DEVELOPMENT AND SELECTION OF WHITE OAT GENOTYPES FOR SUSTAINABLE ENVIRONMENTS

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ABSTRACT

This work aimed to demonstrate the agronomic performance of the new white oat cultivar and to verify if it presents an ideotype for cultivation in sustainable environments. This study took place at Escola Fazenda Unijuí, located in the municipality of Augusto Pestana, in the northwest region of the state of Rio Grande do Sul. The experimental design used was randomized blocks, organized in a factorial scheme 4 white oat genotypes x 2 growing seasons (2021 and 2022). The genotypes used were a control cultivar (URS Taura), two parent cultivars (FAEM Barbarasul and FAEM Brisasul) and a candidate cultivar (URNRS22), arranged in four replications, totaling 32 experimental units. The analysis of variance at 5% probability by the F test was used. Tukey's mean comparison test was used to compare the means of the treatments. The dissimilarity matrix was calculated and multivariate selection indices were used to select genotypes with better agronomic performance. The candidate cultivar called URNRS 22 showed a superior response for panicle weight, number of grains per panicle, thousand grain weight and grain yield.

Keywords: *Avena sativa*; genetical diversity; genetic breeding; MGIDI.

INTRODUCTION

White oats (*Avena sativa L.*) have the highest share of cultivation on the European continent, representing 60.3% of the world's cultivation of the species, followed by the Americas with 25.2% (FAOSTAT, 2021). In South America, Brazil is responsible for approximately 49.5% of the grain production of this cereal, with 1.08 million tons of grains (FAOSTAT, 2021). Its cultivation is intended for the production of grains, forage and soil cover. It is a cereal with high nutritional quality, as it has in its chemical composition the beta-glucan compound, which reduces cholesterol levels, increasing its value by the industry (VETVICKA et al., 2019).

Due to the high demand for grains, the challenge for genetic improvement programs in white oats is to obtain genotypes with broad stability, with a high yield of high quality grains and durable resistance to the main diseases. This fact is justified by the growing demand for this cereal and the significant increase in the cultivated area in recent years, from 157 thousand hectares in 2010 to approximately 500 thousand hectares in the 2022/2023 harvest (CONAB, 2023).

Genetic improvement programs aim to develop superior genotypes that seek not only grain yield, industrial quality, and stability, but also express the maximum of desirable agronomic traits in a constant manner in different environments (CARVALHO; SILVA; MAGANO, 2020). For an ideal white oat genotype, a reduced plant cycle and height is sought, with straight growth, resistant culm, compact leaves and upright disposition (SAVICKI et al.,

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2023), flag leaf angulation of 45º, compact panicle, ease of grain husking, in addition to high stability and harvest index.

A breeding program, which aims to obtain compact genotypes with high grain yield, takes into account several characteristics. In order to have gains for all traits at the same time, it is necessary to use selection indices that can be optimized from the use of individual genotypic averages, which represent a measure of the additive genetic value that will constitute the next generation (OLIVEIRA et al., 2021).

The use of a certain ideotype, that is, a model elaborated through a set of agronomic characters of interest, provides breeders with an ultimate purpose for selection, thus replacing the trials and errors of gradually increasing the performance of the genotype (VAN OIJEN; HÖGLIND, 2016). The most current selection index is the MGIDI (genotype-ideotype distance index) proposed by Olivoto and Nardino (2020), which aims to obtain genotype-ideotype distances, using multivariate techniques, based on multiple character information. This method facilitates the selection of superior genotypes, based on the measured multi-traits, where the factor analysis described in the multivariate techniques is used, which allows the calculation of variance and covariance matrices without biasing the results due to multicollinearity.

In view of this, this work aimed to demonstrate the agronomic performance of the new white oat cultivar and to verify if it presents an ideotype for cultivation in sustainable environments.

MATERIAL AND METHODS

This study took place at Escola Fazenda Unijuí, located in the municipality of Augusto Pestana, in the northwest region of the state of Rio Grande do Sul. Its geographical position is at 28° 26' 25'' S latitude and 54° 00' 07'' W longitude. The soil is classified as a typical dystroferric Red Latosol, characterized by a deep, dark red color profile, with high clay content and well drained (STRECK et al., 2018). According to the Köeppen climate classification, the region's climate fits the description of Cfa (humid subtropical) (WOLLMANN; GALVANI, 2012).

The experimental design used was randomized blocks, organized in a factorial scheme 4 white oat genotypes x 2 growing seasons (2021 and 2022). The genotypes used were a control cultivar (URS Taura), two parent cultivars (FAEM Barbarasul and FAEM Brisasul) and a candidate cultivar (URNRS22), arranged in four replications, totaling 32 experimental units. The experimental units were composed of plots five meters long and one meter wide, with rows spaced at 0.17 meters. Sowings took place in the second half of May 2021 and 2022, with a density of 70 seeds per linear meter. All evaluations took place in the useful area of each experimental unit (4.25 m^2). Cultural practices and phytosanitary management to control insect pests and weeds took place preventively in order to minimize biotic effects on the results of the experiment.

The variables measured were: lemma color; growth habit; lower leaves: sheath pilosity; leaf blade: edge pilosity; plant: frequency of plants with curved leaves; cycle until panicle emergence; culm: superior pilosity; flag leaf: sheath waxy layer; glume: waxy; glume: shape; panicle: position of branches;

glume: length; primary grain: lemma waxy layer; plant: length; panicle: orientation of the branches; panicle: density; panicle: position of the spikelet; grain: husk; grain: type of arista; primary grain: pilosity on the dorsal face of the lemma; primary grain: base pilosity; primary grain: length of basal hairs; primary grain: lemma length; primary grain: rachilla lengt; group: bioclimatic (MAPA, 2021), plant height (PH, centimeters), height of panicle insertion (HPI, centimeters), panicle length (PL, centimeters), panicle weight (PW, grams), grain width (GW, millimeters), grain length (GL, millimeters), ratio of grain length x width (RLW,%), panicle weight (PW, grams), grain weight per plant (GWP, grams), number of grains per plant (NGP, unit), hectoliter weight (PH, g.cm^3) and grain yield (GY, kg ha^{-1}).

Data referring to meteorological variables throughout the cultivation cycle, maximum air temperature (T max.,ºC), mean air temperature (T mean.,ºC), minimum air temperature (T min, ºC), precipitation (Prec., mm) were obtained from the Nasa Power platform (NASA POWER, 2023). Descriptive data analysis was used to understand data distribution and trends. The data obtained were subjected to assumptions of normality of errors by the Shapiro Wilk test and homogeneity of residual variances by the Bartlett test. Subsequently, the analysis of variance at 5% probability by the F test was used. Tukey's mean comparison test was used to compare the means of the treatments.

