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Phenotypic divergence for morphological and yield-related traits in black oat (*Avena strigosa*)

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Abstract

This study aims to evaluate the phenotypic divergence among 46 accessions of *A. strigosa* from Mesoregions Northwest and Northeast of Rio Grande do Sul. The experiment was carried out in the field, in a randomized block design, with three replications. The germplasm was characterized using 40 morphoagronomic, 21 of which were either binary or multicategoric, while 19 were quantitative traits as cycle (days to heading), plant length, peduncle, glume and lemma, and production of biomass and grains. The data were submitted to descriptive, univariate, and multivariate statistical analysis. The accessions were monomorphic in 17 out of 21 among qualitative characters. Vegetative habit, diameter, length, and wall thickness of culm were the main quantitative traits in the discrimination of the accessions. The maximum and minimum dissimilarity, expressed by the generalized Mahalanobis distance, ranged from 2.98 up to 55.71. Based on the magnitude of divergence and performance towards agronomic traits in attributes, some accessions may be incorporated into breeding programs of the species.

Keywords: landraces, multivariate analysis, plant breeding, black oat.

Abbreviations: QTL_quantitative trait locus; OM_organic matter; P_phosphorus; K_potassium; Al_aluminum; Ca_calcim; Mg_magnesium; H+Al_potential acidity; pH_hydrogen potential; N_nitrogen; ANOVA_analysis of variance; D^2_ Mahalanobis distance; UPGMA_Unweighted Pair Group Method with Arithmetic Mean; CCC_ cophenetic correlation coefficient; CV_ coefficient of variation; DM_ dry mass.

Introduction

Avena strigosa Schreb. (black oat, sand oat, bristle oat or lopsided oat) is currently grown in South America as a winter season forage and cover crop. *A. strigosa* populations originate from the Iberian Peninsula are giving rise to the second centre of diversity in South America for this species (Podyma et al., 2019).

In Southern Brazil, the main cover crop prior to summer crops is black oat, and the performance of no-tillage systems depends, among other factors, on the quantity and quality of residues added to the soil (Tiecher et al., 2018). The use of black oat helps to maintain the soil temperature and moisture, and it also makes the environment friendly to the development of micro and mesofauna, which are important in the decomposition process of plant residues (Riquetti et al., 2012). The species is considered an important genetic resource for plant breeding (precocity and resistance of stress) (Weibull et al., 2001). However, as its seeds present dormancy, it may become a weed when the next culture is established.

Although its use is a priority as a forage plant (Masek and Novak, 2018) or ground cover, (Kovář et al., 2017) the black oat has been used as human food in the past (Podyma et al., 2019) and present (Nadtochii et al., 2020). Recent discoveries about the nutritional value of its grains point to the appreciation of this cereal in human food. Its grains present high values of α-tocotrienol and avenanthramides, *β*-glucan, E-vitamers, tocopherols, phenolic alkaloids and phenolic acids (Smitterberg, 2018). The black oat is a cereal that can be used for consumption *in natura*, as flour and its derivatives or groats; besides its potential to become the next healthy, trendy, functional food (Podyma et al., 2017). Also, the gene Pc94 transferred from *A. strigosa* is currently regarded as the most effective gene for resistance to *Puccinia coronata* in *A. sativa* (L.) (Chen et al., 2007). For this reason, the description of morphological and agromorphological traits of *A. strigosa* is essential for the effective conservation and utilization of this resource (Podyma et al., 2019).

In Brazil, one of the countries in which the improvement of *Avena* spp. have made considerable advances, the demand for new varieties of black oat has encourage the search for differentiated genotypes: either with high biomass accumulation, late cycle and prostrate habit for forage production, or with shorter cycle for soil cover or crop rotation. Landraces of black oat may be important sources of genetic resources for breeding programs. Thus, the sources of germplasm may come from agricultural properties, in which the seeds are stored for their own use, from seed laboratories and active germplasm banks. However, the lack of access to phenotype information is still a limiting factor for the use of plant genetic resources, and the documentation of phenotype information is a priority need in biodiversity, crop modelling, breeding, ecology, and evolution research, for association studies, gene discovery, retrospective statistical analysis and data mining, QTL re-mapping, choice of cultivars, and crossbreeding planning (Germeier and Unger, 2019).

