POSITIONING OF WHITE OAT CULTIVARS FOR ORGANIC CULTIVATION IN BRAZIL AND PARAGUAY

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ABSTRACT

This work aimed to position white oat cultivars for the organic system and determine the adaptability and stability of white oat for the organic system located in the states of Paraná, Rio Grande do Sul and Paraguay. Nine white oat genotypes were evaluated in 11 environments during five agricultural years, totaling 22 environments. The experimental design used was randomized blocks, arranged in four replications. The GGE model was used in order to reproduce inferences about the performance of genotypes and environments. Based on the best unbiased linear predictor, the genotypes IPR Artêmis, URS Taura, URS Poente, URS Altanera and URS Olada show high grain yield. Given the environments studied, Três Passos-RS and Ijuí-RS enhance the grain yield of white oats in an organic system. The genotypes URS Poente, URS Olada and URS Altanera were characterized as ideas based on superior performance in Palotina- PR, Três Passos - RS and Entre Rios do Oeste- PR.

Keywords: *Avena sativa L.; Grain yield; Blup; GGE; Genetic variability.*

INTRODUCTION

White oat (*Avena sativa* L.) is a cereal crop with wide adaptability, used for both human and animal consumption. It is composed of proteins, fibers, lipids, and especially β-glucan, a compound associated with cholesterol reduction (LORO et al., 2021). In Brazil, white oat is cultivated across a large portion of the territory, mainly in the southern and southeastern regions, with a sown area of approximately 530 thousand hectares and an average grain yield of 1882 kg ha^{-1} (CONAB, 2024).

Although grain production has historically been the main focus of agriculture, the growing demand for healthier diets has led to important changes in the sector. This resulted in the essential transition to organic cultivation methods, excluding the use of synthetic molecules. Organic cultivation is an alternative to conventional cultivation, with the objective of producing grains using organic fertilizers, as well as biological pesticides, in order to promote greater preservation of environmental resources and food security (PRADEBON et al., 2023).

However, organic cultivation presents challenges in managing insect pests and diseases, in addition to identifying genotypes adapted to these environments. To overcome these difficulties, it is essential to conduct trials in different environments and apply biometric models to evaluate and position the genotypes that best adapt to specific environments or regions. This approach makes it possible to identify the genotypes that present the most effective responses, especially in the face of variations in meteorological conditions. The genotypes used in organic agriculture need to present high competitive capacity

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with weeds, tolerance to fungal diseases and nutritional deficiency, in addition to high nutrient absorption capacity (FELEDYN-SZEWCZYK and JOŃCZYK, 2016). In some research, the authors were efficient in identifying and positioning genotypes of white oat (SCHMIDT et al., 2023) and soybean (PRADEBON et al., 2023), in environments with cultivation in an organic system.

Although the productivity of winter cereals has increased in recent decades, organic cultivation still presents a low yield, this is due to the great variation in environmental conditions between producing regions. According to Carvalho et al. (2016), the variation in productivity between different environments is due to the genotype x environment (G×E) interaction. This interaction makes it difficult to position genotypes, due to the great variation in the expression of grain productivity. Therefore, it is necessary to carry out tests in multiple environments and use biometric models for the appropriate positioning of genotypes. This strategy makes it possible to identify the genotypes that present the best responses to variations, mainly in meteorological variables.

Viana et al. (2022), found that organic production has a higher added value, where a ton of grains has a gross income that is 79% higher compared to conventional cultivation. This is because less input is used to grow this cereal. According to Popović et al. (2017), the global area cultivated with organic products in 2014 was 43.7 million hectares, reaching a market value of 80 billion dollars. According to these same authors, Latin America has approximately 6.9 million hectares of organic crops. In this way, the production of organic food presents itself as a profitable alternative, through the production of foods with high nutritional value, since the potential for production and export of such products is unlimited.

Given the difficulty of selecting and indicating white oat cultivars for cultivation under organic management, this work aimed to position white oat cultivars for the organic system and determine the adaptability and stability of white oat for the organic system located in the states of Paraná, Rio Grande do Sul and Paraguay.

MATERIAL AND METHODS

Nine white oat genotypes were evaluated in 11 environments during five agricultural years (2019, 2020, 2021, 2022 and 2023), the trials were conducted in the following environments: Candói- PR, Itapúa- PY, Londrina- PR, Mangueirinha- PR, Palotina- PR, Passo Fundo- RS, Santo Antonio do Palmital- PR, Toledo- PR, Três Passos- RS, Entre Rios do Oeste- and Ijuí- RS (Table 1).

The experimental design used was a randomized block design, with nine white oat genotypes being evaluated (IPR Artêmis, URS Taura, URS Poente, URS Altanera, URS Olada, URS Brava, IPR Afrodite, IPR Andrômeda, URS Corona) in 11 environments during five agricultural years (Totalizing 22 cultivation environments), arranged in four replications. The experimental units consisted of 17 sowing lines, spaced 0.18 meters apart and 10 meters long. Sowing was took place at a density of 300 seeds per square meter and cultivation was carried out organically. When the plants were at full physiological maturity, the two central rows of each experimental unit were harvested to estimate grain productivity in kg ha-1, with grain moisture corrected to 13%. The meteorological information, average temperature (AT, °C), precipitation (PR, mm), was expressed with the purpose of better understanding the results obtained.

Subsequently, the grain yield data obtained were subjected to analysis of the assumptions of analysis of variance, such as homogeneity of residual variances using the Bartlett test and normality of errors using Shapiro Wilk. Individual variance analysis was performed for each environment and homogeneity of variances between environments was observed. The method based on Restricted Maximum Likelihood (*REML*) was used to estimate the variance components and genetic parameters, as well as their interactions in the model, in which significance was obtained through Deviance analysis at 5% probability at Chi-square test (*x2*).

