SCIENTIFIC ARTICLE

Durability and concentration of organic colorant in the visual quality of Discovery ™ bermudagrass

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Abstract

The painting of sports turfs with colorants is a common practice, with the main objective to maintain grass appearance for maximum aesthetic quality. Colorants are used to provide green color to grasses during periods of stress and dormancy and are considered an alternative for warm weather grasses during the winter months. Recent increases in the use of colorants is due to water conservation efforts as well as lower operating costs compared to winter overseeding. The objective of this study was to evaluate durability and doses of organic colorant in terms of visual quality of Discovery™ bermudagrass. The experiment was installed in the field, subdivided into plots of Discovery™ bermudagrass treated with lawn-specific commercial, organic colorant as follows 0 ml L^{-1} (Control); 33 ml L^{-1}; 50 ml L^{-1}; 66.6 ml L^{-1} (manufacturer's recommendation); 83 ml L^{-1}; 100 ml L^{-1}. At 10 day intervals the green color index, reflectance, normalized difference vegetation index (NDVI), and digital images were measured and assessed. The results indicate that, given the durability of the product, doses between 66.6 and 83.3 ml L^{-1} are recommended.
Keywords: 'Barazur', painting turfgrass, sports turfgrass.

Resumo

Durabilidade e doses de corante orgânico na qualidade visual de grama bermuda Discovery ™

O uso de corantes verdes em gramados esportivos é uma prática comum, tendo como principal objetivo, a manutenção do aspecto da grama, com intuito maximizar a qualidade estética. Os corantes são utilizados para fornecer cor verde as gramas durante períodos de estresse e dormência, sendo considerados uma alternativa para gramas de clima quente durante os meses de inverno. A recente popularidade do uso desse artifício ocorreu devido aos esforços para conservação da água, bem como à redução dos custos das operações, como o "overseeding". Assim, objetivou-se avaliar a durabilidade e doses de corante orgânico na qualidade visual de grama bermuda Discovery™. O experimento foi instalado a campo, subdividido em parcelas de grama bermuda Discovery™, sendo os tratamentos: 0 ml L^{-1} (Testemunha), 33 ml L^{-1}, 50 ml L^{-1}, 66,6 ml L^{-1} (recomendação do fabricante), 83 ml L^{-1}, 100 ml L^{-1} do corante comercial orgânico específico para gramados. A cada 10 dias foram avaliados os índices de coloração verde, reflectância, vegetação por diferença normalizada (NDVI) e imagem digital. Os resultados indicaram doses entre 66,6 e 83,3 ml L^{-1} podem ser recomendadas, visto o tempo da durabilidade do produto.
Palavras-chave: 'Barazur', pintura de gramados, gramados esportivos.

Introduction

The painting of sports lawns with colorants is a common practice that is widely used for a variety of purposes. The main objective is to maintain the aesthetic (visual) quality of turfgrass, thus maximizing the visual experience valued by players and fans (Pinnix et al., 2019). The use of colorants on lawns was first reported in the 1950s, with the goal of making turfgrass look natural in golf courses in Southern California without causing permanent damage. As such, painting techniques used in ornamental lawns were implemented, with the observed outcome being that the use of colorant does not affect gameplay and was well accepted by golfers (Briscoe et al., 2010).

In general, two types of treatments can be used for sports lawns, paints or colorants (Pinnix et al., 2018). Paints are applied routinely on the surface of sports fields to mark regulation lines, and paint logos and ads, among others. Therefore, the focus of manufacturers is to produce glossy coatings that are distinct and uniform and safe to use on turfgrass species that are commonly used for athletic fields (Reynolds et al., 2012). Colorants, in turn, are used to increase the greenness of turfgrass during periods of stress and dormancy, and are considered an alternative for warm climate grasses during the winter months (Pinnix et al., 2018).

Over the last decade, the practice of using colorants has increased in popularity, which according to Hargey et al. (2016), may be related to water conservation efforts, as well as the reduced operating costs when compared to the cost of winter overseeding (a practice widely used on golf courses and football fields in the winter). In Brazil, bermudagrass (*Cynodon* spp.) is commonly used for turfgrass in sports fields (i.e., football, golf, polo, among others), as it is a warm weather species originating in the African continent (Santos et al., 2019). The most common cultivars are `Celebration` and `Tifway 419` (Santos and Castilho, 2018). Recently, new turfgrasses of the genus *Cynodon* spp have been introduced into the country, including the variety Discovery™ bermudagrass or 'Barazur'. This variety has slow vertical growth and a uniform color with shades of dark bluish-green. It is indicated for use in landscaping and sports fields with low traffic, providing an alternative

for golf course fairways (Turf Grass Varieties, 2020; Khanal et al., 2017).

In addition to its aesthetic quality, another distinguishing feature of Discovery™ bermudagrass is the low cost of maintenance when compared with other varieties, as its slow growth corresponds to 75% less trimming than other species (Qually Gramas, 2020).

Such features are attractive in the Brazilian sports lawn market, particularly for golf clubs and private fields, as a means to reduce maintenance costs. Thus, the use of Discovery™ turfgrass in conjunction with the application of colorant during periods of stress and dormancy can reduce costs for sports fields while also improving the aesthetic (visual) quality without changing the physiological features of the turfgrass. Thus, this study aimed to evaluate the durability and doses of an organic colorant on the visual quality of Discovery ™ bermudagrass.

Materials and Methods

The experiment was installed in a previously established bermudagrass experimental area. We used a complete randomized block design, with six treatments and four replications, for a total of 24 experimental plots of 1.0 m² with borders of 0.50 m between plots. The variety used was the Discovery™ bermudagrass, with no irrigation system. The soil is characterized as Dystrophic Red Latosol (DRL), and the chemical characteristics are described in Table 1.

