Influence of irrigation frequency and nitrogen concentration on Tifway 419 bermudagrass in Brazil[1]

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ABSTRACT

Tifway 419 Bermudagrass is widely used on athletic fields, requiring irrigation and fertilization for its maintenance; however, little information is available for Bermudagrass management in tropical countries, as Brazil. Thus, this study aimed to evaluate the effect of irrigation frequency and nitrogen (N) fertilization on the development of Tifway 419 Bermudagrass. The experiment was carried in 2019, applying two irrigation frequencies (daily and every two days) and five N concentrations of 0, 42.19, 63.28, 105.47 and 126.56 kg N ha^{-1} divided into three 30-day increments. Photosynthetic pigments, grass height, accumulated dry mass, relative chlorophyll index, regeneration rate, root length, and dry mass of root, rhizome and stolon were analyzed. The best result was observed in between 63.28 and 105.47 kg N ha^{-1} (15% N) and irrigated every two days. The treatment maintains the green color of the grass. Maximum Bermudagrass regeneration rate was observed within this interval, and the root length and dry mass of roots, rhizomes and stolons were higher compared to the highest concentration.

Keywords: *Cynodon* spp.; athletic fields; nitrogen fertilization; irrigation management.

INTRODUCTION

The ornamental and sporting turfgrass market experienced an economic rise over the last decade, due to the introduction of new hybrids and technologies, as well as increased production and, better maintenance and development of turfgrass areas (Kuhn, 2015). Bermudagrass (*Cynodon* spp.) has assumed an important position in this scenario been used on athletic fields (Santos & Castilho, 2018). The genus represents warm season grasses native to Africa and naturalized in the Bermuda Islands. Bermudagrass is known for the fast growth and excellent mowing recovery (Christians *et al.*, 2016). Several hybrids, from the crossing of *C. dactylon* and *C. transvaalensis*, were introduced to Brazilian soccer fields mainly the Tifway 419 cultivar (Godoy *et al.*, 2012; Santos & Castilho, 2018). This hybrid has a rhizomatous and stoloniferous growth habit, which provides high trampling resistance. It has narrow leaves with intense green color and fine texture, providing softness to Bermudagrass, providing consistent ball rolls on the field and reducing the impact of the players (Godoy *et al.*, 2012; Christians *et al.*, 2016; Amaral *et al.*, 2019).

Areas covered by turfgrass need adequate fertilization and irrigation to maintain the attributes noted previously (Carrow, 2012; Candogan *et al.*, 2015; Zhang *et al.*, 2018). Nitrogen is the nutrient most required by turfgrass (Gazola *et al.*, 2019), and the correct application of nitrogen fertilization is necessary (Dinalli *et al.*, 2015) to maintain both the aesthetic quality (intense green) of turfgrass and the recovery of damage caused by athletes (Santos *et al.*, 2019; Mateus *et al.*, 2020). However, little is known about nitrogen fertilization of Bermudagrass (Godoy *et al.*, 2012; Gazola *et al.*, 2019), mainly in sport fields (Mateus *et al.*, 2020; Santos *et al.*, 2020).

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Irrigation and nitrogen fertilization are required to preserve turfgrass green color and quality (Lee, 2014; Zhang *et al.*, 2018). The ideal irrigation frequency should maintain moisture at the root zone to avoid water stress and leaching (Lee, 2014). However, a reduced amount of irrigation can stimulate deep root growth (Padrón *et al.*, 2015), resulting in a better quality turfgrass, less recovery time, and higher capacity to uptake water and nutrients. Irrigation management is especially important during the winter in tropical countries with seasonally lower temperatures, rainfall and solar radiation, reducing grass development. Thus, the objective of our study was to evaluate the development Tifway 419 Bermudagrass under different irrigation management and nitrogen fertilization.

MATERIAL AND METHODS

The field experiment was conducted from June 23rd to September 21st, 2019 (90 days) in an experimental area with Tifway 419 Bermudagrass established in 2014 (Faculdade de Ciências Agronômicas (UNESP) Botucatu, São Paulo State, Brazil). According to the Köppen climate classification, the regional climate is considered as humid subtropical climate with a well distributed and abundant precipitation throughout the year (Cfa). The average temperature was 18.9 ºC (24.7 ºC maximum and 13.9 ºC minimum), average relative humidity of 69.9% (65.40% maximum and 87.47% minimum) and 161.01 mm of accumulated precipitation during the experimental period. The soil (Table 1) is classified as Dystrophic Red Latosol (Oxisol) and soil acidity correction with dolomitic limestone to raise the base saturation to 65% (Mateus *et al.*, 2017). Prior to the start of the study, the Bermudagrass was mown to a height of 15 mm.

