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Growth and establishment of irrigated lawns under fixed management conditions

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ABSTRACT

Irrigated lawns play an important role in landscaping and sports activities in Brazil and around the world. For maintaining its color and beauty, it is necessary that a considerable amount of water, is applied via irrigation systems. However, when irrigation management is not done precisely, it can cause water waste, increased energy consumption, nutrient leaching, among other problems. The objective of this study was to evaluate the growth and the establishment of different irrigated lawns (*Santo Agostinho* and *Esmeralda* lawns) under simulated conditions of fixed irrigation rate management, using different irrigation strategies (M_1, M_2, M_3, M_4, M_5 and M_6) and different soil root depths (S10, S20, S30 and S40). The experiment lasted over 11 months, and it was possible to analyze the lawns quality during the four seasons of the year, in the city of Piracicaba-SP, Brazil. We evaluated plant height (PH), dry matter yield (DM), leaf water potential (LWP) and irrigation water use efficiency (IWUE). Irrigation management based on a reference plot, with soil moisture level keep almost constant at field capacity (M3) was sufficient to produce optimal levels of DM yield in the remaining irrigated treatments, contrary to the initial hypothesis. The different root depths irrigated (S40, S30, S20, and S10) had no influence on the average height of the lawns during the evaluation period (11 cuts). The LWP of the *Santo Agostinho* lawn was higher than *Esmeralda* lawn in all the evaluated cutting periods, however, the IWUE was higher in the *Esmeralda* lawn compared to *Santo Agostinho* lawn.

1. Introduction

Lawns have an essential role in landscaping and sports, contributing to sustainable development (green spaces) and social welfare (sports and leisure areas), as well as providing economic benefits, as a source of direct and indirect jobs (Beard and Green, 1994; Haydu et al., 2008; Ignatieva et al., 2017).

In landscape designs, lawns are dominant plant types; in the United States, they occupy an area of approximately 164,000 square kilometers, which is more than three times the area occupied by any other irrigated crop (Milesi et al., 2005). In Brazil, there is a growth in the landscaping area of the market and technologies to produce and maintain ornamental plants and lawns (Meganck et al., 2015). There is practically no garden without a lawn, being, in many cases, 90% of the landscaping composition. Lawns are also important in sport fields like soccer, golf, hoquei, equestrian, rugby, football and others.

This high quality lawn demand led to a search for new techniques related to the growth and establishment of lawns and also to pest and disease control. However, to maintain life, color, and beauty of a lawn, the essential element is water (Wanjiru and Xia, 2015; Sisser et al., 2016; Fontanier et al., 2017). Irrigation laws use a large amount of water, and in the United States (USA), it represents the most considerable portion of water used (Mayer et al., 1999). In Florida, as well as many other areas of the southern and western USA, irrigation systems account for more than half of the total water that is used annually in homes (Gerston et al., 2002; Haley et al., 2007).

Also, lawn irrigation accounts for at least half of all water consumed by households in most Australian cities (Brennan et al., 2007). As an aggravating factor, automated systems do not usually distribute water evenly to irrigate the lawns properly, and have many inherent inefficiencies that increase water losses.

Traditionally, the most widely used irrigation methods for large-scale production are conventional sprinkler, self-propelled guns, and central pivot. Smaller areas often use micro-sprinkler and drip systems

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for landscaping purposes. Lack of control of irrigation, when in excess, causes waste of water, increases energy consumption, labor, and leaching of nutrients, reducing the efficiency of fertilization and causing mechanical damage to the leaves, thus creating conditions favorable to the occurrence of diseases.

Lawn irrigation management is a complex practice because water depth must be variable, taking into account the stage of development of lawn in different parts of the garden, which in turn influences the leaf area index (LAI), the crop coefficient (K_c) and evapotranspiration (ET) of the management uniform zones (Birendra et al., 2018; Devitt et al., 1992; Grabow et al., 2012; Graham et al., 2016; Snyder et al., 2015). However, what has been observed at field level, are irrigation practices based on a fixed management zone for the entire irrigated area, without taking into account the differentiated development of specific areas in the garden.

When an irrigation depth is established based on a single portion of the lawn, irrigation depth may be applied that is greater than that required in the plots with smaller leaf area, causing soil water drainage, a decrease of aeration and also environmental nutrient contamination (nitrogen). It may also be applying an insufficient irrigation depth, causing the water stress of the lawn in the plots which can result a negative visual impact for users (yellow areas in the field).

In this context, the objective of this work was to evaluate the growth (plant height) and the establishment (dry matter yield) of different irrigated lawns (*Santo Agostinho and Esmeralda*) under fixed irrigated rate management reference (M_3) condition using different water replacement estrategies and considering different root depths.