Table 1. Results of chemical analysis of the soil of the experimental area.

PH	M.O.	P resin	H+Al	K	Ca	Mg	SB	CTC	V%
CaCl$_2$	g dm^{-3}	Mg dm^{-3}	------------- ^{mmolc} dm^{-3}-------------						
6.0	12	7	11	2.6	25	7	34	46	75

According to the Koppen classification, the climate in the study region is Cfa (humid subtropical climate with abundant rainfall well distributed throughout the year). Throughout the experiment, data for average temperature (21.8º C), average relative humidity (64.7%), and accumulated rainfall (22.3 mm) were obtained from the meteorological station located beside the experimental area.

The experiment was installed in September of 2019, with the following treatments of commercial, organic

colorant specifically for lawns: 0 ml L^{-1} (Control); 33 ml L^{-1}; 50 ml L^{-1}; 66.6 ml L^{-1} (manufacturer's recommendation); 83 ml L^{-1} and 100 ml L^{-1}. The application of treatments was performed with a backpack sprayer nozzle, using an estimated flow rate of 350 L ha^{-1}. 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 (Figure 1).
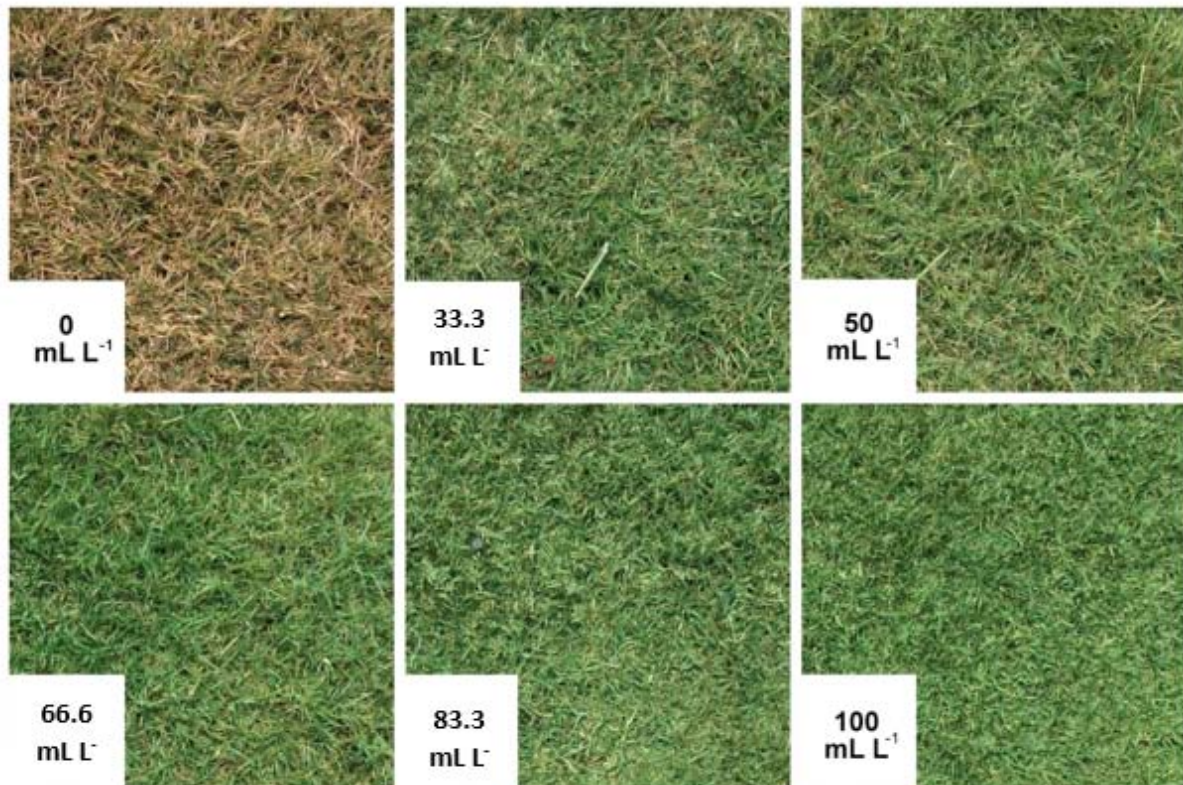
Figure 1. Comparative analysis of the treatments after application of colorant.

Evaluations were conducted every 10 days after application (DAA) for 30 days, for the following: visual quality of the lawn based on reflectance indices and analysis using digital images. The reflectance indices were green color index (GCI) and normalized difference vegetation index (NDVI). The green color index was assessed with two devices:

1) FieldScout CM 1000, which measures light reflectance. Five readings were taken in each plot to calculate the average. The samples were obtained parallel to the surface of the lawn at a height of 1.0 m;

2) FieldScout TCM 500 Turf Color Meter, which measures the reflection of light off the turfgrass in the red, green, and blue (RGB) spectrum. The meter is placed in contact with the turfgrass and pressed to ensure no penetration of light. This generates a grass index (0 to 9.9) and RGB value (0 to 99), which was multiplied by the index of 2.57 to obtain the actual results of the RGB components, varying from 0 to 255. With this, the RGB values were converted into HSB (hue, saturation, and brightness) through a computational program to obtain a dark green color index (DGCI) (Karcher and Richardson, 2003).

The normalized difference vegetation index (NDVI) was obtained with a portable Greenseeker Handheld meter (Trimble®). The samples were obtained parallel to the surface of the turfgrass at a height of 1.0 m.