Techniques of multivariate analysis such as clustering analysis have been successfully employed to identify divergent genotypes and to improve the advantages provided by heterosis (Barbosa et al., 2005). Also, the Mahalanobis distance between genotypes, determined by morphological traits, can be treated as phenotypic similarities between them (Kozak et al., 2011). This study had the objective to evaluate the phenotypic divergence of 46 landraces accessions of black oat (*A. strigosa*) based on their morphoagronomic characterization, using multivariate analysis.

Results

Morphological description

The accessions were monomorphic in 17 out of 21 qualitative traits, what means that 81% of the characters had no variability (Table 2). Most of the accessions had geniculate awn, upright leaf, and average frequency of curved leaf. Regarding the vegetative habit, it was shown a variation between semi-prostrate and semi-vertical, with 67% of germplasm with intermediate type, and only 9% with semi-prostrate habit: P25 and P26 (Rondinha), P33 (Não–Me–Toque) and P7 (Planalto) (Supplementary Table 2).

Multivariate analysis

Relative importance of traits in the phenotypic divergence

Nineteen quantitative traits were analysed in the tested accessions (Table 3). The lowest variations in the traits were detected in the cycle (days to heading), plant height, length of lower glume, lemma and rachis ($CV\leq5.02$) (Supplementary Table 1). The cycle had a variation of nine days: two accessions (P11 and P25) were early (95 d) and two (P22 and P32) were late (104 d); the rachis varied from ≈20 cm (P24 and P42) up to 24 cm (P15). The upper internode, the peduncle, was the longest one (31.14 vs. 12.27 cm).

The highest variation occurred in dry mass (DM) per plant or tiller, number of tillers (total and reproductive), and culm wall thickness (CV≥30%). The dry mass (g DM plant^{-1}) showed a wide variation, ranging from 23–25 g (P3 and P9) up to 55 g (P7 and P18), as well as the number of tillers, ranging from 15 (P40 and P45) up to 30–35 (P4, P12 and P46). The greatest disparity in culm wall thickness was shown by the accessions P46 (0.54 mm) and P 42 (1.58 mm) (Table 3). The culm length (distance between the first node and the panicle insertion node) was the trait with the greatest relative contribution to genetic divergence (S.j = 22%) by Singh's method (1981). In the pool of accessions, 35% had the longest culm, ranging from 47 up to 58 cm (P34); in the others, the length varied from 30 (P25) up to 46 cm. The most divergent accessions regarding culm thickness were P46 (0.54 mm) and P42 (1.58 mm); as for culm diameter: P46 had the lowest value (2.9 mm) and P42 had almost twice that value (5.4 mm).

The most divergent accessions (D^2 = 55.71) were P2 and P12, and the most similar were P3 and P9 (D^2 = 2.98); P2 and P3 were from Pontão, P12 and P9 were from Humaitá and Lagoa Vermelha, respectively (Table 1). The P2 surpassed P12 accession in 1000–grain weight (16.2 vs. 11.2 g), dry weight of plant (53.3 vs. 48.3 g), dry mass of individual tiller (2.4 vs. 1.6 g), culm wall thickness (0.71 vs. 0.62 mm) and culm length (52.2 vs. 35.5 cm); P12 had superiority in the total number of tillers (35 vs. 23) and peduncle length (38.2 vs. 23.4 cm).

Cluster analysis

When testing two clustering methods to analyze the divergence between accessions, Tocher's optimization method detected 11 groups (Table 4): one of the them was composed of 29 accessions (63%), while the others were formed by one to three accessions. In the dendrogram that illustrates the phenotypic divergence according UPGMA method, at $D^2\approx17$ it was obtain eight groups (Figure 3); at this cut–off point there is 76% convergence in relation to the configuration obtained by the Tocher's method (Table 4). The main divergence between the clustering methods was with respect to the accessions P3, P9, P23, P15 and P33, which formed a single group by the UPGMA, but were distributed in three groups by Tocher's method. By the F test, six groups of accessions, whose composition was coincident by the hierarchical and optimization methods, a significant difference was found in six characters (Table 5). The Group IV differentiated ($p<0.05$) from four groups, due to the lower individual weight of tiller. The smallest internode diameter and wall thickness of the culm was presented by Group II, in contrast to Group V; these groups were also the most divergent in the width of the flag leaf, with widest width and length for Group V.

