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SCIENTIFIC ARTICLE

Selection of Brazilian native turfgrass accessions for establishment by sprigs

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Abstract

Researches with Brazilian native species of *Axonopus* and *Paspalum* genus have indicated their lawn-use. Thus, this research aimed to evaluate the use of sprigs, which are rhizomes and/or stolons fragments of plants without substrate and with reduced aerial part, as a propagation method for turfgrass establishment. Two experiments were developed. Experiment 1: turfgrass sods (1026 cm²) from *Axonopus parodii* (AP 01), *Paspalum lepton* (PL 01) and *P. notatum* (PN 01 to PN 06) accessions, were fragmented in a straw crushing machine in order to obtain the sprigs. After cleaning the substrate and organic residues from the sprigs, the following variables were analyzed: total number of sprigs; minimum, maximum and average length of the sprigs; standard deviation; number of sprigs shorter than 2 cm, from 2 to 4 cm, and from 4 to 6 cm long. Experiment 2: sprigs from three different length classes were planted and evaluated at 63 days after planting. The commercial variety *Zoysia japonica* (ZJ 01) was used as a control treatment. The following characters were analyzed: the survival rate of the sprigs, the number of shoots, expansion, soil coverage rate, dry biomass of aerial part, and dry biomass of the roots. Correlations were made among the data obtained. Higher yields were obtained for sprigs shorter than 2 cm and from 2 to 4 cm. All accessions presented better development when established with sprigs longer than 2 cm. The *Paspalum notatum* accessions PN 01, PN 02, PN 03 and PN 05 could be selected for turfgrass establishment by sprigs propagation.

Keywords: *Axonopus parodii*, *Paspalum lepton*, *P. notatum*, rhizomes, stolons, lawn.

Resumo

Seleção de acessos de gramas brasileiras para propagação por *sprigs*

Pesquisas com plantas nativas brasileiras indicam o uso de espécies do gênero *Axonopus* e *Paspalum* como gramados. Esta pesquisa avaliou o uso *sprigs*, que são fragmentos de rizomas e/ou estolões da planta, sem substratos e com parte aérea reduzida, como forma de propagação para implantação de gramados. Dois experimentos foram desenvolvidos. Experimento 1: tapetes de grama (1026 cm²) de acessos de *Axonopus parodii* (AP 01), *Paspalum lepton* (PL 01) e *P. notatum* (PN 01 a PN 06) foram fragmentados em triturador para a obtenção dos *sprigs*. Depois de removido o substrato e resíduos orgânicos dos *sprigs*, foi avaliado: número total de sprigs; comprimento mínimo, máximo e médio; desvio padrão; e número de *sprigs* com comprimento menor que 2 cm; entre 2 e 4 cm; e maior que 4 a 6 cm. Experimento 2: *sprigs* das três classes de comprimentos foram plantados e avaliados aos 63 dias após o plantio. A variedade comercial *Zoysia japonica* (ZJ 01) foi utilizada como tratamento controle. Foram avaliadas: taxa de sobrevivência de *sprigs*; número de perfilhos; expansão; taxa de cobertura do solo; biomassa seca da parte aérea; e biomassa seca radicular. Correlações foram feitas entre os dados. Foram obtidos maior número de *sprigs* com comprimento menores que 2 cm e de 2 a 4 cm. Os acessos apresentaram melhor desenvolvimento quando estabelecidos com sprigs acima de 2 cm de comprimento. Os acessos de *Paspalum notatum* PN 01, PN 02, PN 03 e PN 05 podem ser selecionados para o estabelecimento de gramados por *sprigs*.

Keywords: *Axonopus parodii*, *Paspalum lepton*, *P. notatum*, rizomas, estolões, gramado

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Introduction

Many native *Paspalum* species from Brazil have excellent lawn performance, but there are very few cultivars available on the market. *Paspalum notatum* stands out for its dense lawn with a sturdy root system, drought-tolerant and low-fertilizer requirements. It is very popular in urban areas and it is commonly used in parks, industrial areas and roads or rail ways margins (Castro et al., 2015; Silva et al., 2018). *Axonopus parodii* and *P. lepton* performed exceptionally well in lawn tests under tropical climate and high input conditions (Silva et al., 2018).

Native plants are more adapted to climatic variations and local soil, which help both their growth and resistance to external factors that are aggressive to their survival, such as the absence of rain, insects and pathogens attacks as well as weed invasion. Nevertheless, in most gardens of Brazil, the exotic species *Zoysia japonica* (Zoysiagrass cv. Esmeralda grass) predominates, which requires medium to intensive management (Souza et al., 2020).

The species *Axonopus parodii* are morphologically described as perennial, stoloniferous, with underground rhizomes and vigorous stolons (Maximino et al., 2017). The genus *Paspalum* comprises annual or perennial plants, cespitose, with rhizomes or stolons (Gouvêa et al., 2019), for example, *P. lepton* and *P. notatum.* Species that present rhizomatous growth are easier to propagate, for roots and new plants are emitted from the nodes (Marchi and Sallés, 2015).