For analysis using digital images, photographs were taken of the area with a 12-megapixel camera fixed to a light box similar to that described by Peterson et al. (2011). The light box is completely sealed, with lamps connected to a battery, to standardize the luminosity of the area photographed in all treatments. These images were transferred to a computer, and the RGB value of each image was recorded using Adobe Fireworks®. The data were compiled into a MS Excel spreadsheet and converted to HSB values and DGCI (Karcher and Richardson, 2003).

The results were evaluated using analysis of variance (ANOVA), with Tukey's test at 5% probability to compare means and regression for dose when significant. The statistical program 'Statistix 10' was used for data analysis and 'Sigma Plot' to plot the charts.

Results and Discussion

The results found for the visual quality of the lawn through the reflectance indices (Table 2) showed that only brightness had an interaction effect with time and dose of colorant. Therefore, each of the other evaluated factors act independently. The studied doses were non-significant for NDVI and GCI (TCM 500), while the other variables presented a polynomial regression.

Table 2. Reflectance index of Discovery™ bermudagrass after applying different doses of colorant.

Doses (ml L^{-1})	G Admin.	Hue (2)	Saturation (%)	Brightness (%)	DGCI Admin.	NDVI Admin.	GCI Scout CM1000	GCI Scout TCM500
0	121	36	39	45.39	0.25	0.32	127	6.0
33.3	93	58	26	35.56	0.45	0.33	161	5.7
50	89	80	30	35.36	0.56	0.33	169	5.6
66.6	89	77	28	35.34	0.55	0.33	173	5.6
83.3	78	92	30	34.9	0.63	0.31	164	5.3
100	80	94	31	35.48	0.64	0.35	182	5.4
Time (days)								
10	80 b	78 a	30	33.16 b	0.55 a	0.40 a	189 a	6.2 a
20	98 a	79 a	30	39.07 a	0.54 a	0.34 b	149 b	5.4 b
30	97 a	62 b	31	38.79 a	0.45 b	0.25 c	149 b	5.2 b
DMS	5	11	-----	1.69	0.05	0.04	12	0.6
F$_{doses}$	52.382**	24.329**	8.021**	34.352**	45.354**	0.596ns	13.669**	1.009ns
F$_{time}$	42.612**	8.714**	0.135ns	45.254**	15.225**	37.263**	40.172**	10.67**
F$_{d x t}$	1.285ns	0.883ns	0.963ns	20.327**	1.367ns	0.180ns	0.445ns	5.049ns
F$_{Block}$	0.637ns	0.793ns	3.056*	1.14ns	0.916ns	9.859**	12.37**	0.353ns
CV (%)	8.12	21.09	18.01	6.57	14.34	18.46	10.93	15.09

Average followed by the same letter do not differ statistically by Tukey test at 5% probability.

For the Green component (G), a decreasing, second order regression was observed, reaching the highest value when not subjected to any treatment (Figure 2a). That is, with the increase in dose, there was a decrease in G. As derived from the equation, the dose that provided the lowest G value was 94.45 ml L^{-1}. However, G on its own is not the real color of the lawn, as it also depends on blue and red reflectance values. Thus, the data are not well represented for this variable, as was also reported by Backes et al. (2010) and Gazola et al. (2016) in their evaluation of color in emerald grass (*Zoysia japonica*). Yet, when assessing the results for the duration of the colorant, the lowest value of G was observed at 10 DAA, and with the passing of time (20 and 30 days) this component increased (Table 2) as the plant returned to its natural color due to the degradation of the colorant.
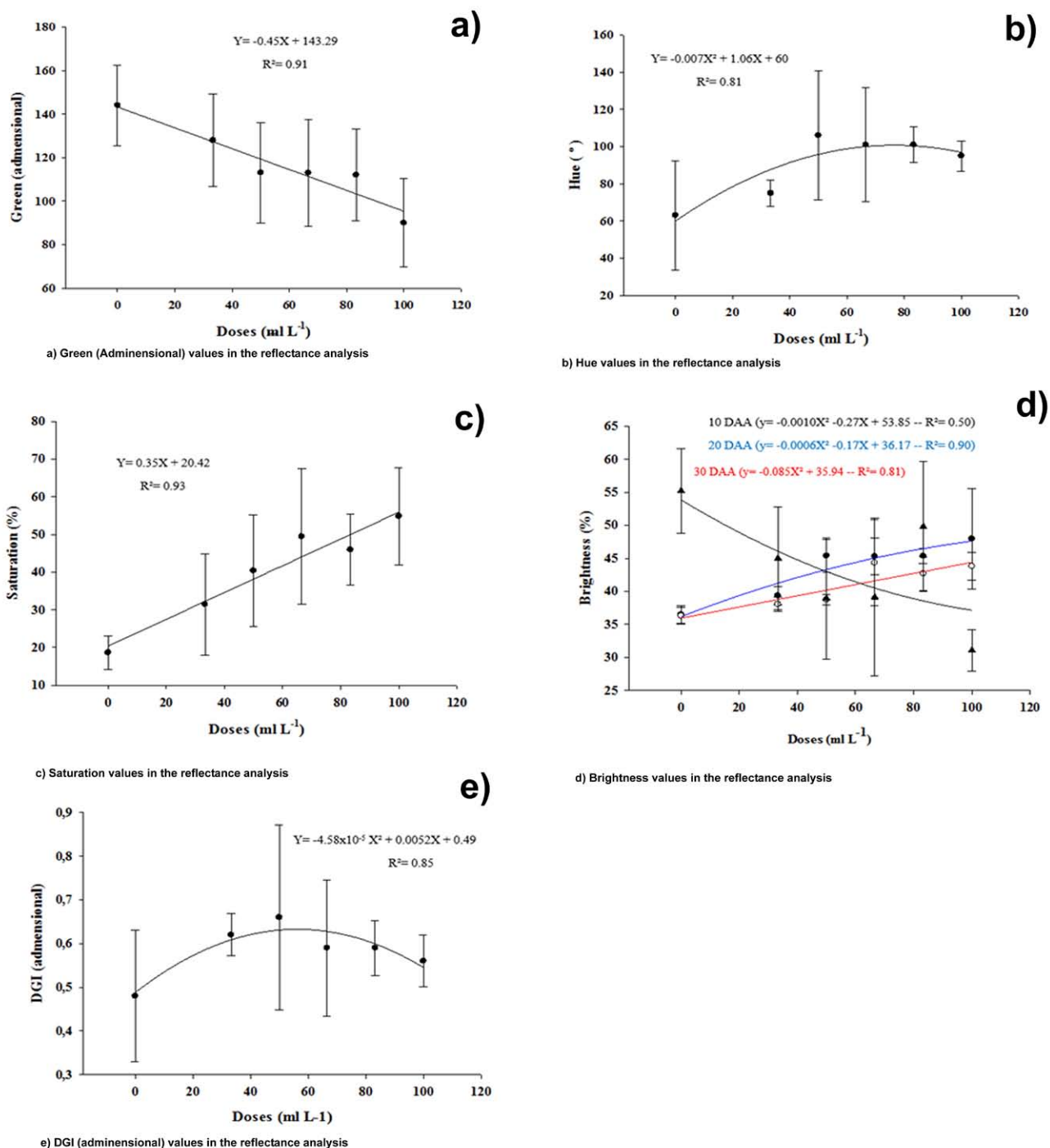
Figure 2. Reflectance index of the Discovery™ bermudagrass after application of colorant.

