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Nitrogen dose and type of herbicide used for growth regulation on the green coloration intensity of Emerald grass

Intensidade da coloração verde das folhas da grama esmeralda submetida a doses de nitrogênio e ao uso de herbicidas como reguladores de crescimento

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ABSTRACT

*Nitrogen (N) is the main nutrient responsible for the green coloration of lawns but also stimulates the growth of the aerial portion of grass, thus increasing mowing expenses. Therefore, herbicides may be used as a growth regulator. The ideal herbicide will reduce lawn height without affecting esthetics. Toward this end, the aim of the present study was to evaluate the green coloration of Emerald grass (**Zoysia japonica** Steud.) under the effect of different N doses or herbicides used as growth regulators. The study site consisted of randomized blocks containing 20 treatments arranged in a 5×4 factorial design with four treatment groups: four herbicides (glyphosate, imazaquin, imazethapyr, and metsulfuron-methyl, accounting for 200, 420, 80, and 140g ha^{-1} of the active ingredient, respectively) and the control sample (no herbicide); and three doses of N in the form of urea (5, 10, and 20g m^{-2}), divided into five applications per year, in addition to a treatment without N. Leaf chlorophyll content (LCC) was assessed and the aerial portion of the lawn was measured with digital image analysis. Doses of N ranging from 10 to 20g m^{-2}, divided into five applications a year, provided the lawn with intense green coloration, and the herbicides glyphosate (200g ha^{-1}), imazaquin (420g ha^{-1}), and imazethapyr (80g ha^{-1}) were reported to be suitable for use as growth regulators of the study species, considering maintenance of esthetic quality (green coloration). The digital image analysis of the aerial portion provided more accurate results than use of a chlorophyll meter with regard to the recommendation of both N dose and herbicides to be used as growth regulators of Emerald grass.*

Key words: ***Zoysia japonica*** *Steud., lawn, leaf chlorophyll content, digital imaging, fertilization, glyphosate, imazaquin, imazethapyr, metsulfuron-methyl.*

RESUMO

*Embora o nitrogênio (N) seja o principal nutriente responsável pela coloração verde dos gramados, o mesmo estimula o crescimento da parte aérea, resultando em maior dispêndio com cortes. Assim, a utilização de herbicidas como reguladores de crescimento seria alternativa, sendo ideal aquele que reduzisse a altura sem afetar a estética do gramado. Diante do exposto, objetivou-se avaliar a coloração verde da grama esmeralda (**Zoysia japonica** Steud.) sob o efeito de doses de N e do uso de herbicidas como reguladores de crescimento. Utilizou-se o delineamento em blocos casualizados com 20 tratamentos dispostos num fatorial 5x4 com quatro repetições, sendo quatro herbicidas: glyphosate, imazaquin, imazethapyr e metsulfuron-methyl (200, 420, 80 e 140g ha^{-1} do ingrediente ativo (i.a.), respectivamente) e a testemunha (sem herbicida); e três doses de N na forma de ureia: 5, 10 e 20g m^{-2}, parceladas em cinco aplicações ao ano, além do tratamento sem N. Avaliaram-se o índice de clorofila foliar (ICF) e a análise por imagem digital da parte aérea do gramado. Doses de 10 a 20g m^{-2} de N, parceladas em cinco vezes ao ano, propiciaram coloração verde intensa do gramado e os herbicidas glyphosate (200g ha^{-1}), imazaquin (420g ha^{-1}) e imazethapyr (80g ha^{-1}) foram adequados para utilização como reguladores do crescimento da espécie estudada, considerando a qualidade estética (cor verde). A análise por imagem digital da parte aérea forneceu resultados mais precisos que o uso do clorofilômetro, quanto à recomendação da dose de N, bem como dos herbicidas a serem utilizados como reguladores de crescimento da grama esmeralda.*

Palavras-chave: ***Zoysia japonica*** *Steud., gramado, ICF, imagem digital, adubação, glyphosate, imazaquin, imazethapyr, metsulfuron-methyl.*

INTRODUCTION

The main purpose of the lawn in residential, public, and industrial areas in Brazil is

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to provide an esthetic (visual) impact. Intense green coloration and good density (i.e., a lush lawn with no flaws exposing the soil) are important aspects from an esthetic perspective. Furthermore, in many of these regions, lawns also often function in slope containment by reducing the risk of erosion (GODOY & VILLAS BÔAS, 2003).