There are few scientific studies that specifically discuss propagation techniques and establishment performance of *Axonopus* and *Paspalum* species, which is an important task to identify the best turfgrass accessions (Dhanasekaran, 2018). According to Souza et al. (2016), the vegetative propagation methods for turfgrass establishment such as sodding, plugging and sprigging maintain the varietal uniformity, besides presenting faster soil coverage and reducing weed development.

Sprigging is the most economical vegetative propagation method for turfgrass establishment (McCarty, 2018). The sprigs are fragments of stolons and/or rhizomes with the presence of nodes, reduced aerial part and without substrate. They are usually about 2.54 cm to 10.16 cm (1 to 4 inches long), and one bushel of sprigs is approximately equal to 1 square yard of sod (Munshaw, 2016). For those fragments have meristematic sites, and they induce bud formation and plant growth (Kojoroski-Silva et al., 2011). The vegetative propagation by sprigs is indicated for the establishment of large areas, such as industrial and recreational gardens, along roads and rail ways margins, aerodromes, fish tanks, and for green roof use (Souza et al., 2016).

Information regarding an accessible, inexpensive and efficient method to obtain and use sprigs for the implementation of Brazilian native turfgrass is scarce. This research aims to selected *Axonopus parodii*, *Paspalum lepton* and *P. notatum* accessions for production and establishment by sprigs.

Material and methods

Two experiments were carried out in Recife, Pernambuco State, Brazil (8°01’06”S, 34°56’49”W and 6 m high), from March to September 2016. The region presents As’ climate (tropical hot humid with rainfall in fall to winter) according to the climate classification of Köppen (1948).

Eight accessions from the Germplasm Active Bank (BAG) of the EMBRAPA Pecuária Sudeste (São Carlos-SP) were evaluated: *Axonopus parodii* (AP 01), *Paspalum lepton* (PL 01), *P. notatum* (PN 01, PN 02, PN 03, PN 04, PN 05 and PN 06).

Experiment 1

In order to obtain the sods to later fragment into sprigs, in March 2016, six seedlings of each accession, with standard size up to 10 cm, were planted in polyethylene trays (27 cm width x 38 cm length x 6 cm depth) equivalent to an area of 1026 cm², which were filled with a commercial substrate. Planting was done by using 2 lines with 3 seedlings per line spaced 9.0 cm x 9.5 cm. The trays were kept in full sun, under sprinkler irrigation with a 5.56 mm day^{-1} water depth applied 3 times a day, which was suspended on rainy days. The trays were disposed in a randomized block with eight treatments and three replicates (8 accessions x 3 turfgrass sods; 24 plots).

The following climate conditions during the experiment were recorded: average precipitation of 10.69 mm dia^{-1}; minimum temperature of 24.13 °C; maximum of 33.12 °C; and the average of 27.88 °C (daily data generated by the Irrigated Agriculture Station of the Federal Rural University of Pernambuco - UFRPE).

At 98 days after planting (DAP), the turfgrass sods of each accession (standardized at 1026 cm²) were sectioned into smaller parts (15 x 15 cm) and fragmented in a domestic straw crushing machine. After the fragmentation, through using a sieve, substrate and residual leaves were removed. The sprigs were quantified, measured and classified by length in: shorter than 2 cm; from 2 to 4 cm; and from 4 to 6 cm long. The fragments of rhizomes and stolons shorter than 2 cm long without meristematic sites (node) were discarded. The sprigs were packed and kept in a refrigerator (5.8 °C) for 12 hours to later be used in the Experiment 2.

The total number of sprigs (N), minimum and maximum length, and descriptive statistic data (average ± standard deviation) of the sprig length per accession were obtained by Excel 2019 tools and analysed by the statistical software Sisvar (Ferreira, 2019). The data of the number of sprigs per accession classified by length (shorter than 2 cm; from 2 to 4 cm; and from 4 to 6 cm long) were transformed into Log10 (Y) in order to present normal distribution (Kolmogorov-Smirnov test; Dn < p-value) and lower coefficients of variance. Those data were analysed by the Scott Knott cluster test, using the statistical software Genes (Cruz, 2013) but the treatment averages in the table are real data.

Experiment 2

For the purpose of evaluating the sprigs viability to use as a propagation method of the accessions, in June 2016 a second experiment was organized. As the control treatment was used Zoysiagrass cv. Esmeralda (*Zoysia japonica*) (ZJ 01), a stoloniferous and rhizomatous exotic grass species, that is the most commercialized grass in Brazil (Castro et al., 2015). The process of obtaining sprigs from turfgrass sods was repeated for the Zoysiagrass and the bags were kept in a refrigerator (5.8 °C) for 12 hours.

