Ornamental Horticulture
ISSN 2447-536X | WWW.ORNAMENTALHORTICULTURE.COM.BR
SBFPO Sociedade Brasileira de Floricultura e Plantas Ornamentais

ARTICLE

Assessment of ornamental grass accessions under varying salinity levels

Avaliação de acessos de gramíneas ornamentais em relação a diferentes níveis de salinidade

Léa de Oliveira da Costa[1], **Ana Cecília Ribeiro de Castro**[2*], **Carlos Alberto Kenji Taniguchi**[2] **and Marlos Alves Bezerra**[2]

[1] Universidade Federal do Ceará (UFC), Centro de Ciências Agrárias, Fortaleza-CE, Brasil.
[2] Embrapa Agroindústria Tropical (CNPAT), Sistema de Produção, Fortaleza-CE, Brasil.

Abstract: Lawns play a key role in enhancing public spaces, preventing soil erosion, and acting as barriers against dust and sludge. In Brazil, *Paspalum notatum* is widely cultivated for its adaptability to the country's ecosystems and the availability of native ecotypes. However, soil salinization, a growing ecological concern, can limit lawn growth due to sodium and chloride ion toxicity. This study aimed to identify the most tolerant among five genotypes (Aruaí and Tiriba cultivars, BRA 010006 and BRA 019178 accessions and the commercial species *Axonopus fissifolius*) subjected to salinity levels (0.5, 1.5, 3.0, 4.5, and 6.0 dS m^{-1}). Analyzed variables included Na and Cl contents in plants, growth parameters (leaf and root dry mass and soil coverage), and morphological symptoms. No significant changes in leaf color or damage compromising aesthetics or functionality at salinity levels from 0.5 to 1.5 dS m^{-1}, with only occasional yellowing or minor scorch. Higher salinity led to leaf burn and yellowing, particularly in accession BRA 010006 and the control. Sodium and chloride contents, especially sodium, was higher in roots than leaves. Accession BRA 019178, followed by cultivars Aruaí and Tiriba, demonstrated moderate tolerance, maintaining satisfactory soil coverage and dry mass across the tested salinity levels. These findings highlight the importance of selecting native turfgrasses with enhanced salt tolerance for landscaping applications in saline-prone areas.
Keywords: germplasm, lawn, *Paspalum notatum,* salt tolerance, turfgrass.

Resumo: Gramados desempenham papéis importantes na valorização de espaços públicos, na prevenção da erosão do solo e na proteção contra poeira e lama. No Brasil, o *Paspalum notatum* é uma espécie muito cultivada, devido à sua adaptação aos diversos ecossistemas do país e ao grande número de ecótipos nativos. No entanto, a salinização dos solos, uma preocupação ecológica crescente, pode limitar o crescimento dos gramados devido à toxicidade dos íons de sódio e cloreto. Este estudo teve como objetivo avaliar cinco genótipos (cultivares Aruaí e Tiriba, acessos BRA 010006 e BRA 019178 e a espécie comercial *Axonopus fissifolius*) submetidos a níveis de salinidade (0,5; 1,5; 3,0; 4,5 e 6,0 dS m^{-1}). As variáveis analisadas incluíram teores de Na e Cl nas plantas e parâmetros de crescimento (massa seca de folhas e raízes e cobertura de solo) e sintomas morfológicos. Não foram verificadas alterações nas cores e danos que comprometeram a estética e a funcionalidade das plantas nas condutividades elétricas de 0,5 a 1,5 dS m^{-1}, com eventual amarelecimento e queima das folhas. O valor mais alto de salinidade provocou queimadura e amarelecimento das folhas, principalmente no acesso BRA 010006 e na testemunha. Os teores de sódio e cloreto, especialmente sódio, foram maiores nas raízes do que nas folhas. O acesso BRA 019178, seguido das cultivares Aruaí e Tiriba, demonstrou tolerância moderada, mantendo cobertura de solo e massa seca satisfatórias nos níveis de salinidade testados. Os resultados destacam a importância da seleção e gramados nativos com maior tolerância aos sais para aplicações paisagísticas em áreas propensas a salinidade
Palavras-chave: germoplasma, grama, gramado, *Paspalum notatum*, tolerância ao sal.

Introduction

Lawns are the most common elements in green spaces in cities worldwide. As components of urban landscapes, lawns offers benefits as mitigating local temperature, sequestering carbon, controlling soil erosion, purifying air, restoring degraded soils, and enhancing aesthetic appeal. (Silva et al., 2020; Matta et al, 2024). Lawns are often used as a quick solution to post-construction areas and improve the appearance of less landscaped locations. Urbanization has led to an increase in grass-covered surfaces, resulting in a decrease in biodiversity and a lack of visual variety (Ignatieva et al., 2020).

In Brazil, 13 types of turfgrass are currently in use, only four of these species: *Axonopus* spp. (Carpetgrass), *Paspalum vaginatum* (Seashore Paspalum), *Paspalum notatum* (Bahiagrass) and *Stenotaphrum secundatum* (St. Augustinegrass) are native to the country (Godoy, 2020; Castilho et al., 2020; Souza et al., 2020; Silva and Oliveira, 2024).

Bahia grass is widely popular in urban areas and has been utilized for various purposes, including lawns in tropical climates, industrial complexes, and roadside plantings (Castro et al., 2015; Silva et al., 2020). Despite its versatility, a 2022 survey based on data from the Ministry of Agriculture (MAPA/Renasem) and the National Association of Legal Turf reported that it accounts for only 0.19% of cultivated turfgrasses (Santos and Carribeiro, 2022). With its excellent suitability for lawns, being both rustic and low-maintenance, Bahia grass holds great potential. However, it is often subject to predatory harvesting, which causes significant environmental damage due to unregulated extraction (Cavallari et al., 2022).