After the mean Euclidean algorithm, performed the genetic dissimilarity where the residual matrix was weighted, the distance dendrogram was built using the UPGMA cluster, where it was possible to visualize the overall variability of the experiment and the multivariate trends. Afterwards, BIPLOT principal component analysis took place to establish a multivariate association between the measured variables and the treatments, obtained by the distance matrix and plotted simultaneously.

The multi-trait index of the distance of the genotype with the intended agronomic ideotype (MGIDI) was used (OLIVOTO; NARDINO, 2021), the objective of the multiple selection was to increase (positive sense) grain weight per panicle (GWP), number of grains per panicle (NGP), hectoliter weight (HW), panicle weight (PW), grain width (GW), grain yield (GY), thousand grain weight (TGW) and grain length (GL), as well as, reduce (negative sense) for panicle length (PL), plant height (PH) and height of panicle insertion (HPI). The multivariate index is based on the model:

$$MGIDI_i = \left[\sum_{j=i}^{f} ('\Upsilon ij - '\Upsilon j)^2 \right] 0{,}5$$

Where: MGIDI$_i$ means the distance index of the genotype to the intended ideotype in the progeny, $'\Upsilon ij$ represents the score of the i-th progeny on the j-th factor, $'\Upsilon j$ is the j-th score of the intended ideotype. Thus, the progeny, which have a lower MGIDI index, are closer to the desired ideotype. The line i of the progeny, explained by the j-th factor (ω_{ij}) it is used in order to highlight potentialities and shortcomings of the progenies (OLIVOTO; NARDINO, 2021). Through the model:

$$wij = \frac{\sqrt{D^2{}_{ij}}}{\sum_{j=1}^{f} \sqrt{D^2{}_{ij}}}$$

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Thus: D_{ij} = means the distance between the i-th progeny and the ideotype for the j-th factor. Low contributions of a given factor show that the characters are close to the ideotype (OLIVOTO; NARDINO, 2021). The analyzes were performed using the R software (R CORE TEAM, 2023) using the packages *agricolae* (MENDIBURU, 2021), *metan* (OLIVOTO; LUCIO, 2020) and *ggplot2* (WICKHAM, 2016).

RESULTS AND DISCUSSION

The average ambient temperature (Figure 1), in general for regions with a subtropical climate, tend to be milder from the second half of May onwards. The recommended sowing time for white oats is from May 20th for regions with a subtropical climate, where temperatures are expected to gradually decrease from that date. The meteorological conditions for the cultivation of oats in both years, presented an average air temperature of 15 to 23°C in the period. For most annual grasses, the relationship between net photosynthesis and air temperature shows a wide optimal range, from 10 to 25 °C (CASTRO, et al., 2012). White oats develop ideally when the vegetative state receives relatively low air temperatures that are not harmful to the plants, however, in the reproductive phase, temperatures below 2ºC and 4ºC can damage the leaves and culms and, mainly, the sterility of the panicle (SAVICK et al., 2023).

Accumulated precipitation showed that in 2021 (Figure 2), there were lower accumulated rates, where the month of July had a volume of approximately 30mm, unlike July 2022 where the accumulated precipitation was close to 300mm. In relation to the year, 2021 showed greater precipitation instability, with water availability within the crop's demand, but poorly distributed, especially at the beginning of the crop's reproductive period.

Regarding the days from emergence to flowering, it was observed that the commercial control (CO_Commercial) in the year 2021, presented a shorter vegetative period with a value of 70 days (Figure 2a), however the cultivars URNRS 22 (C_Candidata), presented a vegetative period of 75 days. In the year 2022, the cultivars URNRS 22 (C_Candidate), FAEM Brisasul (P_Maternal) and FAEM Barbarasul (P_Paternal), presented the same period for flowering (70 days). Mittelmann et al., (2001), evaluating eight F4 populations, observed high heritability values for the cycle with values between 0.25 and 1.05, where Candidate Cultivar (URNRS22), showed a similar cycle to the Paternal parent (P_Paternal).

Days from flowering to maturation (Figure 2b), in the year 2021, a shorter reproductive period with values between 45 and 50 days was evidenced, a fact explained by the occurrence of water deficit and the occurrence of high temperatures in this phase. In 2022, all cultivars had a reproductive period of 80 days. However, a balance is needed between the vegetative and reproductive periods, where the first phase is responsible for the accumulation of photoassimilates and the reproductive period is responsible for the sufficient translocation of these products to promote grain filling (HARTWIG et al, 2006). For the 2021 cycle, greater precocity was observed, and the cultivar Commercial Control (CO_Commercial) was earlier than the others were in the two years of study (Figure 2c). According to Arenhardt et al., (2015), studying the wheat crop indicates that the condition of the year is determinant in the duration of the cycle, mainly due to precipitation, where 2021 had lower volumes than 2022 and consequently a shorter crop cycle.

Related to the number of culms per linear meter, superiority was evidenced by the Commercial Control (CO_Commercial) in both