Twelve sprigs of each accession and the control treatment, in four replicates per length were cultivated in polyethylene trays (27 cm width x 38 cm length x 6 cm depth), equivalent to an area of 1026 cm², filled with a commercial substrate. Planting was done using 3 lines with 4 sprigs per line spaced at 9.0 x 7.6 cm. The trays were kept in full sun, under sprinkler irrigation with a 5.56 mm dia^{-1} water depth applied 3 times a day, which was suspended on rainy days. The trays were disposed in four randomized blocks in a factorial arrangement with 27 treatments (8 accessions and control treatment x 3 sprigs lengths).

Twice a week the trays were irrigated with a nutritive solution containing: 750 mg dm^{-3} of calcium nitrate, 450 mg dm^{-3} of potassium nitrate, 400 mg dm^{-3} of magnesium sulphate, 200 mg dm^{-3} of MAP, 75 mg dm^{-3} of Quelatec AZ, and 75 mg dm^{-3} of 6% (w w^{-1}) of Iron (Fe) chelated with EDDHA in ortho-ortho position (4.2% w w^{-1}).

The following climate conditions during the experiment were recorded: average precipitation of 3.11 mm day^{-1}; minimum and maximum temperatures of 22.18 °C and 31.55 °C, respectively, and average of 26.30 °C (daily data generated by the Irrigated Agriculture Station of the UFRPE).

At 30 DAP, the survival rate of sprigs (SR in %) was analyzed, which was evidenced by the emitted shoots (or trillers). At 63 DAP, the growing pattern of the species were analyzed through a biometric data analyzes: a) Number of shoots (NS), obtained by counting the shoots emitted by the sprigs per tray (plot) and from the 4 replicates, averages were obtained; b) Expansion (E in cm²); obtained by measuring the length of the longest side of the grass (cm) multiplied by the perpendicular side (cm); c) Soil coverage rate (SCR in %), obtained through the image analysis of the green vegetation coverage of the turfgrass tray. The images were captured by a 14.2-megapixel Samsung camera, 5 x Zoom lens 27 mm Wide Recording 280 x 720p, and later were converted into Joint Photographic Experts Group format (JPEG) and processed by the SisCob Embrapa Software.

The grass growth and biomass production were analyzed through the dry biomass of the aerial part (DBAP in g) and dry biomass of the roots system (DBRS in g), which was composed of roots, rhizomes and/or stolons. Fresh biomass of aerial part of the plant and root were segregated by the use of scissors, and later wrapped in paper bags and dried in a forced aeration oven at 65 °C for 72 hours, until constant weight was obtained.

The statistical analyzes of the survival rate of sprigs (SR), number of shoots (NS), expansion (E); soil coverage rate (SCR), dry biomass of aerial part (DBAP) and dry biomass of the roots system (DBRS) were performed by the Kolmogorov-Smirnov Normality Test in the statistical software Sisvar (Ferreira, 2019). Data for the SR, NS, E, SCR and DBAP variables were turned into $\sqrt{(Y + 1)}$ and DBRS into 1 + Log10 (Y), in order for the data present normal distribution (Kolmogorov-Smirnov test; Dn <p-value), and lower coefficients of variance. The data were analysed by the Scott Knott Cluster Test, using the statistical software Genes (Cruz, 2013), but the averages for treatments in the table are real data. The Pearson's correlation Test was used among the data of variables from the accessions using the statistical software GENES (Cruz, 2013) at 1% and 5% probability levels.

Results and Discussion

Experiment 1

After cultivating for 98 days and later fragmentating the sods to obtain the sprigs using a domestic straw crushing machine, it was observed that the length of the sprigs ranged between 0.5 cm to 11.50 cm. From turfgrass sods cultivated in the 3 trays (3078 cm²), were obtained, 390 sprigs for the accession AP 01 with average length of 3.57 ± 1.93 cm (average ± standard deviation), 480 sprigs for the PL 01 with average length of 1.96 ± 1.09 cm, and for the *P. notatum* accessions, 445 to 752 sprigs, with average length of 1.94 ± 0.92 cm (PN 03) up to 2.36 ± 1.12 cm (PN 06) (Table 1). The length of sprigs adopted for propagation of the Bermudagrass and Zoysiagrass varieties are usually of 2.54 cm to 10.16 cm of length (1 to 4 inches) (Munshaw, 2016).

Through the Scott Knott test, the accessions were grouped into a single group to the shorter than 2 cm long (21.67 sprigs to AP 01 and 87.00 to PN 01, respectively) produced sprigs and from 2 to 4 cm long (64.33 sprigs to AP 01 and 141.33 to PN 01, respectively). Two groups were observed in the longer than 4 cm long produced, with AP 01 accession with more sprigs (37.67) and the others accessions with less than 10.67 sprigs (Table 1).

