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Glyphosate as a growth regulator in Bermuda grass under different substrates

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Abstract

Glyphosate may be an alternative to mechanical mowing management, which may reduce turfgrass growth without harming the development of plant, and associated with the use of the correct cultivation base, it may benefit the plant. This work was developed with the objective of evaluating the use of glyphosate as a growth regulator in Bermuda grass, in different cultivation bases. The experiment was achieved in 2017. The hybrid Bermuda grass 'Tifway 419' carpets were planted in 8.46 L containers with different substrates and, after 60 days, the first application of glyphosate was performed, forming a 5 × 4 factorial scheme (substrates x glyphosate doses) with three replicates. The cultivation substrates were: S1 - soil, S2 - sand, S3 - soil + sand (1:1), S4 - soil + sand + organic compost (1:1:1) and S5 - organic compost + sand (1:1); and the following glyphosate doses (g ha^{-1} of active ingredient): 0, 200, 400 and 600. Chemical analyses of the substrates, photosynthetic pigments, fresh and dry mass and leaf macronutrients were performed. Glyphosate has great potential to be used as a growth regulator in Bermuda grass Tifway 419, as there was an effect of the herbicide doses on turf development, and the dose of 400 g a.i. ha^{-1} provided reduction in fresh and dry mass without major changes in macronutrients and photosynthetic pigments, mainly when grown in S4.

Keywords: *Cynodon* spp. Lawn. Tifton 419. Sports fields.

Introduction

Bermuda grass (*Cynodon* spp.) is the most widely used grass in high-performance turf sports in Brazil (Villas Bôas *et al.*, 2020; Castilho *et al.*, 2020), being a warm-season species, originating from the African continent (Santos *et al.*, 2024). The species has high growth rate and excellent recovery after cutting, where several hybrids, resulting from the crossing of *C. dactylon* with *C. transvaalensis*, have been installed in the world in recent years, highlighting cultivar 'Tifway 419' (Godoy *et al.*, 2012; Castilho *et al.*, 2020; Santos *et al.*, 2022).

However, the high demand for N by turfgrasses, associated with the high temperatures in Brazil, the choice of a correct cultivation substrate and adequate water supply, result in excessive growth of shoots, requiring a greater number of mowings, the main factor in the cost of turf maintenance and, consequently, in the increase in nutrient extraction. (Gazola *et al.*, 2019; Lima *et al.*, 2020; Silverio *et al.*, 2020; Santos *et al.*, 2024). For instance, golf greens courses and high-performance football fields are cut almost daily, generating several operations per year (Mateus *et al.*, 2017; Mateus *et al.*, 2020).

Therefore, cutting operation has high yield, but implies high maintenance cost (Santos *et al*., 2020b), thus, the use of plant growth regulators is an alternative for controlling height of lawns (Dias *et al.*, 2019; Begueline *et al.*, 2021). However, in Brazil there is lack of information about products for this purpose (Lima *et al.*, 2020; Tapia, 2022), making it increasingly necessary to search for information.

Consequently, one option would be to use the herbicide glyphosate, which acts on the shikimic acid pathway and is classified as enzyme EPSPs (5-enolpyruvylshikimate-3-phosphate synthase) inhibitor, responsible for the formation of the aromatic amino acids tryptophan, tyrosine, and phenylalanine, essential for plant growth and development (Gazola *et al.*, 2019; Dias *et al.*, 2019; Begueline *et al.*, 2021). Furthermore, its low cost and the wide availability of the active ingredient on market are factors that favor its use for this purpose, so research is needed to indicate the appropriate dose that reduces growth but does not harm aesthetic quality and nutrition in addition to provide good sports performance.

Another important factor to take into consideration is the location where the lawn will be installed, as in high-performance Brazilian fields the construction of the base substrate for grass development is established on international standards of the USGA (United States Golf Association) (Mateus *et al.*, 2017). Therefore, it is essential to seek cultivation bases suitable for Brazilian conditions, at the same time to provide sport good practice and adequate lawn development (Amaral *et al.*, 2019; Santos *et al.*, 2020b).

It is essential that the base has good aeration and drainage, as it rains, flooding or even nutrient unavailability due to compaction may not occur (Nascimento *et al.*, 2021; Santos *et al.*, 2020a). Thus, research began to emerge aiming the best type of substrate for sports fields installation, based on soil, sand and organic compost (Mateus *et al.*, 2017; Amaral *et al.*, 2019; Santos *et al.*, 20219; Santos *et al.*, 2020b; Nascimento *et al.*, 2021).