Discussion

Forty-six black oat accessions, collected in a region with a long tradition of cultivating the species, were evaluated for phenotypic expression. Phenotypic divergence reflects a small fraction (often unknown) of the genes and environmental interaction, which are in general strongly affected by the environment (Kozak et al., 2011). Morphological analysis is important to describe the genetic diversity in the germplasm and to identify variation in the characters (Kaur et al., 2018; Mendoza et al., 2018). Furthermore, it allows more efficient determination of the characters that are important for the study of genetic diversity and the choice of promising parents, as well as the variables that do not contribute to the selection (Coelho et al., 2010).

The accessions of *A. strigosa* here evaluated showed low morphological variability according qualitative traits. Although this type of characterization does not have immediate breeding use, in this case, the variability for growth habit observed here is a relevant aspect. Vegetative habit is a character that largely defines the competitiveness of the crop: for example, plants with a more upright habit allow a greater incidence of weeds (Demétrio et al., 2012). The accessions that presented semi-prostrate habit (P25, P26, P33 and P7) are candidates for inclusion in the breeding programs. Brazilian cultivars of *A. strigosa* are mostly of erect habit, except cv. Iapar 61. This cultivar also has a longer cycle and semi-prostrate habit, which allows a longer grazing period (Noro et al., 2003).

The accessions showed mostly geniculate awn (72%), in relation to the twisted form, in contrast to what Tafernaberri Júnior (2010) found in germplasm of black oat (18 lines and two cultivars), with a preponderance of the twisted type. Many grasses, as they mature, have their awns gradually lose water and therefore change their morphology from a straight to a geniculate condition (Raju, 1984). This morphological change can cause caryopses to dislodge from spikelets by generating considerable torsion and burrow them into the soil (Raju and Ramaswamy, 2011; Stinson and Peterson, 1979). Therefore, it would be important to verify if the type of awn affects the caryopses burial. It is important to answer this question, as this attribute can be an additional factor to seed dormancy in the natural reseeding of the species. When evaluating 55 accessions of black oat from different regions, Podyma et al., (2019) found shorter awns in accessions from South America, suggesting a relationship with its use, once long awns can cause ulcerative stomatitis and oral ulcerations in animals, especially in horse (Linnabary et al., 1986; Mohammadi and Sardari, 2010). A third qualitative character in which variability between the accessions of *A. strigosa* was the position of the flag leaf, mostly upright, concurring with previous evaluations (Tafernabarri Júnior, 2010). Leaves in a more upright position favour the interception of solar radiation, delay the shading and senescence of leaves in the canopy profile, and tend to reach the maximum leaf area index later, but provide the growth between (Fioreze and Rodrigues, 2012; Tanner et al., 1966). The source-sink interaction is influenced by size and position of the flag leaf, and to ensure a continuous supply of assimilates (Peltonen-Sainio, 1993).

In autogamous species, like oat, barley (*Hordeum vulgare* L.) and wheat (*Triticum aestivum* L.), in the landraces composed of a mixture of genotypes is commonly observed greater intra-population variability than inter-population (Ceccarelli et al., 1987; Pecetti and Damania, 1996). In addition to black oat being a diploid and self-fertilizing species, which restricts variability. Thus, black oat breeding programs in Brazil resorted to selection within the “Common” population (Silveira et al., 2010), which, combined with the species' narrow genetic base (Boczkowska et al., 2014) contributed to the low genetic divergence. Currently, the secondary centre of *A. strigosa* diversity seems to be South America, especially Brazil and, in this case, the state of Rio Grande do Sul (Loskutov, 2007).

For dry matter (per plant or per tiller), the high variability within accession may be due to the restricted sample size (10% of the plants), but for the number of tiller, all plants were evaluated, which suggest the existence of several agrotypes. The accessions that have the highest dry mass yield (>56 g DM plant^{-1}), such as P7 and P27, could be tested again, to confirm or discard their value as parents or lineages. Despite other characteristics related to forage yield, tiller number is probably the most important characteristic related to dry matter yield (Boe and Beck, 2008). High tillering potential is only attained if the growing conditions are favourable; however, a drought tolerance is only expected in materials coming from the more stressful environments (Pecetti and Damania, 1996). Therefore, the accessions P4, P46 and P12, with greater number of tillers (>30) deserve inclusion in the next evaluations, because during the tillering stage (July/2017), the accumulated precipitation was only 21.3 mm, nearly 13% the regular (161.8 mm).

