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Soil aeration and liming in Esmeralda zoysiagrass sports turf

Patrick Luan Ferreira dos Santos[1], Mateus Vinícios Leal do Nascimento[2], João Victor Costa[3], Maria Clara Lelles Moreira Begueline[4], Roberto Lyra Villas Bôas[5], Leandro José Grava de Godoy[6]

[1] Universidade Estadual Paulista (UNESP), Faculdade de Ciências Agronômicas, Departamento de Ciência Florestal, Solos e Ambiente, Botucatu-SP, Brazil. Email: patricklfsantos@gmail.com

[2] Universidade Estadual Paulista (UNESP), Faculdade de Ciências Agronômicas, Departamento de Ciência Florestal, Solos e Ambiente, Botucatu-SP, Brazil. Email: matheus.vln@hotmail.com

[3] Universidade Estadual Paulista (UNESP), Faculdade de Ciências Agronômicas, Departamento de Ciência Florestal, Solos e Ambiente, Botucatu-SP, Brazil. Email: jv.costa@unesp.br

[4] Universidade Estadual Paulista (UNESP), Faculdade de Ciências Agronômicas, Departamento de Ciência Florestal, Solos e Ambiente, Botucatu-SP, Brazil. Email: maria.begueline@unesp.br

[5] Universidade Estadual Paulista (UNESP), Faculdade de Ciências Agronômicas, Departamento de Ciência Florestal, Solos e Ambiente, Botucatu-SP, Brazil. Email: roberto.lyra@unesp.br

[6] Universidade Estadual Paulista (UNESP), Faculdade de Ciências Agrárias do Vale do Ribeira, Registro-SP, Brazil. Email: leandro.godoy@unesp.br

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Abstract

Esmeralda zoysiagrass is the most widely marketed among turfgrass species; however, the soil's chemical and physical factors can interfere with its development. Thus, it is essential to seek alternatives to mitigate these effects, and the combined use of liming and soil aeration may be an option. This study aimed to evaluate the impact of soil aeration combined with liming on Esmeralda grass. The experiment was conducted from November 14, 2018, to May 30, 2019, in a 363 m^2 experimental area divided into 30 plots. A randomized block design was used, consisting of five treatments with six replications: T1 – without liming and without aeration; T2 – without liming and with aeration; T3 – with liming and without aeration; T4 – with liming and aeration after liming; and T5 – with liming and aeration before liming. The following parameters were evaluated: soil plant analysis development meter (SPAD); height; dry mass of clippings; root length; dry mass of roots + rhizomes + stolons; and traction resistance. The best results were obtained from treatments combining liming with solid tine aeration (T4 and T5), demonstrating that this practice can be an excellent management strategy for the development of Esmeralda grass in sports fields.

Keywords: *Zoysia japonica*. Decompaction. Acidity correction. Turf management.

Introduction

Grasses belong to the Poaceae family, which includes various species; however, only about 50 of them can be used for the establishment of turfgrass for commercial, ornamental, or sports purposes (Godoy *et al*., 2012). In this context, one species that stands out in Brazil is Esmeralda zoysiagrass (*Zoysia japonica*) (Santos *et al.*, 2020), the most widely sold sod in the country (Santos, Carribeiro, 2022). It is a rhizomatous-stoloniferous species with medium-textured leaves and an Esmeralda-green color, suitable for both residential areas and sports fields (Castilho *et al.*, 2020; Villas Bôas *et al.*, 2020).

However, because of its adaptability to various conditions, Esmeralda grass is often established in inadequate soils without proper preparation, impairing root development due to high compaction. This limits nutrient absorption, impacting shoot growth (Santos *et al.*, 2016). When this occurs in sports fields, the turf becomes less resistant, hindering athletic performance and increasing the risk of injuries (Chang *et al.*, 2017; Straw *et al*., 2018; Santos *et al*., 2022).