Hence, this work was developed in order to evaluate the potential of using sub-doses of glyphosate as a growth regulator in bermudagrass, grown in different cultivation substrates.

Material and methods

The experiment was carried out at Campus II of the Faculty of Engineering – UNESP (São Paulo State University), Ilha Solteira Campus, at latitude 20° 25'S, longitude 51° 21'W and altitude of 330 m, in the municipality of Ilha Solteira – SP, in full sunlight, during the period from April 14 to September 8, 2017. According to Köppen classification, the region climate is Aw, characterized by rainy season in summer and dry season in winter, defined as humid tropical. During the experiment, the average temperature was 23.1 °C, with average relative humidity of 69.9 % and accumulated precipitation of 285.5 mm.

The species used was Bermuda grass 'Tifway 419', planted in black plastic containers (47.5 x 17.5 cm wide, 41.5 x 11.3 cm deep, 15.5 cm high, 8.46 liters in volume).

The experiment was implemented on April 14th, 2017, with five cultivation bases being prepared and added to each container. Three components were used: soil, sand and organic compost, in different proportions: Substrate 1 - soil (Dystroferric Red Latosol), Substrate 2 - sand, Substrate 3 - soil + sand (1:1), Substrate 4 - soil + sand + organic compost (1:1:1), Substrate 5 - organic compost + sand (1:1).

The Dystroferric Red Latosol was removed from the 0.00 – 0.20 m layer, under Brazilian savanna, from Experimental Farm of the higher education institution. The organic compost was in decomposition for one year, being formed from leaves of Bahia grass and manure (1:1) and the washed medium sand was purchased at local market.

The cultivation substrates were characterized, where deformed sample was taken at test installation. The chemical analysis was developed according to resin method cited by Raij *et al.* (2001) and for physical analysis the sand, silt and clay content was determined, according to Embrapa (1997a) method and the type of textural class was classified according to Embrapa (1997b) (Table 1).

Table 1. Chemical and physical analysis of cultivation bases used at the experiment.

Substrate	P-resin	OM	pH	K	Ca	Mg	H+Al	Al	SB	CEC	V
	mg dm^{-3}	g dm^{-3}	$CaCl_2$	---- mmol$_c$ dm^{-3} ----							%
S1	3	9	5.8	0.3	12	8	16	0	20.3	36.3	55
S2	3	6	5.3	0.2	4	2	19	0	6.2	25.2	24
S3	6	13	5.5	0.9	30	24	13	0	54.9	67.9	80
S4	752	48	6.6	10.2	241	79	12	0	330.2	342.2	96
S5	550	28	6.3	7.5	188	52	13	0	247.5	260.5	95

Substrate	Clay	Silt	Sand	Classification (EMBRAPA, 1997b)
	---- g kg^{-1} ----			
S1	448	104	448	Clayey
S2	10	4	986	Sandy
S3	160	32	808	Medium
S4	167	49	784	Medium
S5	87	41	872	Sandy

S1– Soil; S2 – Sand; S3 – Soil + Sand (1:1); S4 – Soil + Sand + Organic Compost (1:1:1); S5 – Sand + Organic Compost (1:1). OM: Organic Matter, SB: sum of bases, CEC: cation exchange capacity; V: base saturation.
Source: authors (2018).

Each container was filled with its respective cultivation base and subsequently the Bermuda grass carpets were planted, followed by the first fertilization with 150 g m^{-2} of commercial lawn fertilizer (13 % N, 5 % P_2O_5, 13 % K_2O, 1 % Ca, 1 % Mg, 5 % S, 0.04 % B, 0.05 % Cu, 0.2 % Fe, 0.08 % Mn, 0.005 % Mo and 0.15 % Zn), which was spread over each treatment and then watered. Other fertilizations were was performed according to the manufacturer recommendations.

Whenever necessary, weed control was performed manually. Irrigation management was done daily, with the containers receiving water until saturation, in order to ensure that the water factor did not interfere with the results of experiment.

After 62 days of experiment implementation, the aerial part was cut with manual scissors, removing all the leaves from the lawn. Thus, with the grass already established, it was possible to perform the first application of glyphosate sub-doses, in the morning period (8:00 h), 10 days after cutting and the second application 30 days after the first one.