Through this method, the larger numbers of sprigs were produced in the length class shorter than 2 cm and from 2 to 4 cm long, for PL 01 and PN accessions. Only for AP 01 there is no difference for the numbers of sprigs between the length classes (Table 1). This accession is a stoloniferous type of grown plant, with long distance between the nodes, thus the longer length and higher number of sprigs were observed, which was allow to adopt different lengths of sprigs.

The method to obtain the sprigs using a domestic straw crushing machine was accessible and inexpensive and it allowed to produce sprigs of *A. parodii*, *P. lepton* and *P. notatum* accessions with different lengths. This information, associated with the study of viability of sprigs, will be useful for the selection of accessions for the sprigs propagation method to turfgrass establishment.

Table 1. Total number of sprigs (N), minimum length (Min.), maximum length (Max.) and average length (average ± standard deviation), and number of sprigs per accession classified by length (shorter than 2 cm; from 2 to 4 cm; and from 4 to 6 cm), produced from turfgrass sods (1026 cm²) of *Axonopus parodii* (AP 01), *Paspalum lepton* (PL 01) and *P. notatum* (PN 01 to PN 06) at 98 DAP.

AC	N	Length of sprigs			Number of sprigs per accession classified by length		
		Min.	Max.	Average ± Standard deviation	Shorter than 2 cm	From 2 to 4 cm	From 4 to 6 cm
AP 01	390	0.50	10.50	3.57 ± 1.93 cm	21.67 aA	64.33 aA	37.67 aA
PL 01	480	0.50	7.00	1.96 ± 1.09 cm	76.00 aA	78.33 aA	5.33 bB
PN 01	752	0.50	11.5	2.04 ± 1.01 cm	87.00 aB	141.33 aA	5.67 bC
PN 02	544	0.50	8.00	2.18 ± 0.97 cm	66.67 aA	109.00 aA	5.67 bB
PN 03	586	0.50	8.00	1.94 ± 0.92 cm	85.67 aA	104.67 aA	5.00 bB
PN 04	533	0.50	7.00	2.25 ± 0.97 cm	57.00 aA	110.00 aA	10.67 bB
PN 05	445	0.50	6.50	2.36 ± 1.12 cm	47.33 aA	93.33 aA	9.00 bB
PN 06	547	0.50	10.00	2.17 ± 1.07 cm	64.33 aA	111.33 aA	6.33 bB
CV%	16.31						

*Abbreviations: AC – accessions; CV% - Coefficient of variance. Means followed by the same uppercase letter in horizontal line or lowercase letter in vertical line do not differ by the Scott Knott test (1974) at 5% probability. The data for number of sprigs were transformed into Log10 (Y), but the averages of the treatments are real data.

Experiment 2

There were significant differences among the accessions regarding turfgrass establishment using the vegetative propagation by sprigs with different lengths. Higher survival rates (SR) were observed in sprigs planted with 2 to 4 cm and with 4 cm to 6 cm long from AP 01 and all the PN accessions (Table 2). The SR of shorter than 2 cm long sprigs planted from PN 02, PN 05 and PN 06 accessions were statistically equal to the longer sprigs' length classes. The control treatment ZJ 01 higher survival rate (SR) was observed only in sprigs from 4 to 6 cm long.

Longer sprigs present more nodes in the propagative unit and these meristematic sites induces adventitious root formation (Kojoroski-Silva et al., 2011), and more nutritional reserves in the stolons or rhizomes that positively influence the survival and development capacity of new seedlings, as observed in this study. Sprig size could be controlled by cutting settings, and the sprigs produced through sod can be improved without risks to the establishment of the grass if associated with high survival rates.

It is worth mentioning that the survival rates of the sprigs of PL 01 and all PN accessions with 4 cm to 6 cm long did not differ from the control treatment (81.25%). The Zoysiagrass cv. Esmeralda, used as the control treatment, is the most commercialized and it is used for ornamental purposes throughout the country, from South to Northeast of Brazil (Santos et al., 2016). It has two types of growth, stoloniferous and rhizomatous, with 1.8 cm long internodes, and meristematic sites with the capacity to development adventitious roots (Kojoroski-Silva et al., 2011). This fact demonstrates that ZJ 01 needs sprig propagules with 4 cm to 6 cm long, for it probably has more internodes and present higher survival rates than shorter sprigs.

The SR of shorter than 2 cm long sprigs from PN 02, PN 05 and PN 06 (29.17% to 43.75%) was higher than all others accessions and the control treatment ZJ 01 (10.42% to 18.75%) (Table 2). From 2 to 4 cm long, all the PN accessions with higher SR (41.67% to 81.25%) were grouped, and it was observed once again that the accessions of *P. notatum* were superior to the control treatment ZJ 01. The AP 01 and PL 01 accessions were statistically equal to the control treatment ZJ 01 (SR of 10.42% to 31.25%) (Table 2).