2. Material and methods

2.1. Location and characterization of the experimental area

The experiment was carried out under a protected environment in the experimental area of the Department of Biosystems Engineering at the University of São Paulo (USP/ESALQ), city of Piracicaba - SP, Brazil, localized at the geographical coordinates of 22°42'45" south latitude and 47°37'54" west longitude; local altitude is approximately 543 m above sea level. The region climate, according to the classification of Köppen, is of type Cwa, that is, dry winter and temperature of the hottest month higher than 22 °C; mean temperature of 21.6 °C; relative humidity of 73% and annual precipitation of 1280 mm.

The green house cover was a transparent polyethylene plastic film, 150 microns and with laterals closed with a black shade screen that provided 30% solar radiation interception (Costa et al., 2015). Forty-eight cement boxes with a capacity of 100 liters with dimensions of 60 cm x 40 cm x 45 cm were distributed in the space of 160m^2 in four 80 cm spaced lines, 50 cm between boxes, maintaining a distance of 100 cm from the sides the greenhouse. The experiment classified the soil as Yellow Red Latosol, with a sandy loam texture. At the bottom of the boxes was placed a layer of gravel with thicknesses according to the soil root desired, covered by a geotextile blanket (Fig. 1a).

The remaining layer of the box was filled with soil (Fig. 1b), thus simulating different water storage capacities. The boxes were filled with depths of the soil of 40, 30, 20 and 10 cm, aiming to simulate different rooting conditions of the plants in the field, corresponding to treatments S40, S30, S20, and S10, respectively.

The irrigation system used was the drip irrigation (Fig. 1c), with a variable flow as a function of soil depths: S40 with two drippers of 8 L h^{-1}, S30 with two drippers of 4 L h^{-1}, S20 with three drippers of 2 L h^{-1} and S10 with two drippers of 2 L h^{-1}. The number and flow of the drippers are different to meet the demand for different soil depths (S40, S30, S20 and S10). The flow variation was deliberate to minimize the operating time of the irrigation system, each treatment has an independent control system.

2.2. Experiment implantation

Four months before the beginning of the evaluations, two species of lawns were planted, the *Santo Agostinho* lawn (*Stenotaphrum secundatum* (Walt.) Kuntze St. Augustinegrass) (Fig. 1d) and *Esmeralda* or Zoysia (Zoysia japonica Steud, Japanese Lawngrass) (Fig. 1e). The anticipation of the plantation was made so that the establishment and the total occupation of the area of each box occurred, before the imposition of the irrigation treatments.

The lawns were planted through rugs or boards, which occupied the entire surface of the boxes. After laying the lawn carpets reaching the top box edge, manual light compaction was carried out in each experimental unit to improve the contact of the carpet roots with soil (17.35% of clay, 8.24% of silt, 74.72% of sand).

2.3. Experiment conducting

Chemical and physical analyzes of the soil were carried out in the depth of 0–40 cm, to determine the need for fertilization at the planting. However, there was no need for pre-plant fertilization, according to the availability of nutrients in the soil. For the maintenance of the lawns, the soil analysis indicated the need for a periodic fertilization of macro and micronutrients: 405 kg ha^{-1} of N, 190 kg ha^{-1} of K_2O and 115 kg ha^{-1} of P_2O_5 per year, distributed in 3 applications during the summer and 2 in winter. Also, 29 kg ha^{-1} of MgO were applied, every time after the cut of each irrigation management. Fertilizer dosages were the same for all treatments.

Irrigation management was performed using a digital tensimeter. Tensiometer tubes with ceramic tips and rubber taps were installed in a single block, referred as reference management zone (M_3). In the treatments with S40 and S30, two tensiometers tubes were installed at 10 cm and 30 cm depth. Meanwhile, for the S20 and S10 treatments, the tensiometers tubes were installed at 10 cm depth. Tensiometer readings were performed daily.

M_1, M_2, M_3, M_4, M_5, and M_6 irrigation treatments were calculated according to the control plot (M_3), independently for each treatment (8 treatments: two lawns x four soil depths), that is, we excluded from the analysis the differentiated stage of plant development. The control block (reference management plots) were kept with soilmoisture close to the water matric potential of −5 kPa, considered as the field capacity potential for these cement vase conditions (without drainage).

The control of a single block (M_3) simulated the management by tensiometry in a traditional sprinkler irrigation system for urban lawns. The justification for the installation of tensiometer batteries in just one reference plot for each one of the 8 treatment combinations (four replications), is the difficulty for lawns owners in installing and reading several soil moisture sensors around the residential garden area.