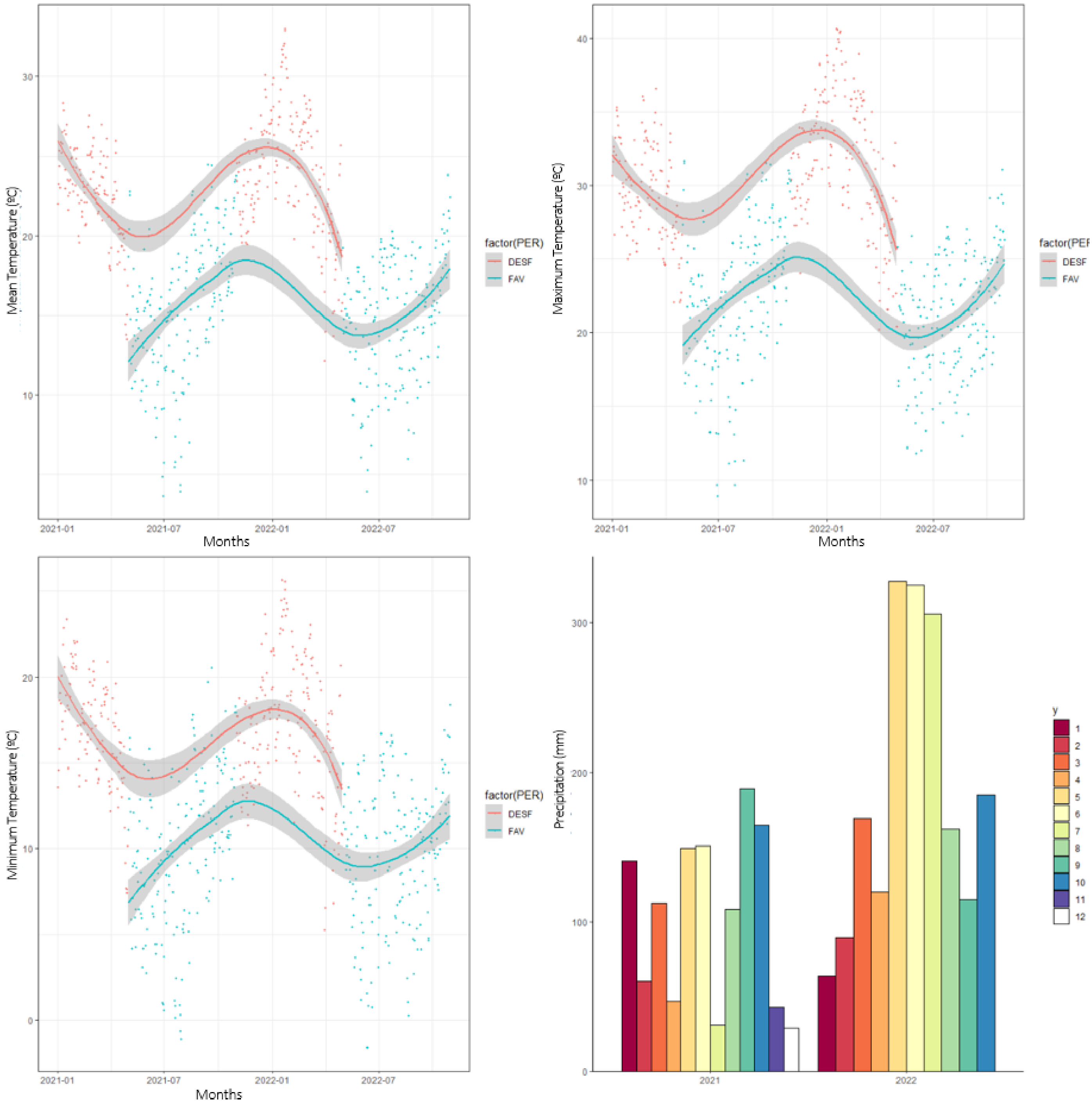

Figure 1. Descriptive analysis of climate variables T mean. - Mean temperature (degrees); T min. - Minimum temperature (degrees); T max. - Maximum temperature (degrees); Prec - Precipitation (mm).

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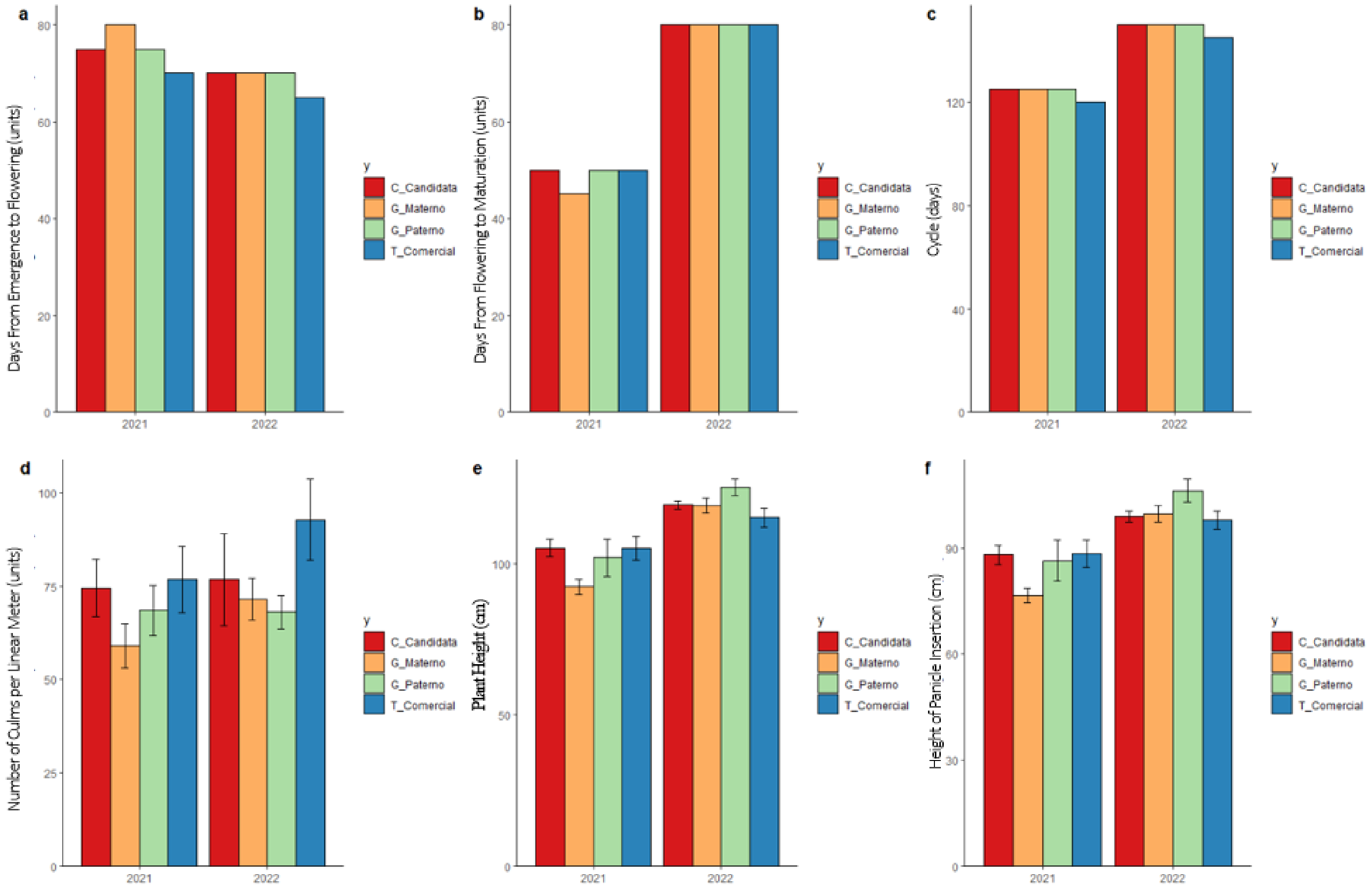

Figure 2.
Descriptive analysis of the variables days from emergence to flowering, days from flowering to maturation, cycle, number of culms per linear meter, plant height, height of panicle insertion in the years 2021 and 2022, for four white oat cultivars.

years, with a stand of 80 and 92 culms per linear meter. Plant height in 2021 (Figure 2e), lower height was observed for the maternal parent (P_Maternal), the other cultivars had plant heights greater than 100 cm. In 2022, less evidence was given for the Commercial Control (CO_Commercial), this is a variable that is strongly influenced by the environment (HAWERROTH et al., 2015), so the objective is to select genotypes with reduced height, of approximately 80 cm, from this This way, lodging tolerance is increased. The height of panicle insertion (Figure 2f), all cultivars presented panicle insertions close to 90 cm, with the exception of the maternal parent (P_ Maternal) with an insertion of 80 cm.

