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Research Paper

Evaluation and strategies of tolerance to water stress in *Paspalum* germplasm

Evaluación y estrategias de tolerancia a estrés hídrico en germoplasma de Paspalum

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Abstract

The evaluation of genetic resources in germplasm banks of *Paspalum* can contribute to their use in breeding programs and for advanced research in biotechnology. This study evaluated the tolerance of 11 *Paspalum* accessions to abiotic stress caused by soil water deficit in a greenhouse experiment at Embrapa Pecuária Sudeste, São Carlos, state of São Paulo, Brazil. The variables analyzed were: dry biomass of green matter, dead matter and roots; leaf area; leaf water potential; number of days to lose leaf turgor (wilting); soil moisture at wilting; and number of tillers per pot. The results showed high genetic variability for all traits, not only among species but also within species, and also reflected the existence of different strategies of response and potential adaptation to water deficit events. For breeding programs, when the aim is to produce materials better adapted to the occurrence of prolonged drought, 5 accessions from this group seem to have good potential: *P. malacophyllum* BGP 289, *P. quarinii* BGP 229, *P. regnellii* BGP 112, *P. conspersum* BGP 402 and *P. urvillei* x *P. dilatatum* BGP 238. Conversely, when the goal is to select materials for short-term water stress conditions, 6 accessions stand out: *P. atratum* BGP 308, *P. regnellii* BGP 215, 248 and 397, *P. dilatatum* BGP 234 and *P. malacophyllum* BGP 293.

Keywords*:* Abiotic stress, genotypes, germplasm bank, water deficit.

Resumen

La evaluación de recursos genéticos en bancos de germoplasma de *Paspalum* constituye una gran ayuda en programas de mejoramiento genético y de investigación avanzada en biotecnología. En un experimento en macetas en Embrapa Pecuária Sudeste, São Carlos, estado de São Paulo, Brasil, se evaluó la tolerancia de 11 accesiones de varias especies de *Paspalum* al estrés abiótico causado por el déficit hídrico en el suelo. Las variables analizadas fueron: biomasa seca de la materia verde, materia muerta y raíces; área foliar; potencial hídrico foliar; número de días hasta la pérdida de la turgencia foliar (marchitamiento); humedad del suelo al momento del marchitamiento de las plantas; y número de brotes por planta. Los resultados mostraron tanto una alta variabilidad genética para todos los parámetros, no solo entre las especies, sino también dentro de las especies, como la existencia de diferentes estrategias de respuesta y potencial adaptación a eventos de déficit hídrico. Para los programas de fitomejoramiento, cuando el objetivo es producir materiales mejor adaptados a la sequía

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prolongada, las accesiones con mayor potencial fueron: *P. malacophyllum* BGP 289, *P. quarinii* BGP 229, *P. regnellii* BGP 112, *P. conspersum BGP 402* y *P. urvillei x P. dilatatum BGP 238.* Por el contrario, cuando el objetivo es seleccionar materiales para condiciones de estrés hídrico de corta duración, se destacan las accesiones: *P. atratum* BGP 308, *P. regnellii* BGP 215, 248 y 397, *P. dilatatum* BGP 234 y *P. malacophyllum* BGP 293.

Palabras clave*:* Banco de germoplasma, déficit hídrico, estrés abiótico, genotipos.

Introduction

According to predictions from the fifth assessment report (AR5) of the Intergovernmental Panel on Climate Change (IPCC 2013) global temperature may increase by up to 4.8 °C by 2100, with increased variability and occurrence of extreme events. In Brazil, a regionalized projection suggests trends for increasing maximum and minimum extremes of temperature and high spatial variability for precipitation when analyzing different emission scenarios (Marengo et al. 2009). The challenges presented by the effects of climate change scenarios on agriculture are adaptation of production systems and mitigation of greenhouse gas emissions.

Plant breeding programs are designed to incorporate relevant traits, such as high dry matter yield, high nutritional value and increased resistance to or tolerance of biotic and abiotic factors into elite genetic resources, with the aim of releasing cultivars better suited to the conditions of use. Knowledge of these characteristics in genotypes conserved in gene banks provides fundamental information that allows the selection of appropriate accessions for use both in breeding programs and in biotechnology research.

The characterization of accessions conserved in germplasm banks is essential to ensure their efficient use for different purposes. For example, the study of responses of forage plants to stress caused by water deficit is of utmost importance, since moisture restriction can greatly reduce forage production and persistence of pasture (Guenni et al. 2002; Melo et al. 2003; Araújo et al. 2012; Volaire et al. 2014).