Thus, one alternative to mitigate this issue is the use of soil decompaction equipment (Malleshaiah *et al*., 2018; Santos *et al*., 2020), such as aeration systems with solid or hollow tines. These improve soil aeration, enhance root development, and increase water infiltration and nutrient absorption (Santos *et al*., 2020).

In addition to improving the soil's physical properties, its chemical attributes should also be considered to ensure maximum turf growth. Thus, a practice that can be combined with tine aeration is liming, which corrects soil pH by reducing acidity and eliminating toxic aluminum, while increasing cation exchange capacity (CEC), base saturation, and providing calcium and magnesium (Godoy *et al*., 2012).

Combining these two practices can yield significant benefits, as some existing lime incorporation techniques in turf have proven effective. For example, hoes can be used at approximately 5 cm depth, allowing rainfall to help the corrective material reach about 10 cm into the soil profile. Another technique involves scarifiers (particularly the star type) which help decompact the soil and improve lime incorporation efficiency (Godoy *et al*., 2012). Therefore, the combination of liming and aeration may enhance turfgrass development, improving its performance for ornamental and sports purposes.

Thus, this study aimed to evaluate the effect of liming applied with or without soil aeration on an established Esmeralda turf area.

Material and methods

Characterization of the experimental area

The experiment was conducted at the School of Agronomic Sciences (FCA) of São Paulo State University (UNESP), in Botucatu, São Paulo State, Brazil, located at 22°53'09" S, 48°26'42" W, and an elevation of 817 m. The study began on November 14, 2018, and continued until May 30, 2019, in an Esmeralda turf area of approximately 363 m^2 (30.50 m long × 11.90 m wide).

According to the Köppen climate classification, the region shows a Cwa climate—dry winters and hot, rainy summers. The annual mean maximum, minimum, and average temperatures are 26.1, 15.3, and 20.3 °C, respectively. The mean annual precipitation is 1,428.4 mm, with rainfall concentrated in December, January, and February (Cunha, Martins, 2009). The mean annual relative humidity is 75 %, although it may drop below 15 %. The climatic data recorded during the experiment are presented in Figure 1.

The soil in the area is classified as a dystrophic Red Latosol (LVd) with medium texture (Table 1). Before the experiment, a chemical analysis of the soil was performed (Table 2).

The 363 m^2 area was divided into 30 plots measuring 4.91 m × 2.18 m (Figure 2), with a useful area of 4.07 m × 1.30 m. A randomized block design was used, consisting of five treatments with six replications:

T1 – without liming (V = 63 % base saturation) and without aeration;

T2 – without liming (V = 63 % base saturation) and with aeration;

T3 – with liming (increasing V to 70 %) and without aeration;

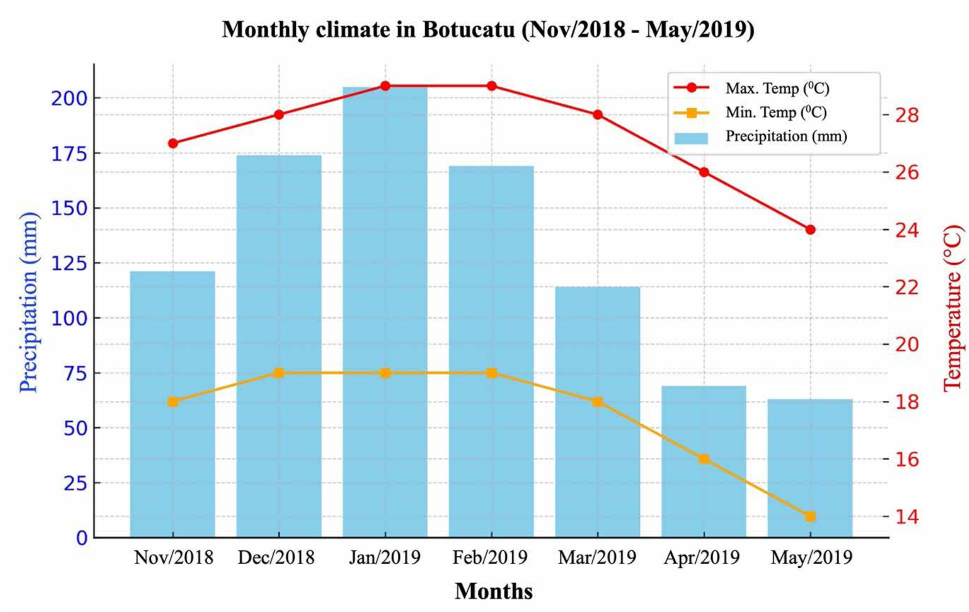
T4 – with liming (increasing V to 70 %) and aeration after liming;