Emerald grass (***Zoysia japonica*** Steud.) is one of the best-selling grass species in Brazil and is used in most residential gardens. It is a perennial grass with narrow to medium-sized leaves depending on the variety. It features an emerald green coloration and usually grows as a stoloniferous rhizome. Emerald grass grows particularly well in areas of abundant sunlight, is highly resistant to treading, requires nitrogen (N) fertilization, and its ideal mowing height is 1.25-3.0cm from the soil level (GURGEL, 2003; GODOY et al., 2012a).

There is still a general lack of information on the use of N fertilization in existing implanted Brazilian lawns, and there is no official recommendation on lawn fertilization practices for the State of São Paulo (GODOY et al., 2012b). Furthermore, the technical information on maintenance fertilization can be considered to be at an incipient stage, as there are currently a wide range of recommendations and few empirical scientific papers published on the topic (MATEUS & CASTILHO, 2012; AMARAL & CASTILHO, 2012). Given the great importance of fertilization for maintaining lawn quality, the use of techniques such as a chlorophyll meter and digital image analysis can assist with the decision-making process concerning the recommended dose of N to be applied, as well as to verify the efficiency of the fertilization applied, thus improving N fertilization management (BACKES et al., 2010). However, few studies have adopted these techniques, especially for implanted lawns.

High doses of N provide a more intense green coloration, which is esthetically desirable but also results in rapid plant growth (GODOY & VILLAS BÔAS, 2003), thus leading to increased maintenance costs owing to the more frequent need for grass mowing (GODOY et al., 2012a). One option to avoid this task is to use a plant regulator such as chemicals that biochemically inhibit the pathways that promote vertical growth (MARCH et al., 2013). For this purpose, several types of herbicides can be used to inhibit the enzymes that promote plant growth/development, such as imazaquin, imazethapyr, and metsulfuron-methyl (inhibitors of the enzyme acetolactate synthase), as well as glyphosate (inhibitor of the enzyme 5-enolpyruvylshikimate-3-phosphate synthase).

Since there is currently no official and safe recommendation for lawn management through the use of plant regulators in Brazil (MACIEL et al., 2011), studies are needed in order to determine the ideal regulator (herbicide). In particular, an herbicide reduce height, while maintaining the quality of the treated area; that is, without reducing the density or inducing visible damage to the plants, such as necrotic points of phytotoxicity, discoloration, or thinning, so as to not interfere with its beauty and characteristic green coloration (CHRISTOFFOLETI & ARANDA, 2001).

Hypothesis of the present study was that plants acquire a more greenish coloration (which is esthetically ideal for lawns) through the application of N fertilizer, and that regulators (herbicides) inhibit grass growth, thus reducing the amount of trimming required. Therefore, by combining the application of N with the use of herbicides, a more esthetically pleasing and lush coloration of the lawn could be achieved requiring relatively less maintenance (mowing). Accordingly, the aim of the study was to evaluate the green coloration of Emerald grass under the effect of different N doses and use of various herbicides as growth regulators.