The genus *Paspalum* belongs to the family Poaceae and includes several grasses with forage potential. More than 330 species have been identified (Zuloaga and Morrone 2003), occurring widely in South America (Quarín et al. 1997), including the Pampas, where the grass is grazed by cattle, in particular. Nevertheless, its use in cultivated pastures is still low in Brazil, while in other countries, like the USA, many species of *Paspalum* that occur in Brazil, such as *Paspalum notatum*, *P. dilatatum*, *P. plicatulum* and *P. guenoarum*, are used successfully as forages (Acuña et al. 2011). The number of accessions and species conserved has been growing in recent years, and the Germplasm Bank (GB) of Embrapa Pecuária Sudeste contains more than 340 accessions of 49 different species of *Paspalum*, most belonging to the informal group Plicatula.

Batista and Godoy (2000) evaluated the dry matter (DM) production of 217 accessions of *Paspalum* from the *Paspalum* GB of Embrapa Pecuária Sudeste, using *B. decumbens* and *Andropogon gayanus* cv. Baetí as controls. While 58 accessions (27%) showed DM production equal to or higher than the cultivars used as controls, the selection and development of new cultivars should also take into account the plasticity in the response of the genotype to specific conditions.

Some species of *Paspalum*, such as *P. vaginatum* (Shahba et al. 2014) and *P. notatum* (Acuña et al. 2010), have characteristics of interest in relation to drought tolerance. While some species have high forage value, no controlled experiments checking the tolerance to water stress of species like *P. atratum*, *P. conspersum*, *P. dilatatum*, *P. malacophyllum*, *P. quarinii* and *P. regnellii* have been conducted. According to Zuloaga and Morrone (2003), *P. malacophyllum* is found from Mexico to northern Argentina, Paraguay, Brazil and Bolivia, at elevations from sea level to 3,000 m. It is found in agricultural fields, roadsides and woodlands. In turn, *P. regnellii* is distributed from the center to the south of Brazil, northeastern Argentina and eastern Paraguay. Both *P. conspersum* and *P. regnellii* are recorded in forest edges or disturbed sites, in heavy clay soils which are subject to waterlogging. Accession BGP 238 used in this study is a natural hybrid derived from a cross between *P. urvillei* and *P. dilatatum*. Since *P. urvillei* has sexual reproductive behavior, it is common to observe hybrids in populations where these species coexist.

This study evaluated the tolerance to soil moisture stress in some germplasm accessions of *Paspalum*, aiming at identifying genes for drought-tolerance and transferring them to other plant families in future breeding programs.

Materials and Methods

The experiment was conducted in a greenhouse, at Embrapa Pecuária Sudeste, in São Carlos, state of São Paulo (21°57’ S, 47°50’ W; 860 m asl). We evaluated 11 accessions of 7 distinct species of *Paspalum* belonging to 5 different informal groups. Seeds were obtained from the germplasm bank of Embrapa Pecuária Sudeste (Table 1).

The accessions were chosen after a previous study identified genotypes more suitable for forage production. Among these genotypes, 2 belonged to the informal botanical group Dilatata (BGP 234, *Paspalum dilatatum* Poir. biotype Uruguaiana and BGP 238, a natural hybrid between *P. urvillei* Steud. and *P. dilatatum*), 2 to the group Malacophylla (BGP 289 and BGP 293, *Paspalum malacophyllum* Trin.), 1 to the group Plicatula (BGP 308, *Paspalum atratum* Swallen), 1 to the group Quadrifaria (BGP 229, *Paspalum quarinii* Mez) and 5 to the group Virgata (BGP 402, *Paspalum conspersum* Schrader and BGP 112, 215, 248 and 397, *Paspalum regnellii* Mez).

Seedlings were grown on trays filled with organic substrate Plantmax® and transplanted to pots at the 3-leaf stage with 2 plants per pot. Pots with capacity of 8.5 L were filled with 7 kg sieved soil, with the following chemical and physical characteristics: pH_{CaCl2} 5.4, OM 25 g/dm^3, P_{resin} 6 mg/dm^3, SO_4-S 21 mg/dm^3, K 1.3 mmolc/dm^3, Ca 26 mmolc/dm^3, Mg 14 mmolc/dm^3, H+Al 24 mmolc/dm^3, Al 0 mmolc/dm^3, CEC 66 mmolc/dm^3, base saturation 63%, sand 417 g/kg, silt 253 g/kg and clay 330 g/kg.