The application of treatments was performed with a backpack sprayer nozzle (with fan spout). The tank was washed after each treatment. The spray treatments were performed in the morning (9:00 h), covering the entire experimental plot without overlap, with each sub-dose was diluted in water at the appropriate concentrations, in a 200 L ha^{-1} solution. The sub-doses used were: 0 g ha^{-1} of a.i. (active ingredient) – checkplots; 200; 400 and 600 g a.i. ha^{-1}.

Thus, the experimental design used was completely randomized in a 5 x 4 factorial scheme (substrates x glyphosate sub-doses) with three replicates, totaling 60 experimental plots.

The evaluated traits were:

Concentration of photosynthetic pigments in leaves: according to the methodology described by Lichtenthaler (1987), chlorophylls a and b and carotenoids were determined, performing 60 days after glyphosate application.

Fresh and dry mass of leaves: all the lawn leaves from each container were manually collected using scissors and placed in previously identified paper bags. After the weight of the bags was discounted, they were weighed and the fresh mass was determined. The dry mass was obtained after placing the samples in an oven with forced circulation air at 60 °C, and weighed after three days, when mass stabilization. All weighing were performed on a 0.001 precision scale, and the collection was performed 61 days after glyphosate application.

Leaf chemical analysis: all macronutrients were determined according to the methodology described by Malavolta *et al.* (1997) 61 days after glyphosate application.

The results were subjected to analysis of variance and, when significant, the means were compared by Tukey test at 5 % of probability level using a statistical computer program.

Results and discussion

Glyphosate has influenced the concentration of photosynthetic pigments (Table 2). Checkplots (without glyphosate) reached the best results, in general, as there was no stress in relation to the applied chemical product, and the cultivation base 4 (S4: Soil + Sand + Organic Compost (1:1:1)) presented the best value, differing from the other treatments. It was also observed that with the increase in doses, the chlorophyll *a* content decreased, however, the doses of 200 and 400 g a.i. ha^{-1} in S4, managed to maintain good values of chlorophyll *a*, when compared to checkplots. For chlorophyll *b*, the dose of 200 g a.i. ha^{-1} cultivated in S4 managed to maintain the pigment levels when compared to the other treatments that suffered the action of herbicide, presenting statistically significant difference. For carotenoids, doses of 200 and 400 g a.i. ha^{-1} in S4 presented the best treatment results after herbicide application with no differences between them (Table 2).

Barbosa *et al.* (2017), evaluating the concentration of pigments as a function of the application of glyphosate doses in Bahia grass, observed that the dosage of 272 g a.i. ha^{-1} promoted decrease in chlorophyll a and b contents, while the dose of 544 g a.i. ha^{-1} provided increment. These results do not corroborate to data obtained at present study, as with the dose of 600 g a.i. ha^{-1} there was decrement of in analyzed pigments content. However, the values observed for chlorophyll a and b are above those found by Santos *et al*. (2022) in Bermuda grass working with irrigation and N doses and close to those observed by Amaral *et al*. (2019), working with different substrates and light conditions in Tifway 419, where the authors observed that the substrates with organic compound in their composition contributed to the best results for the evaluated parameters. It may be inferred that cultivation bases S4 – Soil + Sand + Organic Compost (1:1:1) and S5 – Sand + Organic Compound (1:1), which contain organic compost, may reduce the stress caused by the herbicide.

Glyphosate inhibits the formation of chlorophyll, acting on its synthesis (Yamada and Castro, 2007) as observed in the present study. Chlorophylls are responsible for converting light radiation into chemical energy (Taiz *et al.*, 2017), and the higher the concentration of these pigments, the greater the green hue of the turf, and better the photosynthetic efficiency (Santos *et al.*, 2022; Santos *et al.*, 2024).

However, it is essential that the herbicide does not affect the green color characteristic, does not damage or reduce the concentration of photosynthetic pigments (Gazola *et al.*, 2019), which does not occur in the present study, as there was reduction in levels analyzed due to the increase in doses. However, it is evident that depending on the cultivation base used, this may mitigate this effect, where S4 managed to maintain acceptable pigment levels.

Bases with larger amounts of organic matter have high water retention capacity due to their

Table 2. Photosynthetic pigments (chlorophyll *a*, chlorophyll *b* and carotenoids) of Bermuda grass, according to the application of sub-doses of glyphosate and different substrates.