The lodging index, in the year 2021, lower percentages were observed with all cultivars below 10% of lodging, it should be noted that the commercial control (CO_Commercial) and the maternal parent (P_Maternal), presented zero indexes in 2021 (Figure 3a). Opposite behavior occurred in 2022, where all cultivars showed lodging percentages above 30%, with the paternal parent (P_Paternal) presenting the highest percentage of lodging, a fact justified by the higher plant height in this year. According to Wu and Ma (2016), lodging is one of the main factors that reduce grain quality and productivity. Because it reduces the translocation of photoassimilates and consequently the assimilation of carbohydrates and minerals. In addition to reflecting in greater losses in the harvest (HAWERROTH et al., 2015).

The length of the panicle of the candidate cultivar (URNRS22), showed greater lengths in both years, with a value between 17 and

20 cm (Figure 3b), the objective of the genetic improvement programs is to obtain the most compact panicle to obtain greater homogeneity in the maturation, values higher than this study were found by Kaziu, Kashta and Celami (2019) for this characteristic, with a variation between 26 and 37.8 cm. The panicle weight (PW) and grain weight per panicle (GWP), similar behavior was observed, where the candidate cultivar (URNRS22) showed superior performance with values between 1.18 grams and 2.21 grams. This is explained by the fact that this characteristic is correlated with others, such as number of grains, panicle length and weight of grains per panicle.

Regarding the number of grains in the panicle (Figure 3e), for 2021 the candidate cultivar (URNRS22) and the maternal parent showed greater amounts (56 grains), superior performance for the year 2022 was for the maternal parent with 63 grains, followed by the candidate cultivar (URNRS) with 60 grains per panicle. The thousand grain weight (Figure 3f), in 2021 lower results were observed, with superiority for the paternal parent, in 2022 the commercial control showed a superior response. Because they are quantitative traits governed by a high number of genes, they are greatly influenced by the environment, in studies with white oats, effects of genotype x environment interaction have been observed, where the year of cultivation is the main element in productive instability (SILVA et al., 2015).

Larger grain length (7.95 mm) was observed for the maternal parent in 2021 (Figure 4a). As for grain width (Figure 4b), in the two years greater evidence was given for the candidate cultivar (URNRS22) (2.77mm). The ratio of grain length x width, higher proportions were

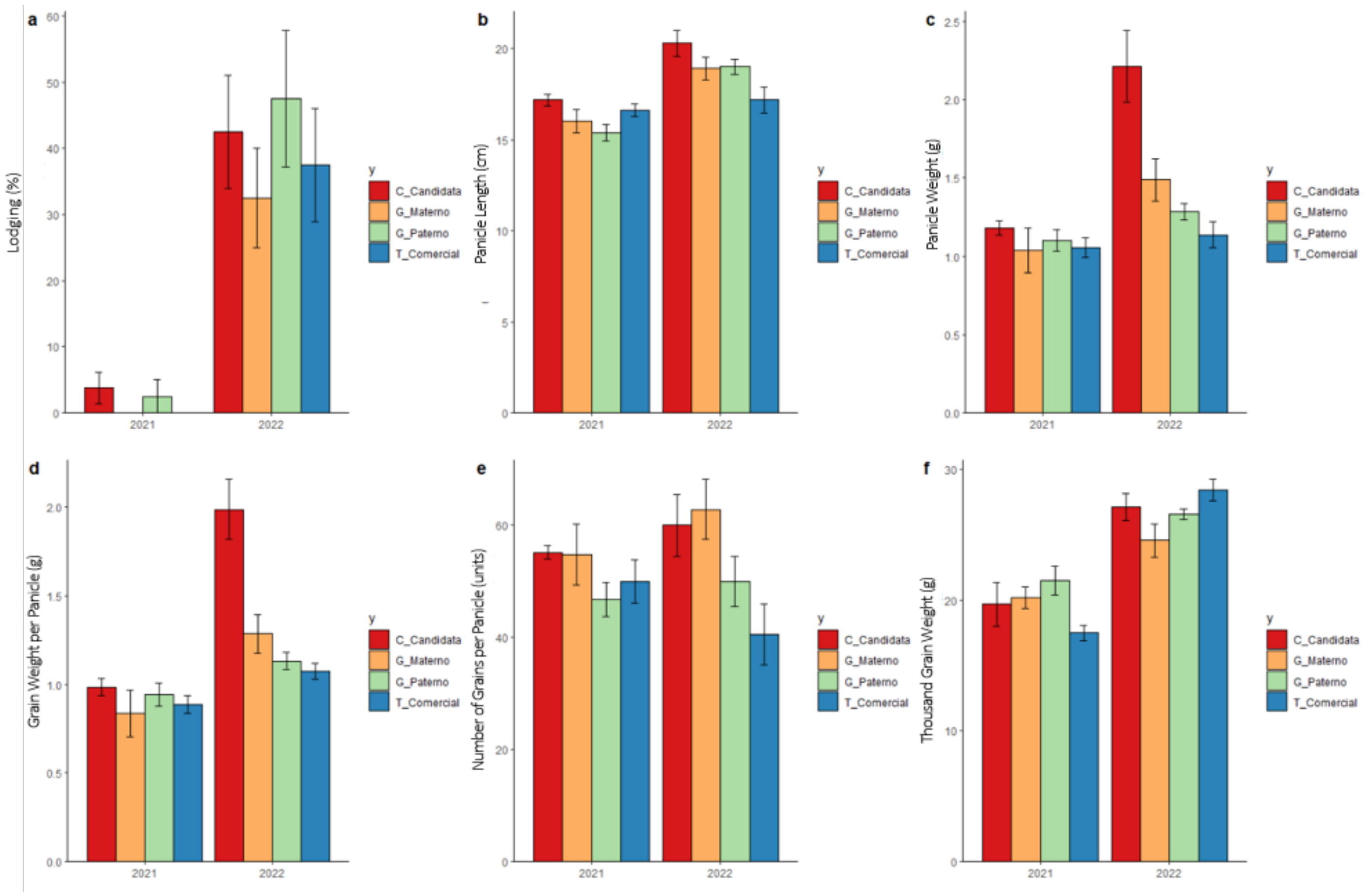

Figure 3.
Descriptive analysis of the variables lodging, panicle length, panicle weight, grain weight per panicle, number of grains per panicle and thousand grain weight in the years 2021 and 2022, for four white oat cultivars.

observed for the paternal parent in 2021 and the candidate cultivar (URNRS22) in 2023. Grain yield (Figure 4d) of the candidate cultivar (URNRS22) was superior for both years, with values close to 4000 kg ha^{-1} of grains and 5500 kg ha^{-1} of grains, respectively. For hectoliter weight in 2021, superiority was observed for the candidate cultivar (URNRS22) 34 $g.cm^3$. For 2022, all cultivars presented weights above 36.5 $g.cm^3$, with a slight superiority for the maternal parent with 37.83 $g.cm^{-3}$.