Similarly, the hue of the turfgrass, which describes the color pigment, did not reach the maximum value for green (120º) for any of the treatments. However, doses of at least 50 ml L^{-1} are within the range for green (60 to 120º), but outside the suitable range for bermudagrass (103) (Godoy et al., 2012). As such, a linear regression was observed with an increase in the dose of colorant (Figure 2b), showing that the applied product accurately reflects the pigment of green, based on the reflectance. Values lower than 60º have a yellowish color, which is not aesthetically

pleasing for ornamental lawns (Gazola et al., 2016). In the present study, doses below 33.6 ml L^{-1} presented hue values below the ideal (Figure 2b), suggesting that they are insufficient to provide the green color characteristic of turfgrass.

With respect to saturation, significance was only observed between doses of colorant, with no difference for time, presenting a positive quadratic regression (Figure 2c). According to Godoy et al. (2012), saturation indicates the vividness or fading of color and is measured in percentage

from 0 to 100, with a higher percentage indicating a «greener» lawn. Data from the present study show that none of the treatments presented saturation greater than 50%. The dose that provided the lowest saturation value for the turfgrass was 60.34 ml L^{-1} (Figure 2).

Brightness relates to the amount of white that a color contains and is also measured in percentage from 0 to 100, with a higher percentage indicating a brighter color (Godoy et al., 2012). This was the only variable that showed an interaction between time and dose of colorant (Table 2). In the first evaluation at 10 DAA, the control (dose of 0 ml L^{-1}) presented a maximum value, with the results decreasing with the gradual increase in the colorant concentration. The dose that showed the lowest value for brightness was 70 ml L^{-1} (Figure 2d). The data show that the colorant negatively influenced lawn brightness, changing its reflectance for this variable. Over time, at 20 and 30 days, there was a degradation of the colorant on the leaves and the lawn started to show its natural color. As such, the brightness increased in comparison to the values at 10 DAA. The doses that provided the lowest value for brightness at 20 and 30 DAA were 50 and 57.69 ml L^{-1}, respectively.

For DGCI, we observed an influence of dose and time in applying the colorant, but no interaction between these factors (Table 2). This variable was essential in order to demonstrate that after application the colorant accurately reflects the dark green of turfgrass, which resulted in a quadratic regression, with a maximum of 103.55 ml L^{-1}. The durability of the colorant was up to 20 days (Table 2), whereas at 30 DAA there was a drop in the lawn color, i.e., the product began to degrade and the lawn returned to its natural color. Higher values of DGCI reflect a darker green turfgrass, that is, greater coverage of deep green without flaws, which is aesthetically pleasing (Lima et al., 2012; Gazola et al., 2016). Considering the results of this study, the effect of the dose of 83.3 ml L^{-1} are within the appropriate value (0.63) for bermudagrass as cited by Godoy et al. (2012).

Consistent with the results described above, the values of NDVI showed no significant differences for dose (Table 2), indicating that only time influences this variable. The results are similar to those reported, who observed a negative effect on the evaluation of NDVI in bentgrass (*Agrostis stolonifera*) after colorant application. According to Obear et al. (2017), NDVI is not an accurate tool to assess turfgrass subjected to colorant application, since the reflectance of the pigment interferes in the device's ability to accurately collect a reading. On the other hand, there were no significant differences for NDVI in relation to time, but with a noticeable reduction in values throughout the study (at 10, 20 and 30 DAA). In addition, the values found indicate poor lawn quality as they differ from the values suggested by Caturegli et al. (2015) and Fotia et al. (2016) as indicative of good turfgrass quality (between 0.82 and 0.96).

The two instruments used to measure reflectance indices of GCI showed conflicting results, with the GCI using the FieldScout CM 1000 showing significant results for dose and durability separately, and the GCI from the FieldScout TCM 500 showing an effect only for durability. As for the evaluation with the FieldScout CM 1000 for GCI, the analysis is performed at approximately 1m above the area and contact with the lawn is not necessary. Thus, the colorant may have influenced the results, showing a negative and quadratic regression, with a maximum value at a dose of 85.3 ml L^{-1} (Figure 2e). According to Godoy et al. (2012), the instrument measures the reflectance of the wavelength from 700-840 (red and infrared) and, from this, measures the sunlight reflected by the area. This may have influenced the differences found for GCI based on dose of colorant (Figure 2e). However, all results were far below the value considered ideal for bermudagrass (445) proposed by Godoy et al. (2012). Obear et al. (2017) also found no statistical difference in their experiment on the use of colorant, observing values of 221 and 205 in treatments with and without colorant, respectively, which are higher than the results of the present study (Table 2).