Photosynthetic pigments (μg kg^{-1} of fresh mass)				
Substrate	Sub-dose (g a.i. ha^{-1})			
	0	200	400	600
	Chlorophyll *a*			
S1	301.90 Da	250.86 Eb	252.72 Db	193.57 Cc
S2	302.63 Da	222.22 Db	223.51 Eb	172.25 Dc
S3	317.31 Ca	300.32 Cb	299.89 Cb	249.58 Bc
S4	402.51 Aa	371.85 Ab	364.07 Ab	320.18 Ac
S5	389.66 Ba	350.05 Bb	337.38 Bc	307.85 Ad
CV (%)	1.83			
	Chlorophyll *b*			
S1	170.54 Ea	148.06 Db	142.92 Db	107.43 Dc
S2	180.51 Da	153.39 Db	131.42 Ec	100.37 Dd
S3	205.79 Ca	180.29 Cb	169.78 Cc	120.17 Cd
S4	306.96 Aa	284.16 Ab	276.03 Ac	231.28 Bd
S5	296.61 Ba	252.75 Bb	228.04 Bc	201.92 Ad
CV (%)	1.86			
	Carotenoids			
S1	97.53 Ca	67.26 Cb	61.51 Cb	40.69 Cc
S2	98.35 Ca	60.44 Cb	62.74 Cb	35.74 Cc
S3	184.58 Ba	151.07 Bb	145.61 Bb	102.69 Bc
S4	241.15 Aa	200.85 Ab	199.58 Ab	166.33 Ac
S5	190.21 Ba	150.25 Bb	151.69 Bb	101.48 Bc
CV (%)	2.5			

Means followed by the same uppercase letter in the column and lowercase letter in the row do not differ from each other at the 5 % significance level by the Tukey test. S1– Soil; S2 – Sand; S3 – Soil + Sand (1:1); S4 – Soil + Sand + Organic Compost (1:1:1); S5 – Sand + Organic Compost (1:1).

Source: authors (2018).

ability to retain ions, nutrients and exchange electrons, significantly increasing soil moisture content, therefore photosynthetic pigment levels tend to be higher (Santos *et al.*, 2019). This fact corroborates the present work, as S4 had the best results of photosynthetic pigments (Table 2) and the highest mass produced (Table 3). S4 associated with 400 g a.i. ha^{-1} was able to reduce fresh and dry mass production by 33.33 % and 32.43 %, respectively, and maintain good pigment levels with reduction of 9.55 %; 10.08 % and 17.23 % of chlorophyll a, b and carotenoits, respectively, when compared to the checkplots (Table 3).

Therefore, it is essential that there is less mass accumulation, maintaining good levels of green coloration (Melero *et al.*, 2020; Rezende *et al.*, 2020). This is desirable because with the increase in mass produced, there is a greater need for maintenance mowing (Mateus *et al.*, 2020). Some authors working in Brazilian conditions have found optimal doses of glyphosate to control growth in lawns, as followed.

Dinalli *et al.* (2015) concluded that glyphosate at a dose of 200 g a.i. ha^{-1} highlighted in controlling lawn growth 30 days after application (DAA) and did not harm its aesthetic quality. Gazola *et al.* (2019), also observed that

Table 3. Average fresh and dry mass of shoot of Bermuda grass, according to application of sub-doses of glyphosate and different substrates.

Substrate	Dose (g a.i. ha^{-1})			
	0	200	400	600
	Fresh mass (kg m^{-2})			
S1	0.37 Ba	0.29 Bb	0.22 Bc	0.19 Bc
S2	0.25 Ca	0.19 Cb	0.16 Cbc	0.14 Cc
S3	0.36 Ba	0.30 Bb	0.26 Bc	0.20 Abd
S4	0.45 Aa	0.40 Ab	0.30 Ac	0.23 Ad
S5	0.39 Ba	0.32 Bb	0.25 Bc	0.21 Abd
CV (%)	6.23			
	Dry mass (kg m^{-2})			
S1	0.29 Ba	0.22 Bb	0.16 BCc	0.14 Abc
S2	0.19 Ca	0.13 Cb	0.11 Cb	0.10 Bb
S3	0.30 Ba	0.23 Bb	0.21 ABbc	0.17 Ac
S4	0.37 Aa	0.34 Aa	0.25 Ab	0.19 Ac
S5	0.31 Ba	0.26 Bb	0.18 Bc	0.15 Abc
CV (%)	10.15			

Means followed by the same uppercase letter in the column and lowercase letter in the row do not differ from each other at the 5 % significance level by the Tukey test. S1– Soil; S2 – Sand; S3 – Soil + Sand (1:1); S4 – Soil + Sand + Organic Compost (1:1:1); S5 – Sand + Organic Compost (1:1).