The experiment was conducted over 11 months (04/12/2006 to 10/23/2007), totaling 324 growing days (11 cuts), with a sequential cut between treatments performed every five days (Table 1), completing a growing cycle every 30 days. Thus, it was possible to analyze the lawns during the four seasons of the year (summer, autumn, winter, and spring).

2.4. Plants height

The manual cutting of the lawns of each management, composed of 8 boxes, was performed after a rest period of 30 days. It was established the cutting height according to the agronomic specificity of each plant. For *Santo Agostinho* lawns, the established cutting height was 2.6–6 cm, whereas for *Esmeralda* lawn, this value was defined as 1.5–3.0 cm. The cutting was made at the edge of the box, leaving a green canopy of 2–4 cm of height for the two species.

For the canopy height determination, an indirect method non-destructive, was applied in all the boxes at each cut based on a ruler and transparent acetate film, placed over the canopy of each lawn. The use

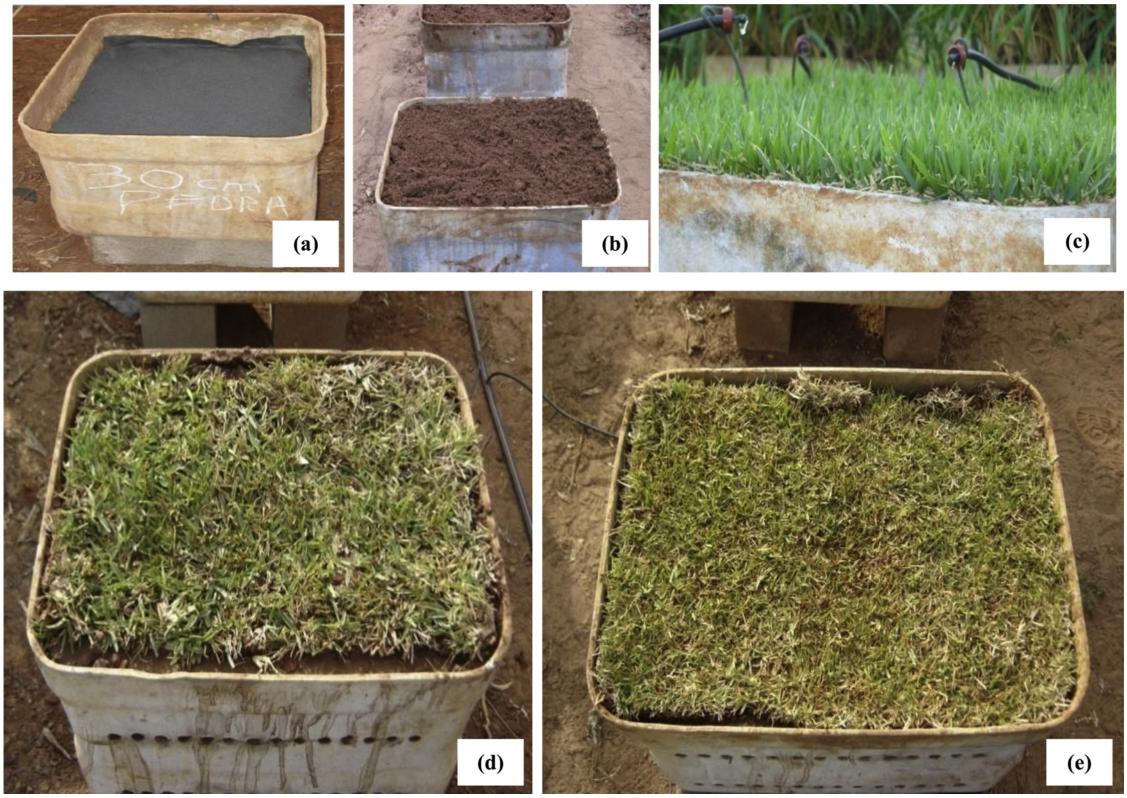

Fig. 1. Box with a layer of gravel coated by a geotextile blanket (a); box used in the experiment filled with soil (b); detail of the drip irrigation system (c); Santo agostinho lawn (*Stenotaphrum secundatum)* (d); Esmeralda lawn (*Zoysia japonica*) (e).

of transparency prevents compression and allows to integrate an area of approximately 600cm^2; besides, the average height of the transparency can be measured much faster and easier than averaging individual heights readings of the same area.

2.5. Dry matter yield

The dry matter (DM) was obtained through the direct method, which consists in performing the cutting, oven drying and weighing lawns dry mass. In order to facilitate the sampling process and to reduce the variation coefficient, it was decided to cut the total area of each box, approximately 0.24 m^2. Each treatment was cut individually and packaged in identified individual paper bags.