T5 – with liming (increasing V to 70 %) and aeration before liming.

Liming

Dolomitic limestone was used, with characteristics determined according to laboratory analysis (Table 3). Based on the results of the chemical analysis (Table 2), the goal was to raise the soil's base saturation (V%) from 63 to 70, following the recommendations of Mateus *et al.* (2010). Thus, 383 g of limestone were applied per plot. The application was performed manually on November 14, 2018, to ensure uniform distribution and minimize drift.

Figure 1. Climatic data for Botucatu during the experiment.



Source: authors (2019).

Table 1. Soil particle-size analysis at depths of 0–20 and 20–40 cm. Botucatu, SP, 2018.

Depth (cm)	Sand			Clay	Silt	Texture
	Coarse	Fine	Total			
	g kg^{-1}					
0-20	348	441	789	164	47	Medium
20-40	361	447	808	158	34	Medium

Source: authors (2018).

Table 2. Soil chemical analysis in the experimental area at 20 cm depth. Botucatu, SP, 2018.

pH	Organic matter	P_{resin}	Al^{3+}	H+Al	K	Ca	Mg	SB	Cation exchange capacity	V%
$CaCl_2$	g/dm³	mg/dm³	$mmol_c/dm^3$							
5.5	26	11	0	17	2.5	17	10	29	46	63

Source: authors (2018).

Table 3. Laboratory analysis of the limestone. Botucatu, SP, 2018.

% Passing			Result (%)					
Mesh10	Mesh20	Mesh50	CaO	MgO	RE	NP	RNP	Moisture
99.8	98.4	60.3	39.4	11.8	83.4	86	72	0.1

Mesh10, Mesh20, and Mesh50: % of material passing through mesh sizes no. 10 (2 mm), no. 20 (0.84 mm), and no. 50 (0.3 mm), respectively. CaO and MgO: % of calcium and magnesium oxides, respectively. RE: Reactivity – percentage of the product that reacts over a specific period, depending on particle size. NP: Neutralization Power – the material's capacity to neutralize soil acidity. RNP: Relative Neutralization Power, derived from NP and RE, representing the actual efficiency of the liming material.

Source: authors (2018).

Figure 2. Experimental area of Esmeralda zoysiagrass.

Source: authors (2018).

Soil aeration (decompaction)

Soil aeration was performed using a Verti-Drain® (Figure 3) equipped with 24 solid tines, each 15 cm long and 1 cm in diameter. The operation was performed at third gear, low speed, producing approximately 408 holes per m^2. The primary goal was to decompact the soil. The procedure was conducted on November 14, 2018.

Turf management

Irrigation was applied by sprinklers, replacing the evapotranspired water from the previous day via a system using six sprinklers: four with a 90° angle (located at the corners) and two with a 180° angle (at the midpoints of the sides). Fertilization was performed every 90 days with 45 g m^{-2} of the 20-05-20 formulation. Weed control was performed manually as needed.

Figure 3. Soil aeration using Verti-Drain® in the Esmeralda turf experimental area.

Source: authors (2018).

All treatments received identical maintenance to prevent management interference with results. Regardless of season (spring, summer, or autumn), all treatments received the same amounts of water, light, and temperature exposure, preventing abiotic variation.