The phenotypic variance (σ^2F) was estimated; broad sense heritability (H^2); coefficient of determination of the effects of genotype-environment interaction ($GEIr^2$); heritability of the genotype mean (H^2mg); accuracy (*ACC*); genotypic correlation between genotype × environment performance (RGE); coefficient of genotypic variation (*CVg**); residual coefficient of variation (*CVr**); coefficient of variation of the proportion between genotypic and residual coefficient of variation (*CV ratio**). Subsequently, the Best linear Unbiased Prediction (*BLUP*) model was used in order to obtain the media components and the classification of white oat genotypes, in general and stratified by environment.

The *GGE* model was used with the aim of reproducing inferences about the performance of genotypes and environments, in this way it is possible to identify discriminatory environments, in addition to genotypes that are more adapted and stable to a specific environment (SILVA *et al*., 2015). This model was used based on the grain yield of different genotypes in the tested environments, allowing the interaction of genotypes x environments to be explored more efficiently and revealing greater accuracy in identifying the selection of stable genotypes adapted to specific environments.

To carry out the statistical analyses, the Exp. Des.pt (FERREIRA *et al*., 2021), *metan* (OLIVOTO and LUCIO, 2020) and *ggplot2* (WICKHAM, 2016) packages were used, through the R Software (R CORE TEAM, 2024).

RESULTS AND DISCUSSION

White oats have an average optimum temperature of between 10 and 25ºC, where there is the highest production of photoassimilates (SAVICK *et al*., 2023). According to Castro *et al*. (2012), temperatures below 3ºC can be harmful to oats, especially in the reproductive phase of the crop, linked to the sterility of the caryopses. It was observed that the highest average temperatures occurred in October 2019, with temperatures above 20ºC in all locations studied. On the other hand, the lowest average air temperatures occurred in 2021 in the month of July, with temperatures between 11.15ºC and 16ºC, in Três Passos- RS, Toledo- PR, Santo Antonio do Palmital- PR, Passo Fundo- RS, Palotina- PR, Mangueirinha- PR, Londrina- PR and Ijuí- RS and Entre Rios do Oeste- PR. Itapuá- PY, the lowest average temperature occurred in 2019 in July with a temperature of 14ºC and Candói- PR showed higher average temperatures, exceeding 23ºC in all months of cultivation.

The month of October 2019 showed the highest average temperatures in practically all locations studied, with the exception of Candói-PY, where the highest average temperatures were in the months of August and September 2023, exceeding 28ºC. In this way, all locations presented temperatures within the optimum range for the crop, that is, it was not a limiting factor for the development of the crop.

The lowest average daily precipitation was observed in the Candói-PR environment, where the year 2022 had an accumulated rainfall of 203 mm, with daily averages between the growing months between 0.3 mm in July and 2.45 mm in October. Similar results were observed in Londrina- PR in 2019. The largest accumulated volumes of precipitation were observed in Ijuí- RS, Três Passos- RS and Passo Fundo- RS, with accumulations exceeding 700 mm. According to Silva *et al*. (2020) the crop presents a demand greater than 400mm, that is, only Candói- PR in the years 2019, 2021 and 2022 presented accumulated precipitation below this, with accumulations of 203 to 220 mm, as well as Londrina-PR in 2019, which had an accumulation of 349 mm, which was a limiting factor for grain productivity in these environments.

There was an occurrence of genetic variability (Table 1) in relation to grain productivity, in the same way, there was an interaction between genotypes and environments for the analyzed variable. According to Loro *et al*. (2022), this indicates that there is a differential response of genotypes to environments and highlights the need to carry out stability analyses.

Given this, it can be stated according to the REML analysis (Table 1), that the heritability (H^2) for the grain productivity variable was considered low (1.52%), this indicates that the environment has an influence of 98.48% on the expression of this character. Studies by Resende (2002) consider low heritability with values alternating between 0.01 and 0.15 for grain productivity. Akhtar *et al*. (2011), reveal that grain productivity is the sum of a set of changes and morphological processes that influence each other and occur at different stages of development, which justifies the great contribution of the environment in the expression of grain productivity.

The coefficient of determination of the effects of the genotype-environment interaction ($GEIr^2$), indicates the participation of the interaction effects in the total variation in grain yield. This analysis revealed that 0.873 of the grain yield expression was explained by the model. Lower values were found by Carvalho *et al*. (2016), when estimating genetic parameters via mixed models for selecting cotton genotypes. This indicates that the phenotypic value was strongly influenced by the genotype x environment interaction.

Regarding the average heritability of genotypes (H^2mg), this is estimated when using averages as an evaluation or selection unit. In other words, this value indicates what percentage of the phenotypic variation is genetic in nature (PUPIN *et al*., 2015). Thus, average heritability values for the genotypes were observed to be 26.9%, thus most of the variation is attributed to the environmental effect. Studies by Pradebon *et al*. (2023), when studying soybean genotypes, they observed higher values, with values 0.56, which attributed most of the variation in the grain yield of these crops to genetic effects.

Accuracy is an indication of experimental precision of genotype competition assays, that is, accuracy depends on the proportion between the genetic and experimental coefficients of variation. Within the *REML* analysis for the grain productivity character, an accuracy of 0.51 was identified, which according to Cargnelutti Filho *et al*. (2012) and Benin *et al*. (2013), when evaluating experimental precision in irrigated rice trials and wheat positioning in different regions, it is classified as moderate.

The genotypic correlation between genotype x environment performance (RGE) makes it possible to classify the incident interaction as simple or complex, thus, it was observed that this correlation was shown to be high for the grain productivity character (0.886). According to Pupin *et al*. (2015) and Correa *et al*. (2015), this interaction is classified as simple.