After cutting, the fresh lawns were weighed using a digital scale with an accuracy of 0.01 g. This measure is called “The green mass (GM).” In order to obtain the DM, the samples were conditioned in a drying oven with forced air circulation for 48 h, with a controlled temperature of 65 °C, and weighed later.

2.6. Leaf water potential

We selected the pressure chamber method (Scholander chamber) to obtain the leaf water potential (LWP), using the model 3005 Soil Moisture Equipment, transporting the pressure chamber to the experimental area coupled to the nitrogen tank is laborious, so it was decided to pack fresh leaves in a styrofoam box with ice and after taking them to the indoor laboratory for pressure chamber readings.

The collection of 6 to 8 tillers from each treatment always occurred at dawn, between 6:00 a.m. and 6:30 a.m. Samples randomly collected in each box followed a standardization of appearance and insertion position. After collection, the samples were stored in zip loc plastic bags, with dimensions of 20 × 24 cm, identified and placed in a black

Table 1
Cuts dates and number of days of the cycle in the different treatments (blocks) performed during the experiment (04/12/2006 to 23/10/2007).

Cuts	M_1	Cycle	M_2	Cycle	M_3	Cycle	M_4	Cycle	M_5	Cycle	M_6	Cycle
1	4/dec	–	9/dec	–	14/dec	–	20/dec	–	22/dec	–	26/dec	–
2	3/jan	31	8/jan	31	12/jan	30	17/jan	29	22/jan	32	28/jan	34
3	1/feb	29	7/feb	30	12/feb	31	16/feb	30	21/feb	30	25/feb	28
4	2/mar	29	6/mar	27	13/mar	29	17/mar	29	23/mar	30	27/mar	30
5	30/mar	28	4/apr	29	11/apr	29	14/apr	28	18/apr	26	22/apr	26
6	26/apr	27	1/may	27	7/may	26	12/may	28	18/may	30	23/may	31
7	29/may	33	1/jun	31	6/jun	30	11/jun	30	17/jun	30	23/jun	31
8	27/jun	29	3/jul	32	6/jul	30	11/jul	30	17/jul	30	23/jul	30
9	27/jul	30	2/aug	30	8/aug	33	13/aug	33	17/aug	31	22/aug	30
10	29/aug	33	3/sep	32	8/sep	31	15/sep	33	19/sep	33	25/sep	34
11	29/sep	31	4/oct	31	8/oct	30	12/oct	27	17/oct	28	23/oct	28
Average cycle		30		30		29.9		29.7		30		30.2

M: managements; M3: Reference management; Cycle in days; Dec: December; Jan: January; Feb: February; Mar: March; Apr: April; Jun: June; Jul: July; Aug: August; Sep: September.

plastic, surrounded by a styrofoam box with ice, to avoid the incidence of light and excessive heat.

Before chamber pressure readings, the fresh material collected was standardized using only the 2+ or 3+ leaves with the petioles cut trying to obtain the best LWP representation. Chamber pressure readings were eye-performed with a magnifying glass (10 times), at a slow nitrogen pressurizing rate. The LWP was measured from the fourth cut of each block because it is necessary to create a measurement and adjustment standard of the measurements of LWP. The LWP readings were made at the end of each cycle of the different treatments, according to Table 1.

2.7. Irrigation water use efficiency

The irrigation water use efficiency (IWUE) was determined only for block M_3 because it was the control block (reference) of the irrigation depths. The IWUE values were obtained by the ratio between the DM yield of the lawns and the amount of water applied in the treatments, according to Eq. (1).

$$IWUE = \frac{PROD}{V} \tag{1}$$

where IWUE is the irrigation water use efficiency (kg m^{-3}), PROD is the dry matter yield (kg ha^{-1}), and V is the amount of water applied by irrigation during the lawns cycle (m^3 ha^{-1}).

2.8. Data analysis

The data of each evaluation of the experiment were interpreted individually, respecting the experimental design adopted (randomized blocks with treatments arranged in bands). Variance analyzes or comparison of means of the characteristics evaluated were performed using SAS software.

Tukey test was used at the 5% probability level by the PROC GLM procedure and Microsoft Excel® software for graphical representation of the behavior of some data collected throughout the experiment.