Mowing was performed as needed. At installation, turf was cut to 12 mm to standardize plots; subsequently, it was maintained at 20 mm. Mowing dates (DAI – Days After Installation) were: December 7, 2018 (23 DAI); December 13, 2018 (29 DAI); December 22, 2018 (38 DAI); January 17, 2019 (64 DAI); February 5, 2019 (83 DAI); February 14, 2019 (92 DAI); February 23, 2019 (100 DAI); March 6, 2019 (111 DAI); March 21, 2019 (126 DAI); March 28, 2019 (133 DAI); April 12, 2019 (148 DAI); and April 25, 2019 (161 DAI).

Assessments

Green color index

In total, three instruments were used to measure this parameter: a portable chlorophyll meter (SPAD-502) and two light reflectance meters, Field Scout CM-1000 and Field Scout TCM 500 Turf Color Meter.

Measurements were taken on January 24, 2019 (71 DAI); February 21, 2019 (99 DAI); and March 22, 2019 (150 DAI), with five readings per plot.

Visual analysis via digital imaging

Photographs were taken using a 13 MP professional camera mounted inside a light box, following the design described by Peterson et al. (2011). The light box is a sealed structure equipped with lamps connected to a battery to ensure uniform lighting and standardized imaging across treatments. Images were transferred to a computer and displayed side by side for comparison. This assessment was conducted on January 25, 2019 (72 DAI).

Turf height

Height was measured using a Grass Height Prism Gauge (Figure 4). Measurements were taken before each mowing event, on the same dates listed in the mowing schedule.

Figure 4. Measurement of Esmeralda zoysiagrass height using a Grass Height Prism Gauge.

Source: authors (2018).

Dry mass of clippings

Mowing was performed with a Toro® GreenMaster 1000 mower, maintaining the turf at 20 mm height. The machine includes a clippings collector for sampling. Collected clippings were dried at 65°C for 72 hours to determine dry mass.

Measurements were taken on: February 5, 2019 (83 DAI); February 14, 2019 (92 DAI); February 23, 2019 (100 DAI); March 6, 2019 (111 DAI); March 21, 2019 (126 DAI); March 28, 2019 (133 DAI); April 12, 2019 (148 DAI); and April 25, 2019 (161 DAI).

Root length and dry mass of roots + rhizomes + stolons

Soil cores ("plugs") 6.8 cm in diameter and 20 cm deep were collected from each plot using a sampling auger. They were washed to remove adhering soil. Root length was measured using a graduated ruler. Samples were then placed in paper bags and oven-dried at 65°C for 72 hours to determine dry phytomass.

Root mass measurements were taken on: January 31, 2019 (85 DAI); February 27, 2019 (120 DAI); March 18, 2019 (146 DAI); and April 28, 2019 (187 DAI). Root length measurements were taken on January 31, 2019 (85 DAI); February 27, 2019 (120 DAI); and March 18, 2019 (146 DAI).

Turf traction resistance

Turf traction was measured with a Rotational Resistance Tester – Deltec Metaal® (Figure 5), which simulates the torque (Nm) produced by a player's cleats. Analyses were conducted at three points within each plot.

The first test was conducted on September 13, 2018 (before the experiment). After installation, five more tests were conducted on: December 7, 2018 (30 DAI); January 26, 2019 (80 DAI); February 25, 2019 (118 DAI); March 18, 2019 (146 DAI); and April 23, 2019 (182 DAI).

Figure 5. Turf traction resistance testing with the Rotational Resistance Tester – Deltec Metaal®.

Source: authors (2018).

Statistical analysis

Data were analyzed using analysis of variance (ANOVA) followed by Tukey's test at the 5 % probability level for mean comparison. The analyses were performed using Statistix 10 software.

Results and discussion

At 71 days after installation (DAI), the SPAD green color index was significantly higher in treatment T5, with no differences compared to T4 and T3. The lowest value was observed in the control (T1), which received no soil management. Both T4 and T5 received liming combined with soil aeration, indicating that the sequence of operations did not affect the efficiency of the process (Table 4). This result reinforces that soil acidity correction, combined with decompaction, directly contributes to greater turf greenness.