The genotypic coefficient of variation (*CVg*) is a fundamental measure that expresses the size of the genetic variability present in the population for the characters under study (SANTOS *et al*., 2018). Thus, low values were observed (4.26%), which indicates a low genetic contribution in the expression of variability, with the genotypes being strongly influenced by the environment in the expression of the phenotype. Berlezi *et al*. (2023), when evaluating white oat grain productivity without and with fungicide, they found values between 11.53 and 16.14%. Values close to this study were found by Pradebon et. al. (2023), when evaluating the positioning of soybean genotypes in organic cultivation.

The residual coefficient of variation (*CVr*) refers to the experimental error, where an average value (11.5%) is noted, indicating the precision of the experiment. In relation to the coefficient of variation of the proportion between genotypic and residual variation coefficient (*CVratio*), for grain productivity, it was low 0.369, that is, this value suggests a condition that is not very favorable to the selection of grain yield, as the greatest contribution existing was of environmental origin, that is, the number of genotypes evaluated was insufficient for the selection of genotypes for grain yield (ROSA *et al*., 2021). This coefficient is low for two reasons, as it contains the only nine genotypes directed to the organic chain and in these environments a greater residual variability is naturally identified.

The use of mixed models allowed for a more precise estimation of genotypic values, considering environmental effects. However, it is important to emphasize that grain productivity was strongly influenced by environmental conditions, as indicated by the low broad-sense heritability ($H^2 = 0.0152$). This reinforces that, under organic management, environmental variability plays a predominant role in productivity expression. The genotypes IPR Artêmis, URS Taura, URS Poente, URS Altanera, and URS Olada showed aboveaverage experimental performance, with grain productivities of 1888 kg ha^{-1}, 1775 kg ha^{-1}, 1772 kg ha^{-1}, and 1770 kg ha^{-1} respectively (Figure 2). Studies by Schmidt et al. (2023), when studying oat genotypes for organic cultivation, they observed superior performance for the IPR Artêmis cultivar, results that reinforce those observed in the present study and the potential of this genotype to be recommended for the cultivation of white oats organically. Although some genotypes showed higher predicted yields, the variation in productivity among cultivars was relatively small. Therefore, the differences should be interpreted with caution, especially considering the strong environmental influence detected. The recommendation of one cultivar over another should take into account specific environmental conditions, management practices, and production objectives.

The increase in white oat production is thanks to advances in genetic improvement, which made it possible to obtain genotypes with broad adaptability. From this, genotypes with high productivity and desired characteristics are selected by experiments with different environments and years, which shows that the same genotype can present different performance when positioned in different locations. The specific *BLUP* for each environment aims to select high-yielding genotypes for each environment (Figure 3).

Thus, it was possible to observe that in the Candói-PR environment in 2019, only the IPR Afrodite genotype performed better, with a yield higher than the average of the experiment. However, the opposite performance was observed in Itapuá- PY in the same year, where only IPR Afrodite performed worse than the experiment average. In Palotina-PR, in the years 2019 and 2022 and in Entre Rios do Oeste-PR in the years 2020, 2021 and 2022, no genotype was higher than the general average. For the environments Três Passos-RS in 2019, Santo Antonio do Palmital- PR 2020, Ijuí- RS 2021, 2022 and 2023 and Três Passos- RS in 2023, all genotypes evaluated in these environments showed high performance. In the Ijuí-RS and Passo Fundo-RS environments, in 2020 only the URS Corona genotype was selected, with a yield of 1901.8 kg ha^{-1} and 1910.22 kg ha^{-1} of grains. In 2020, in Londrina- PR environments, the genotypes IPR Afrodite and IPR Artêmis were selected, with yields of 1990.08 and 1889.06 kg ha^{-1} of grains respectively, in Mangueirinha-PR in 2020, only IPR Artêmis showed high performance with yield of grains of 2041 kg ha^{-1} of grains. The Três Passos-RS environment in 2020, the high-performance genotypes were IPR Artêmis with a yield of 2469.9 kg ha^{-1} of grains and URS Brava which had a yield of 2252.5 kg ha^{-1} of grains. However, in 2021, in the same environment, only URS Taura was superior with a yield of 2207.6 kg ha^{-1} of grains. In the year 2022 in Três Passos- RS and Entre Rios do Oeste- PR in the year 2023 superior performance was observed for IPR Artêmis. In Toledo-PR in 2023 superiority was inferred for the genotypes URS Poente and IPR Artêmis with grain yields of 4347.4 kg ha^{-1} and 1859.4 kg ha^{-1}.

According to the ranking of environments and genotypes as a function of white oat grain productivity, the main components of the interaction (PCI: 81.88% and PCII: 11.58%), presented an explainability of the general effects attributed to the interaction G x E of 93.43%. The ideal environment and genotype are represented by the center of the circles and, therefore, the best genotypes and environments are those in the closest circles (YOKOMIZO *et al*., 2020). When ranking environments (Figure 4a), the average stability of the environments is taken into account, with ideal and high-performance environments being considered, thus it was noticed that the environments that present high performance and greater stability were Três Passos- RS in years 2022 (E20) and 2023 (E21), as well as Ijuí-RS (E7). For the white oat genotypes (Figure 4b), it was observed that the genotypes considered ideal and high performance were URS Poente, followed by the genotypes URS Olada and URS Altanera. This classification indicates that these genotypes are ideal in all environments evaluated and considered promising (LORO *et al*., 2022).

Based on the nine white oat genotypes and eleven environments, the *GGE* method presents the relationship between the average and stability of the genotypes and environments (Figure 5a). It was observed that the most stable environments, those located close to the origin of the data (zero), were E22 (Palotina-PR 2022), E19 (Três Passos- RS 2021) and E5 (Entre Rios do Oeste- PR 2023), in other words, these are the representative environments, classified as most suitable for the production of white oats. Regarding genotypes, the same magnitude was observed for URS Poente, URS Olada and URS Altanera.