Regarding sprigs with 4 cm to 6 cm long, all the accessions of *P. notatum* and PL 01 were statistically equal to the control treatment ZJ 01, with similar performance and higher SR (50.00% to 81.25%). For planting conditions in sandy soils, with warm and dry weather in the Brazilian northeast, it was observed a 100% survival rate of the PN 01, PN 02, PN 03, PN 04, PN 05 and PN 06 accessions propagated by plugs and com high turfgrass establishment (Castro et al., 2015).

The AP 01 accession (*Axonopus parodii*), presented low survival rates (10.42% to 14.59%) for all lengths (Table 1), which implies that the propagation method is not adequate for it. Despite the longer sprigs (Experiment 1), it probably had fewer nodes in the same sprig, decreasing the survival rate. The AP 01 kept under intensive turfgrass management, presents excellent turfgrass appearance and it requires less mowing (Silva et al., 2018), but it presents a lower dry biomass production (Souza et al., 2016).

Table 2. Average percentage of survival rate of sprigs (SR in %), number of shoots (NS), and expansion (E in cm²) of accessions of *Axonopus parodii* (AP 01), *Paspalum lepton* (PL 01), *P. notatum* (PN 01 to PN 06) and *Zoysia japonica* (ZJ 01) at 63 DAP.

AC	SR in %			NS			E in cm²		
	Length of sprigs			Length of sprigs			Length of sprigs		
	Shorter than 2 cm	From 2 to 4 cm	From 4 to 6 cm	Shorter than 2 cm	From 2 to 4 cm	From 4 to 6 cm	Shorter than 2 cm	From 2 to 4 cm	From 4 to 6 cm
AP 01	10.42 bA	10.42 bA	14.59 bA	0.80 bA	1.88 aA	3.21 aA	185.28 aA	92.24 bB	116.02 aB
PL 01	14.59 bB	29.17 bB	72.92 aA	5.92 aA	4.26 aA	7.84 aA	105.27 bA	112.57 bA	78.01 aA
PN 01	18.75 bB	56.25 aA	75.00 aA	4.69 aA	5.55 aA	4.10 aA	80.67 cA	64.23 cA	32.83 bA
PN 02	35.42 aB	81.25 aA	79.17 aA	6.03 aA	5.78 aA	5.22 aA	56.61 cA	39.45 cA	48.93 bA
PN 03	18.75 bB	64.59 aA	70.84 aA	2.34 bA	4.86 aA	4.78 aA	50.77 cA	31.10 cA	39.10 bA
PN 04	10.42 bB	50.00 aA	50.00 aA	2.71 bA	4.36 aA	4.23 aA	59.47 cA	43.93 cA	51.02 bA
PN 05	43.75 aA	60.42 aA	70.83 aA	4.27 aA	3.72 aA	6.38 aA	21.77 cA	18.94 cA	42.59 bA
PN 06	29.17 aA	41.67 aA	52.08 aA	2.27 bA	3.52 aA	2.75 aA	41.88 cA	23.64 cA	23.61 bA
ZJ 01	14.58 bC	31.25 bB	81.25 aA	0.39 bB	4.67 aA	2.99 aA	105.81 bB	226.09 aA	37.42 bC
CV%		30.28			26.80			28.25	

*Abbreviation: AC - Accessions; CV% - Coefficient of variance. Means followed by the same uppercase letter in horizontal line or lowercase letter in vertical line do not differ by the Scott Knott test at 5% probability. The data for the variables SR, NS and E were transformed into √ (Y + 1), but the averages of the treatments are real data.

It was not observed differences for the number of shoots (NS) per sprigs among the length classes for all the accessions. Nevertheless, by comparing the accessions and the control treatment, a greater NS was observed per sprig shorter than 2 cm long for the PL 01, PN 01, PN 02 and PN 05 accessions (4.27 to 6.03), which was higher than the control treatment ZJ 01 with only 0.39 shoots per sprig and AP 01 with 0.80 shoots. There was no significant difference among the accessions and the control treatment ZJ 01 cultivated with sprigs from 2 to 4 cm and from 4 to 6 cm long, with the emission of 1.88 to 7.84 shoots per sprig (Table 2).

McCarty (2018) recommends that sprigs should have at least 15 cm (6 inches) in length, more than two vegetative nodes and few green leaves to ensure high survival rates, for the presence of many leaves could increase nutrients translocation and cause color change to brown. In this study, the highest survival rates for most accessions were obtained with sprigs with 4 to 6 cm long as well as with 2 to 4 cm long for most accessions. Thus, sprigs with longer lengths ensure the presence of more meristematic nodes for greater survival rate results, corroborating with the aforementioned.

The accession AP 01 presented the highest expansion (E) value, grown with sprigs shorter than 2 cm and from 4 to 6 cm long (185.28 and 116.02 cm², respectively), which was superior to the control treatment ZJ 01 (Table 2).

