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Influence of aerification technique on recuperative potential of warm season turfgrasses

SHARATH KUMAR MALLESHAIAH[1], JAWAHARLAL MURUGAIAH[2], VIVEK GOVINDASWAMY[3], GANGA M[4] and SURAKSHITHA N C[5]

Singapore Botanic Gardens, National Parks Board, 1 Cluny Road, Singapore

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ABSTRACT

Soil compaction is the foremost adverse effect of traffic stress that interferes with turf shoot and root growth, and sequentially reduce the performance and quality of turf. Most of turfgrass soil cultivation research was emphasized on water infiltration and thatch responses to different cultivation methods. Lesser emphasis towards details of soil, recuperative potential and rooting responses of turfgrasses led to lesser success in eradicating compaction stress in turfgrass systems. This study evaluated effects of aerification on soil physical properties, growth and recuperative potential of warm season turfgrasses; *Axonopus compressus, Zoysia matrella* and *Paspalum vaginatum*. Aerification by means of hollow tine, solid tine and water injection has found to relieve the turf soil compaction and help turfgrasses to recover from the traffic stress by regaining their growth under improved soil condition. WI evolved as best aerification technique for quick relief from soil compaction, while hollow tine aerification is a long-term relief technique to improve turf quality and turf cover by reducing the thatch and bulk density. *Paspalum vaginatum* exhibited good recuperative potential compared to *Axonopus compressus* and *Zoysia matrella* to recover from the traffic stress. Further, study unravels the importance of aerification techniques in turfgrass systems to rectify soil compaction to achieve a healthy and quality turf.

Key words: Hollow tine aerification, Recuperative potential, Solid tineaerification, Warm season turfgrasses, Water injection

Globally recreational, sports and athletic fields are growing tremendously due to increase in number of participants and popularity of sports (soccer, lacrosse, cricket, golf, and rugby). Greater emphasis is being placed on the quality of the turf surface, and the quality of an turfgrass system is determined by many factors, including field safety for the athletes, playability (correct ball bounce and roll), and appearance. To meet these diverse requirements, a playing surface must have secure footing, high shoot density and uniformity, be firm but not hard, and should have a dark green colour (Miller 2003). But in reality turfgrass systems were exposed to many kinds of stresses which deteriorate their quality. Traffic stress is one of the stresses which affect the turfgrasses anatomically and morphologically by reducing their growth and development mainly due to soil compaction (Sharath *et al*. 2017). Soil compaction is one of the major contributor for poor aeration in turfgrass systems caused by vehicular and foot traffic.Research has shown that soil compaction reduces water, heat, and gas exchange (Grable and Siemer 1968, Linn and Doran 1984, Warkentin 1971, Willis and Raney 1971), root penetration (Taylor *et al.* 1966), and as a result crop production reduces (Hakansson *et al*. 1988). Research on soil compaction in turf fields is very limited albeit it is a common and serious problem. Soil bulk density values greater than 1.5 g/cm^3 are generally indicative of compacted soil, to a point where turfgrass root growth is seriously impaired (Taylor and Gardner 1963). Increases in bulk density were associated with an increase in field surface hardness (Rogers *et al.* 1996).

Most of the research related to reducing soil compaction has been conducted in conventional tillage row crops. This type of tillage causes severe surface disruption as soil is turned over and fractured.Cultivation in the turfgrass arena is completely different than most cultivation employed in cropping systems.Turfgrass systems are well manicured landscapes, regardless of cultivation method turfgrass managers goal is to achieve thatch removal or modification and to relieve compaction with the least possible surface disruption. To relieve compaction and to achieve good quality turf systems, different aerification or cultivation methods are employed. Aerification is a method of turf cultivation in which holes are created in the compacted turf ground to a defined depth. It is one of a few ways to cultivate

[1](e mail: sharathhort@gmail.com), Singapore Botanic Gardens, [3](e mail: vivegam2005@gmail.com), Centre for Urban Greenery and Ecology, National Parks Board, Singapore. [2](e mail: jawaharflori@yahoo.in), [4](e mail: gangasivakumar@yahoo.com), [5](e mail: surakshithahort@gmail.com), Horticulture College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.