With the aim of differentiating genotypes in relation to productive performance (Figure 5b), the *GGE* method inferred the division of six sections. It was observed that the genotypes allocated at the ends of the polygon are genotypes considered to be of high performance, namely IPR Artêmis, URS Poente, URS Altanera, URS Corona and IPR Andrômeda. Therefore, environments located outside the polygon are characterized as environments with high variability, so only E4 (Entre Rios do Oeste- PR 2022) is considered a stable environment. The URS Poente and URS Altanera genotypes expressed the highest grain productivity and showed high stability, especially in the largest number of environments. In the same way, the URS Corona genotype presents high performance only in E14 (Passo Fundo- RS 2020) and IPR Artêmis in E12 (Mangueirinha- PR 2020).

Identifying genotypes with superior and stable performance in different environments provides practical guidance for organic farmers and breeding programs. The IPR Artêmis, URS Poente, URS Altanera, and URS Olada genotypes showed high grain roductivity under organic management, indicating potential for placement in organic systems. Therefore, cultivar selection should prioritize stability and performance in multiple environments, rather than small differences in average productivity. The favorable performance observed in Três Passos-RS and Ijuí-RS suggests that regions with similar climatic conditions may offer greater productivity potential. The high genotype × environment interaction, associated with low heritability, reinforces the importance of selection under organic conditions and in multiple environments to identify resilient and widely adaptable cultivars.

CONCLUSION

Based on the best unbiased linear predictor, the genotypes IPR Artêmis, URS Taura, URS Poente, URS Altanera and URS Olada show high grain yield.

Given the environments studied, Três Passos-RS and Ijuí-RS enhance the grain yield of white oats in an organic system.

The genotypes URS Poente, URS Olada and URS Altanera are characterized as ideas based on stability with superior performance in Palotina- PR, Três Passos - RS and Entre Rios do Oeste- PR.

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Table 1. Location and characteristics of soil and climate of the environments: Três Passos- RS, Toledo- PR, Santo Antônio do Palmital- PR, Passo Fundo- RS, Palotina- PR, Londrina- PR, Itapúa- PY, Ijuí- RS, Entre Rios do Oeste- PR, Candoi- PR and Mangueirinha- PR.

Environments	Anos	Latitude	Longitude	Altitude	Soil Type	Climate
Três Passos- RS	2019, 2021, 2022, 2023	27°29’52’’ S	53 °54’00’’ W	438 m	Dystrophic Red Latosol	*Cfa subtropical*
Toledo- PR	2023	24° 43' 12" S	53° 44' 36" W	550 m	Dystrophic Red Latosol	*Cfa subtropical*
Santo Antonio do Palmital- PR	2020	23°49’29” S	51°25’27” W	680 m	Red Latosol	*Cfa subtropical*
Passo Fundo- RS	2020	28° 15’ 40’’ S	52° 24’ 30’’ W	680 m	Distroferric Red Latosol	*Cfa subtropical*
Palotina- PR	2019, 2022	24°17’38’’ S	53°48’03’’ W	338 m	Dystrophic Red Latosol	*Cfa subtropical*
Londrina- PR	2020	23° 17' 34" S	51° 10' 24" W	550 m	Eutrophic Red Latosol	*Cfa subtropical*
Itapúa- PY	2019	26°47’20” S	55°40’15” W	200 m	Red Latosol	*Cfa subtropical*
Ijuí- RS	2020, 2021, 2022, 2023	28° 23’ 19’’ S	53° 54’ 56’’ W	330 m	Dystrophic Red Latosol	*Cfa subtropical*
Entre Rios do Oeste- PR	2020, 2021	24° 42’ 24’’ S	54° 14’ 36’’ W	253 m	Purple Latosol	*Cfa subtropical*
Candoi- PR	2019	25°27’55’’ S	51°56’31.27’’ W	962 m	Dystrophic Red Latosol	*Cfa subtropical*
Mangueirinha- PR	2020	25° 56’ 42’’ S	52° 11’ 16’’ W	849 m	Dystrophic Red Latosol	*Cfa subtropical*