The stoloniferous and rhizomatous types of growth of AP 01, PL 01 and ZJ 01, favor the expansion and occupation of new spaces. According to Souza et al. (2016) the growth habit (stoloniferous, rhizomatous, stoloniferous-rhizomatous) determines the soil coverage capacity and the growing vigor (aggressiveness) of the plant, and for Kojoroski-Silva et al. (2011), longer stolons provide greater capacity for mobility and colonization of new areas.

All *Paspalum* accessions were statistically equal to the value of E (cm²), for the shorter than 2 cm, from 2 to 4 cm and with 4 cm to 6 cm long sprigs, and presented lower expansions (E in cm²) compared to the control treatment ZJ 01, cultivated with sprigs shorter than 2 cm and from 2 to 4 cm in length. Moreover, there was no significant difference to ZJ 01 cultivated with sprigs with 4 to 6 cm long (Table 2). *P. notatum* present creeping shoots, growing horizontally close to the mother plant, being easily identified by the stolons with extremely short internodes, covered by leaf sheaths (Gouvêa et al., 2019).

Higher values of soil coverage rate (SCR in%) were observed in PN 01, PN 02 and PN 05 accessions (13.05% to 17.11%) when it was cultivated with sprigs shorter than 2 cm long. These accessions along with PN 03 and PN 04 presented higher SCR (21.32% to 46.16%) when it was cultivated with sprigs with 2 to 4 cm long, which were superior to AP 01, PL 01 and to the control treatment ZJ 01. All the *P. notatum* accessions and PL 01 showed the highest SCR (46.03% and 42.28%), even higher than the control treatment in ZJ 01 (Table 3) with the sprigs with 4 to 6 cm long.

Silva et al. (2018) observed that PN 01, PN 03 and PN 05 lawns presented excellent coverage capacity and pleasant appearance. The ability to occupy the available space efficiently influences the management of water and nutrients and it is related to the quality of the turfgrass. In addition, greater soil coverage, reduces the lawn establish period, and consequently the soil exposure and it also prevents weed incidence.

The sprigs length classes from 2 to 4 cm and from 4 to 6 cm allowed the development of turf plants with a better soil coverage for most accessions (PN 02 to PN 06). Only the AP 01 and the control treatment ZP 01 presented similar values of SCR (%) in the three length classes (Table 3).

Regarding biomass rates, there was no significant difference in the dry biomass of the aerial part (DBAP) in the accessions propagated with the shorter than 2 cm long sprigs (2.55 to 7.08 g). However, higher DBAP was observed in the PN 01 and PN 02 cultivated with the 2 to 4 cm long sprigs (12.43 and 15.95 g, respectively), which were superior to other accessions and to the control ZJ 01. Moreover, they presented greater values than the 4 cm to 6 cm, for the PL 01, PN 01, PN 02, PN 03 and PN 05 accessions presented higher DBAP (9.13 to 13.26 g) (Table 4). These results provide positive attributes for turfgrass establishment, for the production of dry biomass is associated with lawn (Souza et al., 2016).

Dense lawns are especially desired for landscaping, recreational and sporting purposes, for it contributes with the ornamental quality (Souza et al., 2016). Generally, faster growth provides a higher occupancy rate, shading and consequently greater biomass of the turfgrass foliage, which reduces weed development (Silva et al., 2018). However, dense lawns cause high demand for mowing, and high clipping production that may increase problems of disposal, soil nutrient replacement, and increase maintenance costs (Souza et al., 2020). Therefore, higher accumulations of biomass in the aerial part, composed by foliage, rhizomes and/or stolons, as observed in PL 01, PN 01, PN 02, PN 03 and PN 05 accessions are indicative of high coverage capacity (Table 4).

In order to improve soil coverage, it is desirable along with high aerial biomass, a vigorous root system. It was observed that PN 02, PN 03 and PN 05 accessions were statically equal with higher values of dry biomass of the roots system (DBRS), when cultivated with sprigs shorter than 2 cm long and they didn't differ of the control treatment ZJ 01. With 2 to 4 cm long sprigs, PN 02 accession stood out with DBRS (47.74 cm) production higher than the control treatment ZJ 01. With 4 to 6 cm long sprigs, the PL 01, PN 01, PN 02, PN 03, and PN 05 accessions evaluated showed higher DBRS (29.63 cm to 68.62 cm, respectively), which were superior to the control treatment ZJ 01 (Table 4). These accessions showed significant densities of the root system, whose largest accumulation of dry mass for stolons and rhizomes, quickly assists turfgrass establishment.