Each pot was fertilized with 1.07 g N as urea, 1.4 g P as simple superphosphate, 0.53 g K as potassium chloride, following the recommendations of Malavolta (1980) for experiments in pots.

The experimental layout was an 11 (accessions) x 2 (water conditions) x 3 (replications) factorial in a complete randomized block design. The 2 watering treatments were unwatered and irrigated regularly. When the plants had at least 3 tillers, irrigation of pots in the treatment with water stress was suspended, while irrigation of pots in the control treatment continued with a daily amount of water equivalent to the air evaporative demand as measured by several Piche evaporimeters located at random in the greenhouse.

Plants of particular accessions in the unwatered treatment were harvested when the first leaf blade displayed wilting in the predawn period, so different accessions were collected on different days. Concomitantly, in the same block, we collected a pot with 2 plants of the same accession from the control treatment. Therefore, 2 pots were collected on each occasion for each accession, 1 from the stressed treatment showing symptoms of wilting and another with well-watered plants from the control.

Table 1. Identification codes (BGP and collection), species names, collection sites and informal botanical groups of *Paspalum* accessions evaluated in this study.

Site code (BGP)	Collection code	Species	Collection site	Botanical group
112	VDBdSv 10073	*P. regnellii* Mez	Praia Grande - Santa Catarina - Brazil	Virgata
215	Lr 2	*P. regnellii* Mez	Itirapina - São Paulo - Brazil	Virgata
229	VTsDp 14220	*P. quarinii* Morrone & Zuloaga	São Miguel das Missões - Rio Grande do Sul - Brazil	Quadrifaria
234	VTsDp 14251	*P. dilatatum* Poir. biotipo Uruguaiana	Uruguaiana - Rio Grande do Sul - Brazil	Dilatata
238	VTsZi 14285	*P. urvillei* x *P. dilatatum*	Xangri-lá - Rio Grande do Sul - Brazil	Dilatata
248	VTsRcRm 14424	*P. regnellii* Mez	Capão Alto - Santa Catarina - Brazil	Virgata
289	VRcMmSv 14582	*P. malacophyllum* Trin.	Aral Moreira - Mato Grosso do Sul - Brazil	Malacophylla
293	VRcMmSv 14606	*P. malacophyllum* Trin.	Japorã - Mato Grosso do Sul - Brazil	Malacophylla
308	VRcMmSv 14525	*P. atratum* Swallen	Terenos - Mato Grosso do Sul - Brazil	Plicatula
397	-	*P. regnellii* Mez	unknown origin	Virgata
402	-	*P. conspersum* Schrader	unknown origin	Virgata

Collectors: Bd = I.I. Boldrini; D = M. Dall´Agnol; Dp = Dario Palmieri; Lr = L.A.R. Batista; Mm = M.D. Moraes; Rc = Regina Célia de Oliveira; Rm = R. Miz; Sv = Glocimar P. da Silva; Ts = T. Souza-Chies; V = José Francisco M. Valls; Zi = F. Zilio.

When the plants were harvested, the following parameters were measured: leaf water potential (MPa), determined in the last expanded leaf, in the pre-morning period, with the aid of a psychrometer (Wescor micrometer Psypro model and sample chamber model C52), where a microvoltmeter is connected to chambers where, after being calibrated with NaCl standard solution, 25 mm diameter leaf discs are placed to be measured; green biomass; dead biomass; and root biomass determined after each of the parts was packed in paper bags and dried in a circulation oven at 65 °C until reaching constant weight; total leaf area, measured using the LI-COR leaf area integrator, model LI-3100; days to turgor loss (wilting); soil moisture at wilting determined by weighing wet soil and then drying to constant oven weight at 105 °C; and number of tillers per pot.

At the completion of the harvests, data were analyzed using the PAST software (Hammer et al. 2001), using principal component analysis. This analysis is based on grouping assessments to determine the genetic differences (Cruz 2006).

Results

There were no significant interactions among genotypes and watering treatments for any of the variables. There was an increase (P<0.0001) in dry biomass of dead material of shoots (Figure 1A) in all studied accessions under water restriction, especially for *P. regnellii* BGP 215, which showed 62% more dead material than the control. There was no significant difference among genotypes (P = 0.09).