It is a species that occurs in all regions of Brazil, in the phytogeographic domains of the Amazon Rainforest, Central Brazilian Savanna, Atlantic Rainforest, and Pampa, comprising various types of vegetation: Anthropized Areas, High Altitude Grassland, Flooded Field (Várzea), Grassland, Cerrado, Riverine Forest and/or Gallery Forest, Ombrophilous Forest (Tropical Rainforest), Mixed Ombrophilous Forest, Coastal Forest (Restinga), Rock Outcrop Vegetation (Valls et al., 2024). It has adaptability to various climates and different situations as low fertility soils, water deficit, and frequent trampling (Castilho et al., 2020) and salinity tolerance (Nandu et al., 2023).

The problem of salt accumulation in the soil affects millions of hectares of agricultural land worldwide, and its severity increases every year, impairing food production globally (Nandu et al., 2023). Several agricultural practices contribute to this phenomenon, with irrigation being one of the main ones, as often the quality and quantity of water used are not adequately considered. For this reason, approximately 33% of irrigated agricultural land is already affected by salinity (Otlewska et al., 2020). Additionally, arid and semi-arid regions, where evapotranspiration exceeds precipitation face an extension of this problem (Hanin et al., 2016).

The presence of high levels of salts in the soil has adverse effects on plants, causing stress due to the accumulation of toxic ions and osmotic and nutritional impacts. These effects impair crucial processes for healthy plant development, resulting in a significant reduction in productivity (Nandu et al., 2023).

Salinity can be a limiting factor for the normal growth of turfgrasses; however, different grass species can define their tolerance to different environmental factors through various factors: tolerance to shade, tolerance to water deficiency, nutritional requirements, tolerance to trampling, and even tolerance to salinity (Castilho et al., 2020). Additionally, there are

*** Corresponding author:** cecilia.castro@embrapa.br | https://doi.org/10.1590/2447-536X.v30.e242812 | Editor: Gilmar Schafer, Universidade Federal do Rio Grande do Sul, Brasil | Received: Sep 03, 2024 | Accepted: Oct 30, 2024 | Available online: Nov 18, 2024 |

differences in salinity tolerance at the varietal level among warm-season turfgrass species (Liu et al., 2023).

Salt-tolerant turfgrasses are becoming critical around the world due to rising levels of salt accumulation in soil, restrictions on groundwater usage, and the encroachment of saltwater into freshwater sources (Nandu et al., 2023).

The objective of the study was to evaluate four accessions of *Paspalum* subjected to five different levels of salinity to select the best species that could be used as vegetative cover in public areas and provide minimal maintenance in areas that may be subject to saline stress.

Material and Methods

The experiment was conducted at the Pacajus Experimental Field, belonging to Embrapa Tropical Agroindustry, located 55 km from Fortaleza, Ceará State, with geographical coordinates 4°10'S and 38°27'W and an altitude of 70 m. According to Köppen, the predominant climate type in the area is Aw, described as a tropical climate with a dry winter. Environmental parameters throughout the experiment (March to June 2015) were: maximum and minimum daily temperatures (°C) and relative humidity (%) of 31.1 ± 1.5; 22.9 ± 0.9; and 85.0 ± 4.2, respectively.

The experimental design used was split plots, with five electrical conductivity (ECw) values evaluated in the plots (well water with 0.5 and saline solutions of 1.5; 3.0; 4.5; and 6.0 dS m^{-1}), five accessions of warm-season turfgrasses in the subplots. Four rhizomatous accessions belonging to the species *Paspalum notatum* and one stoloniferous (control), and three replicates.

The genotypes used were the cultivars Aruaí and Tiriba, along with the accessions BRA 010006 and BRA 019178 from the *Paspalum* Gene Bank (BGP), which is managed by Embrapa Pecuária Sudeste. As a control (C), the commercial species *Axonopus fissifolius,* commonly known as Carpet grass, was used. *Axonopus* spp. is considered slightly tolerant (2–4 dS m^{-1}, 22–44 mM NaCl) to tolerant (8–30 dS m^{-1}, 110–410 mM NaCl), while *Paspalum notatum* is regarded as slightly to moderately tolerant (4–8 dS m^{-1}, 44–110 mM NaCl) (Liu et al., 2023).

Each experimental unit consisted of two plots of 0.3 x 0.3 m, spaced 0.1 m apart, with one plot intended for the evaluation of soil cover by the turfgrasses and the other for obtaining dry matter mass and conducting plant chemical analysis.

The soil of the area is classified as Arenic Haplustults and presented the chemical attributes: pH in H_2O = 6.3; OM = 7.3 g kg^{-1}; P = 1.6 g dm^{-3}; K^+ = 1.3 $mmol_c$ dm^{-3}; Ca^{2+} = 11.5 $mmol_c$ dm^{-3}; Mg^{2+} = 5.7 $mmol_c$ dm^{-3}; Na^+ = 1.1 $mmol_c$ dm^{-3}; Al^{3+} = 0 $mmol_c$ dm^{-3}; H+Al = 6.6 $mmol_c$ dm^{-3}; CEC = 26.2 $mmol_c$ dm^{-3}; V = 74.8%; Zn = 1.2 mg dm^{-3}; Cu = 1.5 mg dm^{-3}; Fe = 2.9 mg dm^{-3}; and Mn = 5.1 mg dm^{-3}. Based on the soil analysis results, the application of lime was not necessary, and a phosphorus dose equivalent to 100 kg ha^{-1} of P_2O_5, was applied once to the entire area in all treatments (Godoy et al., 2022).

The turfgrasses were planted using vegetative propagules measuring 0.1 x 0.1 x 0.05 m in length, width, and height, respectively. A total of five propagules were arranged alternately within each plot. After planting, the gaps between the propagules were filled with washed sand to level the soil surface. Following this, a drip irrigation system was installed, with drip lines spaced 0.4 m apart. Irrigation was applied daily using two surface drip lines per plot, one on each edge, with emitters placed at the center point and at each side of the plot. The average daily application was 1.8 L per 900 cm² plot (30 cm x 30 cm), sufficient to ensure the wetting zone in the plot remained near field capacity.