3. Results and discussion

3.1. Plants height

Comparing lawns height between species before cuttings, we verified that there was a significant difference in the majority of the cuts, as expected before because they were different species (Fig. 2). The *Santo Agostinho* lawn presented average height superior to the *Esmeralda* lawn in all the periods of evaluation. Regarding the variation of height throughout the evaluated period, the *Santo Agostinho* lawn showed values of an average height of 7 cm before cutting 9 and 10.94 cm before cutting 3. Meanwhile, for the *Esmeralda* lawn, height values ranged from 5.10 cm (before cutting 7) and 9.84 cm (before cutting 4).

The environmental conditions, during the growing periods of each

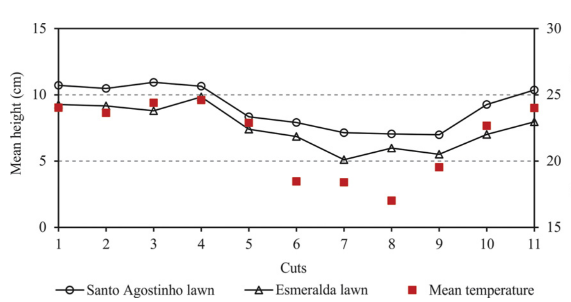

Fig. 2. Mean height (cm) of the Santo Agostinho (o) and Esmeralda (Δ) lawns before the different cuts and mean temperature (ºC) for these different periods.

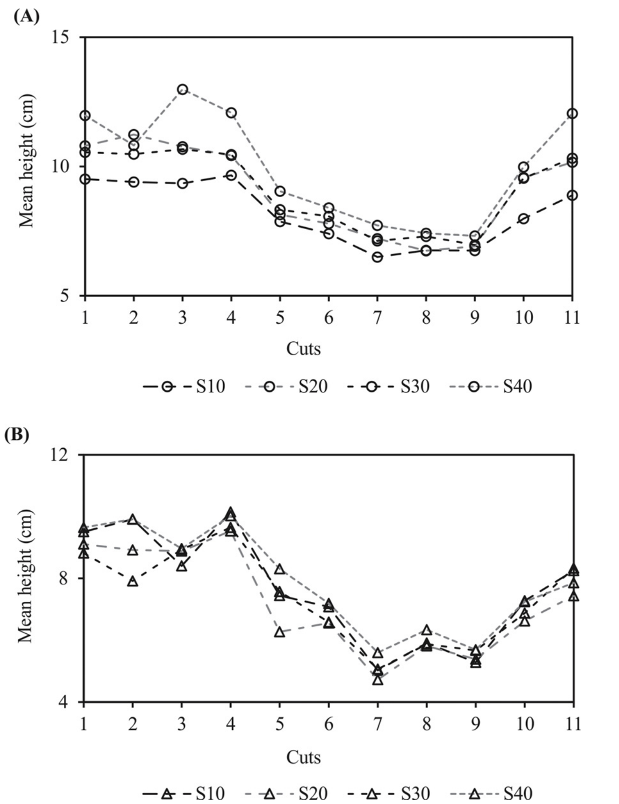

Fig. 3. Mean height (cm) of the Santo Agostinho (A) and Esmeralda (B) lawns according to the different soil depths adopted (S40, S30, S20, and S10) in the different cuts.

cut, influenced the total dry mass of each treatment. Air temperature during the evaluation period ranged from 17 to 24.6 °C, and this micrometeorological variable directly influenced the growth of lawns. According to Santiago et al. (2002), the metabolism and the growth of the lawns are accelerated in environments with an air temperature between 25 and 35 °C, whereas in average monthly temperatures lower than 20 °C (winter), periods of lower lawns growth.

There were no statistically significant differences ($p > 0.05$) for both the *Santo Agostinho* lawn (Fig. 3a) and the *Esmeralda* lawn (Fig. 3b) when we analyzed the mean height of the two lawns as a function of the different depths (S40, S30, S20, and S10). Soil layer explored by lawns roots, had no influence on the average height of lawns during the evaluation period (11 cuts).

Ju et al. (2012) studying the influence of different substrates, irrigation intervals and soil depths at plant height and leaf width of *Esmeralda* lawn, verified that at a depth of 15 cm there was no significant difference in leaf height and leaf width. At 25 cm depth, a significant difference in plant height was observed.

3.2. Dry matter yield

The DM of the *Santo Agostinho* lawn was superior to that of the *Esmeralda* lawn in almost all the cuts performed in the experimental period (Fig. 4). For *Santo Agostinho* lawn the DM values ranged from 0.1 to 0.28 kg m^{-2}. Meanwhile, for the *Esmeralda* lawn, the DM yield observed values ranged from 0.1 to 0.22 kg m^{-2}. Taking into account all cutting season, the *Santo Agostinho* lawn presented an autumn/winter DM yield 2.8 times lower than summer/spring DM yield. Meanwhile, the *Esmeralda* lawn presented a DM yield in the fall/winter 2.2 times smaller than the DM yield in summer/spring.