Despite the lack of significant differences in green biomass between accessions (P = 0.066), there was wide variation among accessions in response to drying (P<0.0001). Dry biomass of green matter of accessions *P. malacophyllum* BGP 293 and *P. regnellii* BGP 248 was reduced by only 7 and 8%, respectively, as a result of moisture stress, while accessions *P. regnellii* BGP 215 and BGP 112 showed decreases of 36 and 40% (Figure 1B).

Root biomass varied among accessions (P = 0.0004) as did responses to drying (Figure 1C). Under irrigated conditions, accessions *P. urvillei* x *P. dilatatum* BGP 238 and *P. conspersum* BGP 402 produced the highest root yields, while *P. malacophyllum* BGP 289 and BGP 283 produced the lowest. Drying out under moisture stress produced quite variable responses in root biomass, with a range from an increase of 34% in root biomass for *P. regnellii* BGP 215 to a decrease of 42% for accession *P. conspersum* BGP 402. For this variable, there was no significant difference among treatments (P = 0.3099).

Moisture stress caused a reduction (P<0.0001) in leaf area (Figure 1D) in all accessions, reaching 85% in *P. regnellii* BGP 215, with no significant differences among genotypes (P = 0.43).

Drying caused significant differences (P<0.0001) in leaf water potential values in all accessions (Figure 1E), with no significant differences among accessions (P = 0.33). In contrast, the number of tillers per pot (Figure 1F) was affected differently by drying for different genotypes (P<0.0001). Responses ranged from an increase in the number of tillers under water stress conditions of 19% for *P. quarinii* BGP 229 to a decrease of 34% in tiller numbers for *P. malacophyllum* BGP 293. There was considerable variation among accessions in time to wilting following the cessation of watering, with a range from 9 days for *P. regnellii* BGP 215 to 22 days for *P. malacophyllum* BGP 289 (Figure 1G) (P<0.0001). However, most accessions wilted between 17 and 22 days after watering ceased. At the point of wilting for all accessions, soil moisture levels were about 12% (Figure 1H).

Principal Component Analysis (PCA) was performed to group accessions according to the variables that had most influence on their responses. Figure 2A illustrates the PCA comparing the accessions under both drought and well-watered conditions, and considering all the variables recorded in this study. The cumulative variance of the first 2 components was 73.9%. The x-axis was characterized by leaf area and the y-axis by the number of tillers. Two distinct groups were formed, one consisting of accessions under water restriction (to the left) and the other composed of non-stressed accessions (to the right), indicating differences between the groups; water restriction was critical in changing the main characteristics of plants.

The principal component analysis run only with accessions under water stress, indicated that the variables that explained best the distribution of genotypes were soil moisture on the x-axis, and dry biomass of roots on the y-axis (Figure 2B). The cumulative variance for the 2 axes was 68.4%. In Figure 2B, accessions were grouped according to certain characteristics in main number of tillers, wilting days, leaf area, water potential and soil moisture. Accession *P. regnellii* BGP 215 stood out among other accessions by the higher dry biomass of roots, *P. malacophyllum* BGP 293 by the larger leaf area, *P. regnellii* BGP 248 by the higher dry biomass of green matter and soil moisture and accession *P. urvillei* x *P. dilatatum* BGP 238 by dry biomass of dead matter and roots. The variable water potential grouped the accessions *P. dilatatum* BGP 234, *P. regnellii* BGP 397 and *P. atratum* BGP 308, while number of tillers and days to wilting determined the group formed by *P. malacophyllum* BGP 289, *P. quarinii* BGP 229, *P. conspersum* BGP 402 and *P. regnellii* BGP 112.