The saline solutions were prepared and stored in 5,000 L water tanks. Commercial sodium chloride and a portable conductivity meter (CD 4301, Lutron) were used to achieve the desired electrical conductivity value. The application of saline solutions, with a flow rate of 3.6 L h^{-1} for 25 minutes, began 15 days after planting (DAP). In topdressing fertilizations carried out 30 and 60 DAP, 60 kg ha^{-1} of N and 80 kg ha^{-1} of K_2O were applied in all treatments, in the form of urea and potassium chloride, respectively. The fertilizers rates were based on Godoy et al. (2022) recommendations with some adaptations. There were no occurrences of pests and diseases, and manual eradication of weeds was carried out monthly.

Soil coverage by the turfgrasses was assessed at 15, 45, and 75 DAP using images captured by a 12-megapixel digital camera. The images were analyzed with the Siscob® software to evaluate soil coverage, and the results were expressed as a percentage. The images were consistently captured from a standard height of 1.5 meters, with the area being defined using a template with sides measuring 20 cm, representing 0.04 m² (400 cm²) of surface area.

At 90 DAP, plant samples of the leaves (shoot) and roots were collected for determining the dry matter mass, as well as for chemical analysis. To standardize sample size, a volumetric ring with a volume of 270 cm³ and an Uhland auger were used. The plant samples were separated into leaves and roots, washed to remove soil, placed in paper bags, and dried in a forced air circulation oven at 60 °C until reaching a constant weight. The dry matter mass was determined by weighing, and the results were expressed in grams per square meter (g m^{-2}).

The Na and Cl contents in the leaves and roots were determined after preparing an extract containing 0.5 g of ground plant material and 25 mL of ultrapure water. The quantifications of Na and Cl were performed using the flame photometry method and UV spectrophotometry, respectively, according to Malavolta et al. (1997), with the results expressed in g kg^{-1}.

The results were subjected to analysis of variance, and the electrical conductivity values were evaluated through regression analysis. The turfgrasses were compared using the Scott-Knott test at a 5% probability level, through the AgroEstat software (Barbosa and Maldonado Junior, 2015).

Results and Discussion

The occurrence and progression of salt-induced symptoms followed a similar pattern across all evaluated accessions. In general, no significant changes in leaf color or damage that would compromise the aesthetics or functionality of the turfgrasses were observed at saline doses ranging from 0.5 to 1.5 dS m^{-1}, with only occasional yellowing or minor leaf scorch (Fig. 1). However, at doses between 3.0 and 4.5 dS m^{-1}, there was a noticeable increase in the number of yellowed, reddened, and scorched leaves. At the highest dose of 6.0 dS m^{-1}, these symptoms became more pronounced, particularly in accessions BRA 01006 and control, as salinity stress often limits or inhibits plant growth and development (Liu et al., 2023).

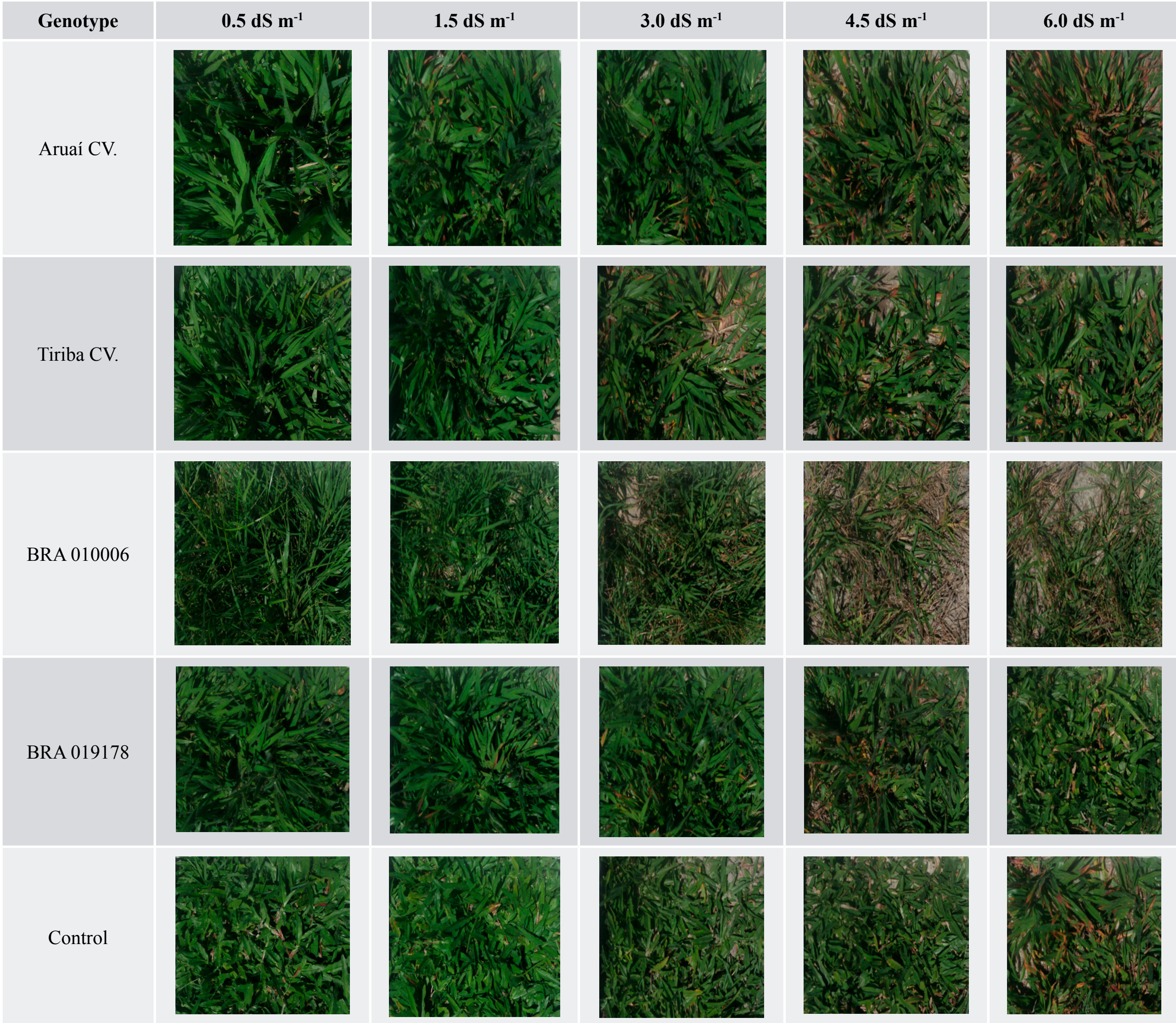


Fig. 1 Progression of salt-induced symptoms in *Paspalum* genotypes at various salinity levels, 60 days after planting.