Backes et al. (2010) evaluated the production, accumulation, and exportation of nutrients in *Esmeralda* lawn fertilized with sewage sludge in Itapetininga/SP and verified that dry matter yield in January,

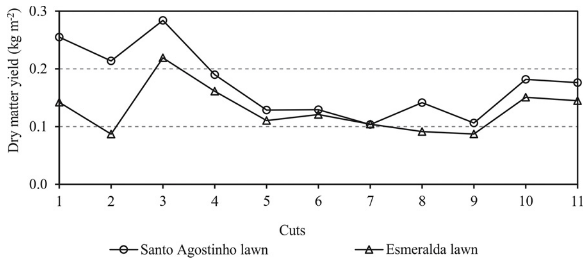

Fig. 4. Dry matter yield (kg m^{-2}) of the Santo Agostinho (o) and Esmeralda (Δ) lawns in the different cuts.

Table 2
Dry matter yield (kg m^{-2}) of the São Agostinho and Esmeralda lawns in the different cuts made, due to the different soil depths adopted.

Cuts	Santo Agostinho				Esmeralda			
	Soil depths				Soil depths			
	S40	S30	S20	S10	S40	S30	S20	S10
1	0.17	0.14	0.14	0.12	0.30	0.32	0.23	0.23
2	0.12	0.08	0.08	0.06	0.20	0.21	0.17	0.17
3	0.24	0.21	0.21	0.22	0.29	0.27	0.30	0.28
4	0.19	0.17	0.14	0.14	0.18	0.19	0.18	0.21
5	0.12	0.12	0.11	0.10	0.13	0.12	0.12	0.15
6	0.12	0.13	0.13	0.11	0.12	0.13	0.13	0.14
7	0.10	0.11	0.11	0.09	0.10	0.09	0.09	0.13
8	0.10	0.09	0.09	0.09	0.13	0.12	0.15	0.17
9	0.09	0.09	0.09	0.08	0.11	0.09	0.11	0.11
10	0.16	0.15	0.15	0.14	0.18	0.17	0.18	0.20
11	0.16	0.15	0.15	0.12	0.18	0.18	0.16	0.18

S40: soil depth 40 cm; S30: soil depth 30 cm; S20: soil depth 20 cm; S10: soil depth 10 cm; There was no significant difference between the means within the same species (Santo Agostinho and Esmeralda lawns) at a 5% probability level, by the Tukey test.

February, March and April 2006 was 0.18, 0.11, 0.07 and 0.05 kg m^{-2}, respectively, to the condition where the highest dose of sewage sludge (40 Mg ha^{-1}) was applied.

In the comparison of the average of DM yields as a function of the different soil depths, neither the *Santo Agostinho* lawn nor the *Esmeralda* lawn presented a statistically significant difference ($p > 0.05$) among soil depths in which they are cultivated (Table 2). In general, the highest average values of DM yield were found at a depth of soil of 40 cm, when compared to the means obtained in treatments S30, S20 and S10.

Vieira et al. (1999) studied the production and nutritive value of Bermuda lawn (*Cynodon dactylon* L.) at different growth ages (cuts at 20, 30, 40, 50, 60 and 70 days after initial cutting), in Itapetininga-SP, verified that shoot DM increased in a quadratic form, with a maximum value of 0.22 kg m^{-2} at 70 days.

Comparing the accumulated DM yield, in the period of 11 cuts, as a function of the different irrigation managements (Fig. 5), the M_3 block did not show superiority over other blocks. This result contrasts to the initial hypothesis of the work, which predicted a higher production in this block because it was precisely maintained at field capacity soil moisture condition during the whole period of the experiment.

According to Wherley (2011), in contrast to most crops, for lawns, any reductions in plant growth are considered beneficial, provided that the visual and functional qualities are not significantly sacrificed. A review study by Gómez-Armayones et al. (2018) stated that the lawn irrigated with better irrigation depths presents higher values of DM yield, and it is essential to highlight the positive correlation between lawn quality and DM yield daily.