Irrigations were differentiated by frequency as daily (F1), replacing the evapotranspirated blade from the previous day, or every two days (F2), replacing the sum of the evapotranspirated blades from the previous two days. The irrigation blades were calculated using data obtained from a meteorological station located next to the experimental area. The sprinkler irrigation system was automated with four sprinklers (retractable rotor type), one at each end of the plot, irrigating sectorally at a 90° angle. The system featured a rain sensor to interrupt scheduled irrigation after 5 mm of precipitation.

The nitrogen (ammonium sulfate, 21% N) fertilization treatments were 0 kg N ha^{-1} (Control), 42.19 kg N ha^{-1}, 63.28 kg N ha^{-1}, 105.47 kg N ha^{-1} and 126.56 kg N

Table 1: Soil chemical analysis result of the the experimental area. O.M. = Organic Matter, SB = Sum of Bases, CEC = Cation Exchange, V = Capacity Base Saturation

Layer	pH	O.M.	P_{resin}	H+Al	K	Ca	Mg	BS	CEC	V
cm	$CaCl_2$	g dm^{-3}	mg dm^{-3}	mmol$_c$ dm^{-3}						%
0-10	5.1	19	80	19	3.2	16	5	24	43	56
10-20	5.1	10	32	17	3.1	13	3	19	35	53

Supplemental Tables:

S1: ANOVA table for photosynthetic pigments in Tifway 419 Bermudagrass as a function of different nitrogen concentrations and irrigation frequencies

Concentration	Chlorophyll *a*	Chlorophyll *b*	Carotenoids
(kg N ha^{-1})	µg g^{-1} FW		
0.00	186.15	101.49	95.42
42.19	208.03	105.16	102.46
63.28	249.47	131.42	102.17
105.47	283.43	151.43	104.01
126.56	289.32	185.87	103.71
Irrigation frequency			
F1 - Daily	243.40	136.00	102.48
F2 - Every 2 days	243.16	134.14	100.62
CVC	4.47	4.22	2.91
$F_{concentration}$	345.07**	229.06**	4.871**
$F_{frequency}$	0.013^{ns}	0.812^{ns}	1.695^{ns}
$F_{d x f}$	3.585*	0.629^{ns}	0.143^{ns}
CV (%)	2.85	4.83	4.44

** - Significant at 1%, * - Significant at 5%, ns - Not significant.

ha^{-1}. The fertilization was splitted into three parts and applied at 0, 30 and 60 days (June 23, July 23 and August 23, 2019) after the start of the research (DAI).

The parameters evaluated were chlorophylls *a*, *b* and carotenoids (photosynthetic pigments), according to the methodology described by Lichtenthaler (1987). Relative chlorophyll index (RCI) was determined with a FieldScout CM 1000 Chlorophyll Meter (Spectrum Technologies, Aurora, IL, USA), taking readings parallel to the Bermudagrass surface at a height of 1.0 m. Bermudagrass height was determined with a HGPRISM-G - Height of Cut Prism Gauge device (Turf-Tec International, Tallahassee, FL, USA). The Bermudagrass was mowed 3 times (every 30 days), at a height of 15 mm, and measurements were always made before the next mowing. To measure dry mass accumulated from the clippings, grass was mowed every 30 days with a GreenMaster 1000 mower (The Toro Company, Bloomington, MN, USA), and the clippings were dried in an oven with forced air at 60 °C for 72 h. Photosynthetic pigments, RCI and Bermudagrass height data were collected on the 27, 55 and 87th DAI (July 20, August 17 and September 18, 2019), and the final data were an average of the three measurements. Dry mass of clippings was carried out on the same dates, and data were the sum of the three dates, i.e., total accumulation. Roots, rhizomes and stolons were collected at 90 DAI (September 21, 2019) to analyze root length and roots, rhizomes and stolons dry mass (60 ºC for 72 h in a forced-air oven).

To simulate the effect of an athletic competition, a plug (6 cm in diameter and 5 cm in length) from each experimental plot (on July 23, 2019) of the same size was removed with an auger. Thirty days after removal of the plug (August 23, 2019), images of the hole were taken with a "light box", similar to the device produced by Peterson *et al.* (2011). The images were analyzed with Canopeo® software to calculate the Bermudagrass coverage rate and damage recovery (Karcher *et al.*, 2005).