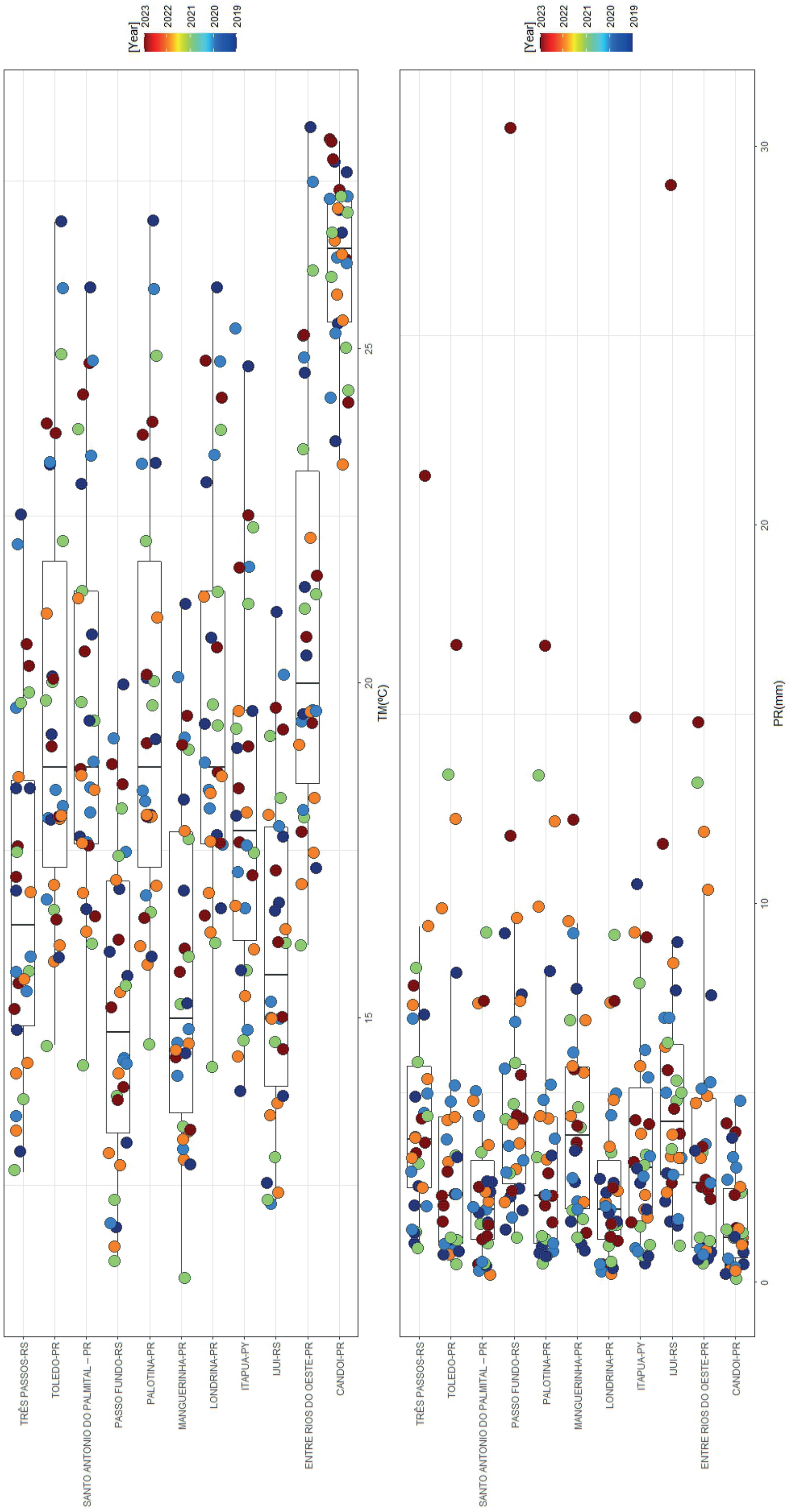

Figure 1. Meteorological variables average air temperature (AT, ºC) and precipitation (PR, mm) in the eleven organic white oat cultivation environments. The different colors used refer to the respective years in which the tests were carried out.

Table 2. Estimates of variance components and genetic parameters for oat grain productivity grown in different environments in Brazil and Paraguay.

VAR	MODEL	LOG LIK	AIC	LRT	PR(>CHISQ)
GY	GEN	68	-1284	0.105	7.46E-01
GY	GEN:ENV	68	-1376	184	5.81E-42
PARAMETERS					
σ^2F			371782		
H^2			0.0152		
$GEIr^2$			0.873		
H^2mg			0.269		
ACC			0.518		
RGE			0.886		
CVg (%)			4.26		
CVr (%)			11.5		
CV ratio (%)			0.369		

Var: Variable; Model: Model; Log Lik: Restricted Maximum Likelihood Logarithm; AIC: Akaike Informational Criterion; LRT: Restricted Maximum Likelihood Ratio; PR: Probability by Chi-Square test: σ^2F: Phenotypic variance; H^2: broad-sense heritability GEI: coefficient of determination of the effects of the genotype-environment interaction; H^2mg: Heritability of the genotype mean; RGE: genotypic correlation between genotype x environment performance; CVg: Genotypic coefficient of variation; Cvr: Coefficient of residual variation; CV ratio: coefficient of variation of the proportion between genotypic and residual coefficient of variation.