The phenotypic variability determination was performed using the multivariate analysis technique, whose characteristics analysed simultaneously. This tool has several advantages, such as identifying sources of genetic diversity and assessing the importance of the characters analysed for genetic divergence (Singh, 1981). Multivariate techniques such as clustering analysis have been successfully employed to identify divergent genotypes and better utilize the advantages provided by heterosis (Barbosa et al., 2005). This technique reveals relationships between accessions that may not be possible with univariate analysis (Hair et al., 2005). The clustering methods can be either hierarchical or optimization, but both use a distance matrix from multivariate data. For both cases, the process starts from obtaining a matrix of dissimilarity between the accessions. In studies of genetic divergence, the Mahalanobis distance (D^2) is recommended since the evaluated characteristics have a significant degree of correlations between them. In addition to their use in cluster analysis, distance matrices are extremely useful to support breeders in choosing parents. The high D^2 amplitude (52.73) showed the phenotypic divergence in the germplasm; together with the examination of the clusters, it is an important aid for understanding relations between accessions, since the hybridizations can be based on the magnitude of their dissimilarities and without potential per se of the parents (Bertan et al., 2006).

In this study, the UPGMA method was the one that best fitted the D^2 matrix (CCC = 0.76), which should preferably be higher than 0.70 (Rohlf, 1970). The UPGMA hierarchical method uses the average distances between each of the accessions pairs for the formation of each group and, therefore, it is called the average distance method. Alternatively, the optimization method proposed by Tocher adopts the criteria of maintaining the average intragroup distance always lower than any intergroup distance (Cruz and Regazzi, 2001). In this study, UPGMA and Tocher methods were highly convergent (76%) as grouping partition. By cluster analysis, both by the hierarchical method (UPGMA) and by Tocher's optimization method, the formation of a group with a high number of accessions shows a high similarity between genotypes (Silva et al., 2013; Kaur et al. 2018). Also, the presence of more than one accession in the same group induces the probability of duplicates (Oliveira et al., 2000). Consequently, the pool of conserved genes can be restricted (Podyma et al., 2019).

On the other hand, the dissimilarity between P35 (Ibirapuitã), P34 (Tapejara) and P42 (Água Santa) can be explored in breeding programs, since they formed exclusive groups in both grouping methods. These materials, along with P12 (Humaitá) and P46 (Gentil), displayed particularities regarding the attributes of flag leaf and culm. By the Singh’s method and F test, culm attributes were important variables in the discrimination of accessions or groups of them. Recently, a culm biometry has been investigated the bioenergetic potential of winter cereal straw (Zając et al., 2017).

An improvement program should not be based on the selection of accessions only due to genetic and phenotypic divergence, being necessary to consider the performance of each accession for the purpose for which it is intended. The genetic divergence, evaluated with molecular markers, provides a more precise and potentially more representative divergence for the genome as a whole; phenotypic divergence reflects a small fraction (often unknown) of the genes and environmental interaction (Kozak et al., 2011; Tamm, 2003). Therefore, the choice of parents must

Table 1. Accessions of Avena strigosa, collection site and geographic coordinates.

Accession	Collection site	Geographic coordinates
P1, P2, P3, P4, P5, P6	Pontão[1]	28° 3’ 34” S, 52° 40’ 34” W
P7	Planalto[1]	27° 19' 44" S, 53° 03' 31" W
P8	Frederico Westphalen[1]	27º 21' 33" S, 53º 23' 40" W
P10, P11	Sarandi[1]	27° 56' 38" S, 52° 55' 22" W
P12	Humaitá[1]	27° 33' 46" S, 53° 58' 26" W
P13, P14, P15	Ronda Alta[1]	27° 46' 01" S, 52° 48' 07" W
P16, P17	Barra Funda[1]	27º 55’ 23” S, 53º 02’ 21” W
P18, P19	Campinas do Sul[1]	27° 42' 57" S, 52° 37' 40" W
P20, P21	São José das Missões[1]	27° 46' 48" S, 53° 07' 19" W
P22, P23, P24, P25, P26, P27	Rondinha[1]	27° 49' 40" S, 52° 54' 36" W
P28	Nova Boa Vista[1]	27° 59' 38" S, 52° 58' 44" W
P29	Trindade do Sul[1]	27° 31' 19" S, 52° 53' 38" W
P30, P31	Almirante Tamandaré[1]	28° 06' 46" S, 52° 54' 32" W
P32	Machadinho[1]	27° 34' 01" S, 51° 40' 04" W
P33, P40, P43	Não–Me–Toque[1]	28° 27' 32" S, 52° 49' 15" W
P34	Tapejara[1]	28° 04' 04" S, 52° 0' 50" W
P42	Água Santa[1]	28° 10' 37" S, 52° 02' 02" W
P44, P45	Trindade do Sul[1]	27° 31' 19" S, 52° 53' 38" W
P46	Gentil[1]	28° 25' 48" S, 52° 02' 09" W
P35	Ibirapuitã[1]	28° 37' 26" S, 52° 30' 39" W
P36, P37, P38	Palmeira das Missões[1]	27° 53' 56" S, 53° 18' 50" W
P39	Passo Fundo[1]	28° 15' 46" S, 52° 24' 25" W
P41	André da Rocha[2]	28° 37' 51" S, 51° 34' 15" W
P9	Lagoa Vermelha[2]	28° 12' 32" S, 51° 31' 33" W