Source: authors (2018).

glyphosate was effective in reducing the growth of emerald grass at a dose of 400 g a.i. ha^{-1}. In Bahia grass, Barbosa *et al.* (2017) observed a reduction in height with a dose of 246 g a.i. ha^{-1}. Dias *et al.* (2019) concluded that glyphosate concentrations of 5.625 to 22.5 g a.i. ha^{-1} (for Bahia grass) and up to 90 g a.i. ha^{-1} (for Carpet grass) reduced plant growth without affecting the phytotoxicity of the plant visual quality. Finally, Begueline *et al*. (2021) obtained good results with the dose of 400 g a.i. ha^{-1} in Bermuda grass.

The reduction in Bermuda grass mass production with glyphosate application provided by Bermuda grass may be related to its mechanism of action, where the shikimic acid pathway, in which the herbicide acts, is responsible for the formation of phenolic compounds, which may represent a reduction in plant biomass (Yamada and Castro, 2007; Gazola *et al.*, 2019), which was found in the present study. It is worth mentioning that the cultivation substrate used also influenced the production of fresh and dry mass of the turf after the application of glyphosate, S4 and S5 resulted in the best chemical analysis data.

S4 (soil + sand + organic compound), which presented a higher pH value (6.6), the lawn was possibly able to better absorb the available nutrients to recover from the stress caused by the herbicide, as lawns have greater capacity to absorb nutrients when the pH approaches seven (Godoy *et al.*, 2012) and this treatment maintained high levels of foliar macronutrients (Tables 4 and 5).

N and Mg levels in leaves decreased with increasing herbicide doses, and there was decrement in photosynthetic pigments as function of the doses applied (Table 4). According to Santos *et al*. (2019), photosynthetic pigments indirectly reflect the amount of N and Mg absorbed by plants, with N being the nutrient required in greater quantities by the lawn and, when maintained at adequate levels, promoting vigor, visual quality and recovery from injuries (Gazola *et al.*, 2019; Prates *et al.*, 2020; Silva *et al.*, 2020).

The decrease in foliar N concentrations in lawn is due to the fact that the herbicide alters the plant N metabolism, inhibiting the enzyme EPSPs (5-enolpyruvylshikimate-3-phosphate synthase). It is responsible for the formation of aromatic amino acids tryptophan, tyrosine, and phenylalanine, which contain N in their composition and are essential for plant growth and development (Taiz *et al.*, 2017). Thus, with higher doses, there is greater inhibition of this enzyme and, consequently, lower foliar concentration of the nutrient. Thus, all values were below 12 g kg^{-1} of N, which according to Godoy and Villas Boas (2010) indicates critical nutrient deficiency. However, they are within the range found by Santos *et al.* (2019) for the same lawn species.

For P foliar content, there was no effect with increasing doses, as it is part of the DNA and ATP molecules, providing energy to the plant (Taiz *et al.*, 2017). Thus, with the stress caused by the herbicide. The values of S4 and S5 were higher than those of the other bases, as the availability of P was much greater (Table 1).

In relation to K leaf content, S4 and S5 were able to maintain levels within those recommended by McCarty and Miller (2002) (10 to 25 g kg^{-1}) even with increased glyphosate

Table 4. Average values of Nitrogen (N), Phosphorus (P) and Potassium (K) of Bermuda grass leaves (g kg^{-1}),, according to the application of sub-doses of glyphosate in different substrates.

Substrate	**Dose (g a.i. ha^{-1})**			
	0	**200**	**400**	**600**
	Nitrogen (N)			
S1	8.4 Ba	7.5 Bb	7.0 Bbc	6.6 Ac
S2	8.5 Ba	7.5 Bb	7.0 Bb	6.9 Ab
S3	8.9 Ba	8.1 Abb	7.6 Bbc	7.1 Ac
S4	10.0 Aa	9.2 Ab	8.7 Ab	7.1 Ac
S5	10.5 Aa	8.4 Bb	7.4 Bc	6.8 Ac
CV (%)	4.03			
	Phosphorus (P)			
S1	2.2 Ba	2.0 Ba	2.2 Ba	1.9 Ba
S2	2.1 Ba	2.1 Ba	2.5 Ba	2.3 Ba
S3	2.4 Ba	2.1 Ba	2.2 Ba	2.3 Ba
S4	4.0 Aa	3.2 Aa	4.1 Aa	3.6 Aa
S5	4.6 Aa	3.6 Aab	4.0 Ab	3.4 Ab
CV (%)	14.91			
	Potassium (K)			
S1	9.4 Ba	8.4 Ba	8.2 Ba	7.7 Ba
S2	8.6 Ba	8.5 Ba	7.8 Ba	6.5 Ba
S3	8.9 Ba	8.4 Ba	8.0 Ba	7.9 Ba
S4	13.4 Aa	12.0 Aab	11.3 Aab	10.5 Ab
S5	11.8 Aa	10.9 Aa	12.6 Aa	11.4 Aa
CV (%)	10.40			