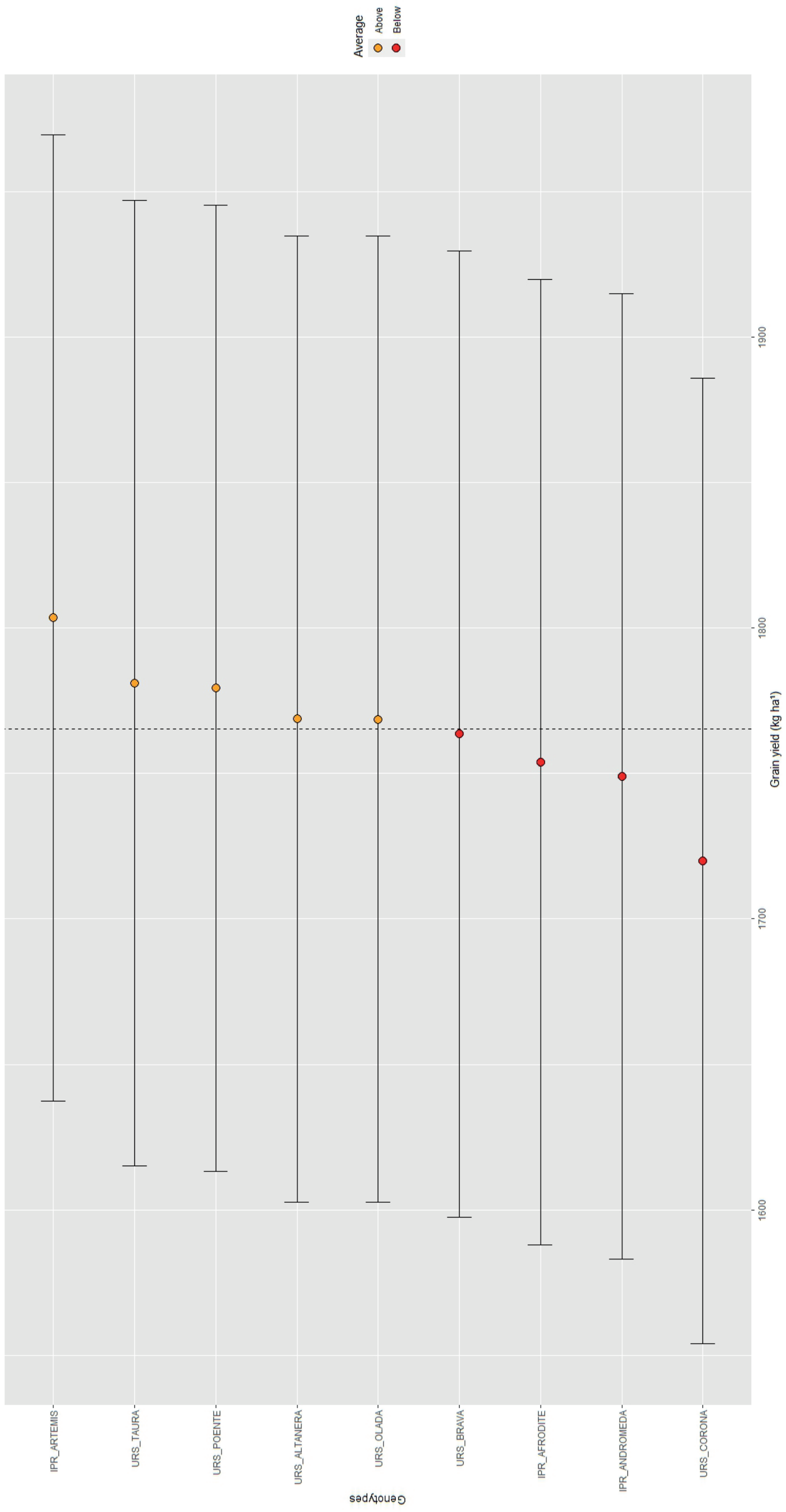

Figure 2. Representation of the estimates obtained by the Restricted Maximum Likelihood/Best Unbiased Linear Predictor (*REML/BLUP*) analysis method, for the grain productivity character of nine white oat genotypes. IPR Artêmis, URS Taura, URS Poente, URS Altanera, URS Olada, URS Brava, IPR Afrodite, IPR Andromeda and URS Corona. The dashed line indicates the overall experiment average of 1765 kg ha^{-1} of white oat grains.

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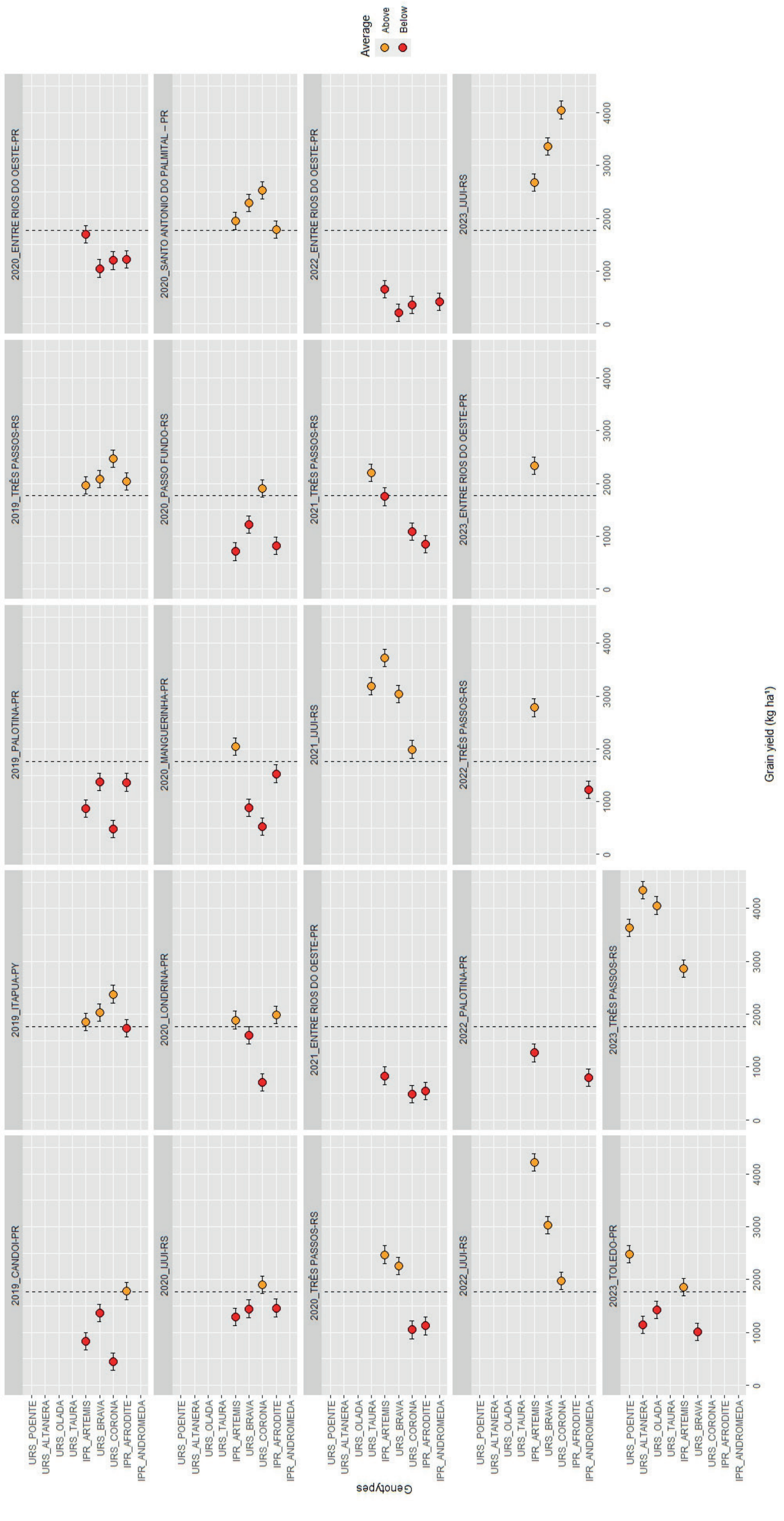


Figure 3. Estimates of the components of the average grain yields per specific *BLUP* measured in 9 genotypes and 11 environments.