perennial turfgrass soil with minimal surface disruption without destroying the playing surface or killing the turf. Aerification is principally used to reduce soil compaction and to improve drainage (Christians 2007). It also helps in reducing thatch accumulation, ultimately improving the soil microbial activity, drainage, gas exchange, water penetration and also healthy and deeper rooting in highly compacted soils (McCarty 2005).Aerification works in two ways to reduce thatch. Primarily, aerification reduces thatch by physically removing pieces of thatch. Secondly, it opens up the thatch layer providing a better environment for microorganisms to decompose organic matter (Brauen *et al.* 1998). Different aerification methods are available to turfgrass managers include coring (hollow tine, solid tine), slicing and water injection. However, these aerification methods are not necessarily equal in their efficiency to accomplish important cultivation objectives such as alleviation of soil compaction, thatch removal.

Hollow tine aerification (HTA) is accomplished by driving a hollow tine into the soil and pulling it out, leaving an open cylinder in the turf and a soil plug resting on top of the grass surface. Research on HTA has shown mixed results when tested for its influence on soil and turf properties. Some studies have concluded HTA increases water infiltration, while others have reported it decreases infiltration (McCarty *et al.* 2007, Roberts 1975, Waddington *et al.* 1974). Reports from Murphy *et al*. (1993) demonstrated that HTA reduces soil bulk density, In contrary, HTA resulted in increased bulk density below the zone of aerification (Brauen *et al*. 1998). HTA research studies have shown improvement in plant rooting, while others studies have reported it either does not change root mass, or even decreases root mass (Murphy *et al*. 1993, Smith 1979) and further benefit of HTA is the reduction and or control of thatch.

Solid tine aerification (STA) creates a hole and does not remove a core which makes it less disruptive and it is often used for this reason (Murphy *et al.* 1993). A study which looked at solid tine compaction on a bentgrass putting green found that solid tine aerification reduced soil strength by 45 per cent but the benefits were short lived (Murphy *et al*. 1993). There is also much debate on the effectiveness of STA. The speculation lies in the fact that no core is removed to allow for soil expansion. In fact the insertion of a solid tine into the soil could create sidewall compaction and a hardpan at the bottom of the hole, this has not been proven yet to till date. Recently, water injection (WI) evolved as an innovative method of aerification and used in most golf courses. High-pressure jets of water are utilized to produce deep, irregular channels into the soil with no surface disruption nor any significant damage to turfgrass. Initial research at Michigan State University compared WI to HTA on a sandy loam soil. WI generally performed as well or better than standard aerification, and the results were similar on either bentgrass or Kentucky bluegrass turf. WI has similar effects on soil properties as HTA, but imparts less damage to crown and root tissue of the turf.

High utility lawns (recreational turfgrass systems) are very common in densely populated urban city conditions, and in such lawns traffic stress is a major problem affecting turf quality and severity of damage depends on the turfgrasses (Sharath and Vivek 2015).Surface layer soil compaction in utility turfgrass system can be rectified by following a suitable soil aeration techniques. However, these aerification methods are not necessarily equal in their efficiency under all traffic conditions and turfgrass systems. With this background, the study was conducted to assess the recuperative ability of warm season turfgrasses by differentaerification techniques and to identify the suitable aerification technology for traffic stressed turfgrass systems.

MATERIALS AND METHODS

The study was undertaken in a turf research plot at the Hort Park, National Parks Board, Singapore, which is geographically situated at an altitude of 10 m above mean sea level (MSL) and between 1°22" North latitude and 103°48” East longitude. Singapore is located in the northern hemisphere with tropical climate and is hot and humid throughout the year without any seasonal variation. The mean annual rainfall during research period was 228.4 mm. Diurnal mean maximum and minimum temperatures were 31.6°C and 24.4°C respectively. The mean relative humidity recorded was 80-90% (NEA, Singapore 2013). The experimental plots (1×0.7 m^2) each on which the turfgrasses were grown with Approved Soil Mixture (ASM) comprising of loamy soil, compost and sand in the ratio of 3:2:1 (CUGE Standards).