GCI indirectly reflects the amount of leaf chlorophyll and the nutritional status of the lawn, where higher concentrations of photosynthetic pigment mean greener turfgrass, and a greater value read by the instrument (Lima et al., 2012; Santos and Castilho, 2015; Gazola et al., 2016; Oliveira et al., 2018). Thus, we can infer that even with the application of colorant, the GCI values may be accurate for measuring lawn nutrition. An increase in dose provided greater false «green» color, however, the GCI remained far below that recommended for well-nourished lawns (445) (Godoy et al., 2012). The durability of the colorant also influenced the results (Table 2), where at 10 DAA, the GCI was greater than at 20 and 30 DAA, both of which showed similar results (149). Thus, the colorant influences this variable for only a short period of time.

The GCI based on FieldScout TCM 500, showed no statistical difference between doses, possibly because measurement requires direct contact with the lawn, and thus, the reflection of light off the turfgrass in the red, green, and blue spectrum were accurately measured. However, the results for time ranged in the analyses, with a decrease in value with the passing of time, showing an increase at 10 days, and significantly lower results at 20 and 30 DAA. This is related to the lack of fertilization, which affected lawn development. Therefore, the index had a tendency to decrease, indicating the true nutritional status of the turfgrass.

The results obtained through the analysis of reflectance indices (Table 2) showed that the colorant increased the green color of the lawn; nevertheless, the tools used revealed the true nutritional status of the turfgrass and demonstrated the durability of the colorant, as shown in Figures 4, 5 and 6.

On the other hand, the results obtained through digital image analysis presented an inaccurate representation of lawn color. For the variables G, Hue, Saturation, and DGCI, we found significant differences between the doses; however, only the saturation showed a difference in terms of the durability of the colorant, while brightness was the only variable to present interaction between the factors (Table 3).

Table 3. Values of Green (G), hue (H), saturation, brightness and DCGI in Discovery™ bermudagrass obtained by digital image after applying colorant.

Doses (ml L⁻¹)	G	Hue	Saturation	Brightness	DGCI
	Admin.	(2)	(%)	(%)	Admin.
0	144	63	18.7	42.65	0.48
33.3	128	75	31.48	40.79	0.62
50	113	106	40.37	40.00	0.66
66.6	113	101	49.48	42.94	0.59
83.3	112	101	45.98	45.94	0.59
100	90	95	54.84	40.95	0.56
Time (days)					
10	110	93	48.13 a	43.19	0.55
20	121	92	39.10 b	42.81	0.57
30	120	96	33.1 b	40.65	0.62
DMS	---	-----	7.77	----	----
F_{doses}	9.111**	5.926**	16.853**	1.759ns	3.434**
F_{time}	2.372ns	0.253ns	10.950**	1.421ns	2.691ns
$F_{d\,x\,t}$	1.123ns	0.756ns	0.826ns	5.749**	1.448ns
F_{Block}	1.981ns	3.851*	2.312ns	1.048ns	5.383*
CV (%)	17.56	23.81	27.76	13.29	19.48

Average followed by the same letter do not differ by Tukey test at 5% probability.

In contrast to the results for reflectance index (Figure 2a), the analysis by digital image for the green component (G) showed a negative linear regression, where an increase in dose produced lower values (Figure 3a). However, as previously discussed, the green component on its own does not reflect the color of the lawn, as R and B values are also required. The hue presented higher values (Table 3) than those from reflectance (Table 2), which showed a negative quadratic regression, with a maximum of 75.57 ml L⁻¹ (Figure 3b). Thus, we can infer that the digital image analysis visually recorded the green pigment after colorant application, as the results remained within the range for green color (60 to 120°).

With the exception of the control (0 ml L⁻¹), all other doses showed higher values for saturation based on digital image analysis (Table 3) than reflectance index (Table 2).

However, we found a positive linear regression, where a constant increase in the dose provided greater percentage of saturation of the lawn color (Figure 3c). This variable was the only one to present significance for durability. With the passing of time, there was a decrease in the value, showing less vivacity of green at 10 DAA. This differs from the results of saturation obtained by reflectance index, where there was no statistical difference over time.