MATERIALS AND METHODS

The experiment was conducted between June 2012 and December 2013 at the Education, Research and Extension Farm of the School of Engineering, UNESP, Ilha Solteira Campus, at latitude 20°22' S, longitude 51°22' W, and an elevation of 330m, in eutrophic sandy-clay Red Argisol soil (EMBRAPA, 2013). The soil was prepared on June 8, 2012 by lightly plowing it with a disc harrow, with subsequent leveling. Initial chemical analysis of the soil in the experimental area (0–20cm) was evaluated according to the methodology of RAIJ et al. (2001), and revealed the following characteristics: 16mg dm^{-3} of P (resin); 18g dm^{-3} of organic matter (M.O.); pH = 4.8 ($CaCl_2$); 2.3, 12.0, 4.0, and 22.0$mmol_c$ dm^{-3} of K, Ca, Mg, and H+Al, respectively; and a base saturation (V%) of 45%. Liming was performed on June 9, 2012 by throwing 1.2t ha^{-1} of dolomitic limestone (PRNT 85%) over the soil surface, with the aim of increasing base saturation to 70% (GODOY et al., 2012a), with the limestone incorporated to a depth of 20cm. After the liming, on July 10, 2012, fertilization with P and K was performed using triple superphosphate (45% P_2O_5) and potassium chloride (60% K_2O), respectively, at a dose of 10g m^{-2} $year^{-1}$ each. Subsequently (August 1, 2012), chemical analysis of the soil (0-20cm) (RAIJ et al., 2001) was conducted again showing the following results: 26mg dm^{-3} of P (resin); 17g dm^{-3} of M.O.; pH = 6.6 ($CaCl_2$); 2.7, 28.0, 22.0, and 11.0$mmol_c$ dm^{-3} of K, Ca, Mg, and H+Al, respectively; and a V% of 83%.

Emerald grass was planted in plots (63×40cm) on August 3, 2012 and irrigated by sprinkling throughout the experiment. Application of treatments (doses of N and herbicides) began on day 45 after introduction, when the lawn was well-formed; i.e., rooted.

The study consisted of randomized blocks containing 20 treatments arranged in a 5×4 factorial design with four herbicides (growth regulators: glyphosate, imazethapyr, imazaquin, and metsulfuron-methyl applied at doses of 200, 80, 420, and 140g ha^{-1} of the active ingredient, respectively) and the control sample (no herbicide); and three doses of N (5, 10, and 20g m^{-2}) plus a treatment without N, divided into five applications throughout the year (corresponding to 1, 2, and 4g m^{-2} of N per application/assessment), with 4 repetitions at 10m^2 per plot.

The N doses used in this experiment were based on the results of the graduate thesis submitted by DINALLI (2011). Source of N used was urea (45% N), which was applied manually soon after cutting the lawn on the following dates: March 14, July 5, September 14, and November 1 of 2013, for the fifth, sixth, seventh, and eighth assessments, respectively. After each fertilization application, the lawn was irrigated in order to minimize losses due to N volatilization.

The application of herbicides (May 14, August 5, September 27, and November 16 of 2013) was conducted in the morning under mild temperature conditions, using a CO_2-pressurized backpack sprayer fitted with a 2-L-capacity tank (disposable bottles of polyethylene terephtalate (PET)), with an anti-drip four-nozzle wand and 0.50m spacing, model 80.02, a drench consumption equivalent to 200L ha^{-1}, and service pressure of 3 psi. The application was performed on day 15 or 30 after fertilization. The first interval corresponded to the spring/summer months (seventh and eighth assessments) and the second interval corresponded to the fall/winter months (fifth and sixth assessments). This difference is due to the fact that, under Brazilian conditions, grass growth is not as intense during the fall/winter as it is during spring/summer.

Eight assessments were conducted 30 days after the application (DAA) of herbicides. The data presented in this paper refer to the fifth, sixth, seventh, and eighth assessments conducted on June 14, September 5, October 27, and December 16 of 2013, respectively. Following the collections of plant material, the lawn was mowed using a gas-powered brush cutter with a clippings bag to level off the size of the Emerald grass in the treatments so that the height was consistently maintained at close to 3cm from soil level.