Analysis of variance revealed a significant effect of year for all characters, with the exception of grain length. (Table 1). In a study conducted by Nörnberg et al. (2014) with five oat genotypes over three years of cultivation did not identify significant differences in grain yield in relation to the year factor. The cultivar factor showed significant effects for panicle length, panicle weight, grain width, grain weight per panicle, number of grains per plant and hectoliter weight. For year x cultivar interaction, significance was given to panicle weight, grain weight per plant and hectoliter weight. This indicates that different genotypes can perform differently depending on the environment in which they were grown.

This interaction emphasizes the importance of considering the adaptability of genotypes in different environmental conditions when carrying out selection and genetic improvement, aiming to obtain more stable and productive cultivars. Luche et al. (2013) observed a significant effect of Genotypes (G) and Years (Y) of cultivation in wheat, as well as their interaction (GxY), similar results were observed by Loro et al. (2022), in white oats. The coefficient of variation ranged from 2.38 (PH) to 17.94 (PW). This indicates good experimental precision and confers reliability for genotype selection. According to the multiple mean comparison test (Table 2), for

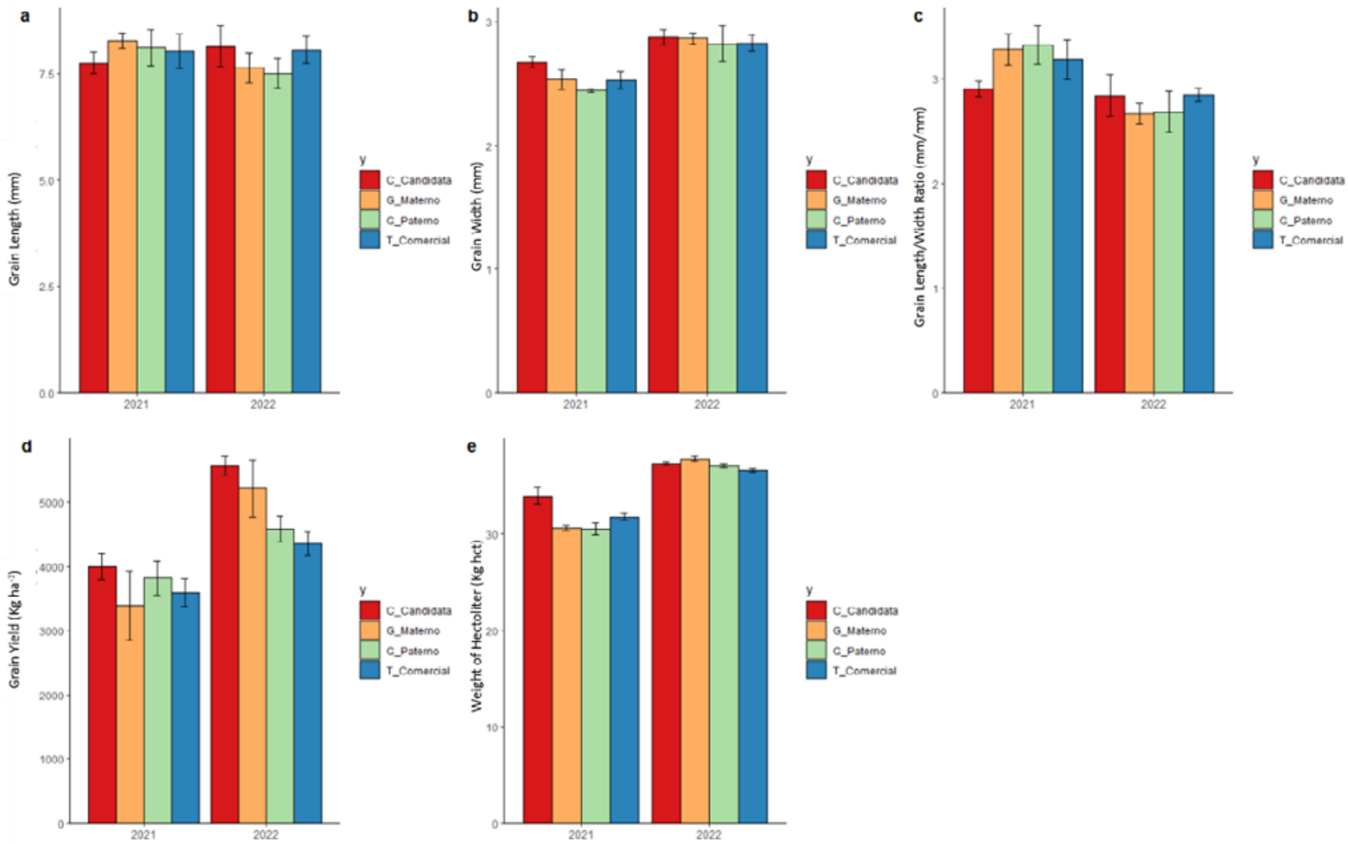

Figure 4.
Descriptive analysis of the variables lodging, grain length, grain width, ratio of grain length x width, grain yield and hectoliter weight, in the years 2021 and 2022, for four white oat cultivars.

Table 1. Analysis of variance for plant height (PH), height of panicle insertion (HPI), panicle length (PL), panicle weight (PW), grain width (GW), grain length (GL), grain weight per panicle (GWP), thousand grain weight (TGW), number of grains per panicle (NGP), hectoliter weight (HW), ratio of grain length x width (RLW) and grain yield (GY).

FV	DF	PH	HPI	PL	PW	GW	CL	GWP	TGW	NGP	HW	RLW	GY
		MS											
BLOCK	3	3	2	2	3	3	6	3	2	5	3	5	5
YEAR	1	4*	3*	6*	6*	6*	3	6*	6*	3	4*	6*	2*
GENOTYPES	3	6	6	5*	5*	5	2	5*	5	4*	5*	2	6
YEAR*GENOTYPES	3	2	5	4	4*	2	5	4*	3*	2	6*	4	4
RESIDUE	21	5	4	3	2	4	4	2	4	6	2	3	3
TOTAL	31	1	1	1	1	1	1	1	1	1	1	1	1
CV (%)		6.46	7.36	6.49	17.94	5.66	8.46	16.61	7.04	17.38	2.38	9.85	13.32

**Significant at 5% probability by F test.*

the year factor, a superior performance was observed in the year 2022 for all the variables measured, with the exception of the ratio of grain length x width, where the year 2021 showed superior performance.

These results are explained by the occurrence of water deficit throughout the cultivation cycle in 2021, mainly in the reproductive phase of the crop (Figure 2). For genotype effect, the panicle length was observed, superior performance for the candidate cultivar (URNRS22) with 18.72cm. Regarding the number of grains per panicle, a superior result was evidenced for the maternal parent (P_Maternal).

The genotype x year interaction, a superior performance was observed in the year 2022 for grain weight per panicle, panicle weight and hectoliter weight and, with the exception of panicle weight for the paternal parent and commercial control cultivars whose two years of cultivation, did not differ statistically (Table 3). The candidate cultivar (URNRS22) was superior for grain weight per panicle, panicle weight in relation to the other cultivars in the year 2022 and hectoliter weight (34 g.cm3) in 2021. The thousand grain weight in the year 2022, the control cultivar showed the highest mass (28.4 grams).