[1]Northwest mesoregion of Rio Grande do Sul, Brazil; [2]Northeast mesoregion of Rio Grande do Sul.

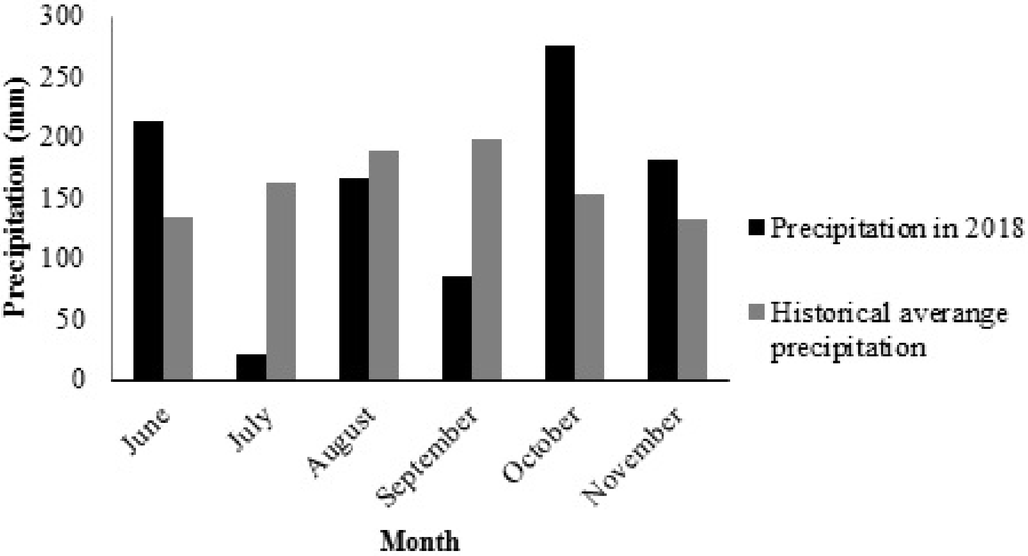

Fig 1. Monthly rainfall occurring in the experimental period and climatology normals. Passo Fundo, Rio Grande do Sul, Brasil [Source: Embrapa wheat].

Table 2. Qualitative traits in 46 accessions of *Avena strigosa*, the scale and frequency of character's state Passo Fundo, 2017.

Trait	Scale of character's scale	Frequency of state
Hairiness of glume	Absence; Presence	Absence: 100%
Waxiness of lemma	Absence; Presence	Absence: 100%
Hairiness back of lemma Hairiness on the external surface of the lemma	Absence; Presence	Presence: 100%
Grain husk	Absence; Presence	Presence: 100%
Waxiness of lemma of grain	Absence; Presence	Presence: 100%
Hairiness of uppermost node	Absence or very weak; Weak; Medium; Strong; Very strong	Absence: 100%
Intensity of hairiness of sheaths of lowest leaves	Weak; Medium; Strong	Weak: 100%
Hairiness of margins of leaf below the flag leaf	Absence or very weak; Weak; Medium; Strong; Very strong	Absent or very weak: 100%
Intensity of hairiness of uppermost node	Absent or very weak; Weak; Medium; Strong; Very strong	Very weak: 100%
Attitude of branches of panicle	Erect; Semi-erect; Horizontal; Semi-drooping; Drooping	Semi-drooping: 100%
Orientation of branches of panicle	Equilateral; Unilateral; Partially unilateral	Equilateral: 100%
Orientation of spikelets	Erect; Drooping	Drooping: 100%
Intensity of waxiness of lemma of grain	Very weak; Weak; Medium; Strong; Very strong	Very weak: 100%
Glume shape	Elliptic; Pointed; Lanceolate	Pointed: 100%
Hairiness of base of grain	Absence or very weak; weak Medium; Strong ou very strong	Weak: 100%
Length of basal hairs of grain	Short; Medium; Long	Short: 100%
Length of rachilla	Short; Medium; Long	Short: 100%
Color of lemma of grain	White, yellow, black, grey or brown	Yellow: 100%
Growth habit	Semi-erect Intermediate Semi-prostrate	24% 67% 9%
Shape of awn	Geniculate Twisted	72% 28%
Position of flag leaf	Erect Decumbent	65% 35%
Frequency of plants with recurved flag leaves	Absent or Very low Low Medium High Very high	17% 0% 70% 2% 11%