According to Prates *et al*. (2020), the SPAD index reflects leaf chlorophyll and nitrogen content, which explains the better performance of T4 and T5. These results are similar to those reported by Mota et al. (2019) in a study using sewage sludge on Esmeralda zoysiagrass and fall within the range reported by Oliveira *et al*. (2018). At 99 and 150 DAI; however, there were no statistical differences between treatments, possibly due to the maintenance fertilization conducted during this period.

Reflectance measurements (Table 5) showed greater sensitivity compared with SPAD, with significant differences at all evaluation times. The highest green color indices were observed in T4 and T5, while T1 and T2 had the lowest values. This effect is associated with the increase in soil pH promoted by liming (T3, T4, and T5), which enhances nutrient availability and uptake, especially N and Mg (Godoy *et al*., 2012). Similar results were reported by Mateus et al. (2010) and Santos and Castilho (2016) in experiments with Esmeralda zoysiagrass.

An important point to note is that the green color index (GCI) obtained by leaf reflectance showed greater sensitivity than the SPAD readings, since differences among treatments were observed in all evaluations.

Aeration in T4 and T5 also contributed to more efficient water and nutrient absorption, as compaction limits soil diffusion. Thus, the combination of liming and aeration was essential for optimizing turf development and color. As observed by Santos et al. (2022), greener turf tends to have higher chlorophyll content, resulting in greater photosynthetic efficiency. This effect was visually noticeable and confirmed by digital imaging (Figure 6), suggesting a correlation between visual appearance and turf nutrition, as also reported by Silva et al. (2020) and Silverio et al. (2020).

Considering that green color index (GCI) values were higher in T4 and T5, these treatments also showed greater turf development, reflected in increased plant height (Table 6) and dry clipping mass (Table 7). The supply of Ca and Mg through liming, combined with improved soil physical conditions, likely promoted greater leaf elongation (Godoy *et al*., 2012). However, although greater height is associated with larger photosynthetic area, this growth and higher dry mass production imply more frequent mowing and, consequently, increased maintenance costs, a particularly relevant issue in athletic fields (Santos *et al*., 2022; Mateus *et al*., 2017). The height values found in this study were lower than those reported by Dinalli *et al.* (2015), who recorded averages between 53 and 61 mm (height) and 67.8 to 81.4 g m^{-2} (dry mass); however, they were closer to those of Gazola *et al.* (2019), who observed heights ranging from 31 to 55 mm.

Table 4. SPAD green color index. Botucatu, SP, 2019.

Treatment	71		99	150
	SPAD			
T1	21.98	c	26.47	23.00
T2	25.40	b	26.77	24.70
T3	27.07	ab	25.30	24.50
T4	28.70	a	30.22	26.48
T5	28.31	a	28.78	26.02
Least significant difference	2.57		5.77	4.37
F_{test}	20.27**		2.08^{ns}	1.77^{ns}
CV (%)	5.65		12.14	10.15

Means followed by the same letter in the column do not differ by Tukey's test at 5 %. ** – significant at 1 %. T1 – Control; T2 – No liming + aeration; T3 – Liming only; T4 – Liming + aeration after liming; T5 – Liming + aeration before liming.

Source: authors (2019).