Genotypes: URS Poente, URS Altanera, URS Olada, URS Taura, IPR Artemis, URS Brava, URS Corona, IPR Afrodite and IPR Andrômeda. Environments: Candói- PR, Itapuá-PY, Palotina- PR, Três Passos-RS, Entre Rios- PR, Ijuí- RS, Londrina- PR, Mangueirinha-PR, Passo Fundo- RS, Santo Antônio do Palmital-PR and Toledo- PR.

The dashed line indicates the overall experiment average of 1765 kg ha^{-1} of white oat grains

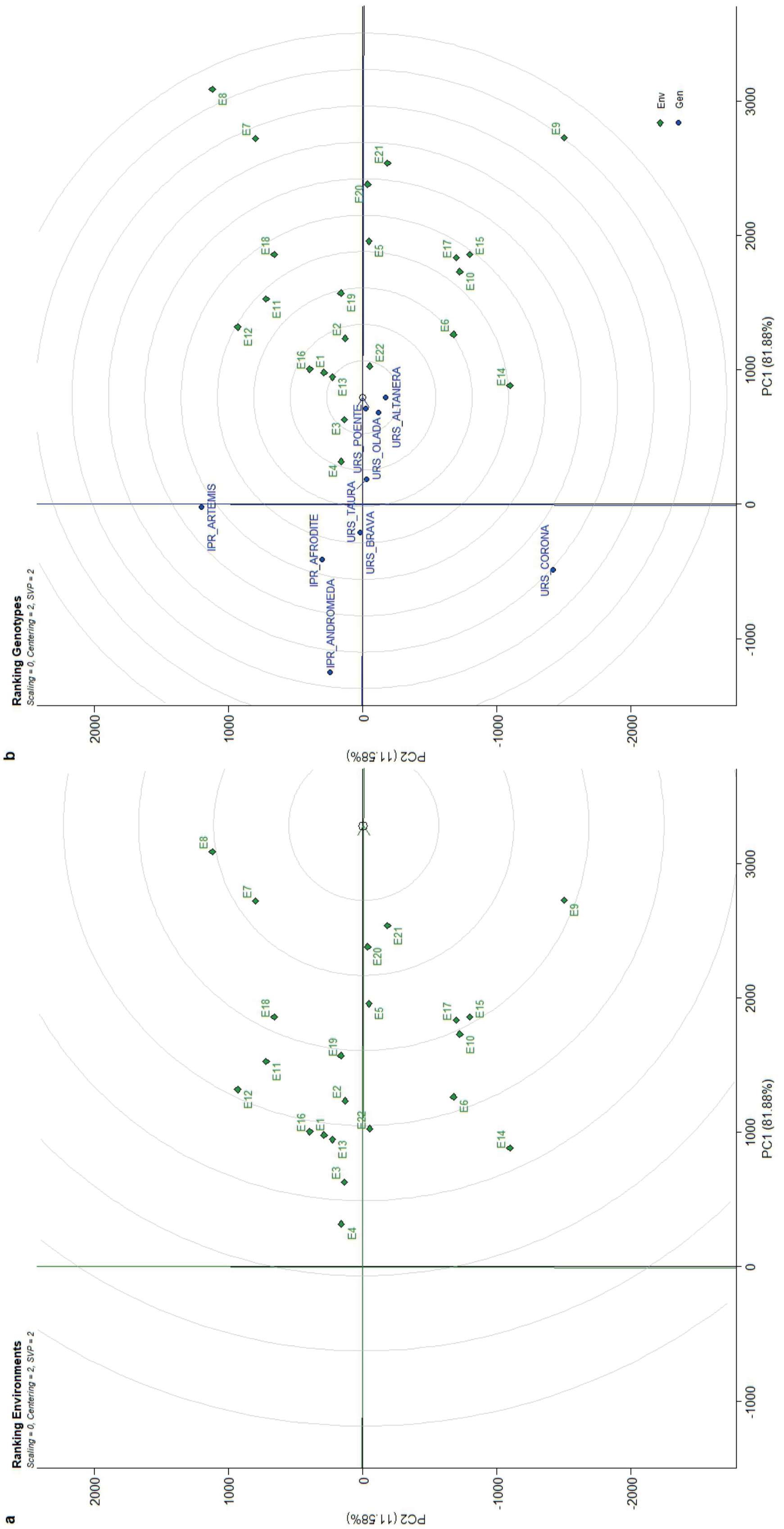


Figure 4. *GGE* biplot indicating the ranking of the eleven environments (Figure 4a) and nine white oat genotypes (Figure 4b) with their respective stabilities, discrimination and representativeness of the genotypes and production environments referring to the variable grain productivity.