The experimental design adopted was a factorial scheme (2x5) with two irrigation management frequen-

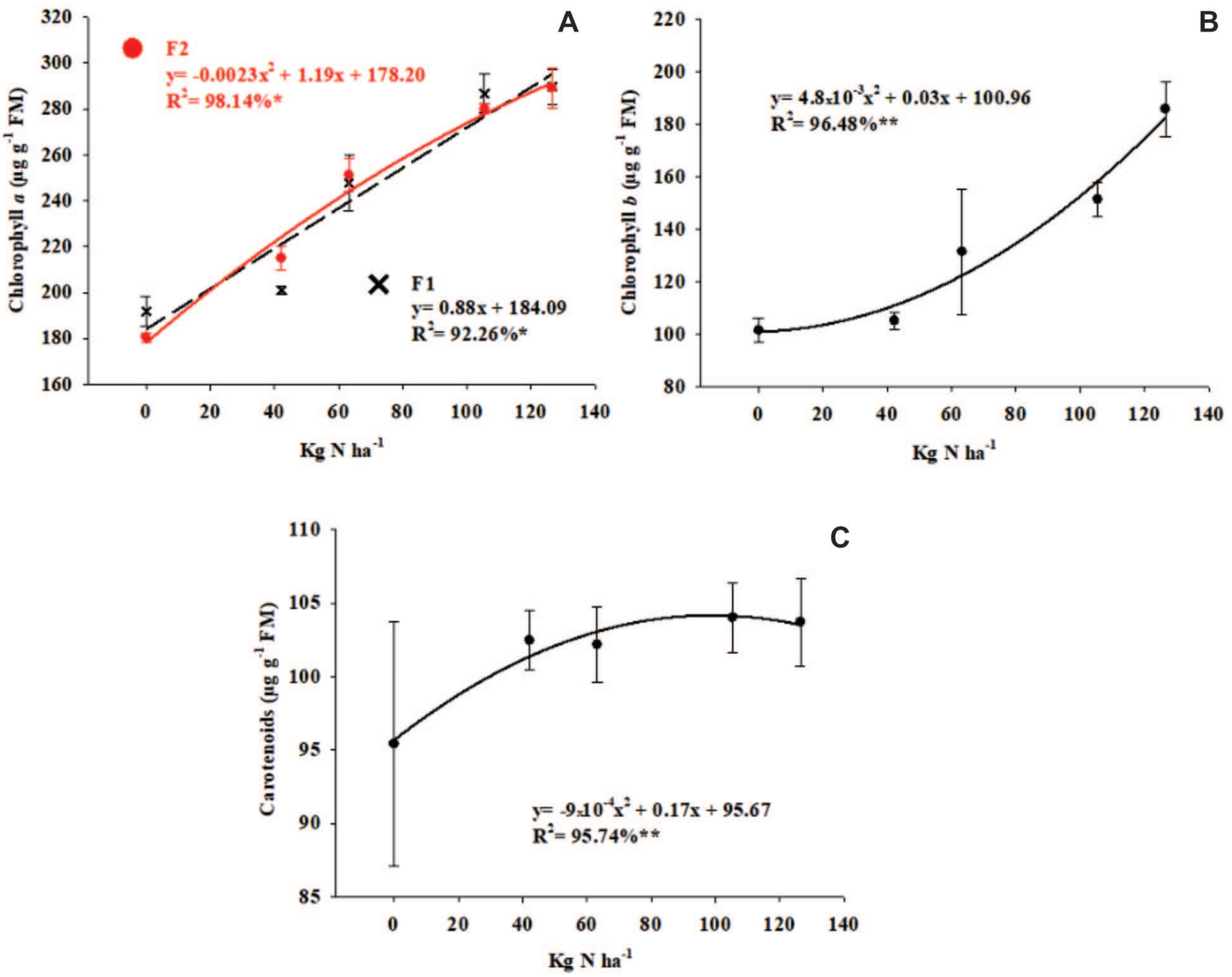

Figure 1: Photosynthetic pigments in 'Tifway 419' Bermudagrass as a function of nitrogen concentrations (Kg N ha^{-1}). a) chlorophyll *a*. b) chlorophyll *b*. c) carotenoids. ** - Significant at 1%; * - Significant at 5%. F1 - Irrigation frequency daily; F2 - Irrigation every 2 days.

cies and five N concentrations, with four replications, totaling 40 experimental plots. Each plot was composed of a 5.0 x 5.0 m (25 m^2) plot with 1.0 m of border. The data were evaluated by variance analysis and Tukey's test ($p \leq 0.05$) at 5% for frequency and regression for concentration, using "Statistix 10" for data analysis and "Sigma Plot" for graphics.