The accumulated DM yield for the *Santo Agostinho* lawn (Fig. 5a) was higher at the 40 cm soil depth in all management, except M_1, in

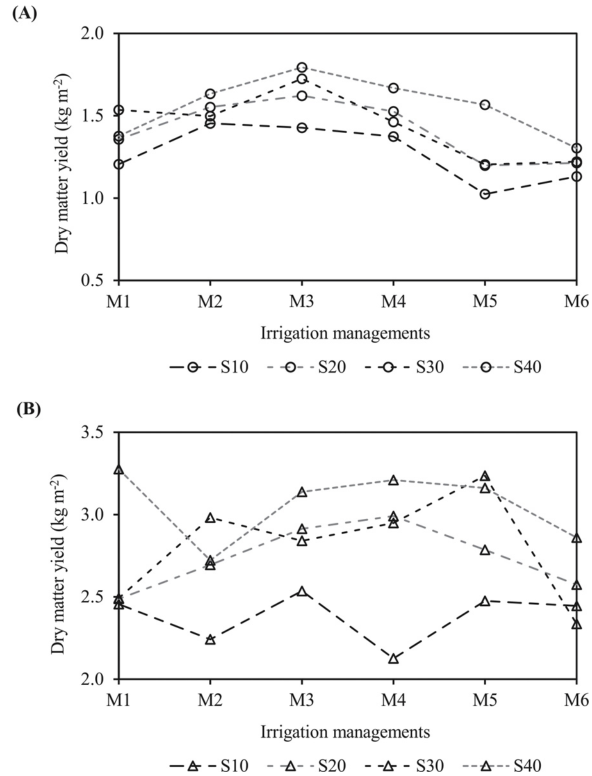

Fig. 5. Dry matter yield (kg m^{-2}) of the Santo Agostinho (A) and Esmeralda (B) lawns as a function of the different irrigation management, in the different soil depths, adopted.

which the S30 treatment presented the highest values DM yield cumulative. In general, all the management adopted (M_1, M_2, M_3, M_4, M_5, and M_6) had lower values DM yield cumulative in treatments S20 and S10. The mean of DM yield cumulative for the *Santo Agostinho* lawn in the different blocks was 1.56, 1.44, 1.41 and 1.27 kg m^{-2} for treatments S40, S30, S20, and S10, respectively.

For the *Esmeralda* lawn (Fig. 5b) the DM yield cumulative was lower at the 10 cm depth of soil in all management, except the M_6. The average DM yield cumulative for the *Esmeralda* lawn in the different blocks was 3.06, 2.81, 2.74 and 2.38 kg m^{-2} for treatments S40, S30, S20, and S10 respectively.

Backes et al. (2010) evaluated the DM yield cumulative of *Esmeralda* lawn fertilized with sewage sludge in the first four months of 2006, in Itapetininga/SP, and verified that the results were 0.41, 0.25 and 0.14 kg m^{-2} for the condition in which the sewage sludge doses of 40, 30 and 20 Mg ha^{-1}, respectively, were applied.

3.3. Leaf water potential

The mean values of LWP of the *Santo Agostinho* lawn were higher than the values found for the *Esmeralda* lawn in all cut periods evaluated (Fig. 6). The *Santo Agostinho* lawn had mean values of LWP ranging from −7.56 to −5.35 bar. Meanwhile, for the *Esmeralda* lawn, these average values were found to be between −9 and −6.87 bar.

A comparison of the LWP of the *Santo Agostinho* lawn at different soil depths (Fig. 7a) showed that all treatments (S40, S30, S20, and S10) presented LWP values interspersed within a range ranging from −8.23 at −4.94 bar.

Meanwhile, in the comparison of the LWP of the *Esmeralda* lawn in the different soil depths (Fig. 7b), it was verified that the soil depth of 40 cm resulted in higher values of LWP in most of the evaluation period, varying from −9.67 at −5.87 bar. The other treatments (S30, S20, and S10) showed LWP values intercalated and concentrated in the range of

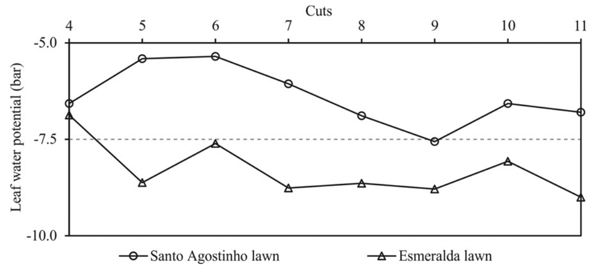

Fig. 6. Leaf water potential (bar) of Santo Agostinho (o) and Esmeralda (Δ) lawns in the different cuts performed.