The genetic dissimilarity dendrogram intends to show the genetic distance between the four cultivars. There was the formation of two large distinct groups between cultivars in relation to qualitative characteristics. The first large group formed by subgroup I and II and the second large group formed by subgroup III. Subgroup I formed by the candidate cultivar (URNRS22) and the maternal parent due to the similarity in characteristics: frequency of plants with recurved flag leaf, cycle until panicle emergence, primary grain: base pilosity, primary grain: length of basal hairs, panicle: length, panicle: position of branches, glume: waxy. Subgroup II formed by the paternal parent by the characteristics: Culm: upper node pilosity and primary grain: rachilla length. Qualitative traits are governed by

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Table 2. Test of averages for the years of cultivation and cultivars of white oats, for the variables plant height (PH), height of panicle insertion (HPI), panicle length (PL), grain width (GW), number of grains per panicle (NGP), ratio of grain length x width (RLW) and grain yield (RY).

Variables	YEAR	
	2021	2022
PH	101 B	119.6 A
HPI	84.81 B	100.66 A
PL	16.29 B	18.84 A
GW	2.54 B	2.84 A
RLW	3.16 A	2.75 B
GY	3699.28 B	4927.27 A
CULTIVARS	**PL**	**NGP**
C_CANDIDATE	18.72 a	57.51 ab
P_MATERNAL	17.46 ab	58.75 a
P_PATERNAL	17.18 ab	48.30 ab
CO_COMMERCIAL	16.88 b	45.16 b

Means followed by the same lowercase letter in the column do not statistically differ between treatments using Tukey's test at the 5% error probability level. Means followed by the same capital letter in the row do not statistically differ between Tukey's test treatments at the 5% error probability level.

Table 3. Test of means for the years of cultivation and cultivars of white oats, for the variables grain weight per panicle (GWP), thousand grain weight (TGW), panicle weight (PW) and hectoliter weight (HW).

YEAR	GWP			
	C_CANDIDATE	P_MATERNAL	P_PATERNAL	CO_COMMERCIAL
2021	0.98 Ba	0.83 bA	0.94 aA	0.88 aA
2022	1.98 Aa	1.28 aB	1.13 aB	1.07 aB
	TGW			
2021	19.66 bAB	20.18 bAB	21.4 6 bA	17.47 bB
2022	27.10 aAB	24.55 aB	26.56 aAB	28.40 aA
	PW			
2021	1.18 bA	1.03 bA	1.10 aA	1.05 aA
2022	2.21 aA	1.48 aB	1.28 aB	1.13 aB
	HW			
2021	34.00 Ba	30.64 bB	30.55 bB	31.79 aB
2022	37.35 Aa	37.83 aA	37.12 aA	36.64 aA

Means followed by the same lowercase letter in the column and uppercase letter in the row do not statistically differ the treatments by the Tukey test at the 5% error probability level.

one or a few genes, which form distinct phenotypic classes that are easily separable from each other, being little influenced by the environment and largely by genetic variance (BALDISSERA et al., 2014). Therefore, this explains the similarity between the candidate cultivar (URNRS22) and its parents.

The large group II, formed by the control cultivar, presented the following distinguishing characteristics from the others: plant: frequency of plants with recurved flag leaf, cycle until panicle emergence, culm: upper node pilosity, flag leaf: sheath waxy layer, glume: waxy, glume: shape, panicle: position of the branches, glume: length, primary grain: lemma waxy layer, plant: length, panicle: length, panicle: orientation of the branches, panicle: density, panicle: position of the spikelet, grain: husk, grain: type of arista, primary grain: pilosity in the dorsal phase of the lemma, primary grain: base pilosity and primary grain: length of the basal hairs.

For the quantitative characters (Figure 5 and 6), two large groups were formed, the first large group, consisting of subgroups I and II, where subgroup I grouped the maternal and paternal parent, which showed similarities for panicle length. Subgroup II was formed by the commercial control, which was distinguished from the others by the thousand grain weight (2022). As for the large group II, composed of the candidate cultivar (URNRS22), hectoliter weight (2021), panicle weight (2022) and grain weight per panicle (2022) and panicle length.

According to the graph of multivariate analysis of principal components (BIPLOT), which explains 78.67% of the collected data (Figure 7), in this way it is possible to represent the affinity between the measured variables and the cultivars (LORO et al., 2021). The variables plant stand (STAND), grain length (GL), primary grain: basal hair length (PGBHL), primary grain: lemma waxy layer

Figure 5. Dendrogram with genetic dissimilarity using the standardized Euclidean distance, obtained by the UPGMA mean linkage method, for the minimal descriptors of white oats. Commercial Control (CO), Paternal Parent (P), Candidate Cultivar (C) and Maternal Parent (M).

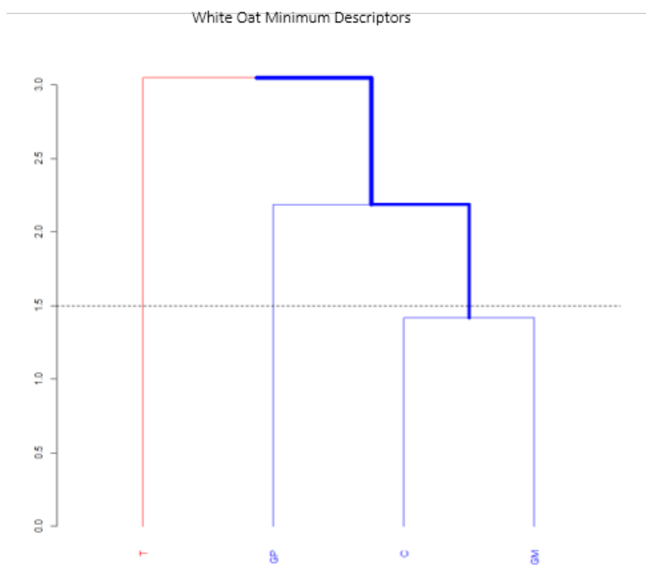

Figure 6. Dendrogram with genetic dissimilarity using the standardized Euclidean distance, obtained by the UPGMA mean linkage method, for the quantitative traits of white oats. Commercial Control (CO), Paternal Parent (P), Candidate Cultivar (C) and Maternal Parent (M).