At 15 DAP, the Aruaí cultivar showed the lowest soil coverage, indicating slower adaptation compared to the other accessions and the control (Table 1). Soil coverage was influenced by genotype (15 days after planting, DAP), level of water electrical conductivity (45 DAP), and the interaction between these factors (75 DAP).

At 45 DAP, the genotypes did not differ in soil coverage, but were negatively affected by the increase in irrigation water electrical conductivity (Fig. 2A). By 75 DAP, the genotypes responded differently to salinity levels in the water: at both the lowest (0.5 dS m^{-1}) and the highest level (6 dS m^{-1}), the Tiriba cultivar and accession BRA 019178 reduced their percentage of soil coverage, dropping from 82.99% and 83.43% to 42.18% and 69.85%, respectively (Fig. 2B).

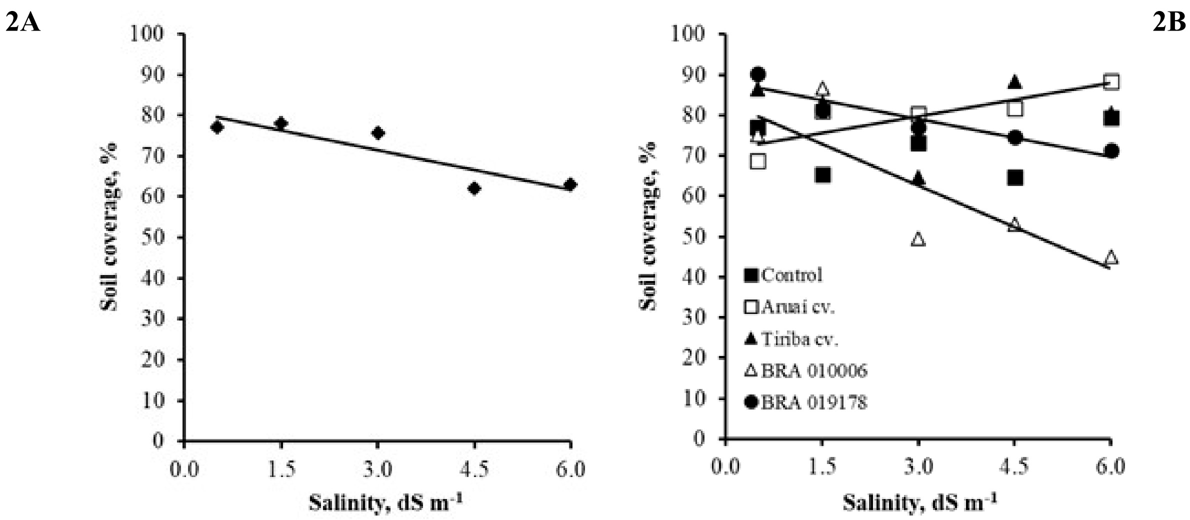
In contrast, the Aruaí cultivar showed an increase in soil coverage, reaching 88.05% at the highest salinity level (6 dS m^{-1}), indicating its partial tolerance to elevated levels of water electrical conductivity. While *Paspalum vaginatum*, commonly referred to as Seashore Paspalum, is renowned for its exceptional salt tolerance, handling up to 25 dS m^{-1} with a 50% reduction in growth, it is important to note that this species differs from *Paspalum notatum*, which was used in this experiment. Unlike Seashore *Paspalum*, which thrives in saline environments, *P. notatum* is valued for its rusticity and low-maintenance characteristics rather than extreme salinity tolerance. As such, *P. notatum* is typically more suited for areas where soil and water management are less intensive, demonstrating resilience under less optimal conditions (Uddin et al., 2013). However, the response to salinity can vary significantly among different ecotypes (Ntoulas and Varsamos, 2021).

Table 1. Soil coverage by turfgrass genotypes as a function of salinity level, 15; 45 and 75 days after planting (DAP).

Genotype	Soil coverage		
	15 DAP	45 DAP	75 DAP
	.... %		
Control	56.5 a[1]	68.7 a	72.0 b
Aruaí CV	45.7 b	77.7 a	80.0 a
Tiriba CV	53.4 a	71.6 a	80.6 a
BRA 010006	53.0 a	64.8 a	61.9 c
BRA 019178	57.1 a	73.1 a	78.8 a
	F test[2]		
Salinity (S)	1.27^{ns}	6.33*	2.46^{ns}
Genotypes (G)	3.50*	2.74*	21.82**
S x G	1.44^{ns}	1.66^{ns}	7.85**
CV $(\%)_{Salinity}$	36.21	17.23	15.44
CV $(\%)_{Genotypes}$	17.73	15.87	8.81

1 Means followed by the same letter in the column do not differ from each other according to the Scott-Knott test at a 5% probability level.

2 ns; ** and *: not significant; significant at 1% and 5% probability levels, respectively.



$y = 81.1730 - 3.2188x$ ($R^2 = 0.804$**)

Control: $y = {}^{ns}$
Aruaí CV.: $y = 71.4775 + 2.7621x$ ($R^2 = 0.753$**)
Tiriba CV.: $y = {}^{ns}$
BRA 010006: $y = 82.9934 - 6.8022x$ ($R^2 = 0.698$**)
BRA 019178: $y = 88.4349 - 3.0973x$ ($R^2 = 0.884$**)

Fig. 2. Soil coverage by grass genotypes, 45 (2A) and 75 (2B) days after planting (DAP), as a function of salinity levels.

ns , ** e *: not significant; significant at 1% and 5% probability levels, respectively.