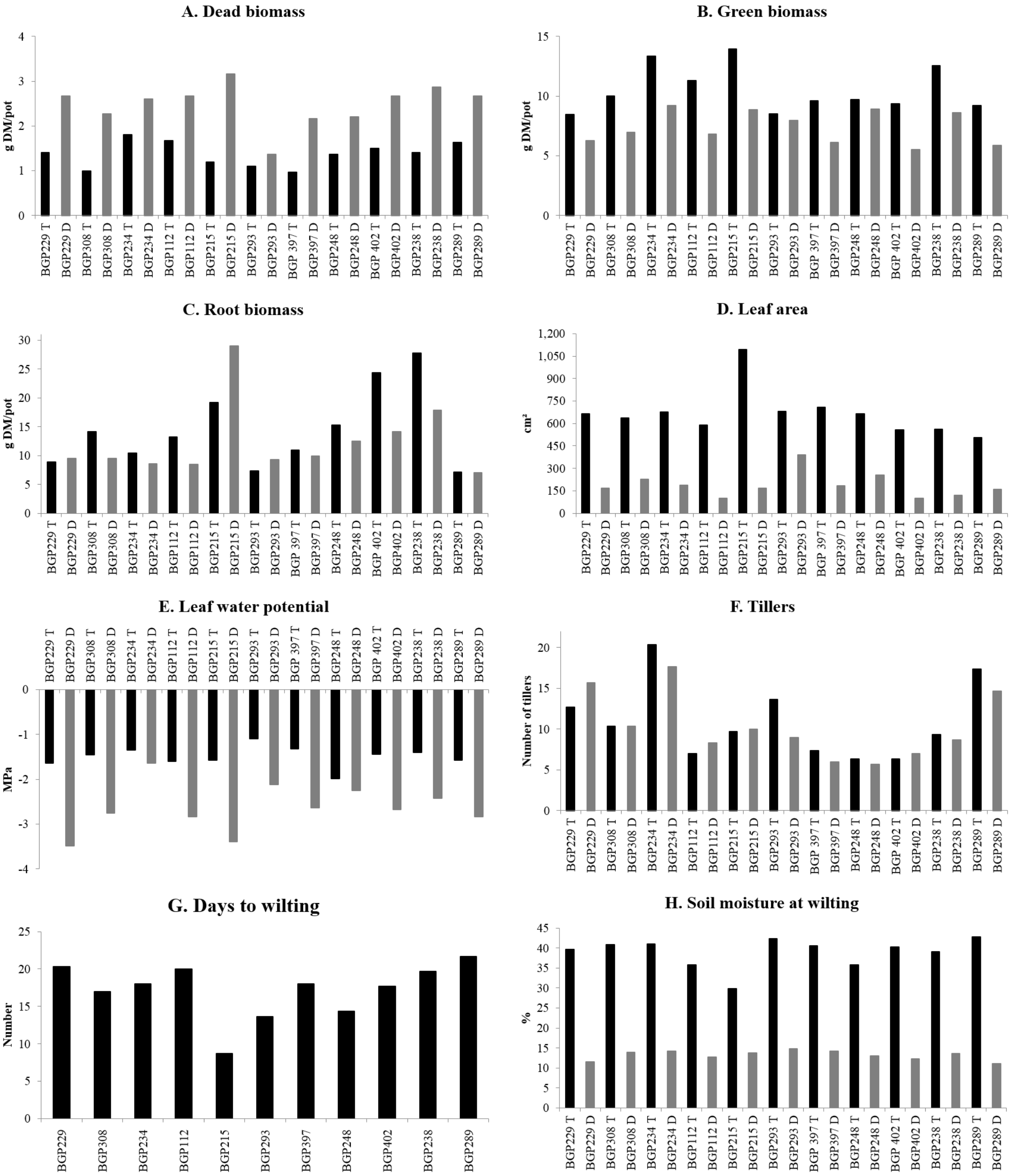

Figure 1. Mean values of the measured variables for the *Paspalum* accessions used in this study. Black bars indicate non-stressed plants and grey bars indicate plants under water stress. **A.** Dead biomass (g DM/pot); **B.** Green biomass (g DM/pot); **C.** Root biomass (g DM/pot); **D.** Leaf area (cm^2); **E.** Leaf water potential (MPa); **F.** Number of tillers; **G.** Days to wilting; **H.** Soil moisture at wilting (%).