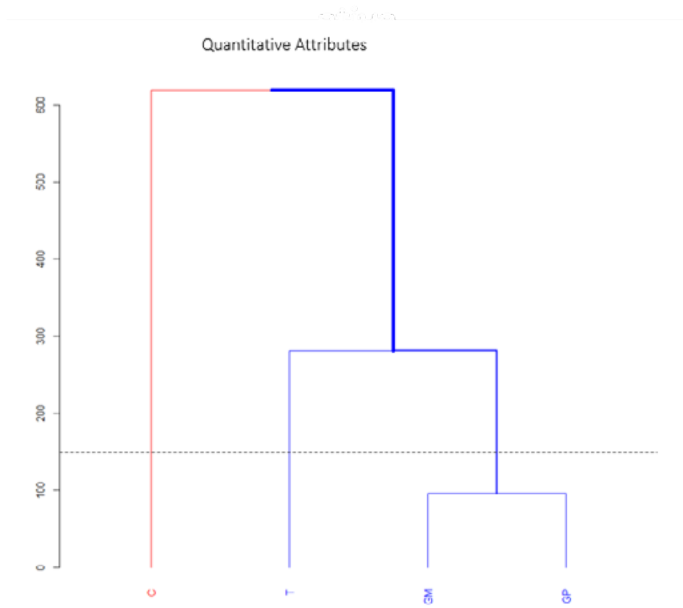

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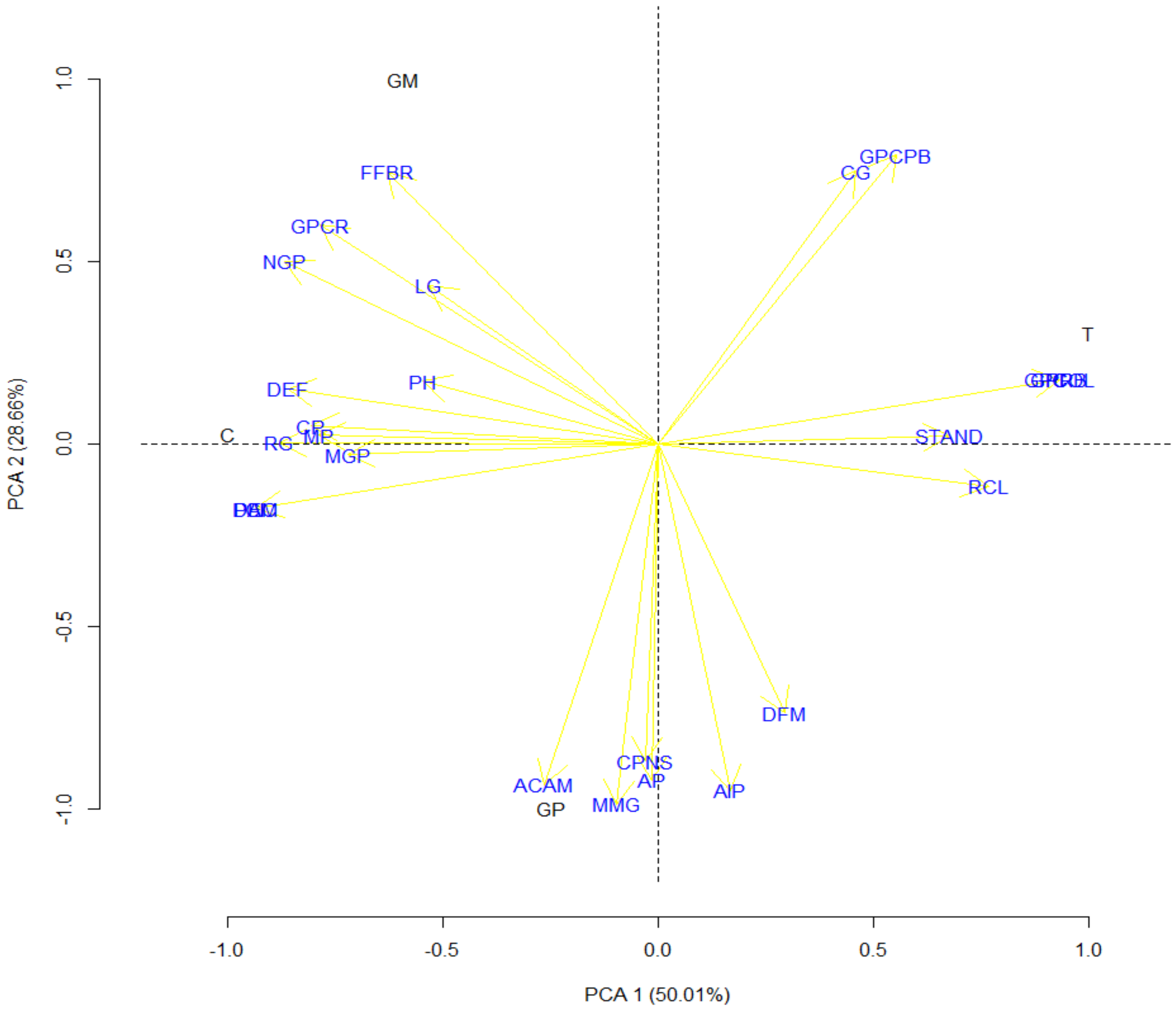
Figure 7. Plot of PCA principal component scores referring to the agronomic variables plant stand (STAND), grain length (GL), Primary grain: basal hair length (PGBHL), Primary grain: lemma waxy layer (PGLW), Grain primary: lemma length (PGLL), Panicle: position of branches (PB) and ratio of grain length x width (RLW), plant: Frequency of plants with recurved flag leaf (FRFL), primary grain: rachilla length, number of grains per panicle (NGP), grain width (GW), hectoliter weight (HW), days from emergence to flowering (DEF), panicle length (PL), panicle weight (PW), grain yield (GY) , panicle grain weight per panicle (GWP), days from emergence to maturation (DEM), lodging (LOD), thousand grain weight (TGW), plant height (PH), Culm: upper node pilosity (CUNP), height of panicle insertion (HPI) and days from flowering to maturation (DFM).



(PGLW), primary grain: lemma length (PGLL), Panicle: position of branches (PB) and ratio of grain length x width (RLW), tended towards the commercial cultivar (CO). The maternal parent (M) showed higher magnitudes for frequency of plants with recurved flag leaf (FRFL), primary grain: rachilla length, number of grains per panicle (NGP) and grain width (GW).

As for hectoliter weight (HW), days from emergence to flowering (DEF), panicle length (PL), panicle weight (PW), grain yield (GY), grain weight per panicle (GWP), days of emergence to maturation (DEM), were expressed in greater magnitude by the candidate cultivar (URNRS22) (C). The paternal parent (P), trends were observed for lodging (LOD), thousand grain weight (TGW), plant height (PH), Culm: upper node pilosity (CUNP), height of panicle insertion (HPI) and days from flowering to maturation (DFM).

The factor analysis performed for white oat cultivars showed three groups (Factors) (Table 4). Among the variables presented, factor one is mentioned, which includes panicle length in a positive direction (decrease) and increase in grain weight of panicle, number of grains per panicle, hectoliter weight, panicle weight, grain width and grain yield.