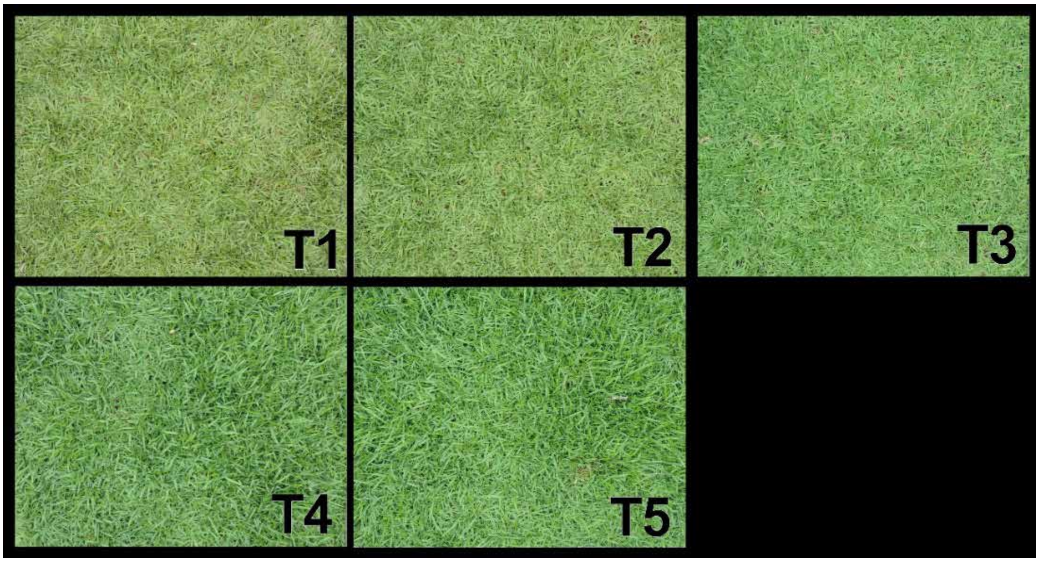
Table 5. Green color index of Esmeralda zoysiagrass measured with the FieldScout Chlorophyll Meter CM 1000 and FieldScout Turf Color Meter TCM 500 according to soil aeration and liming. Botucatu, SP, 2019.

Treatment	71	99	150
	Days after installation (DAI)		
	Scout CM 1000		
T1	365 c	367 c	376 c
T2	435 bc	440 c	441 bc
T3	484 ab	468 bc	473 ab
T4	559 a	554 ab	543 a
T5	582 a	586 a	566 a
Least significant difference	110	103	96
CV (%)	13.13	12.42	11.59
F	11.72**	13.03**	11.47**
Treatment	Scout TCM 500		
T1	7.09 c	7.28 b	6.58 b
T2	7.58 bc	7.33 b	6.78 ab
T3	8.05 ab	7.75 ab	7.25 ab
T4	8.50 ab	8.45 a	7.57 a
T5	8.55 a	8.20 ab	7.48 a
Least significant difference	0.92	0.96	0.9
CV (%)	6.73	7.16	9.26
F	8.12**	5.14**	2.58^{ns}

Means followed by the same letter in the column do not differ by Tukey's test at 5 %. ** – significant at 1 %. T1 – Control; T2 – No liming + aeration; T3 – Liming only; T4 – Liming + aeration after liming; T5 – Liming + aeration before liming.

Source: authors (2019).

Figure 6. Visual aspect of Esmeralda zoysiagrass 72 days after installation. T1 – Control; T2 – No liming + aeration; T3 – Liming only; T4 – Liming + aeration after liming; T5 – Liming + aeration before liming.



Source: authors (2019).

Table 6. Leaf height of Esmeralda zoysiagrass according to soil aeration and liming. Botucatu, SP, 2019.

Treatment	23	29	38	64	83	92
	Days after installation (DAI)					
	mm					
T1	16.5 c	23.5 b	35.7	29.8 c	32.7 c	34.7 c
T2	18.7 c	24.0 b	36.3	33.8 b	33.0 c	36.2 bc
T3	21.0 b	25.0 b	36.8	34.2 b	34.2 bc	36.7 bc
T4	25.5 a	29.8 a	37.8	38.0 a	38.8 ab	39.3 ab
T5	24.7 a	30.5 a	39.3	38.8 a	40.2 a	40.8 a
Least significant difference	2.2	3.3	3.8	3.4	5.1	3.2
CV (%)	6.1	7.1	5.9	5.6	8.3	5.0
F	52.40**	18.88**	2.57ns	20.30**	8.37**	10.67**
Treatment	100	111	126	133	148	161
	Days after installation (DAI)					
	mm					
T1	32.0 b	37.7 a	36.7 b	35.8 c	37.7 d	35.3 c
T2	33.2 b	36.5 a	37.7 b	35.0 c	38.8 cd	36.8 c
T3	32.7 b	39.3 a	37.5 b	37.7 b	40.5 bc	37.3 bc
T4	38.7 a	39.7 a	40.3 a	39.2 a	42.3 ab	39.2 ab
T5	39.7 a	40.0 a	40.3 a	40.0 a	43.2 a	41.3 a
Least significant difference	5.1	4.0	2.4	1.4	2.1	2.2
CV (%)	8.42	6.06	3.55	2.16	3.02	3.33
F	9.00**	2.44ns	9.46**	41.29**	21.33**	20.01**