RESULTS AND DISCUSSION

A significant interaction was observed between irrigation and fertilization for chlorophyll *a* (Supplemental Table S1), with a linear increase in the F1 regime, maximum value obtained at the highest concentration of N, and quadratic adjustment in the F2 regime (Figure 1a). For chlorophyll *b* and carotenoids, significant difference was only observed for fertilizer concentrations, indicating that the concentration of these pigments continued the same, regardless the irrigation regime (Figures 1b and 1c). Carotenoid concentrations were adjusted as a quadratic curve, according to N concentrations, and reached maximum value at 112.5 kg N ha^{-1}. These results are similar to those observed by Santos *et al.* (2019) for Tifway 419 Bermudagrass and lower than the values observed by Barbosa *et al.* (2017) for Bahiagrass (*Paspalum notatum*). The increase of pigments concentrations can be explained by the fact that chlorophylls are molecules formed by complexes derived from porphyrin, with magnesium as the central atom, linked to four others of nitrogen (Taiz *et al.*, 2017). Additionally, 50 to 70% of total foliar N consists of enzymes associated with chloroplasts (Taiz *et al.*, 2017; Santos *et al.*, 2019). Thus, a high correlation exists between photosynthetic pigments and grass nutrition (Santos & Castilho, 2015; Oliveira *et al.*, 2018; Santos *et al.*, 2019). Higher pigment concentrations are important for plant development because they play a significant role in Bermudagrass photosynthetic rates. While chlorophyll *a* plays a key role in the light