Two measures were taken to determine the extent of green coloration of the grass under different treatments. Leaf chlorophyll content (LCC) was assessed in a laboratory rather than in the field, owing to the small size of the grass leaves and the difficulty in handling them (GODOY, 2005; LIMA, 2009). A handheld chlorophyll meter (Falker model CFL 1030) was used to assess 15 leaves per plot, which were collected manually in the morning, placed in brown paper bags, and then identified and stored in a styrofoam box on ice to prevent the leaf blades from curling (which would jeopardize the readings). One measurement per leaf was taken in the middle of each leaf. Furthermore, to quantify the intensity of green coloration, digital image analysis of the aerial portion was conducted in accordance with the methodology described by GODOY (2005). Since the green component of the digital image (G) alone, which ranges from 0 to 255, does not define the color green, the green color hue (H) was also determined in degrees (where 60° is yellow and 120° is green) along with the Dark Green Color Index (DGCI), which ranges from 0 to 1.

The data were analyzed with analysis of variance and a post-hoc Tukey test at a 5% probability to compare the means under different herbicide treatments and the polynomial regression for the doses of N. As no significant interactions were determined, the herbicide and N dose data were statistically analyzed separately using SISVAR software (FERREIRA, 2008).

RESULTS AND DISCUSSION

There was no interaction between the doses of N and the herbicides applied in any of the assessments carried out either for the LCC or for the color components assessed in the digital image analysis of the lawn's aerial portion (G, H, and DGCI). The mean values of LCC for the lawn increased linearly in proportion to the increase in N dose in all assessments (Table 1). The same result was reported by BACKES et al. (2010), who reported that different doses of sewage sludge (0, 100, 200, 300, and 400kg ha^{-1} of N, without dividing the applications) influenced the green color intensity of the leaf of Emerald grass in a commercial area, as determined by a chlorophyll meter (SPAD-502) 45, 105, and 165 DAA of the sludge. In the present study,

Table 1 - Mean values of leaf chlorophyll content (LCC), green component of the digital image (G), dark green color index (DGCI), and green color hue (H) of leaves of Emerald grass resulting from the application of different doses of N and four types of herbicides over four assessment periods.

Treatment	-----LCC-----				-----G (adim.)-----			
Doses of N (g m^{-2})	5^{th}	6^{th}	7^{th}	8^{th}	5^{th}	6^{th}	7^{th}	8^{th}
0	$16.7^{**(1)}$	$16.0^{**(2)}$	$16.2^{**(3)}$	$16.7^{**(4)}$	139^{ns}	146^{ns}	101^{ns}	103^{ns}
1	17.2	17.0	17.2	16.9	139	141	97	100
2	17.2	17.2	17.5	17.7	140	144	98	101
4	18.1	18.0	18.4	18.4	138	143	98	100
-----Herbicides-----								
control	17.1 a	16.8 a	17.4 a	17.3 a	143 a	148 a	95 a	97 a
imazaquin	16.8 a	17.3 a	18.1 a	17.0 a	138 a	143 a	99 a	101 a
imazethapyr	17.4 a	16.5 a	17.7 a	18.2 a	137 a	146 a	101 a	103 a
glyphosate	17.2 a	16.8 a	17.0 a	17.5 a	136 a	139 a	99 a	101 a
metsulfuron-methyl	18.0 a	16.9 a	17.3 a	17.2 a	141 a	142 a	99 a	102 a
D.M.S. (5%)	1.4	1.5	1.1	1.4	8	9	6	5
C.V. (%)	7.15	7.50	5.61	6.65	5,18	3,92	4,48	4,45
$F_{Doses\ x\ Herbicides}$	0.54^{ns}	0.54^{ns}	1.22^{ns}	0.52^{ns}	$0,51^{ns}$	$0,93^{ns}$	$0,64^{ns}$	$0,65^{ns}$
Doses of N (g m^{-2})	-----DGCI (adim.)-----				-----H (degrees)-----			
0	$0.68^{*(5)}$	$0.61^{*(6)}$	$0.72^{**(7)}$	$0.73^{**(8)}$	87^{ns}	$79^{**(9)}$	$86^{*(10)}$	$88^{*(11)}$
1	0.69	0.64	0.75	0.76	89	83	90	92
2	0.70	0.65	0.74	0.76	90	85	89	92
4	0.68	0.65	0.74	0.75	89	86	89	91
-----Herbicides-----								
control	0.68 a	0.63 a	0.75 a	0.77 a	87 a	83 a	91 a	93 a
imazaquin	0.70 a	0.63 a	0.75 a	0.77 a	90 a	83 a	91 a	93 a
imazethapyr	0.70 a	0.63 a	0.73 a	0.75 a	89 a	83 a	89 a	90 a
glyphosate	0.68 a	0.65 a	0.74 a	0.76 a	88 a	86 a	90 a	92 a
metsulfuron-methyl	0.68 a	0.63 a	0.69 b	0.71 b	88 a	83 a	83 b	85 b
D.M.S. (5%)	0.03	0.04	0.03	0.03	4	7	4	4
C.V. (%)	3.37	6.56	3.90	3.83	3,05	7,10	4,25	4,30
$F_{Doses\ x\ Herbicides}$	0.91^{ns}	0.68^{ns}	0.83^{ns}	0.83^{ns}	$0,99^{ns}$	$0,70^{ns}$	$0,74^{ns}$	$0,84^{ns}$