The brightness showed similar results to the data obtained by reflectance index (Table 2), with an interaction between time and dose of colorant. At 10 days, a quadratic and positive regression was observed, having a minimum point at a dose of 120 ml L⁻¹, and the highest value found for the control (Figure 3d). At 20 and 30 DAA, we found the opposite effect, where the increase in dose of colorant showed higher percentages for brightness (Figure 3).
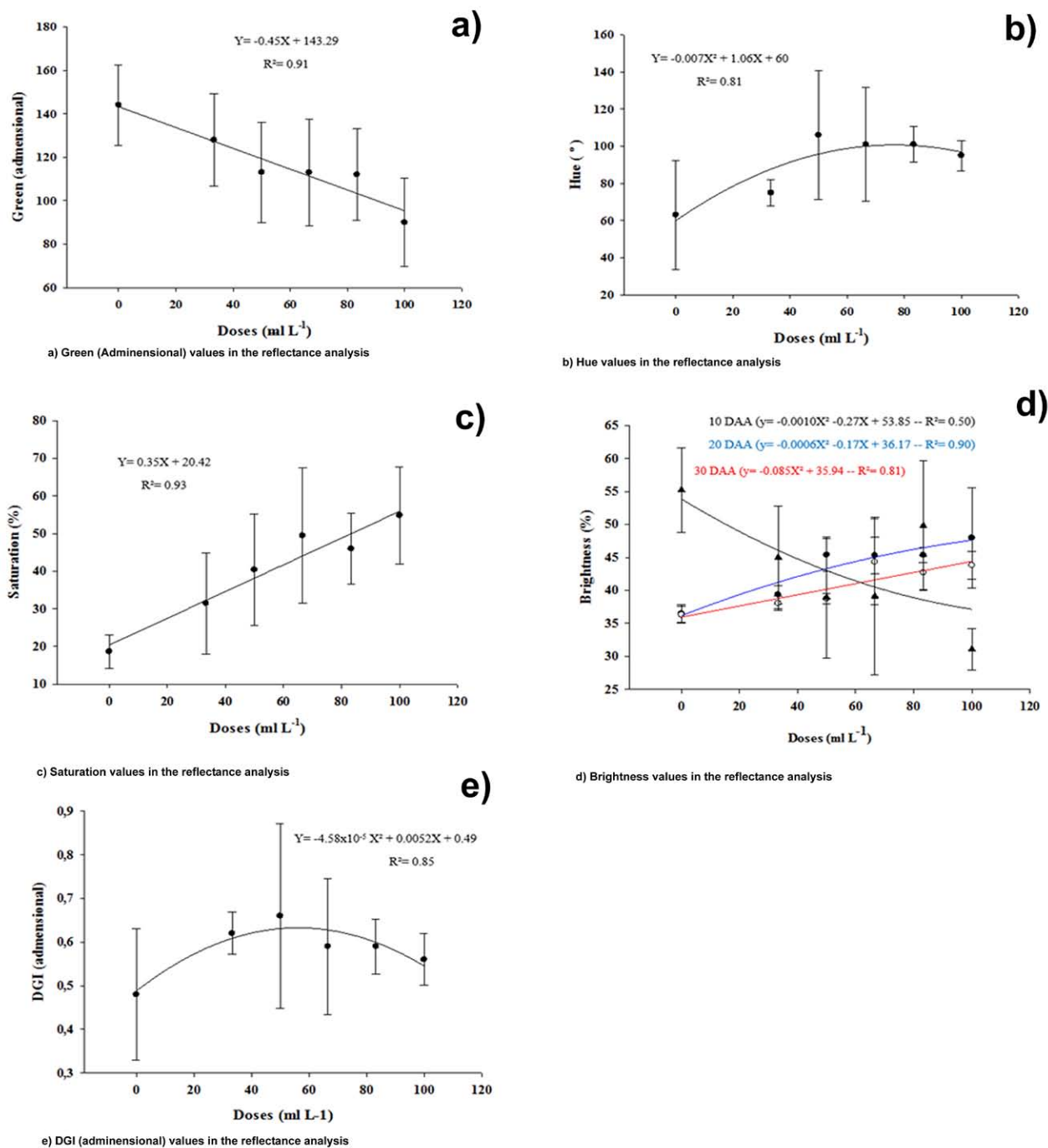
a) Green (Adminensional) values in the reflectance analysis

b) Hue values in the reflectance analysis

c) Saturation values in the reflectance analysis

d) Brightness values in the reflectance analysis

e) DGI (adminensional) values in the reflectance analysis

Figure 3. Values of Green (G), hue (H), saturation, and DCGI for Discovery™ bermudagrass obtained by digital image after application of colorant.

The DGCI obtained by digital image (Table 3) showed similar results to those obtained by reflectance (Table 2), and are similar to those considered ideal by Godoy et al. (2012) (0.63). However, the ideal dose for maximum DGCI, as derived from the equation, is 56.77 ml L^{-1}, which is much lower than the concentration found for DGCI based on reflectance (103.55 ml L^{-1}).

Thus, the data obtained from the reflectance index (Table 2) are accurate to estimate the nutritional status of the lawn, as well as the durability of the colorant, without providing the false impression that the lawn is well nourished. In contrast, the digital image analysis showed significant results for dose, producing the perception that the turfgrass is greener, and better nourished. As a result, the dose of colorant had an influence on the visual quality (aesthetic) of the lawn, despite the fact that the lawn was nutritionally deficient. The results contradict that observed by Obear et al. (2016) who concluded that the application of colorant increased the visual quality of the lawn, but with inconsistent effects on the measurements

based on reflectance indices. Although there is a high correlation between the values of reflectance indices and digital image analysis for estimates of nutritional status of bermudagrass (Lima et al., 2012), when colorant is applied this relationship no longer holds.