Accessions with high values for aerial and root biomass can guarantee a good soil coverage, and their lawns can perform different functions such as protective soil cover. For in several Brazilian regions, where lawns are exposed to variable or sporadic care (such as at highways and urban avenue or airport runways) (Souza et al., 2020), it is necessary plant resistance and adaptation as well as a good green soil coverage, which tends to efficient manage nutrients for its survival. It is worth mentioning that PL 01, PN 01, PN 02, PN 03, and PN 05 accessions have these particular biomass characteristics. In addition to soil coverage, root characteristics such as root depth, extensiveness and spatial distribution also influence the amount of soil moisture that is available for the grass in terms of initial drought tolerance (Zhang et al., 2019). It could demonstrate a possible resistance of these accessions to low water availability compared to Zoysiagrass cv. Esmeralda, which requires intensive maintenance for ornamental lawns.

DBRS was statistically equal in all sprig lengths for the AP 01 accession. The others accessions cultivated with 4 to 6 cm long sprigs presented higher DBRS values than in the shorter than 2 cm length class and were superior (PL 01; PN 03; PN 05; PN 06; and ZJ 01) or statistically similar (PN 01; PN 02; and PN 04) when grown with 2 to 4 cm sprigs (Table 4).

Table 3. Development of accessions of *Axonopus parodii* (AP 01), *Paspalum lepton* (PL 01), *P. notatum* (PN 01 to PN 06) and *Zoysia japonica* (ZJ 01), and soil coverage rate (SCR in %) at 63 DAP.

AC	Images			SCR in %		
	Length of sprigs			Length of sprigs		
	Shorter than 2 cm	From 2 to 4 cm	From 4 to 6 cm	Shorter than 2 cm	From 2 to 4 cm	From 4 to 6 cm
AP 01				2.91 bA	3.52 bA	5.53 bA
PL 01				9.72 bB	14.08 bB	29.13 aA
PN 01				17.11 aB	38.23 aA	46.03 aA
PN 02				24.07 aB	46.16 aA	35.69 aA
PN 03				9.86 bB	34.06 aA	42.28 aA
PN 04				8.33 bB	29.19 aA	25.27 aA
PN 05				13.05 aB	21.32 aB	37.09 aA
PN 06				1.92 bB	18.40 bA	30.25 aA
ZJ 01				2.90 bA	7.01 bA	14.47 bA
CV%	30.14					

* Abbreviations: AC - accessions; CV% - Means followed by the same uppercase letter in horizontal line or lowercase letter in vertical line do not differ by the Scott Knott test (1974) at 5% probability level. The data for the variable SCR were transformed into √ (Y + 1), but the averages of the treatments are real data.

Table 4. Dry biomass of the aerial part (DBAP in g) and dry biomass of the root system (DBRS in g) of accessions of *Axonopus parodii* (AP 01), *Paspalum lepton* (PL 01), *P. notatum* (PN 01 to PN 06) and *Zoysia japonica* (ZJ 01) at 63 DAP.

AC	DBAP in g			DBRS in g		
	Length of sprigs			Length of sprigs		
	Shorter than 2 cm	From 2 to 4 cm	From 4 to 6 cm	Shorter than 2 cm	From 2 to 4 cm	From 4 to 6 cm
AP 01	4.59 aA	4.01 bA	1.85 cA	2.87 bA	5.53 cA	2.31 cA
PL 01	2.55 a B	5.67 bB	12.00 aA	3.07 bC	11.31 bB	29.63 aA
PN 01	4.44 aB	12.43 aA	17.20 aA	4.03 bB	18.33 bA	36.92 aA
PN 02	6.38 aB	15.95 aA	13.26 aA	8.33 aB	47.74 aA	68.62 aA
PN 03	7.08 aA	6.95 bA	9.13 aA	9.61 aB	16.47 bB	48.78 aA
PN 04	2.95 aA	6.81 bA	6.02 bA	2.87 bB	11.27 bA	14.96 bA
PN 05	6.39 aB	4.91 bB	11.88 aA	13.36 aB	14.55 bB	37.36 aA
PN 06	4.54 aA	4.42 bA	7.14 bA	5.41 aB	8.50 bB	16.10 bA
ZJ 01	3.88 aA	1.32 bA	3.52 cA	5.65 aB	3.36 cB	11.64 bA
CV%		25.83			16.81	

*Abbreviation: AC – Accession; CV% - Coefficient of variance. Means followed by the same uppercase letter in horizontal line or lowercase letter in vertical line do not differ by the Scott Knott test at 5% probability level. The data were transformed into √ (Y + 1) for the variable DBAP and 1 + Log10 (Y) for RDBS, but the averages of the treatments are real data.

Pearson's correlation indicates the association between two variables, observed the positive correlation between the SR with SCR (r = 0.821**) and with NS (r = 0.675*), indicating that greater sprig survival rate was observed in the accessions with greater soil coverage rate and number of shoots. The NS was also positive when correlated to SCR (r = 0.723*) and demonstrated that higher number of shoots were associated with better soil coverage rate, for it provides greater lawn density with reduced spacing between plants, which contributes to soil coverage (Table 5).