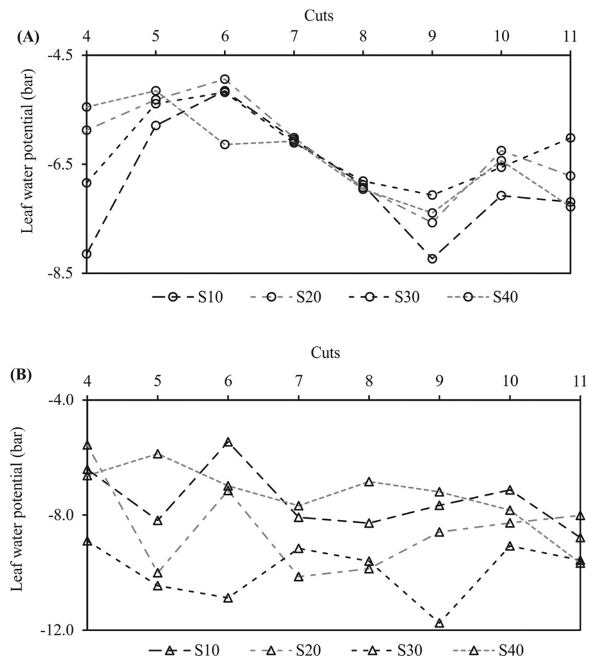

Fig. 7. Leaf water potential (bar) of the Santo Agostinho (A) and Esmeralda (B) lawns in the different soil depths adopted.

Table 3
Irrigation water use efficiency (kg DM m^{-3}) of the Santo Agostinho and Esmeralda lawns in the different cuts made, due to the different soil depths adopted.

Cuts	Santo Agostinho				Esmeralda			
	Soil depths				Soil depths			
	S40	S30	S20	S10	S40	S30	S20	S10
1	1.60	1.99	1.60	1.31	1.73	4.36	1.50	1.28
2	0.54	0.50	0.63	0.69	0.69	1.47	1.14	3.38
3	3.45	3.78	3.21	3.01	3.35	4.89	3.28	3.96
4	1.88	2.21	1.44	1.37	0.77	1.15	1.43	1.30
5	1.56	1.32	1.63	1.29	2.11	2.93	2.12	1.45
6	2.41	3.02	3.27	1.96	3.36	2.86	3.04	1.97
7	2.17	1.98	1.79	1.95	1.46	1.81	1.89	2.47
8	1.27	1.87	1.56	1.56	1.99	2.19	7.26	8.59
9	0.76	2.78	2.04	1.12	3.24	2	1.64	2.27
10	1.37	0.96	1.97	1.87	2.26	2.13	2.72	2.03
11	1.93	0.73	0.87	0.41	1.94	1.06	0.93	0.46
Average	2.76	1.92	1.82	1.50	2.08	2.44	2.45	2.65

S40: soil depth 40 cm; S30: soil depth 30 cm; S20: soil depth 20 cm; S10: soil depth of 10 cm.

−11,75 to −5,45 bar.

Mwendia et al. (2017) studying LWP for grasses in tropical environments (East Africa), Muguga and Katumani regions, observed values ranging from −14 to −4 bar and observed also that most of the differences between LWP occurred in the morning when the weather was mild.

3.4. Irrigation water use efficiency

The *Esmeralda* lawn presented an average IWUE higher than the *Santo Agostinho* lawn (Table 3). At soil depths of 40, 30, 20 and 10 cm, the *Esmeralda* lawn presented IWUE averages of 2.08, 2.44, 2.45 and 2.65 kg DM m^{-3}, respectively. Meanwhile, *Santo Agostinho* lawn presented IWUE averages of 2.76, 1.92, 1.82 and 1.50 kg DM m^{-3}, respectively.

Cathey et al. (2011) observed by studying the tolerance of three lawns of warm season, among them the *Santo Agostinho* and *Esmeralda* lawns, the increase and the prolonged deficit of soil water under greenhouse conditions at the University of Florida, that the *Esmeralda* lawn had the lower rate of water use and less burning under dry stress than the other lawns tested, indicating their potential for better IWUE.

4. Conclusions

The irrigation management of laws based on a fixed reference plot does not compromise the growth and establishment of the *Santo Agostinho* and *Esmeralda* lawns. The irrigation management of lawns based on the monitoring of the matric potential at the area reference plot was sufficient to maintain optimal dry matter (DM) levels in all others irrigated plots with variable leaf area, contrary to the initial hypothesis of the work, even for very restricted root depths (10 and 20 cm).

The lawns heights studied were influenced by cutting season, presenting, in periods of unfavorable low temperature (winter), lower values of height. The different depths of cultivation (S40, S30, S20, and S10), representing the soil layer explored by the roots, had no influence on the average height of the lawns during the evaluation period (11 cuts).

The mean values of leaf water potential (LWP) of the *Santo Agostinho* lawn were higher than the values found for the *Esmeralda* lawn in all the cut periods evaluated, however, the irrigation water use efficiency (IWUE), in the general average, was higher in the *Esmeralda* lawn.

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