With respect to durability of the colorant, only the reflectance index accurately captured the data, where results at 10 days already showing a degradation of the product (Table 2). This result is similar to that described by Obear et al. (2017) in an experiment with the use of colorant in bentgrass, where an interval of 14 days was used. However, Braun et al. (2016) observed good results in the application of the same colorant used herein on the visual quality of *Zosya japonica* 'Chisholm'. They concluded that the lawn presented color permanence for up to 197 days in the autumn/winter, but with significant loss in color at approximately 60 days. Hargey et al. (2016) affirm that it is necessary to increase the number of applications to maintain the color during the winter months, which is dependent on several factors, including cultivated species and conditions of application (Figures 4 to 6).
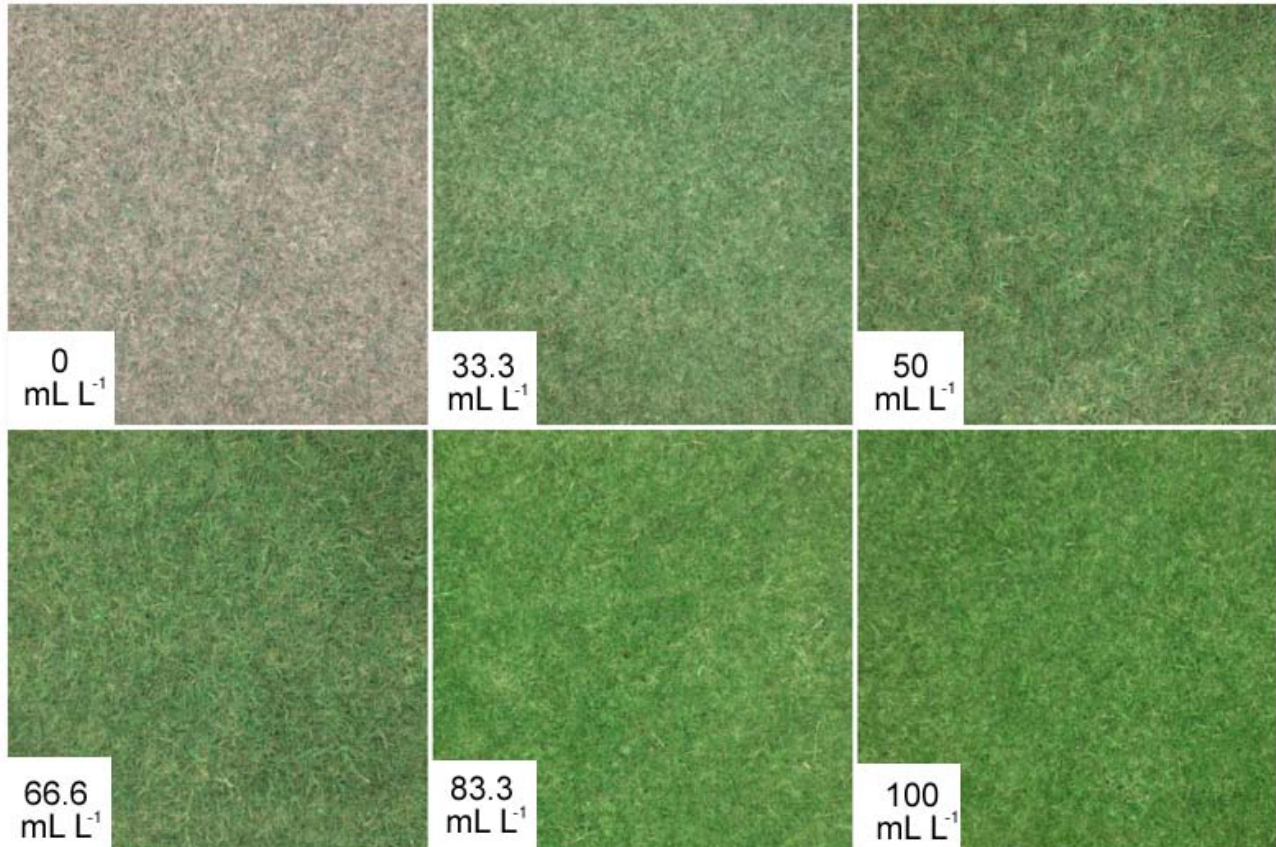