Factor 2 brings together plant height, height of panicle insertion with the aim of reducing and increasing the thousand grain weight. Meier et al. (2021) also observed traits for plant height reduction and panicle insertion in wheat. For factor three, there is only selection to increase the grain length. The selection differential values were 6.60, 30.30, 9.69, 3.45, 29.2, 2.85, 10.80, 1.65, 0.78, 0.90 and 0. 11% respectively, considering the increase in variables. According to Meira et al. (2019), studying black oats, panicle weight and grain weight per panicle demonstrate high heritability, and these variables are highly correlated and can be used in the selection of superior genotypes.

The multi-trait analysis for the white oat cultivars in relation to the distance from the genotype to the agronomic ideotype of the white oats (Figure 8), revealed that the selected cultivar was Candidate Cultivar (URNRS22). This was

Table 4. Analysis of multi-trait distance of genotype-ideotype, multi-trait selection of White Oat Cultivar (MGIDI).

VAR[1]	FACTOR	Xo[5]	Xs[6]	Sd[7]	Sense
PL[8]	FA1[2]	17.60	18.70	6.60	Descrease
GWP[9]	FA1[2]	1.14	1.49	30.30	Increase
NGP[10]	FA1[2]	52.4	57.50	9.69	Increase
HW[11]	FA1[2]	34.50	35.70	3.45	Increase
PW[12]	FA1[2]	1.31	1.70	29.2	Increase
GW[13]	FA1[2]	2.70	2.77	2.85	Increase
GY[14]	FA1[2]	4313.00	4778.00	10.80	Increase
PH[15]	FA2[3]	110.00	112.00	1.65	Descrease
HPI[16]	FA2[3]	92.70	93.50	0.78	Descrease
TGW[17]	FA2[3]	23.20	23.40	0.90	Increase
GL[18]	FA3[4]	7.93	7.94	0.114	Increase

[1]Variables: VAR; [2] FA1: Factor1; [3]FA2: Factor 2; [4]FA3: Factor 3; [5]Xo: observed mean; [6]XS: mean of cultivars (Xs); [7]Sd,%: percentage difference; [8]PL: Panicle Length; [9]GWP: Grain weight per panicle; [10]NGP: Number of grains per panicle; [11]HW: Hectoliter weight; [12]PW: Panicle weight; [13]GW: Grain Width; [14]GY: Grain yield; [15]PH: Plant height; [16]HPI: Height of panicle insertion; [17]TGW: Thousand grain weight; [18]GL: Grain length.

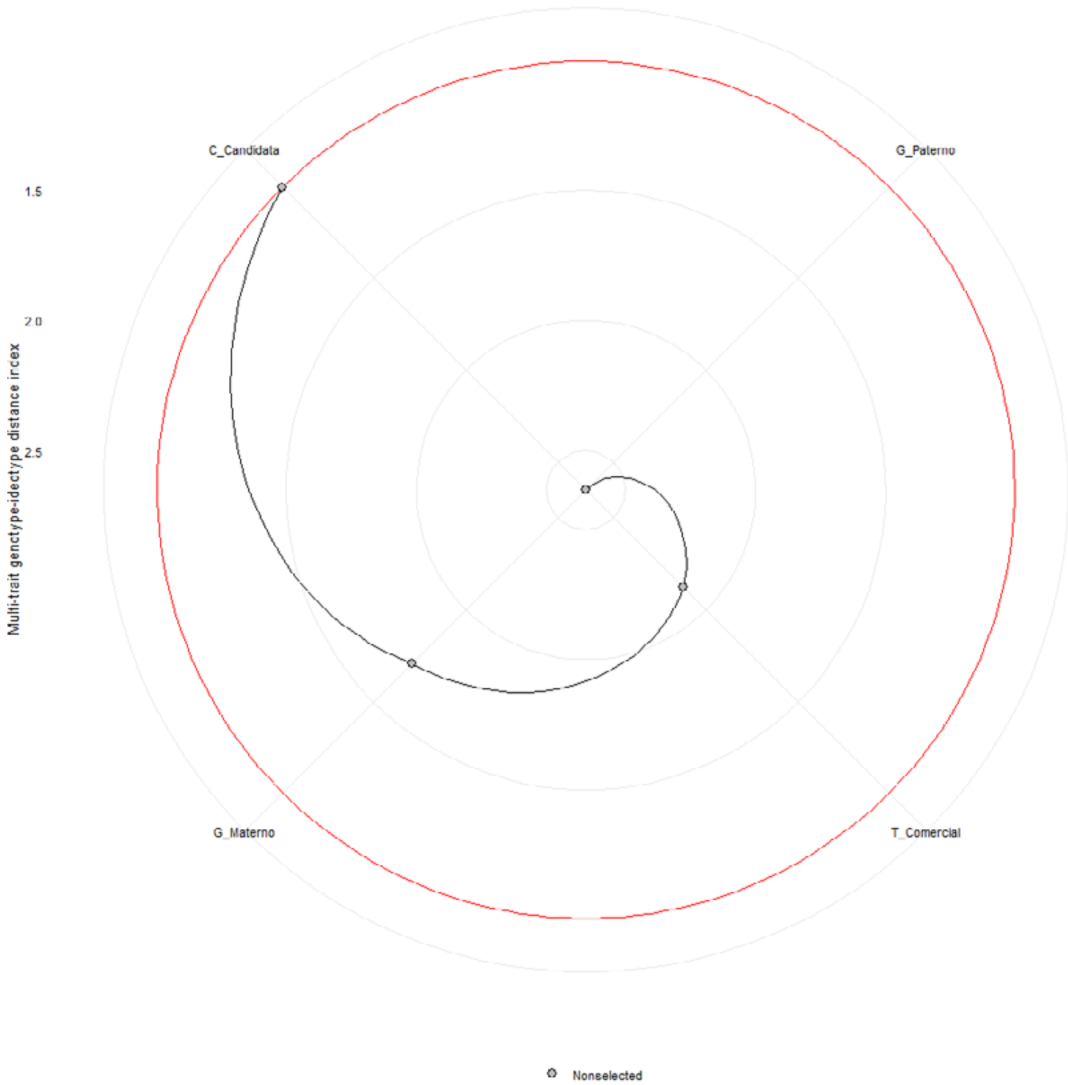
closer to the intended agronomic ideotype. Therefore, there is evidence of potential for the use of this genotype.

The use of multivariate analysis, together with the multi-trait index (MGDI), are important tools in the selection of promising cultivars for the traits of interest. This makes it possible to analyze the response of genotypes with traits of agronomic importance sought by genetic improvement programs.

CONCLUSIONS

The candidate cultivar called URNRS 22 showed a superior response for panicle weight, number of grains per panicle, thousand grain weight and grain yield. This evidenced characteristics that meet the ideotype for cultivation in sustainable environments. Greater affinity was verified with the maternal parent.

Figure 8.
Classification of genotypes in ascending order for the MGIDI index. Selected genotypes are shown in red. The red circle represents the cutoff point according to the selection pressure.



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