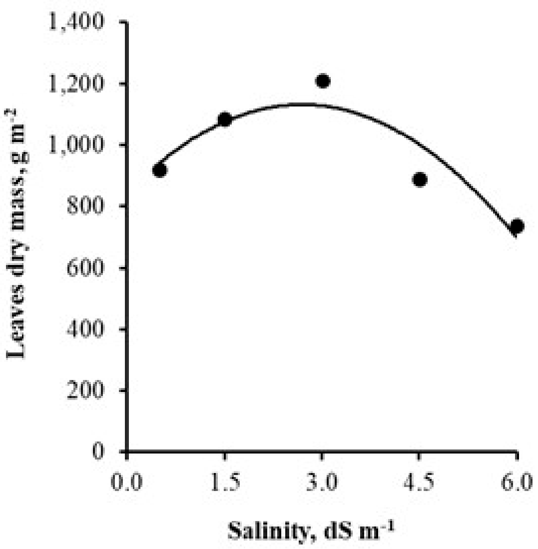
The cultivars Aruaí and Tiriba, along with accession BRA 019178, exhibited higher dry leaf mass than accession BRA 010006 and the control (Table 2). Salts in the irrigation water promoted an increase in the dry leaf mass of the turfgrasses up to a level of 2.69 dS m^{-1} (Fig. 3). All accessions showed higher root dry mass production than Carpetgrass, which could be advantageous for faster plant establishment.

The reduction in dry mass production as salinity levels increase is likely due to the higher concentration of salts in the soil solution, which can lead to elevated osmotic pressure that hinders water absorption by plants, even under relatively moist soil conditions (Saddiq et al., 2021). Additionally, the toxic effects of Na^+ and Cl^- ions on plant cells further contribute to this decline (Fan et al., 2020). Furthermore, the decrease in water availability for plants can lead to the closing of stomata, affecting photosynthesis and resulting in significant reductions in the amount of biomass, especially in the leaves (Santos et al., 2022).

Table 2. Production of leaves and root dry mass of grass genotypes, 90 days after planting, as a function of salinity levels.

Genotype	Dry mass	
	Leaves	Root
	.... $g\ m^{-2}$	
Control	842 b[1]	874 b
Aruaí CV	1.001 a	1.554 a
Tiriba CV	1.015 a	1.537 a
BRA 010006	841 b	1.657 a
BRA 019178	1.149 a	1.675 a
	F test[2]	
Salinity (S)	3.67*	0.79^{ns}
Genotypes (G)	3.91**	15.76**
S x G	1.21^{ns}	1.63^{ns}
CV (%)$_{Salinity}$	38.04	30.78
CV (%)$_{Genotypes}$	26.36	22.24

[1] Means followed by the same letter in the column do not differ from each other according to the Scott-Knott test at a 5% probability level.[2] ns; ** e *: not significant; significant at 1% and 5% probability levels, respectively.



$y = 845.9145 + 212.51x - 39.50x^2$ ($R^2 = 0.838^*$)

Fig. 3. Production of leaf dry mass, 90 days after planting, as a function of salinity levels.

*: Significant at 5% probability levels.

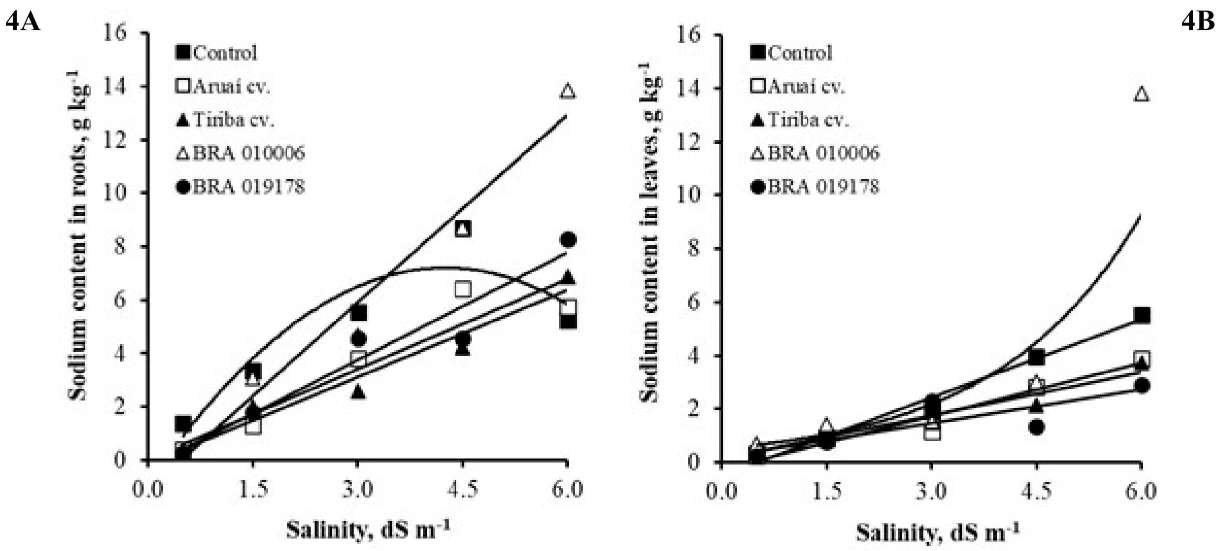
Sodium content in leaves and roots was influenced by the interaction between salinity levels and genotypes (Table 3). Among the *Paspalum* genotypes, sodium content in the roots increased up to the highest salinity level evaluated, with accession BRA 010006 standing out at 12.92 g kg^{-1} (Fig. 4A). Despite the higher sodium content in the roots of accession BRA 010006, there was no difference in root dry mass production compared to the other *Paspalum* genotypes, indicating its ability to absorb sodium without hindering root growth. In the control treatment, sodium content in the roots increased only up to an electrical conductivity value of 4.25 dS m^{-1}. This, combined with lower root dry mass production compared to the *Paspalum* genotypes, suggests greater sensitivity of the control species to higher salinity levels. Salt-tolerant turfgrasses can minimize detrimental effects through a series of anatomical, morphological, and physiological adaptations, including the restriction of saline ion accumulation in shoots (Uddin et al., 2013).