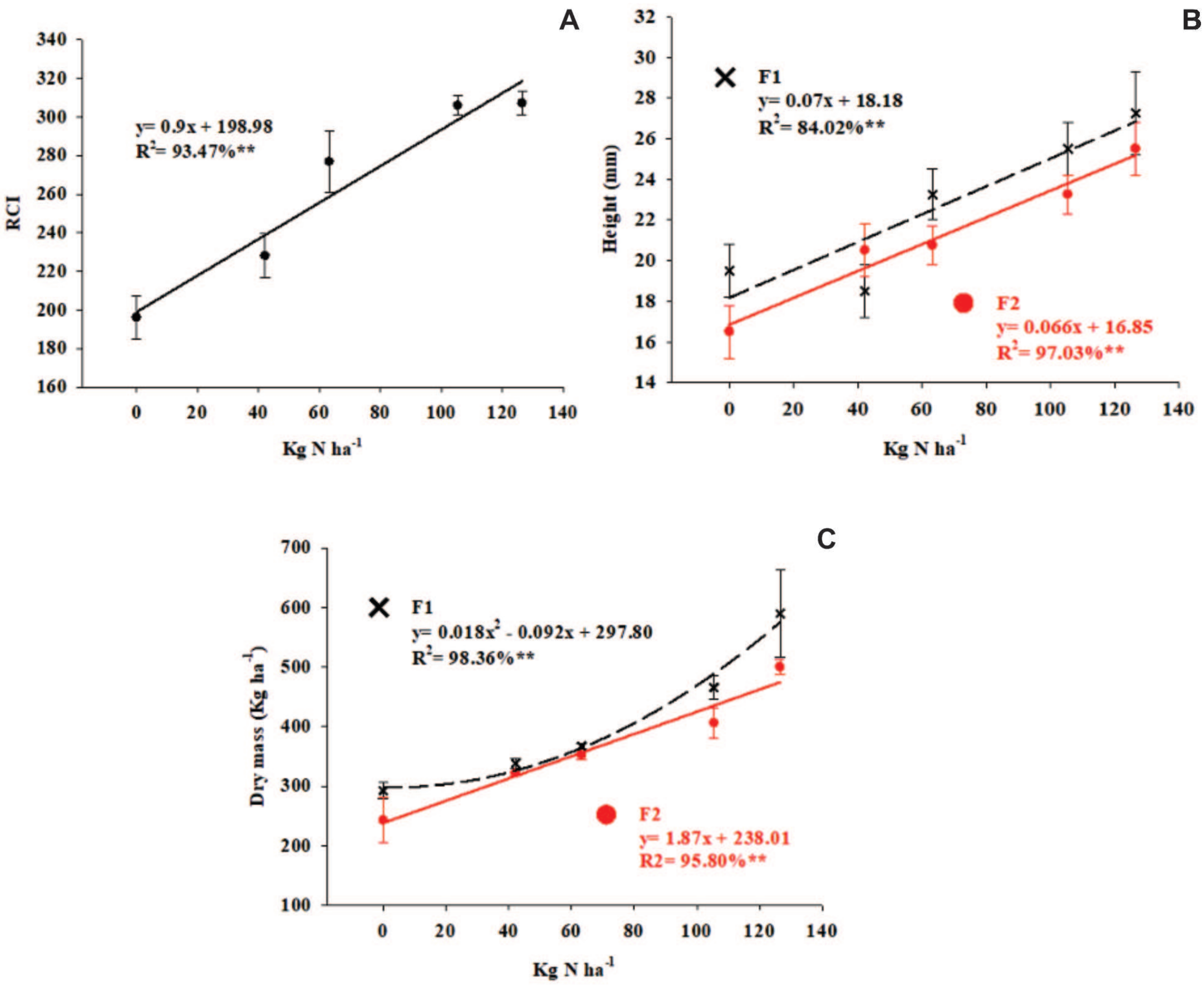

Figure 2: Green Color Index (GCI) (a), leaf height (b) and dry mass clippings (c) of 'Tifway 419' Bermudagrass as a function of different nitrogen concentrations (Kg N ha^{-1}). ** - Significant at 1%; * - Significant at 5%. F1 - Irrigation frequency daily; F2 - Irrigation every 2 days.

bioconversion process, chlorophyll *b* and carotenoids, also called accessory pigments, are able to dissipate excess energy (Taiz *et al.*, 2017).

There was a linear increase in relative chlorophyll index (RCI), as a function of N concentration (Figure 2a). RCI was also unaffected by irrigation frequency, indicating that the green color of leaves can be preserved, irrespective of irrigation frequency, whether daily or every other day (Supplemental Table S2). The results were within the range of 150 to 600 units, as observed by Lima *et al.* (2012) in Celebration Bermudagrass fertilized with nitrogen. A fast and easy way to maintain athletic fields is using a portable equipment for indirect color evaluation of Bermudagrass by relative chlorophyll indices. After all, one of the main objectives is the aesthetic appeal of Bermudagrass with good density and intense green color (Lima *et al.*, 2012). Particularly in winter in Brazil, with shortage of rainfall and solar radiation, greener Bermudagrass can perform its physiological processes in the presence of low water and light stress (Taiz *et al.*, 2017; Santos *et al.*, 2019). Bermudagrass was taller in the F1 regime in all N concentrations, except for 42.19 kg N ha^{-1}. Bermudagrass height increased linearly in both F1 and F2, according to the concentration of N (Figure 2b). The accumulated dry mass of clippings showed a quadratic curve and maximum value at the highest N concentration (Figure 2c). No interaction occurred between height and dry mass of clippings and less dry mass in the F2 regime. Increasing N concentration correlated with an increase in dry mass, as observed by Lima *et al.* (2015) on Celebration Bermudagrass, and Dinalli *et al.* (2015) on Emerald grass. Height and dry mass clippings in relation to irrigation frequency were the two main factors in our study. Daily irrigation showed grass with greater height and dry mass, while irrigating Bermudagrass every two days reduced shoot development. Daily irrigation was shown to maintain moisture in the root zone, without