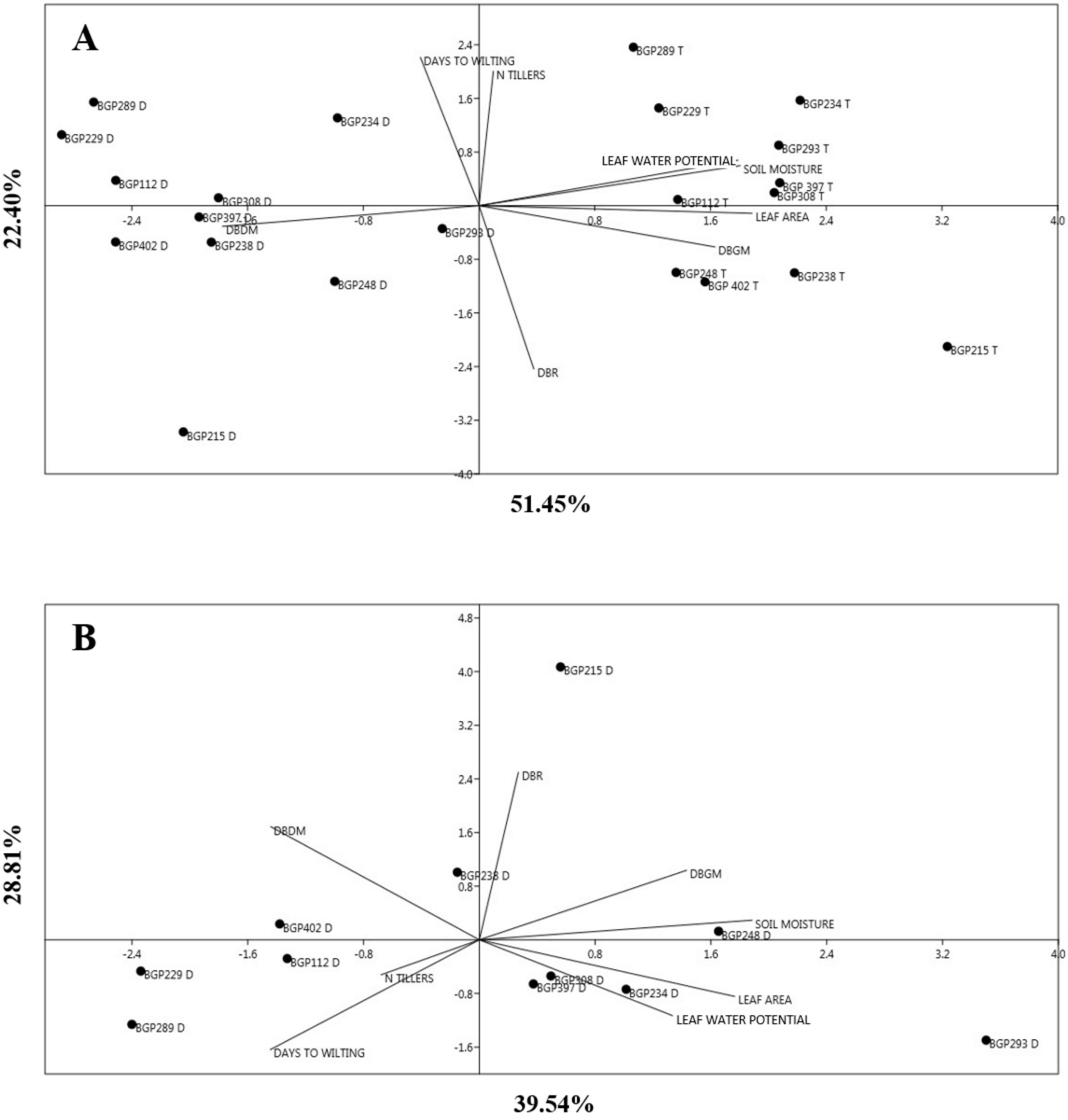

Figure 2. **A** – Principal component analysis of accessions of *Paspalum* subjected (represented by letter D) or not (represented by letter T) to water stress. **B** – Principal component analysis with only accessions of *Paspalum* subjected to water stress. Analyses were made considering all variables evaluated (dry biomass of: dead matter - DBDM, green matter - DBGM and roots - DBR; leaf area; leaf water potential; number of tillers; soil moisture at wilting; and days to wilting).

Discussion

This study has provided interesting data on the comparative tolerances of a range of *Paspalum* accessions to low soil moisture situations. As such it provides indications of which accessions might be appropriate for inclusion in breeding programs with specific aims. However, more real differences between accessions might exist than appear from our results. The number of significant differences obtained between accessions may have been limited by the low numbers of plants examined for each treatment combination as large differences in treatment means in some cases proved to be non-significant (P>0.05). If larger numbers of plants had been included per treatment, more differences might have been recorded as significant.

Mechanisms of tolerance to stress by water deficit in Paspalum

Physiological responses of plants to drought conditions are considered primary characteristics because they are rapidly triggered in the presence of stress (Sherrard et al. 2009). According to Garcez Neto and Gobbi (2013), all effects caused by water stress lead to production loss and possible adjustments should be achieved for ecological sustainability and productivity of forage grasses grown in environments with eventual or permanent water restrictions.