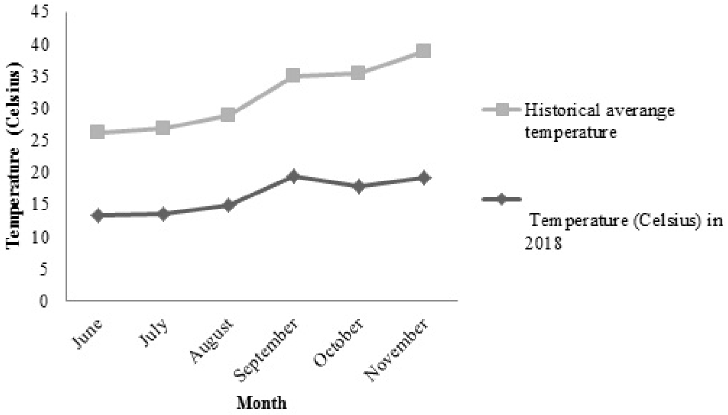

Fig 2. Average monthly temperature occurring in the experimental period and climatology normals. Passo Fundo, Rio Grande do Sul, Brasil [Source: Embrapa wheat].

Table 3. Mean, coefficient of variation (CV) range, and relative importance of traits in the phenotypic divergence (*S.j*) of 46 accessions of *Avena strigosa*.

Trait	Mean	CV (%)	Range	*S.j* (%)
Cycle	99.00	4.25	95.0–104.0	3.50
Length of lemma (mm)	14.96	5.02	13.8–16.5	6.63
Length of lower glume (mm)	18.38	4.95	17.3–19.5	3.62
Length of rachis (cm)	22.10	4.94	20.3–24.1	6.09
Length of peduncle (cm)	31.34	22.94	20.7–40.5	5.64
Average length of internodes (cm)	12.27	17.57	9.2–15.7	0.00
Length of culm (cm)	44.66	21.14	30.5–57.7	22.01
Length of flag leaf (cm)	18.76	25.90	11.5–27.9	5.13
Width of flag leaf (mm)	12.32	14.37	9.5–14.9	4.74
Culm diameter (mm)	4.38	13.05	2.8–5.3	4.00
Culm wall thickness (mm)	0.81	31.18	0.5–1.6	5.93
Number of internodes of culm	4.00	18.44	3.0–5.0	0.00
Number of reproductive tiller (number/plant)	18.00	31.05	12.0–27.0	3.30
Number of total tillers/plant	22.00	31.96	14.0–35.0	8.95
Tiller dry mass (g/tiller)	1.97	31.96	1.1–2.9	3.06
Plant dry mass (g/plant)	41.63	39.03	23.3–60.0	3.44
Plant height (cm)	107.09	4.27	100.3–115.0	3.86
Grain yield (g/plant)	5.73	18.59	3.5–8.4	5.66
1000 grain weight (g)	12.60	11.38	9.2–16.2	4.47