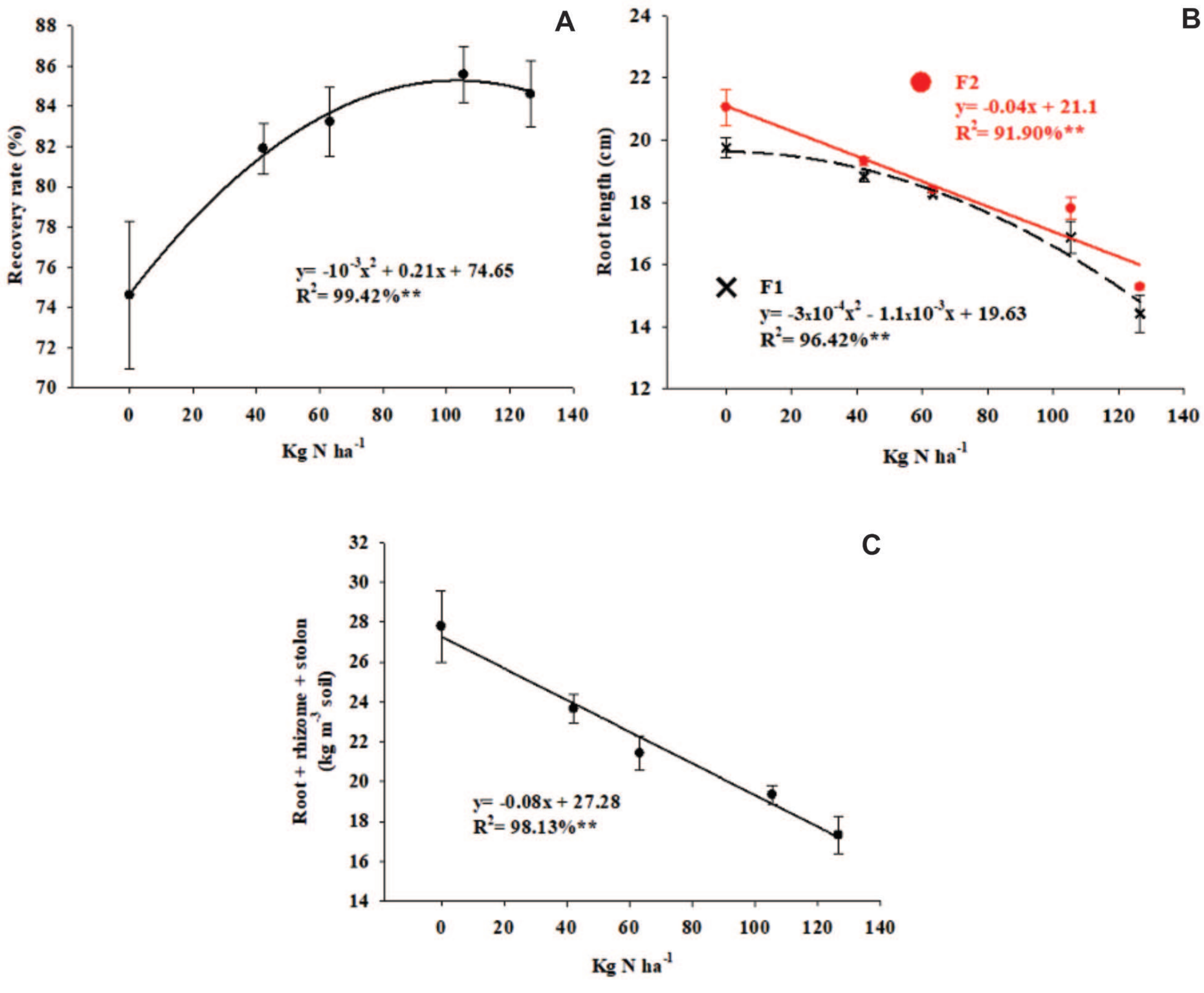

Figure 3: Recovery rate (a), root length (b) and dry mass (root + rhizome + stolon) (c) of 'Tifway 419' Bermudagrass as a function of different nitrogen concentrations (Kg N ha^{-1}). ** - Significant at 1%; * - Significant at 5%. F1 - Irrigation frequency daily; F2 - Irrigation every 2 days.

causing water stress, promoting shoot development (Lee, 2014), as observed for F1. However, an increase in either height or dry mass accumulation is not necessarily a desirable result for Bermudagrass used in athletic fields because of the corresponding need for more mowing (Santos & Castilho, 2018, Gazola *et al.*, 2019).