The increase in dry biomass of dead matter in unwatered treatments was not surprising as death of plant parts as a result of moisture stress is well recognized (Figure 1A, 1B and 1D). Mattos et al. (2005) studied 4 species of *Urochloa* subjected to low water availability and observed a decrease in leaf elongation rate and increased senescence of leaf blades for all species.

Some species lose leaves as drought is intensified, which is known as an avoidance mechanism. This strategy allows water savings, because the smaller leaf area reduces transpiration of water by the plant, favoring the maintenance of turgor, plus some photosynthetic activity and carbon gain for a longer time period (Givnish 1987; Lamont et al. 2002; Escudero et al. 2008). Reduction in water loss and protection of meristems can also ensure regrowth and survival of plants when drought conditions occur, and thus represent a strategy that some plants use to tolerate drought (Volaire and Lelièvre 2001; Munne-Bosch and Alegre 2004; Volaire et al. 2014).

Besides decreasing the production of plant biomass, drought can change the photoassimilate partitioning in plants. Studies with *Urochloa* and *Paspalum* subjected to water deficit demonstrated a greater allocation of photoassimilates to the root system enabling the exploitation of a larger volume of soil for water absorption, maintaining hydration levels in the tissue for longer (Baruch 1994; Casola et al. 1998). The results of biomass partitioning showed that some accessions invested in root biomass to a greater extent than others.

The decrease in leaf water potential with decreasing soil moisture (Figure 1E) was observed previously by Mattos et al. (2005) in *Urochloa* species, where the leaf water potential reduced by a factor of 8 in *U. mutica* and by a factor of 4 in the other species studied, *U. humidicola, U. decumbens* and *U. brizantha*. The reduction in leaf water potential is the consequence of losing water from stomata, which is not compensated for by water extraction from the soil. Osmotic adjustment is considered as a physiological mechanism to maintain turgor at low leaf water potentials. The decrease in the osmotic potential, due to the accumulation of sugars, organic acids and ions in the cytosol, allows the plant to continue to absorb and translocate water to the shoot under conditions of lower water availability (Bray 1997).

In this experiment, the effect of water restriction on number of tillers varied according to genotype (Figure 1F). This result suggests a variation among *Paspalum* genotypes in relation to the capacity to protect meristematic tissues from dehydration during periods of water restriction. The reduction in the number of tillers is related to lower activity of cell division in the meristematic zone, responsible for leaf initiation (Skinner and Nelson 1995), which also influences the activation of axillary buds in the formation of new tillers, prioritizing existing tillers (Garcez Neto and Gobbi 2013).

The ability of accessions *P. quarinii* BGP 229, *P. regnellii* BGP 112, *P. urvillei* x *P. dilatatum* BGP 238 and *P. malacophyllum* BGP 289 to delay dehydration longer than others would have been partially due to the reduction in leaf area and water potential, which would have led to energy savings.

Grouping and classification of Paspalum *genotypes according to tolerance to drought*

Among the accessions there is genetic diversity, as seen in the PCA. However, there was no grouping per species or per botanical group, which reflects the high genetic variability that may be present not only among species but also within each species of this genus. Our results suggest that these *Paspalum* accessions can be grouped according to response strategies to stress caused by water restriction. The first group comprised of *P. regnellii* BGP 215, 248 and 397, *P. malacophyllum* BGP 293, *P. dilatatum* BGP 234 and *P. atratum* BGP 308 showed the best values in variables of development; the second group made up of accessions *P. malacophyllum* BGP 289, *P. quarinii* BGP 229, *P. regnellii* BGP 112 and *P. conspersum* BGP 402 were characterized by the greatest number of days to lose turgor in the predawn period and genotype *P. urvillei* x *P. dilatatum* BGP 238 was not grouped with the others, forming a specific group. Apparently, there was no correlation between collecting site and strategy used by plants to overcome water deficit.

Accessions that stood out in terms of development variables can be further divided into 3 subgroups: *P. regnellii* BGP 215 (group 1); *P. malacophyllum* BGP 293 (group 2); *P. atratum* BGP 308, *P. regnellii* BGP 397, *P. dilatatum* BGP 234 and *P. regnellii* BGP 248 (group 3).