Averages followed by the same letter in the column do not differ by the Tukey's test, at 5% probability.

ns; *;** - not significant; significant by the F test, at 5% e 1% probability. $^{(1)}Y = 16.7 + 0.3314^{**}X$ ($R^2 = 0.94$); $^{(2)}Y = 16.2 + 0.4629^{**}X$ ($R^2 = 0.92$); $^{(3)}Y = 16.4 + 0.5171^{**}X$ ($R^2 = 0.95$); $^{(4)}Y = 16.6 + 0.4486^{**}X$ ($R^2 = 0.96$); $^{(5)}Y= 0.69 + 0.018^{*}X - 0.0045^{*}X^2$ ($R^2 = 0.95$); $^{(6)}Y = 0.61 + 0.031^{*}X - 0.0055^{*}X^2$ ($R^2 = 0.99$); $^{(7)}Y = 0.72 + 0.020^{**}X - 0.0041^{*}X^2$ ($R^2 = 0.63$); $^{(8)}Y = 0.73 + 0.028^{**}X - 0.0059^{*}X^2$ ($R^2 = 0.90$); $^{(9)}Y = 79 + 4.366^{*}X - 0.6591^{*}X^2$ ($R^2 = 0.99$); $^{(10)}Y = 86 + 2.87^{*}X - 0.5282^{*}X^2$ ($R^2 = 0.71$) e $^{(11)}Y = 88 + 3.65^{*}X - 0.75^{*}X^2$ ($R^2 = 0.90$).

Obs.: G - adimensional (0 to 255), DGCI - obtained by digital image, adimensional (0 to 1) e H - was also determined in degrees (where 60° is yellow and 120° is green). Doses of N = 1, 2 e 4 (5, 10 and 20g m^{-2} of N, divided into five applications throughout the year).

the highest LCC values obtained (dose of 4g m^{-2} of N) (Table 1) were within and close to the maximum range value reported by DINALLI (2011), from 14.3 to 22.1, assessed 30 days after fertilization, in a study that was conducted in the same region using Emerald grass fertilized with 100kg ha^{-1} of N (urea), divided into five applications per year.