Table 5. Pearson's correlation analysis for survival rate (SR), soil coverage rate (SCR), number of shoots (NS), expansion (E), dry biomass of the aerial part (DBAP) and dry biomass of the root system (DBRS) evaluated from accessions of *Axonopus parodii* (AP 01), *Paspalum lepton* (PL 01) and *P. notatum* (PN 01 to PN 06) at 63 DAP.

Pearson's Correlation					
Variables	SCR	NS	E	DBAP	DBRS
SR	0.821**	0,675*	-0.680*	0.740*	0.843**
SCR	-	0.723*	- 0.721*	0.942**	0.858**
NT	-	-	-0.372ns	0.764*	0.717*
E	-	-	-	- 0.552ns	-0.551ns
DBAP	-	-	-	-	0.869**

Significant difference at 1% (**) and 5% (*) probability level by the T test for the variable.

However, the negative correlations between E with SR (r = - 0.680*) and SCR (r = - 0.721*) indicated that accessions with higher expansion presented lower survival rate, and that high expansion leads to less soil coverage. This was observed in AP 01 accession, which showed high growth of the lateral stolons and rhizomes but presented low biomass of the aerial part (mainly foliage) and low root biomass, consequently it did not present high soil coverage rate (Tables 3, 4). The PL 01 accession also showed high expansion, due to its stoloniferous and rhizomatous growth type.

The high biomass of the aerial part and root biomass contribute to cover the soil surface and soil by hooking it by the roots tangle, together culminating in a high ground cover. However, the AP 01 and PL 01 showed emissions of large stolons, with long distance between the nodes, increasing expansion (E) (Table 2). Thus, when plant produces lateral growth mechanisms through the production of rhizomes and stolons, it tends to present high expansion rates (E). But when it tends to produce many shoots, it culminates in increased grass density with reduced spacing between the plants and, thus the turfgrass sod is formed (Table 2).

Positive correlations were also observed between SR and DBAP (r = 0.740*) and between SCR and DBAP (r = 0.942**). This indicates that the higher the sprig survival rate and the greater soil coverage, provided by the sprig plants, greater the biomass production of the aerial part of the grass.

Positive correlations among NS, DBAP and DBRS (r = 0.764* and r = 0.717*) (Table 5) shows that the highest number shoots occur in accessions with higher biomass of aerial part and root production.

Positive correlations were also observed between DBRS and SCR (r = 0.858**), and between DBAP and DBRS (r = 0.869**) (Table 5). It indicates that soil coverage rate doesn't depend only on the aerial part (leaf structure), but also on the roots, rhizomes and stolons; and that greater leaf production culminates in greater development of the root system.

The use of correlation permitted the selection of accessions for better soil coverage with higher survival rate and less expansion. For those are variables of easy and fast measurement, and less laborious than obtaining the dry biomass of the plant or evaluating soil coverage capacity.

The PN 01, PN 02, PN 03 and PN 05 accessions planted with longer than 2 cm sprigs reached higher values for survival and soil coverage rate, shoot number, dry biomass of the aerial part and roots. Therefore, those accessions are recommended for turfgrass establishment by the sprigging method.

Conclusions

The domestic straw crushing machine allowed to obtain sprigs from turfgrass sods of *Axonopus parodii*, *Paspalum lepton* and *P. notatum* with higher production of shorter than 2 cm and from 2 to 4 cm long sprigs. Sprigs longer than 2 cm present greater viability for vegetative propagation of *A. parodii*, *P. lepton* and *P. notatum*. The accessions of *P. notatum* PN 01, PN 02, PN 03 and PN 05 are indicated for turfgrass establishment by sprigs longer than 2 cm long. Based on the correlations, the selection of accessions for better soil coverage may be indirectly based on the higher survival rate and less expansion, for those variables are of easy and fast measurement.

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Author Contribution

S.Á.C.G.S.: Original draft preparation; Synthesis of the research idea; formulation of research goals and aims; development of the methodology; character analysis; creation of an experimental design; installation of the experiment in the field; images analysis of vegetation coverage by the SisCob Software; conducting of research and experiment in the field; collecting data; and data analysis; data and statistical analysis, data interpretation and creation of graphs and tables; and final article preparation (including substantive translation). **J.C.C.A.F.:** Application of statistical analysis of the original data; assistance during the application of the experimental methodology; data entry, spreadsheet organization, scrub data and maintain research data for statistical analysis; and data interpretation for subsequent graphs and tables. **S.S.L.S.:** Development of the methodology; character analysis, creation of an experimental design; and installation of the experiment in the field; article review. **C.E.F.C.:** Article review, specifically critical and correction, including pre stages for publications. **V.L.:** Synthesis of the research idea, formulation of research goals and aims; development of the methodology; character analysis; creation of an experimental design; installation of the experiment in the field; article review, specifically critical and correction, including pre stages for publications.

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