Means followed by the same uppercase letter in the column and lowercase letter in the row do not differ from each other at the 5 % significance level by the Tukey test. S1– Soil; S2 – Sand; S3 – Soil + Sand (1:1); S4 – Soil + Sand + Organic Compost (1:1:1); S5 – Sand + Organic Compost (1:1).

Source: authors (2018).

Table 5. Average values of Calcium, Magnesium and Sulfur of Bermuda grass leaves (g kg^{-1}), according to the application of sub-doses of glyphosate in different substrates.

Substrate	Dose (g a.i. ha^{-1})			
	0	200	400	600
	Calcium (Ca)			
S1	5.8 Ba	5.40 Aa	5.6 Aa	4.8 Aa
S2	5.4 Ba	5.17 Aa	4.8 Aa	4.7 Aa
S3	5.9 Ba	5.60 Aa	5.5 Aa	5.3 Aa
S4	7.7 Aa	6.37 Ab	5.3 Abc	5.0 Ac
S5	6.0 Ba	5.37 Aa	5.3 Aa	5.2 Aa
CV (%)	9.85			
	Magnesium (Mg)			
S1	1.2 Ca	0.9 Cbc	0.8 BCc	1.1 Bab
S2	1.1 Ca	0.9 Cab	0.7 Cb	0.8 Bb
S3	1.4 BCa	1.0 BCb	0.8 BCb	0.8 ABb
S4	1.6 Aba	1.3 ABb	1.0 ABbc	0.9 Abc
S5	1.7 Aa	1.5 Aa	1.1 Ab	1.0 Ab
CV (%)	11.76			
	Sulfur (S)			
S1	1.2 Aa	1.3 Aa	1.4 Aba	1.2 Ba
S2	1.3 Aa	1.4 Aa	1.3 Ba	1.3 Ba
S3	1.1 Aa	1.1 Aa	1.5 ABa	1.5 Ba
S4	1.7 Aab	1.5 Ab	2.0 Aab	2.1 ABa
S5	1.6 Aa	1.7 Aa	1.9 Aa	1.4 Aa
CV (%)	17.53			

Means followed by the same uppercase letter in the column and lowercase letter in the row do not differ from each other at the 5 % significance level by the Tukey test. S1– Soil; S2 – Sand; S3 – Soil + Sand (1:1); S4 – Soil + Sand + Organic Compost (1:1:1); S5 – Sand + Organic Compost (1:1).

Source: authors (2018).

doses, demonstrating the importance of the crop substrate in plant development. It is essential to maintain adequate nutrient content when using growth regulators in grass, as it directly affects the concentration of leaf nutrients (Lima *et al.*, 2020; Melero *et al.*, 2020). In addition, K is important in plant resistance to adverse conditions (Godoy *et al.*, 2012; Taiz *et al.*, 2017), such as trampling, which is very important in sports fields, where there is intense circulation of people.

Foliar Ca contents were negatively influenced by increasing herbicide doses (Table 5), however, the results were close to those recommended by McCarty *et al.* (2003), 5 to 10 g kg^{-1}. It is essential to maintain Ca at adequate foliar concentrations, as it is part of the plant structure, mainly in cell wall, where it confers rigidity to the tissue (Taiz *et al.*, 2017) and thus protects the turf from damage caused by playing.

Regarding S leaf content (Table 5), it was below from values proposed by McCarty (2005), of 5 to 6 g kg^{-1}. This possibly occurs due to this nutrient is part of the amino acid structure (Taiz *et al.*, 2017) and, as previously stated, glyphosate inhibits the EPSPs enzyme, which is an amino acid builder responsible for plant growth. However, S4 was able to maintain the highest nutrient content when compared to the other crop bases (Table 5).

Conclusion

Glyphosate has potential to be used as a growth regulator in Tifway 419 Bermuda grass, and the sub-dose of 400 g a.i. ha^{-1} provided reduction in fresh and dry shoot mass without severe changes in foliar macronutrients and photosynthetic pigments of the turfgrass, especially when cultivated on a soil + sand + organic compost base (1:1:1).

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