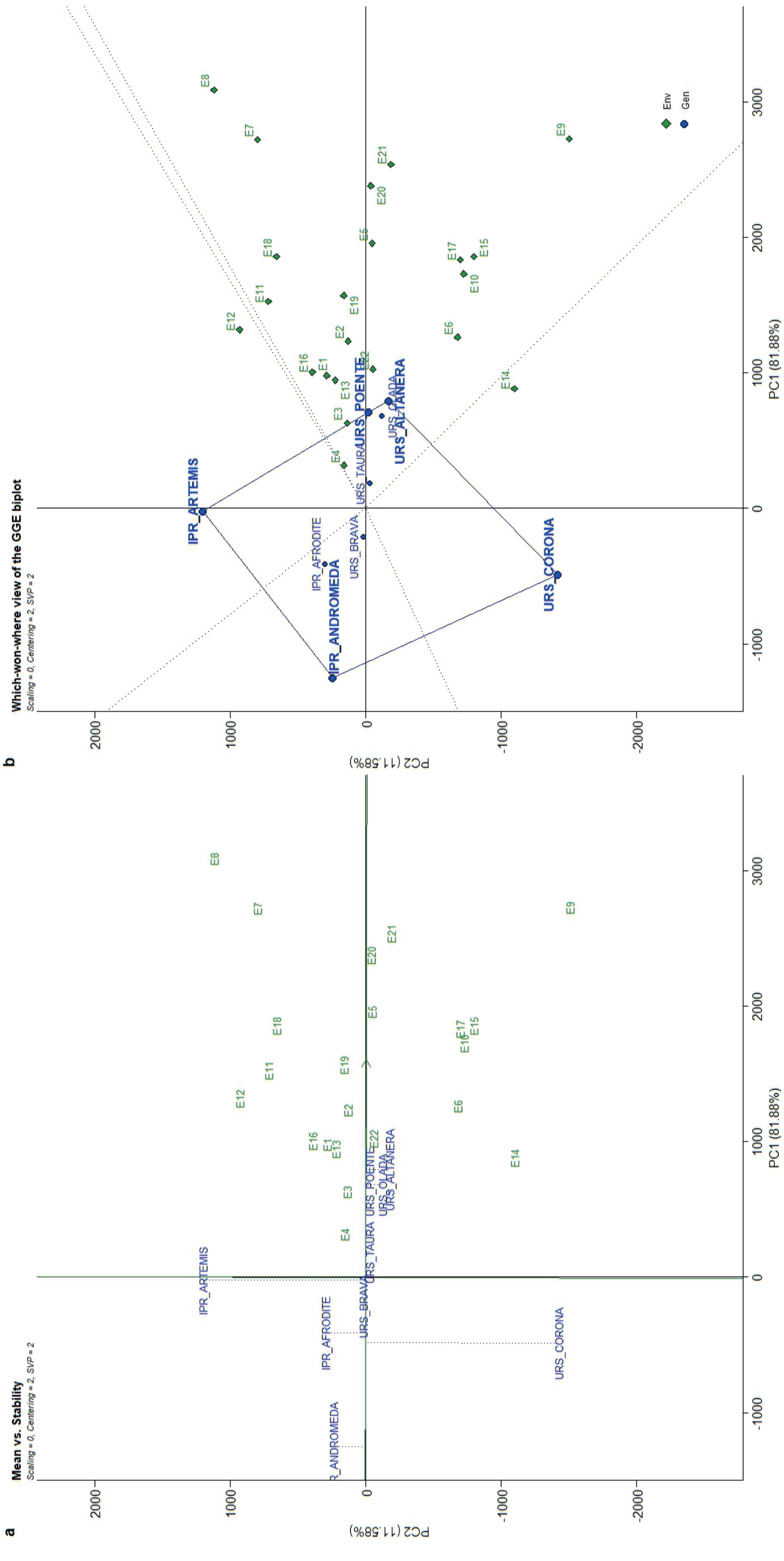
Environments (Env):
E1: Candói- PR 2019;
E2: Entre Rios do Oeste- PR 2020;
E3: Entre Rios do Oeste- PR 2021;
E4: Entre Rios do Oeste- PR 2022;
E5: Entre Rios do Oeste- PR 2023;
E6: Ijuí- RS 2020;
E7: Ijuí- RS 2021;
E8- Ijuí- RS 2022;
E9 Ijuí- RS 2023;
E10- Itapuá- PY 2019;
E11- Londrina- PR 2020;
E12- Mangueirinha- PR 2020;
E13- Palotina- PR 2019;
E14- Passo Fundo- RS 2020;
E15- Santo Antônio do Palmital- PR 2020;
E16- Toledo- PR 2023;
E17- Três Passos- RS 2019;
E18- Três Passos- RS 2019;
E19- Três Passos- RS 2021;
E20- Três Passos- RS 2022;
E21- Três Passos- RS 2023;
E22- Palotina- PR 2022.

Genótipos:
URS Poente, URS Altanera, URS Olada, URS Taura, IPR Artêmis, URS Brava, URS Corona, IPR Afrodite and IPR Andrômeda.

Figure 5. *GGE* Biplot, indicating discrimination and representativeness of genotypes and production environments referring to the grain yield variable (Figure 5a). *GGE* BIPLOT indicating the ranking of the nine white oat genotypes, with their respective stabilities.

Environments (Env):
E1: Candói- PR 2019;
E2: Entre Rios do Oeste- PR 2020;
E3: Entre Rios do Oeste- PR 2021;
E4: Entre Rios do Oeste- PR 2022;
E5: Entre Rios do Oeste- PR 2023;
E6: Ijuí- RS 2020;
E7: Ijuí- RS 2021;
E8: Ijuí- RS 2022;
E9: Ijuí- RS 2023;
E10: Itapuá- PY 2019;
E11: Londrina- PR 2020;
E12: Mangueirinha- PR 2020;
E13: Palotina- PR 2019;
E14: Passo Fundo- RS 2020;
E15: Santo Antônio do Palmital- PR 2020;
E16: Toledo- PR 2023;
E17: Três Passos- RS 2019;
E18: Três Passos- RS 2019;
E19: Três Passos- RS 2021;
E20: Três Passos- RS 2022;
E21: Três Passos- RS 2023;
E22: Palotina- PR 2022.

Genótipos:
URS Poente, URS Altanera, URS Olada, URS Taura, IPR Artêmis, URS Brava, URS Corona, IPR Afrodite and IPR Andrômeda.



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