Salinity levels led to an increase in sodium content in the leaves of all genotypes; however, at the highest salinity level (6.0 dS m^{-1}), accession BRA 010006 exhibited sodium levels that were 2.4 and 3.8 times higher than those in the control and other genotypes, respectively (Fig. 4B). This suggests that BRA 010006 has a less effective mechanism for compartmentalizing sodium within the roots compared to the other genotypes. The inefficient sodium exclusion likely resulted in increased translocation of sodium to the leaves, which in turn contributed to a reduction in leaf dry mass (Fan et al., 2020). Consequently, despite its ability to absorb and accumulate sodium, accession BRA 010006 appears to be the most sensitive to sodium exposure among the *Paspalum* genotypes, potentially limiting its performance under high salinity conditions.

Table 3. Sodium and chlorine contents in roots and leaves of grass genotypes, 90 days after planting, as a function of salinity levels.

Genotypes	Sodium content		Chlorine content	
	Roots	Leaves	Roots	Leaves
	.... g kg^{-1}			
Control	4.85 a[1]	2.52 b	7.45 a	11.27 a
Aruaí CV	3.54 b	1.79 b	6.99 a	10.83 a
Tiriba CV	3.23 b	1.82 b	7.19 a	11.24 a
BRA 010006	6.15 a	4.10 a	7.34 a	11.49 a
BRA 019178	3.90 b	1.69 b	7.31 a	10.00 a
	Test F[2]			
Salinity (S)	44.65**	27.38**	68.77**	31.23**
Genotypes (G)	5.59**	13.85**	0.19^{ns}	1.85^{ns}
S x G	2.38*	10.77**	2.21*	6.19**
CV (%)$_{Salinity}$	40.39	68.27	18.88	24.92
CV (%)$_{Genotypes}$	44.82	44.10	21.23	15.30

[1] Means followed by the same letter in the column do not differ from each other according to the Scott-Knott test at a 5% probability level.



Control: $y = -0.8739 + 3.8009x - 0.4469x^2$ ($R^2 = 0.863$**)
Aruaí CV.: $y = 0.0617 + 1.1207x$ ($R^2 = 0.885$**)
Tiriba CV.: $y = -0.1408 + 1.0863x$ ($R^2 = 0.957$**)
BRA 010006: $y = -1.0830 + 2.3339x$ ($R^2 = 0.969$**)
BRA 019178: $y = -0.2384 + 1.3346x$ ($R^2 = 0.936$**)

Control: $y = -0.4915 + 0.9736x$ ($R^2 = 0.978$**)
Aruaí CV.: $y = -0.2472 + 0.6587x$ ($R^2 = 0.952$**)
Tiriba CV.: $y = 0.1623 + 0.5352x$ ($R^2 = 0.914$**)
BRA 010006: $y = 3.0951 - 3.2271x + 0.8125x^2$ ($R^2 = 0.932$**)
BRA 019178: $y = 0.1926 + 0.4858x$ ($R^2 = 0.903$*)

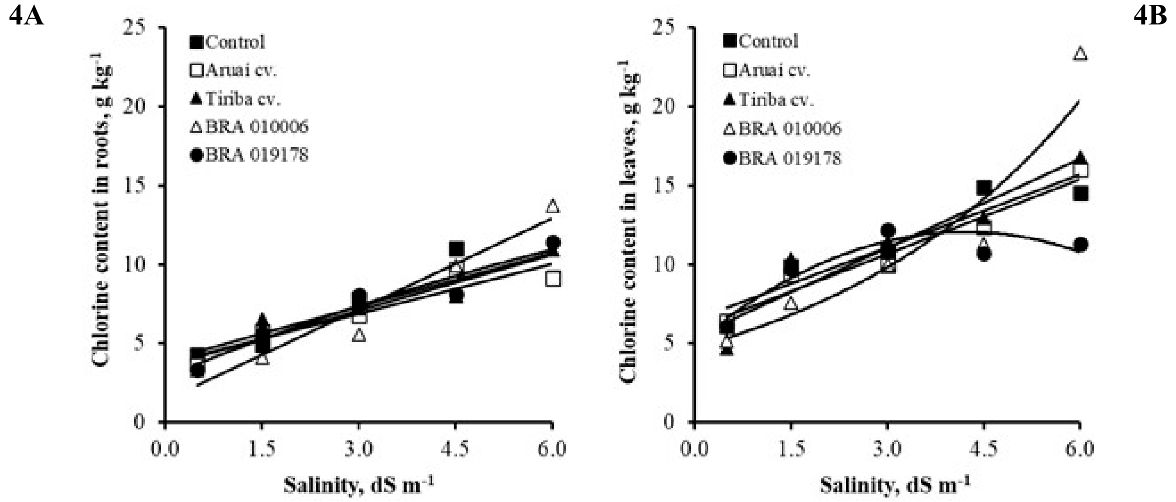
Fig. 4. Sodium content in roots (4A) and leaves (4B) of grass genotypes, 90 days after planting, as a function of salinity levels.

** and *: not significant; significant at 1% and 5% probability levels, respectively.

The increase in salinity levels in the irrigation water raised chlorine content in the roots of all genotypes (Fig. 5A). From the lowest to the highest salinity level, there was a 2.7 to 4.4-fold increase in Cl content in the roots. Similarly, an increase in Cl content was also observed in the genotype shoots as salinity levels increased (Fig. 5B). In the control treatment, the highest Cl content in the shoots was found at the highest salinity level (6 dS m^{-1}) in the cultivars Aruaí and Tiriba and in the accession BRA 010006, while in accession BRA 019178, the highest Cl content was obtained at an EC value of 4.2 dS m^{-1}. The decrease of Na^+ and Cl^- accumulation in the leaves at high salinity levels may be linked to the characteristics of salt stress tolerance, as in plant species with this trait there is the ability to eliminate excess salt from the leaves (Fan et al., 2020).