Figure 4. Visual appearance of Discovery™ bermudagrass at 10 days after applying colorant. 0; 33.3; 50; 66.6; 83.3; 100 ml L^{-1}
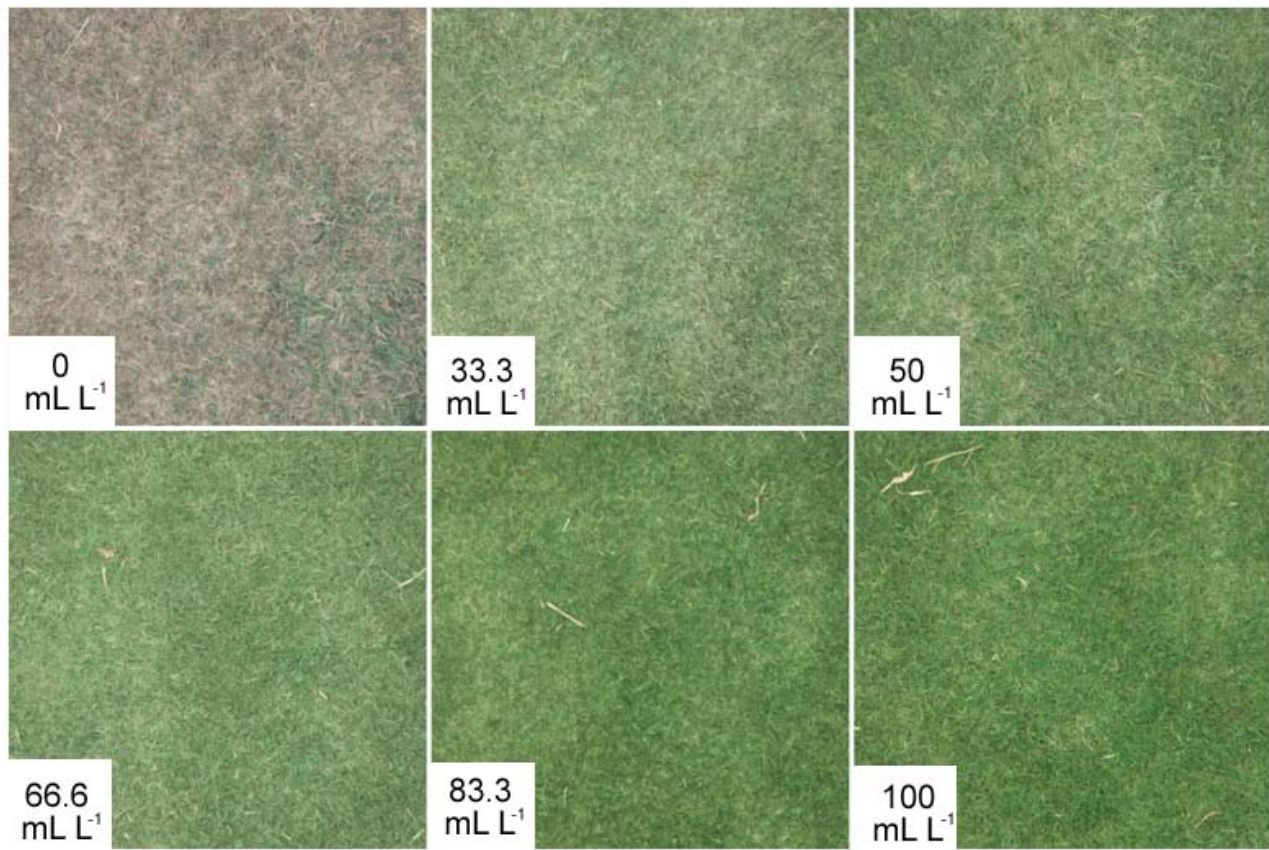
Figure 5. Visual appearance of Discovery™ bermudagrass at 20 days after applying colorant.
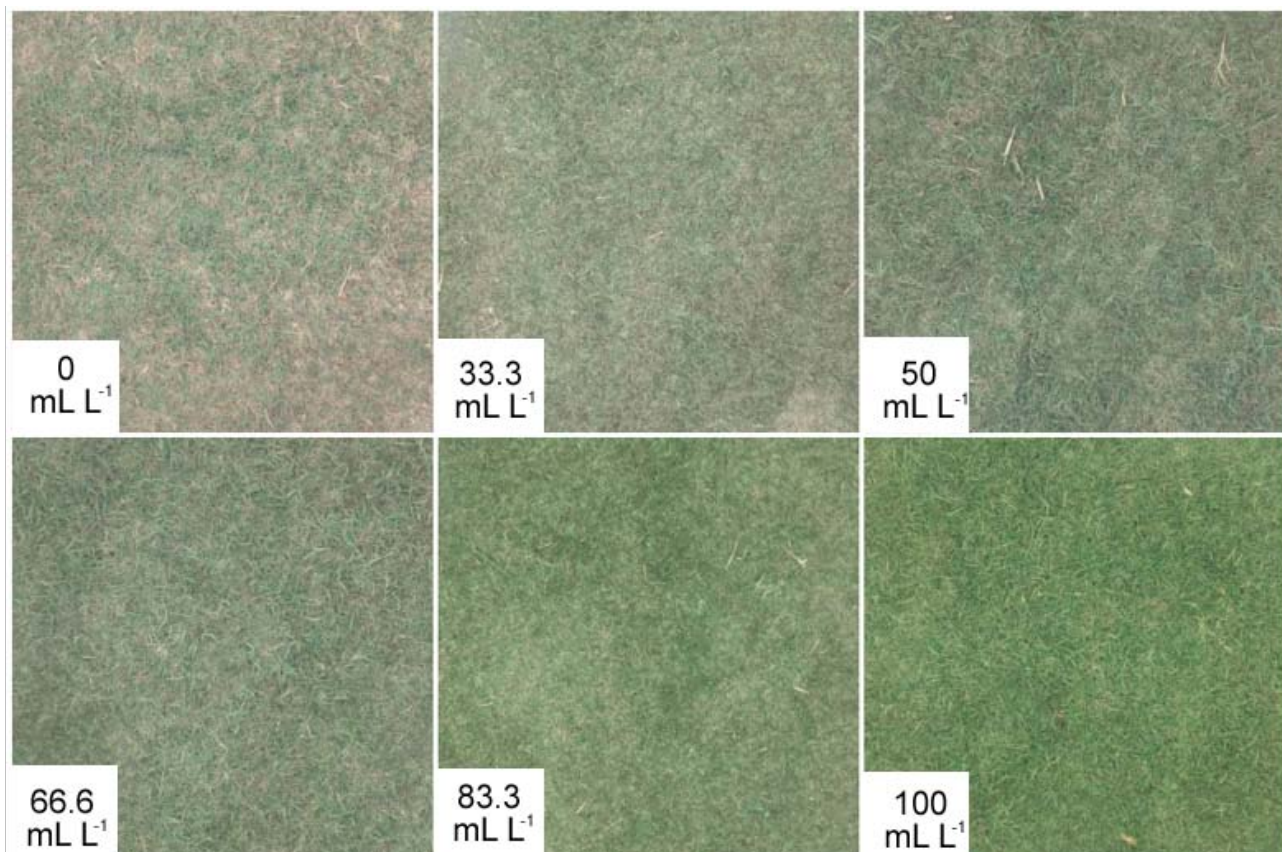0; 33.3; 50; 66.6; 83.3; 100 ml L^{-1}

Figure 6. Visual appearance of Discovery™ bermudagrass at 30 days after applying colorant.
0; 33.3; 50; 66.6; 83.3; 100 ml L^{-1}

Conclusions

The use of organic colorant can be an alternative to increase the aesthetic (visual) quality of Discovery™ bermudagrass. Doses between 66.6 and 83.3 ml L^{-1} are recommended at an interval of 10 days based on the durability of the product.

Author Contribution

MVLN: experiment idea, field analysis, data collection and analysis, interpretation, preparation and writing of the article, critical review and translation. **PLFS:** critical review, analysis and interpretation of data, approval of the final version. **JVC:** field analysis and data collection. **JTM:** critical review, analysis and interpretation of data. **RLVB:** critical review, approval of the final version, work advisor. **LJGG:** critical review, analysis and interpretation of data, co-supervisor of the work.

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