Means followed by the same letter in the column do not differ by Tukey's test at 5 %. ** – significant at 1 %. T1 – Control; T2 – No liming + aeration; T3 – Liming only; T4 – Liming + aeration after liming; T5 – Liming + aeration before liming.

Source: authors (2019).

Table 7. Dry mass of clippings of Esmeralda zoysiagrass according to soil aeration and liming. Botucatu, SP, 2019.

Treatment	83	92	100	111	126	133	148	161
	Days after installation (DAI)							
	$g\ m^{-2}$							
T1	11.71 d	21.90 c	22.17 c	25.20 bc	27.71 b	23.88 b	16.93 c	14.71 c
T2	18.41 c	23.90 c	24.39 c	23.90 c	27.38 b	17.77 c	18.21 bc	17.91 c
T3	22.78 b	29.13 b	30.67 b	28.56 b	27.70 b	24.33 b	20.06 b	22.84 b
T4	30.16 a	37.06 a	33.96 ab	37.63 a	52.03 a	36.17 a	24.58 a	28.46 a
T5	29.18 a	36.14 a	34.67 a	34.60 a	51.45 a	34.66 a	24.43 a	28.88 a
Least significant difference	3.46	4.00	3.62	3.55	4.81	3.70	2.69	3.53
CV (%)	8.92	7.81	7.19	6.85	7.47	7.84	7.47	9.07
F	88.48**	53.31**	43.43**	50.30**	135.56**	79.69**	30.77**	56.69**

Means followed by the same letter in the column do not differ by Tukey's test at 5 %. ** – significant at 1 %. T1 – Control; T2 – No liming + aeration; T3 – Liming only; T4 – Liming + aeration after liming; T5 – Liming + aeration before liming.

Source: authors (2019).

For the root system length data (Table 8), differences were observed only from 120 DAI onward. Treatments T3, T4, and T5, which underwent liming, showed greater root length compared with the control. The lack of soil decompaction in T1 likely restricted root expansion, reducing water and nutrient uptake, as previously reported by Backes *et al.* (2017). The absence of liming in T2 also hindered root growth, possibly due to the acidic pH (5.5), which is below the ideal range of 6.5 to 7.5 for Esmeralda zoysiagrass reported by Santos et al. (2016).

The dry mass of roots, rhizomes, and stolons (Table 9) reinforces the same pattern as root length, with the highest values observed for T3, T4, and T5 from 120 DAI onward, possibly due to the positive effect of liming (Godoy *et al.*, 2012). Thus, these treatments presented more robust root systems, suggesting that they may be more resistant to traffic and stress, as reported by Zhang *et al.* (2018) and Santos et al. (2022).

Turf traction resistance (Table 10) varied over time. At 30 DAI, results for T1, T2, and T3 were higher and did not differ significantly. However, from 80 DAI onward, treatments with liming (T3, T4, and T5) showed greater resistance, particularly T4 and T5 at 118 and 146 DAI, which underwent both processes. This trend indicates that root and vegetative development determines turf resistance, likely due to greater mechanical anchorage of rhizomes and stolons in managed soil. The values obtained were within the range recommended by FIFA (2016), ranging from 25 to 50 Nm, with 35 to 45 Nm considered ideal.

