seasons. The authors showed that two of 12 evaluated genotypes, presented high stability and adaptability on the tested environments, making possible the recommendation of these lines as new cultivars. Beside that the authors point out that methodology allowed estimate with security the presence of genotypes x environment interactions. [6]Evaluated adaptation and stability of ten wheat genotypes on five environments in Ethiopia, through GGE biplot methodology. The authors reported the importance of this methodology on analysis by allow by simple form and easy visualization of interaction results of genotypes x environments through graphic analysis. [19]Also demonstrated how this methodology can be a useful tool and effective in evaluate interactiongenotype x environment, allowing identify genotypes with high productive potential and stable for wheat growing regions. c

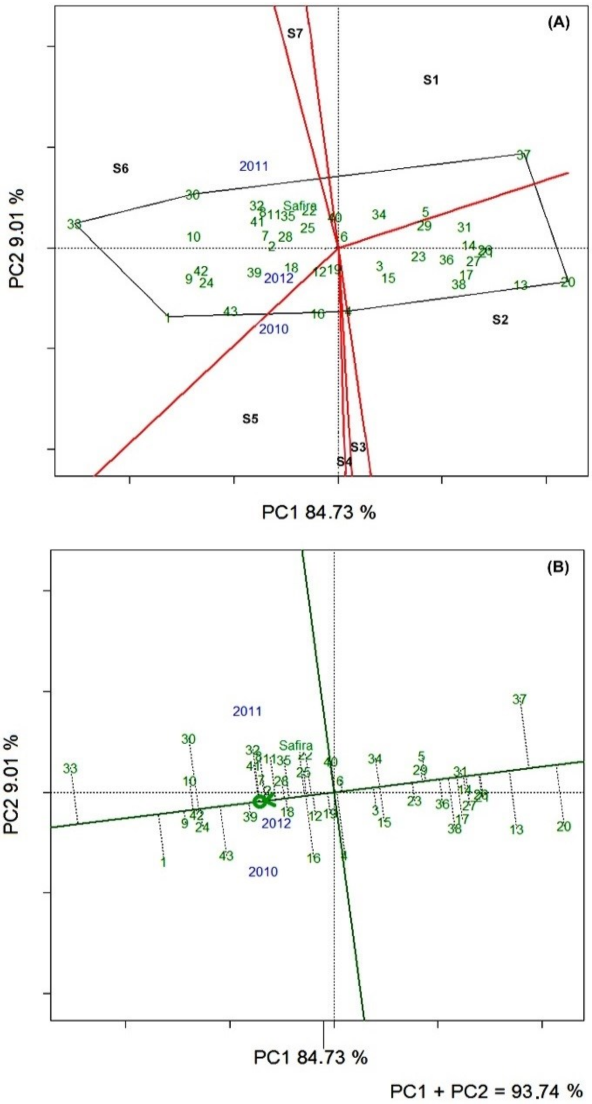

Fig. 3. Characterization of wheat lines according principal components (PC1 and PC2). (A) Visualization of polygon formed by GGE biplot analysis "Which-won-were". (B) AEC (Average Environment Coordination) showing the average performance and stability for 44 wheat genotypes in function of plant height in cm. *S: sector.

IV. Conclusion

The GGE biplot analysis enabled easy graphic interpretation of results from interaction of genotype x environment, allowing identify, in a safe way, wheat F_8 lines more promising to cultivate on Ponta Grossa region in function of adaptability and phenotypic stability. The breeding program lines L8, L15, L17, L31, L34, L38 and L40 highlighted great agronomic adaptation and stability for grain yield. This group of new lines presented productive potential superior to commercial cultivar Safira, being it strong candidates to new wheat commercial cultivars.

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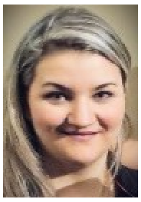

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