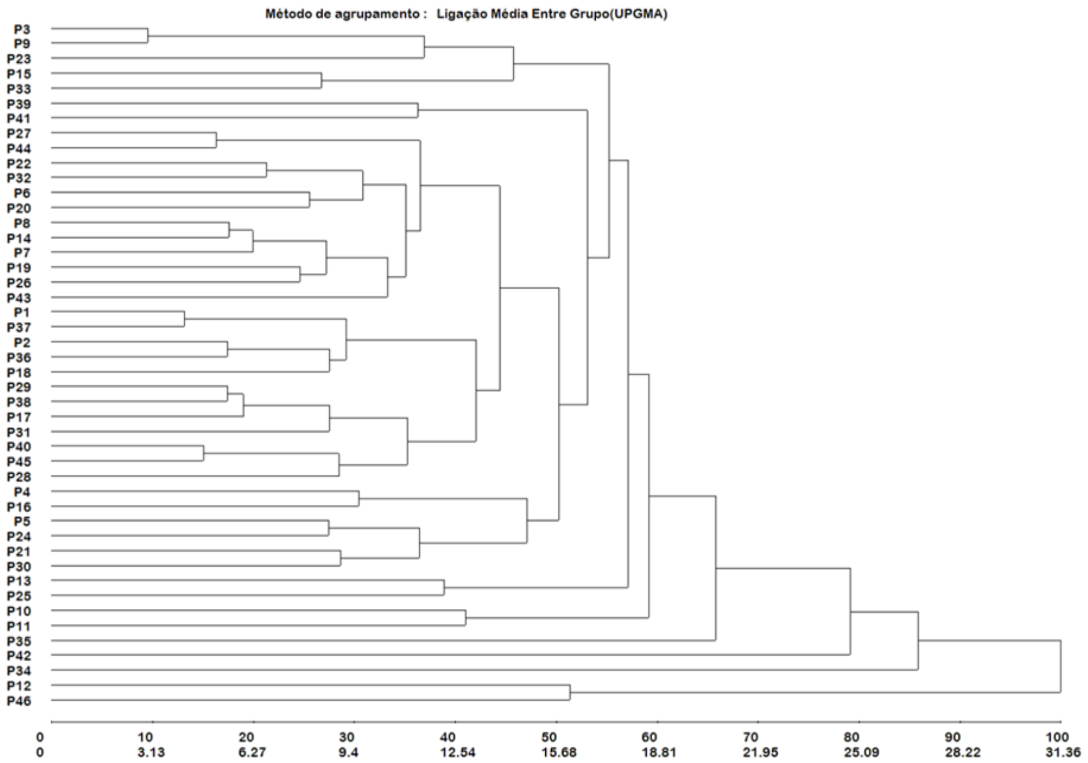

Fig 3. Dendrogram obtained by UPGMA method with Mahalanobis matrix distance (D^2) of 46 accessions of *Avena strigosa* based in 19 quantitative phenotypic traits. Cut-off: $D^2 \approx 17$. The first line of values on the abscissa axis corresponds to percentage values in relation to the dissimilarity (D^2) in the last fusion.

Table 4. Clusters of 46 accessions of *Avena strigosa* produced by the Tocher's optimization method based in 19 quantitative traits.

Cluster	Landrace accessions
I	P3, P9, P17, P40, P8, P19, P27, P14, P20, P6, P22, P32, P1, P45, P44, P37, P36, P7, P26, P28, P29, P38, P31, P30, P16, P24, P39, P18, P43
II	P15, P33
III	P5, P21, P4
IV	P13, P25
V	P23, P41
VI	P10, P11
VII	P12, P46
VIII	P34
IX	P35
X	P2
XI	P42

Table 5. Phenotypic characteristics of six groups (G) of the same composition of *Avena strigosa* landrace accessions according to different clustering methods.

Traits	GI .0, P11)	GII (P12, P46)	GIII (P35)	GIV (P34)	GV (P42)	GVI(1)
Tiller dry mass (g/tiller)	2.59 a	1.58 ab	2.60 a	1.14 b	2.29 a	2.00 a
Culm diameter (mm)	4.29 b	3.58 c	4.45 b	4.55 b	5.36 a	4.32 b
Culm thickness (mm)	0.97 ab	0.58 b	0.66 b	0.87 ab	1.58 a	0.77 ab
Width of flag leaf (mm)	13.88 a	10.20 b	12.65 ab	12.69 ab	13.61 a	12.02 ab
Length of flag leaf (cm)	22.33 ab	15.11 c	21.60 ab	18.93 bc	25.33 a	18.19 bc

In each row, the averages followed by the same letters do not differ from one another according to Tukey ($p>0.05$).

(1) P1, P6, P7, P8, P14, P16, P17, P18, P19, P20, P24, P26, P27, P28, P29, P30, P31, P36, P37, P38, P39, P40, P43, P45.

consider those who have high performance in characters of agronomic importance (Carpentieri-Pípolo et al., 2000; Loskutov, 2010), which are relevant and of high economic value. In autogamous crops such as oats, landraces could be utilized in two broad-ways: firstly, as sources of readily available genetic material to be transferred to otherwise deficient genetic backgrounds; secondly, by developing cultivars through selection of homozygous lines (Belay, 1993).