Bermudagrass recovery rate (Figure 3a) showed that only N concentration changed positively the percent of coverage (Supplemental Table S2). The lowest result for irrigation frequency was observed in the control treatment (without fertilization). This result implies that the lack of N in the soil makes it harder and slower for Bermudagrass to recover from an injury caused by athletic activity. However, very high concentrations of N can be lost in fertilization. For example, the concentration with the highest RR value derived from the regression was 102.27 kg N ha^{-1}, and it would be enough to recover from the damage cause by athletic activity, irrespective of irrigation frequency. A significant interaction between irrigation and root length was observed with polynomial regression decreasing to 1% (Figure 3b). The increase of N concentration decreased

S2: ANOVA table for relative Chlorophyll Index (RCI), height and dry mass of the Tifway 419 Bermudagrass clippings as a function of different nitrogen concentrations and irrigation frequencies

Concentration (kg N ha^{-1})	RCI	Height (mm)	Dry mass (Kg ha^{-1})
0.00	196	18	267.43
42.19	228	20	329.57
63.28	277	22	359.24
105.47	306	24	435.78
126.56	307	26	544.77
Irrigation frequency			
F1 - Daily	265	23 a	410.50 a
F2 - Every 2 days	260	21 b	364.21 b
CVC	6	1	18.54
$F_{concentration}$	210.80**	53.229**	110.78**
$F_{frequency}$	1.655^{ns}	12.736**	26.01**
$F_{d x f}$	0.331^{ns}	4.564**	2.398*
CV (%)	3.65	6.03	7.41

Averages followed by the same letter in the column do not differ by Tukey's test at 5% probability. ** - Significant at 1%, * - Significant at 5%, ns - Not significant.

S3: ANOVA table recovery rate, root length and dry mass (root + rhizome + stolon) of 'Tifway 419' Bermudagrass as a function of different nitrogen concentrations and irrigation frequencies

Concentration (kg N ha^{-1})	Recovery rate (%)	Root length (cm)	Dry mass(root + rhizome + stolon) (kg m^{-3} soil)
0.00	74.61	19.3	27.79
42.19	81.90	19.3	23.65
63.28	83.23	19.1	21.42
105.47	85.59	17.5	19.35
126.56	84.61	14.9	17.31
Irrigation frequency			
F1 - Daily	82.10	17.6 b	21.28 b
F2 - Every 2 days	81.88	18.4 a	22.52 a
CVC	1.31	0.2	0.53
$F_{concentration}$	36.62**	279.801**	194.661**
$F_{frequency}$	0.113^{ns}	44.67**	22.93**
$F_{d x f}$	1.631^{ns}	3.080*	1.098^{ns}
CV (%)	2.48	1.96	3.75

Averages followed by the same letter in the column do not differ by Tukey's test at 5% probability. ** - Significant at 1%, * - Significant at 5%, ns - Not significant.

root length, which was influenced by the frequency of irrigation. The highest root length value was found in the control treatment (0.00 kg N ha^{-1}), when irrigated every two days, but a lower root length value was obtained with N concentration (126.56 kg N ha^{-1}) and daily irrigation. The accumulation of dry matter from the roots, rhizomes and stolons was related to irrigation frequency and N; however, with no significant interaction between the factors (Figure 3c). Plants fertilized with a higher concentration of N accumulated less dry matter, and plants irrigated with F2 (every two days) had higher dry matter values compared to F1 (daily). Less frequent irrigation associated with adequate nitrogen fertilization stimulates roots to grow deeper (Lee, 2014). Deeper roots can uptake more nutrients and water, improving grass growth and allowing faster recovery from stress or mowing. On the other hand, as observed in this study, high concentrations of N and irrigation frequency produce fine and superficial roots, resulting in less resistant grass, owing to the imbalance between roots and shoot (Zhang *et al.*, 2018). Fertilization in plants with high concentrations of N promotes the depletion of carbohydrate reserves to synthesize amino acids and the construction of new cells to produce new leaves and is, therefore, detrimental to root system development (Taiz *et al.*, 2017; Zhang *et al.*, 2018). Thus, it is essential to balance N fertilization and irrigation to stimulate root development and grass with a high level of quality (Lee, 2014, Candogan *et al.*, 2015; Zhang *et al.*, 2018).

CONCLUSIONS

Our results showed that nitrogen fertilization with concentrations between 63.28 kg N ha^{-1} and 105.47 kg N ha^{-1}, distributed in three applications, combined with irrigation on alternate days, is recommended for Tifway 419 Bermudagrass managing. These treatments preserve the green color of the grass, mostly as chlorophyll *a*, produce less dry mass than higher concentrations of N (126.56 kg N ha^{-1}), produce deeper roots and more dry mass of roots, rhizomes and stolons. Additionally, the maximum regeneration taxa of the Bermudagrass in this study was obtained within the ideal fertilization range (102.27 kg ha^{-1}), demonstrating that our results are in accordance with the desired characteristics of grass for athletic fields.

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