In soccer fields, the main goal of turf maintenance is to ensure good playing conditions, reduce player impact on the soil, and offer spectators the best possible visual appearance (Chang *et al.*, 2017; Santos et al., 2022). Therefore, it can be inferred that treatments T4 and T5 showed better conditions compared with the others. According to Straw *et al.* (2018), turf compaction in soccer fields increases the occurrence of knee and ankle injuries. Moreover, full turf coverage and surface leveling are essential for quality play, ensuring a uniform pitch and allowing a higher success rate in passes and progressions toward the goal (Santos *et al*., 2020).

Table 8. Root length of Esmeralda zoysiagrass according to soil aeration and liming. Botucatu, SP, 2019.

Treatment	85	120	146
	Days after installation (DAI)		
	cm		
T1	20.0	19.4 b	18.8 b
T2	20.3	18.9 b	19.2 b
T3	21.0	20.1 ab	21.8 a
T4	21.7	21.5 a	23.2 a
T5	21.2	21.5 a	22.5 a
Least significant difference	1.8	2.0	2.1
CV (%)	5.05	5.73	5.8
F	2.41^{ns}	6.42**	15.82**

Means followed by the same letter in the column do not differ by Tukey's test at 5 %. ** – significant at 1 %. T1 – Control; T2 – No liming + aeration; T3 – Liming only; T4 – Liming + aeration after liming; T5 – Liming + aeration before liming.

Source: authors (2019).

Table 9. Dry mass of roots, rhizomes, and stolons of Esmeralda zoysiagrass according to soil aeration and liming. Botucatu, SP, 2019.

Treatment	85	120	146	187
	Days after installation (DAI)			
	g			
T1	12.20	18.95 b	19.83 b	19.08 c
T2	11.59	19.12 b	20.95 b	20.95 bc
T3	12.12	22.35 a	23.44 ab	23.31 ab
T4	12.49	22.78 a	25.88 a	24.83 a
T5	11.27	21.65 a	22.85 ab	26.21 a
Least significant difference	5.86	2.45	3.68	3.57
CV (%)	28.42	6.76	9.44	9.03
F	0.13^{ns}	9.83**	7.24**	11.65**

Means followed by the same letter in the column do not differ by Tukey's test at 5 %. ** – significant at 1 %. T1 – Control; T2 – No liming + aeration; T3 – Liming only; T4 – Liming + aeration after liming; T5 – Liming + aeration before liming.

Source: authors (2019).

Thus, the combination of these two practices (decompaction and liming) may provide significant advantages, as existing techniques for lime incorporation into turf have proven efficient (Godoy *et al*., 2012), making the turf more resistant and ensuring better playability during matches. Thus, turf traction resistance can be used as a measure of playability

Table 10. Turf traction (torque) of Esmeralda zoysiagrass according to soil aeration and liming. Botucatu, SP, 2019.

Treatment	0	30	80	118	146	182
	Nm					
T1	40	46 a	37 c	39 d	38 c	40 b
T2	41	43 ab	37 c	41 c	40 bc	42 ab
T3	43	45 ab	39 b	44 b	40 bc	42 ab
T4	42	42 b	41 a	46 a	43 a	43 ab
T5	43	42 b	40 ab	46 a	45 a	44 ab
Least significant difference	5	4	2	2	3	3
CV (%)	6.57	5.73	3.04	2.79	4	3.56
F	1.37^{ns}	3.76*	11.38**	39.72**	14.00**	5.16**

Means followed by the same letter in the column do not differ by Tukey's test at 5 %. ** – significant at 1 %. T1 – Control; T2 – No liming + aeration; T3 – Liming only; T4 – Liming + aeration after liming; T5 – Liming + aeration before liming.

Source: authors (2019).

Conclusion

The best results were obtained from treatments combining liming with solid tine aeration (T4 and T5), demonstrating that this practice can be an excellent management strategy for the development of Esmeralda grass in sports fields.

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