Materials and methods

Plant material and experimental design

Forty-six accessions of *A. strigosa* landraces from rural areas located in the Northwest and Northeast mesoregions of Rio Grande do Sul (IBGE, 1990) (Table 1). The 46 accessions were arranged in randomized block design, with three replicates. Each plot consisted of a 5 meter row with 26 plants, 20 cm apart from each other. The rows were spaced 50 cm apart from each other.

The experiment was conducted in the field, in a Humic Dystrophic Red Latosol, throughout 2017, in Passo Fundo, state of Rio Grande do Sul , Brazil (28.2623° S, 52.4103° W; 690 m elevation). The regional climate is humid subtropical (Maluf, 2000). During the experimental period, the average temperature was 16.7 ºC (Figure 1) and the precipitation was 700.5 mm (Figure 2). The soil presents 39.5% clay content; 5.0 pH in water; 3.3% of OM ; P 25.5 mg dm^{-3}; K 286.0 mg dm^{-3}; Al 0.7 cmol$_c$ dm^{-3}; Ca 4.6 cmol$_c$ dm^{-3}; Mg 1.4 cmol$_c$ dm^{-3}; H + Al 7.7 cmol$_c$ dm^{-3}; CTC 14.4 cmol$_c$ dm^{-3}; base saturation 46.0%; Al saturation 9.0%; K saturation 5.1%. Fertilization was applied at sowing, with 200 kg ha^{-1} 5–20–20, in June 21, 2017; nitrogen topdressing fertilization was carried out with urea, in the proportion of 67 kg ha^{-1} N, which were splitted into two applications, at the tillering and culm elongation. During the culture cycle, cultural treatments were carried out for weed, insects and diseases control.

Evaluations

The accessions were characterized according the assessment of distinctness, uniformity, and stability to 26 descriptors by *Avena* L. (BRASIL, 2002) and 21 of them were either binary or multicategoric, while five were quantitative: cycle (days to heading), plant length, peduncle, glume and lemma. The evaluations were carried out in predetermined phenological stages according to the decimal code for the cereals' growth stages (Zadoks et al., 1974). These evaluations were carried out in ten plants per plot, in a total of thirty plants. Additionally, at the full bloom stage it was evaluated the number of total tillers per plant, the number of reproductive tillers per plant, the diameter and wall thickness of the second internode of the main culm, the number of internode of the main culm, the average length of internode, the width and length of the flag leaf, the accumulation of dry mass per plant, the yield and weight of thousand grains. The dry mass was obtained by drying the plant material in a forced air oven at 60 ºC ± 3 °C until constant weight.

Statistical analysis

Data on qualitative descriptors were considered based on the observation of the statistical mode, the most commonly occurring value in a set of data. For the quantitative data, analysis of variance (ANOVA) was performed using F test. The Mahalanobis distance (D^2) was adopted as a dissimilarity measure, and the relative contribution of character to phenotypic divergence was evaluated using Singh's method (Singh, 1981). The clustering analysis was performed using Tocher's optimization method and the UPGMA hierarchical method using the D^2 matrix. The choice by the UPGMA method was based on the cophenetic correlation coefficient (*CCC*= 0.75) magnitude, which was superior to the other tested methods (Ward, Complete Linkage and Simple Linkage). The groups formed by the same accessions, according to the methods of Tocher and UPGMA, were submitted to ANOVA: the groups constituted the treatments and the accessions constituted the replication (Costa et al., 2012). When significant, the means were compared by the Tukey test ($p<0.05$). All statistical analyses were performed using the software Genes (Cruz, 2006).

Conclusion

There is significant phenotypic divergence among accessions of *A. strigosa* from Northwest and Northeast mesoregions of Rio Grande do Sul, what indicates the possibility of exploitation in breeding programs of the species. Habit growth, thickness, diameter, and length of culm are important characters in the discrimination of the 46 accessions. The accessions P25 and P26 (Rondinha), P33 (Não-Me-Toque) and P7 (Planalto) are promising for obtaining cultivars of semi-prostrate habit. The accession P42 (Água Santa) is opposite to P12 (Humaitá) and P46 (Gentil) in terms of diameter and thickness of culm and size of flag leaf, which can subsidize the development of cultivars with different features. P12 and P46 still deserve attention due to the high tillering, which occurred in a drought period, indicating better incidence of this type of stress than in other accessions. Further studies are needed to confirm this characteristic including studies with other stress conditions (drought, salinity, cold or nutrient).

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