Therefore, the results obtained in this study confirmed the assertion that higher doses of N provide lawns with a more intense green coloration, which is esthetically desirable (GODOY et al., 2012a). Moreover, considering the data from each of the four assessments, there was a positive correlation between the foliar concentrations of the N and LCC values ($r=0.96^{**}$), which corroborates the findings reported by BACKES et al. (2010) for Emerald grass. According to OLIVEIRA et al. (2010), the green leaf color index can also be used to estimate the concentration of N owing to the close relationship between chlorophyll content and the N concentration in plants.

LCC values did not differ between each herbicide treatment and the control sample or among the herbicide treatments themselves (Table 1). Values ranged from 16.5 to 18.2, which is within the same range reported by DINALLI (2011).

The green component of the digital image (G) was not influenced by either the dose of N or the type of herbicide applied (Table 1). In a study with St. Augustine and Emerald grasses, GODOY (2005) did not find statistically significant changes to G following application of several doses of N (0, 150, 300, 450, and 600kg ha^{-1}, urea), divided into three applications for St. Augustine grass or into three or six applications for Emerald grass. However, BACKES et al. (2010) reported that G was significantly influenced by different doses of sewage sludge (0, 100, 200, 300, and 400kg ha^{-1} of N, without dividing the applications) at 45 DAA, but there was no change observed at 105 and 165 DAA. Therefore, the authors concluded that this characteristic is not useful for evaluating the green color of the species under study, thus corroborating the results obtained in the present research.

With respect to the DGCI, there was a quadratic change observed with increasing dose of N in all assessments, which was verified by measurement of the green color hue of the grass image (H), except for the fifth assessment (Table 1). In contrast, GODOY (2005) reported that both H and DGCI changed linearly with increasing dose of N (0, 150, 300, 450, and 600kg ha^{-1}, divided into three applications, using urea as the N source), over three assessment periods (192, 227, and 296 days after the harvest [DAH] of the previous plot) in St. Augustine grass. However, for Emerald grass, similar to the current results, GODOY (2005) reported that H and DGCI changed according to a quadratic model with increasing N dose (0, 25, 50, 75, 100, 150, and 200kg ha^{-1} of N, using urea as the source) at 90 DAH.

The highest DGCI values obtained in this research (0.71 at 2.06g m^{-2} of N, 0.66 at 2.9g m^{-2} of N, 0.74 at 2.5g m^{-2} of N, and 0.76 at 2.4g m^{-2} of N for the fifth, sixth, seventh, and eighth assessments, respectively) (Table 1) were higher than those reported for Emerald grass by GODOY (2005), at 0.53 for 200kg ha^{-1} of N at 90 DAH; BACKES et al. (2010), at 0.55 with 400kg ha^{-1} of N; and KARCHER & RICHARDSON (2003), at 0.45, 0.46, and 0.48 for doses of 4.8, 7.2, and 9.6g m^{-2} of N, respectively (reapplied four times).

The highest H values (Table 1) were 86° (at 3.3g m^{-2} of N), 90° (at 2.7g m^{-2} of N), and 92° (at 2.4g m^{-2} of N), respectively, for the sixth, seventh, and eighth assessments. In studies with Emerald grass, BACKES et al. (2010) reported an H value of 98° for grass fertilized with sewage sludge (400kg ha^{-1} of N), and KARCHER & RICHARDSON (2003) obtained H values ranging from 83.6° to 86.6° with the application of 4.8, 7.2, and 9.6g m^{-2} of N (reapplied four times), which were close to the values obtained in this study.

The lowest H value (79°) was obtained for the control sample on the sixth assessment, which was closest to the yellow color hue value of 60°, indicating loss of the intense green coloration without fertilization, which is not visually appealing for lawns (Table 1).

Based on these results, the maximum DGCI and H values were observed with application of N doses ranging from 2 to 4g m^{-2} of N. It should be stressed that the other studies conducted in Brazil and used for comparison here were performed in production areas of grass carpets (GODOY, 2005; BACKES et al., 2010), unlike the current study, which was performed with an implanted lawn.