The uptake of sodium and chloride, particularly sodium, was higher in the roots than in the leaves, suggesting a mechanism that restricts the translocation of these salts to the shoots, which are more sensitive to elevated salt levels. Additionally, salt compartmentalization may have occurred in the vacuoles of mesophyll cells, isolating the salts and mitigating damage to cytosolic metabolic processes. This behavior aligns with the adaptations of warm-season turfgrasses, which are generally well adapted to drought and salinity conditions due to the development of specific mechanisms for ion translocation, compartmentalization, and excretion (Chavarria et al., 2021).

The reduced ion translocation to the shoots observed in this study can be viewed as a strategy for minimizing salt accumulation in the leaves, where the impact of salt stress is more pronounced due to the heightened sensitivity to elevated ion levels. The ability to restrict salt mobility to the leaves and compartmentalize them in vacuoles provides a significant adaptive advantage in saline environments (Chavarria et al., 2021; Liu et al., 2023).



Control.: $y = 2.2546 + 2.8131x - 0.2603x^2$ ($R^2 = 0.882^*$)
Aruaí CV.: $y = 3.7398 + 1.0491x$ ($R^2 = 0.879^{**}$)
Tiriba CV.: $y = 3.5553 + 1.1740x$ ($R^2 = 0.901^{**}$)
BRA 010006: $y = 3.1348 + 0.1819x + 0.2686x^2$ ($R^2 = 0.994^*$)
BRA 019178: $y = 3.2338 + 1.3151x$ ($R^2 = 0.933^{**}$)

Control: $y = 6.5196 + 1.5339x$ ($R^2 = 0.880^{**}$)
Aruaí CV.: $y = 5.9311 + 1.5803x$ ($R^2 = 0.951^{**}$)
Tiriba CV.: $y = 5.4155 + 1.8774x$ ($R^2 = 0.895^{**}$)
BRA 010006: $y = 6.7836 - 1.3526x + 0.6565x^2$ ($R^2 = 0.934^{**}$)
BRA 019178: $y = 5.0077 + 3.3522x - 0.3984x^2$ ($R^2 = 0.859^*$)

Fig. 5. Chlorine content in roots (5A) and leaves (5B) of turfgrass genotypes, 90 days after planting, as a function of salinity levels.

** and *: not significant; significant at 1% and 5% probability levels, respectively.

The reduction of leaf area may be associated with the accumulation of chemical elements chloride and sodium, which can cause necrosis and burns along the edges of the leaves, leading to a decrease in leaf area (Saddiq et al., 2021).

According to the standards, slightly saline soils have ECe values of 2.1 to 4.0 dS m^{-1}, moderately saline soils range from 4.0 to 8.0 dS m^{-1}, strongly saline soils range from 8.1 to 16.0 dS m^{-1}, and very saline soils exceed 16.0 dS m^{-1} (Ievinsh, 2023). The performance of certain accessions suggests moderate salt tolerance, with salinity effects varying across accessions.

The differential response of the evaluated genotypes to salinity highlights the complexity of salt stress adaptation mechanisms in turfgrasses. While certain genotypes like Aruaí and Tiriba cultivars exhibit traits that mitigate the negative impacts of salinity, such as effective ion compartmentalization and maintenance of aesthetic features, others, like BRA 010006, reveal vulnerabilities that could limit their use in high-salinity environments. These findings underscore the importance of selecting ornamental native turfgrasses with enhanced salt tolerance for landscaping applications in saline-prone areas (Liu et al., 2023).

Conclusions

The cultivars Aruaí, Tiriba, and accession BRA 019178 showed moderate salinity tolerance, maintaining satisfactory soil coverage and dry mass even under elevated salinity. Accession BRA 010006, however, exhibited higher sensitivity, with significant sodium accumulation in leaves, hindering its development.

Acknowledgements

The authors would like to thank to Embrapa Agroindústria Tropical and Embrapa Pecuária Sudeste.

Author Contribution

LOC: conceptualization; data curation; investigation; writing – original draft. **ACRC**: conceptualization; resources; methodology; data curation; writing – review & editing. **CAKT:** conceptualization; data curation, writing – review & editing. **MAB:** conceptualization; methodology; validation; data curation; writing – review & editing**.**

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Data Availability Statement

Data will be made available on request.

References:

BARBOSA, J.C.; MALDONADO JUNIOR, W. 2015. AgroEstat - Sistema para análises estatísticas de ensaios agronômicos. Jaboticabal: FCAV/UNESP. 396p.

CASTRO, A.C.R.; TANIGUCHI, C.A.K.; SOUZA, F.H.D.; SILVA, T.F.; CAFÉ, F.B.S.; ARAGÃO, F.A.S.; LOGES, V. Evaluation of native Brazilian *Paspalum* germplasm as lawn for landscaping purposes. **Acta Horticulturae**, v.1104, p.505-510, 2015. http://dx.doi.org/10.17660/ActaHortic.2015.1104.73.05

CASTILHO, R.M.M.; FREITAS, R.C.; SANTOS, P.L.F. The turfgrass in landscape and landscaping. **Ornamental Horticulture**, v.26, n.3, p.499-515, 2020. https://doi.org/10.1590/2447-536X.v26i3.2237

CAVALLARI, M.M.; GUSMÃO, M.R., SOUZA, F.H.D. Programa gramados da EMBRAPA. In: SANTOS, P.L.F.; GODOY, L.J.G.; VILLAS BÔAS, R.L.; CARRIBEIRO, L.S. **Tópicos atuais em gramados V**. Botucatu: Fundação de Estudos e Pesquisas Agrícolas e Florestais - UNESP/FCA, 2022. p.06-14.

Chavarria, M.R., Wherley, B., Jessup, R., Chandra, A. Leaf anatomical responses and chemical composition of warm-season turfgrasses to increasing salinity. **Current Plant Biology**, v.22, 100147, 2020. https://doi.org/10.1016/j.cpb.2020.100147

FAN, J.; ZHANG, W.; AMOMBO, E.; HU, L.; KJORVEN, J.O.; CHEN, L. Mechanisms of environmental stress tolerance in turfgrass. **Agronomy**, v.10, p.522, 2020. https://doi.org/10.3390/agronomy10040522

GODOY, L.J. Turfs and turfgrasses in Brazil. **Ornamental Horticulture**, v.26, n.3, p.326-327, 2020. https://doi.org/10.1590/2447-536X.v26i3.2224

GODOY, L.J.G; VILLAS BOAS, R.L.; BACKES, C.; MATEUS, C.M.D.; Gramados. IN: CANTARELLA, H.; QUAGGIO, J.A.; MATTOS JÚNIOR. D.; BOARETTO, R. M. van RAIJ, B. Recomendações de adubação e calagem para o Estado de São Paulo (Boletim Técnico, 100). Campinas: IAC, 2022. p.475-482.