According to PCA and the mean values of variables represented in it, accession *P. regnellii* BGP 215 was the first to wilt, despite increased root system biomass and reductions in leaf area. This result suggests that this accession is able to maintain productivity under mild water stress by expanding the root system and exploration of a greater volume of soil, but is not tolerant of severe drought. Pérez-Ramos et al. (2013) found that accessions with a more aggressive survival strategy based on increased acquisition of resources, when in deep soils, reduce the rate of dehydration of the meristem by deepening the root system and increasing the absorption of water.

Santos et al. (2013) studied forage plants of the genus *Urochlo*a under water stress and also observed different behavior among the cultivars, which presented different strategies of survival. *Urochloa brizantha* cv. Piatã decreased vegetative development, consequently reducing production, indicating a conservative strategy, lowering metabolism for its survival; *U. brizantha* cv. Marandu presented a more aggressive strategy, which did not reduce productive development, but maintained high productivity, which, according to the authors, promoted advantages under mild stress, but under conditions of severe stress, survival may be compromised because there was no reduction of metabolism.

Accession *P. malacophyllum* BGP 293 presented a distinct response (Figure 1); even though wilted at 14 days, it maintained a relatively high leaf area and little biomass of dead matter at the time of harvest (Figures 1A and 1D). The high leaf water potential (Figure 1E) indicates that osmotic adjustment is not among the main mechanisms of tolerance to water stress of this genotype, because early stomatal closure helps control water loss. On the other hand, little change in root biomass (Figure 1C), along with the other observed results, suggests that it may use stomatal control mechanisms to reduce water loss and delay tissue dehydration.

Accession *P. urvillei* x *P. dilatatum* BGP 238 behaved similarly to accession *P. regnellii* BGP 215 because it also has high values of biomass of dead matter and roots but, unlike BGP 215, the moisture stress had a negative effect on root biomass, with 35% reduction compared with the control (Figure 1C). Time to wilting of BGP 238 was relatively long, being similar to that of genotypes that were grouped by this characteristic (*P. regnellii* BGP 289, *P. quarinii* BGP 229, *P. regnellii* BGP 112 and *P. conspersum* BGP 402; Figures 2 and 1G), but the biomass of green matter was higher, suggesting that this accession has good potential for use under conditions where there is risk of severe drought (Figures 2 and 1B).

Accessions *P. malacophyllum* BGP 289, *P. quarinii* BGP 229, *P. regnellii* BGP 112 and *P. conspersum* BGP 402, which were characterized by the greatest number of days to wilting (Figures 2 and 1G), presented a more conservative strategy of use of natural resources, which provided high tolerance to conditions of severe water stress. More conservative genotypes in the use of resources have smaller leaf area, maintain turgor and activate osmoregulation mechanisms at the leaf blade level during moderate drought, and under reduced water availability, they prioritize meristems and tips of the roots, ensuring the recovery of plants after the elimination of stress (Volaire and Lelièvre 2001; Volaire et al. 2014). This is because meristems exhibit higher osmotic adjustment than other tissues during drought (Munns et al. 1979; Matsuda and Riazi 1981; West et al. 1990) and therefore have potential for regeneration when the aerial part of the plant is dead (Van Peer et al. 2004).

The *Paspalum* accessions evaluated in this study can be categorized according to their strategies in response to abiotic stress due to imposed water restriction. Knowledge of these survival strategies, which may focus on reduced development or maintenance of productivity, will contribute to the creation and selection of genotypes for use in the *Paspalum* breeding program. This assumes greater importance as more severe global climate change scenarios are forecast.

Under the conditions of this experiment, where the evaluation assessment was interrupted when the genotype's shoots wilted in the predawn period and no recovery period was allowed, it is suggested that accessions be separated into 2 groups so that they can be used in breeding programs aimed at tolerance to drought.

For environments subjected to the occurrence of prolonged droughts, the most promising candidates appear to be: *P. malacophyllum* BGP 289, *P. quarinii* BGP 229, *P. regnellii* BGP 112, *P. conspersum* BGP 402 and *P. urvillei* x *P. dilatatum* BGP 238, as they adopt strategies in which survival under adverse conditions is prioritized. On the other hand, for cases of mild-moderate water stress, priority should be given to accessions *P. atratum* BGP 308, *P. regnellii* BGP 215, BGP 248 and BGP 397, *P. dilatatum* BGP 234 and *P. malacophyllum* BGP 293, where productivity losses during water restriction are lower.

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