Taking into account the data from the four assessments, there was a positive correlation observed between both DGCI and H with respect to the concentration of N in the leaf ($r=0.81^{*}$ and $r=0.83^{*}$, respectively). Similarly, BACKES et al. (2010) reported a good correlation between DGCI ($r=0.91^{**}$ and 0.93^{**} at 45 and 105 DAA of sewage sludge, respectively) and H ($r=0.83^{**}$ and 0.88^{**} at 45 and 105 DAA of sludge, respectively) with the foliar concentration of N. For G; however, there was a negative and non-significant linear correlation observed in relation to the foliar concentration of N (r=-0.75), which is similar to that reported by BACKES et al. (2010) (r -0.81^{**}, -0.48^{*}, and -0.31^{ns} at 45, 105, and 165 DAA of the sludge, respectively).

The fact that these correlations with the N concentration of the leaves were verified for both digital image components (G, H, and DGCI) as well as for the LCC values indicates that both assessments could accurately quantify the green color in Emerald grass. The correlations reported for the digital image components were lower compared to those obtained for the LCC ($r=0.96^{**}$). However, there are problems associated with the use of a chlorophyll meter owing to the difficulty of accurately measuring the grass leaves, which are very thin and short and also tend to curl up quickly after being collected, in addition to the fact that the reading area of the device is very small. Furthermore, the area sampled to calculate the indexes based on the digital image is much larger than that sampled with the chlorophyll meter; in particular, a photograph containing thousands of leaves per plot was used for digital analysis, whereas far less leaves (15 leaves per plot in this study) are generally sampled for chlorophyll meter measurements (GODOY, 2005; BACKES et al., 2010).

Despite the lack of difference in the LCC values between herbicide treatments and the control sample (Table 1), the results of digital image analysis showed a difference for both DGCI and H in the treatment with metsulfuron-methyl, which showed the lowest values in relation to the control sample and other herbicide treatments in the seventh and eighth assessments (Table 1). The H values observed for this herbicide were closer to the color yellow (60°) when compared to the control sample value and other herbicides (which ranged from 89° to 91° in the seventh assessment and from 90° to 93° in the eighth assessment). These results indicated that metsulfuron-methyl caused chlorosis in the leaves due to the reduced concentration of chlorophyll (BACKES et al., 2010), which can be explained based on the mode of this herbicide action. Indeed, in addition to stopping the growth in susceptible plants, within 7-10 DAA of metsulfuron-methyl, the development of interveinal chlorosis and/or foliar purpling has been previously observed (OLIVEIRA JUNIOR, 2011).

Metsulfuron-methyl, along with glyphosate, showed strong effects in the control of lawn growth (assessed by measuring leaf length [mm] using a ruler and determining leaf dry matter content; (data not shown). However, as described above, metsulfuron-methyl damaged the esthetic quality of the grass and is therefore not recommended as a growth regulator for this species.

Considering the importance of intense green coloration in ornamental lawns, digital image analysis appears to be a valuable tool to infer color changes; in addition to its ability to determine the green color intensity and hue of Emerald grass, it serves as an index to assist in determining the dose of N that is most suitable for maintenance of color, as well as the influence of herbicides on coloration. Therefore, digital image analysis can be used to select the appropriate N fertilizer dose and the best herbicide to simultaneously control growth and maintain green coloration.

CONCLUSION

Doses of N ranging from 10 to 20g m^{-2}, divided into five applications per year, provided the lawn with intense green coloration, and the herbicides glyphosate, imazaquin, and imazethapyr at doses of 200, 420, and 80g ha^{-1}, respectively, did not impact the esthetic quality of the grass. Due to the maintenance of intense green coloration, these herbicides appear to be suitable for use as growth regulators for Emerald grass. Digital image analysis of the aerial portion of the lawns provided more accurate results than the use of a chlorophyll meter with regard to the recommendation of both N dose and herbicides to be used as growth regulators of Emerald grass.

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