HANIN, M.; EBEL, C.; NGOM, M.; LAPLAZE, L.; MASMOUDI, K. New insights on plant salt tolerance mechanisms and their potential use for breeding. **Frontiers in Plant Science**, v.7, n.1787, p.1-17, 2016. https://doi.org/10.3389/fpls.2016.01787

IGNATIEVA, M.; HAASE, D.; DUSHKOVA, D.; HAASE, A. Lawns in Cities: From a globalised urban green space phenomenon to sustainable nature-based solutions. **Land**, v.9, n.3, p.73, 2020. https://doi.org/10.3390/land9030073

IEVINSH, G. Halophytic clonal plant species: Important functional aspects for existence in heterogeneous saline habitats. **Plants,** v.12, n.1728, 2023. https://doi.org/10.3390/plants12081728

LIU, H.; TODD, J.L.; LUO, H. Turfgrass Salinity Stress and Tolerance - A Review. **Plants**, v.12, p.925, 2023. https://doi.org/10.3390/plants12040925

MALAVOLTA, E.; VITTI, G.C.; OLIVEIRA, S.A. **Avaliação do estado nutricional das plantas: princípios e aplicações**. 2.ed. Piracicaba: Associação Brasileira de Potassa e do Fósforo, 1997. 319 p.

MATTA, F.P.; FÁVERO, A.P; VIGNA, B.B.Z.; CAVALLARI, M.M.; ALVES, F.; OLIVEIRA, F.A.; SOUZA, A.P.; POZZOBON, M.T.; AZEVEDO, A.L.S.; GUSMÃO, M.R. Characterization of *Paspalum* genotypes for turfgrass cultivars development. **Crop Science**, p.1-14, 2024. https://doi.org/10.1002/csc2.21233

NANDU, P.K.; TOPNO, S.E.; PRASAD, V.M.; KUOTSU, N.R. Effect of salinity on warm season turf grass species. **International Journal of Plant & Soil Science**, v.35, n.19, p.316-326, 2023. https://doi.org/10.9734/IJPSS/2023/v35i193558

NTOULAS, N.; VARSAMOS, I. Performance of two seashore *Paspalum* (*Paspalum vaginatum* Sw.) varieties growing in shallow green roof substrate depths and irrigated with seawater. **Agronomy**, v.11, n. 250. 2021, https://doi.org/10.3390/agronomy11020250

OTLEWSKA, A.; MIGLIORE, M.; DYBKA-STE˛PIEN´, K.; MANFREDINI, A., STRUSZCZYK-S´, W.K., NAPOLI R, BIAŁKOWSKA, A.; CANFORA, L.; PINZARI, F. When Salt Meddles Between Plant, Soil, and Microorganisms. **Frontiers in Plant Science**, v.11, n.553087, 2020. https://doi.org/10.3389/fpls.2020.553087

SADDIQ, M.S.; IQBAL, S.; HAFEEZ, M.B.; IBRAHIM, A.M.H.; RAZA, A.; FATIMA, E.M.; BALOCH, H.; JAHANZAIB; WOODROW, P.; CIARMIELLO, L.F. Effect of salinity stress on physiological changes in winter and spring wheat. **Agronomy**, v.11, n.1193, 2021. https://doi.org/10.3390/agronomy11061193

SANTOS, T.B.; RIBAS, A.F.; DE SOUZA, S.G.H.; BUDZINSKI, I.G.F.; DOMINGUES, D.S. Physiological responses to drought, salinity, and heat stress in plants: A Review. **Stresses**, v.2, p.113-135, 2022. https://doi.org/10.3390/stresses2010009

SANTOS, P.L.F.; CARRIBEIRO, L.S. Atualidades na produção de Gramas. IN: tópicos Atuais em Gramados V. In: SANTOS, P.L.F.; GODOY, L.J.G.; VILLAS BÔAS, R.L.; CARRIBEIRO, L.S. **Tópicos atuais em gramados V,** Botucatu: Fundação de Estudos e Pesquisas Agrícolas e Florestais - UNESP/FCA, 2022. p.35-51.

SILVA, C.; OLIVEIRA, R.P. *Stenotaphrum* in Flora e Funga do Brasil. Jardim Botânico do Rio de Janeiro. Available in: <https://floradobrasil.jbrj.gov.br/FB13635>. Accessed on: April 17th 2024

SILVA, S.A.C.G.; ALBUQUERQUE FILHO, J.C.C.; SILVA, S.S.L.; CASTRO, A.C.R.; LOGES, V. Development of *Paspalum* accession plugs for turfgrass establishment. **Ornamental Horticulture**, v.26, n.3, p.356-366, 2020. https://doi.org/10.1590/2447-536X.v26i3.2163.

SOUZA, F.H.D.; GUSMÃO, M.R.; CAVALLARI, M.M.; BARIONI JÚNIOR, W.B. Characterization of the potential of native grasses for use as lawns. **Ornamental Horticulture**, v.26, n.1, p.109-120, 2020. https://doi.org/10.1590/2447-536x.v26i1.2067

UDDIN, K.; JURAIMI, A.S. Salinity tolerance turfgrass: History and Prospects. **The Scientific World Journal**, v.2013, n. 409413. https://doi.org/10.1155/2013/409413

VALLS, J.F.M.; MACIEL, J.R.; SOUSA, M.W.D.S.; OLIVEIRA, R.C.; PIMENTA, K.M.; RUA, G.H. *Paspalum* in Flora e Funga do Brasil. Jardim Botânico do Rio de Janeiro. Available in: <https://floradobrasil.jbrj.gov.br/FB13487>. Accessed on: April 17th 2024