Three types of trafficated warm season turfgrasses namely, Cowgrass (*Axonopus compressus)*- G_1, Manilagrass (*Zoysia matrella*)-G_2 and Seashore paspalaum grass (*Paspalum vaginatum*)- G_3 were used with four aerification techniques, viz. Zero aerification (ZA)- A_0, Water injection (WI)- A_1, Solid- tine aerification (STA)- A_2 and Hollow tine aerification (HTA)- A_3. The turfgrasses were planted by means of sodding. The sod rolls were cut into 1×0.7 m^2 dimensions and planted randomly as per treatments in the experimental plots.Rolling was undertaken a day after planting, to ensure adequate contact between the soil and sod, and to enable stabilization and levelling of the turf surface. The major nutrients namely N, P and K were applied in the ratio of 24:3:10 at fortnightly intervals through fertilizer spreader at the rate of 2 kg N/1000m^2 (CUGE Standards).

The turfgrasses were mowed with a rotary mower with cutting width of 56cm. Mowing was done at fortnightly intervals and the clippings were collected using a rotary mower with a bag attachment.Individual experimental plots were edged using hand hoe all along the beds to avoid excess growth of stolons and rhizomes, thus enabling maintenance of each of the experimental plot as a separate unit without the influence of the other plots.A Kesmac KTR 30 walk-behind turf roller, weighing 240 kg with 63 inches of length and 34 inches width was used as a traffic simulator to apply traffic stress (twelve traffic passes per week in alternate days) on the experimental plots for the period of six months.

ZA refers to no aerification treatment was imposed which serves as a control. WI comes in a single large tine of 42cm with 6 nozzle, a stream of pressurized water is injected from the surface that forces the water into the soil (The machine applies bursts of water rather than a continuous flow) with no surface disruption. STA involves driving solid metal tines into the surface of the turf, Solid tine aerator with solid tines measuring1.2cm in diameter and 8cm in length were used to aerate the soil without removing a core. HTA was performed with an aerator equipped with 16 numbers of hollow tines placed 3.5 cm apart.Outside diameter of the tines was 1.3 cm and tines were allowed to penetrate the ground to a depth of 5.1cm. Hollow tines consist of a tapered metal tube open along one side which is driven into the profile removing a plug of soil as it is extracted. The plug of soil in the tine is then forced from the tine by the next penetration and cast out onto the surface of the soil. After aerification by three methods, all cores were removed and topdressing was performed using sand. Sand was applied manually and incorporated into turf by brushinguntil all holes were completely filled.

The experiment was arranged in a factorial randomized block design replicated four times. The experiment was repeated twice in the year 2012 and 2013 and the data were pooled. An analysis of variance (ANOVA) was run on the data, and the differences between the treatments mean were further determined with the IBM SPSS statistics V. 21 software.

The growth parameters like turfgrass visual quality score (1 to 9 as per National turfgrass evaluation programme (NTEP) of United States); turf cover (% by using 'digital image analysis technique'); DGCI -Dark green colour index (digital images were analysed with Sigma Scan Pro v.5.0, SPSS, Inc., Chicago, IL 60611 and colour was determined by using the formula:DGCI= [(Hue-60)/60 + (1-Saturation) + (1-Brightness)]/3;clipping yield (gm^{-2}), surface hardness (gmax), and shoot length (cm) were measured at fortnightly interval. Relative water content (%) (Barr and Weatherly 1950) and root parameters such as root length (cm), root volume (cm^3), root fresh and dry weight (g) and thatch content (g/m^2) were measured at the end of the experiment. Soil parameters namely, bulk density (mg/m^3) (Blake 1965) and infiltration rate (mm/s) were recorded at the end of the experiment.

RESULTS AND DISCUSSION

The data indicated that aerification treatments showed significant differences among the turf growth parameters and soil properties and which was found superior over the ZA (control). Aerification treatments enhanced the quality of turf compared to ZA (Fig 1a). The best turf quality was observed with Seashore paspalum in WI (7.75) which was on par with Cowgrass under same treatment (6.75) and the poorest turf quality was observed with Cowgrass and Manilagrass under ZA (3.75) at 15 days after aerification (DAA). At 30 DAA, WI in Cowgrass (8.75) recorded highest turf quality which

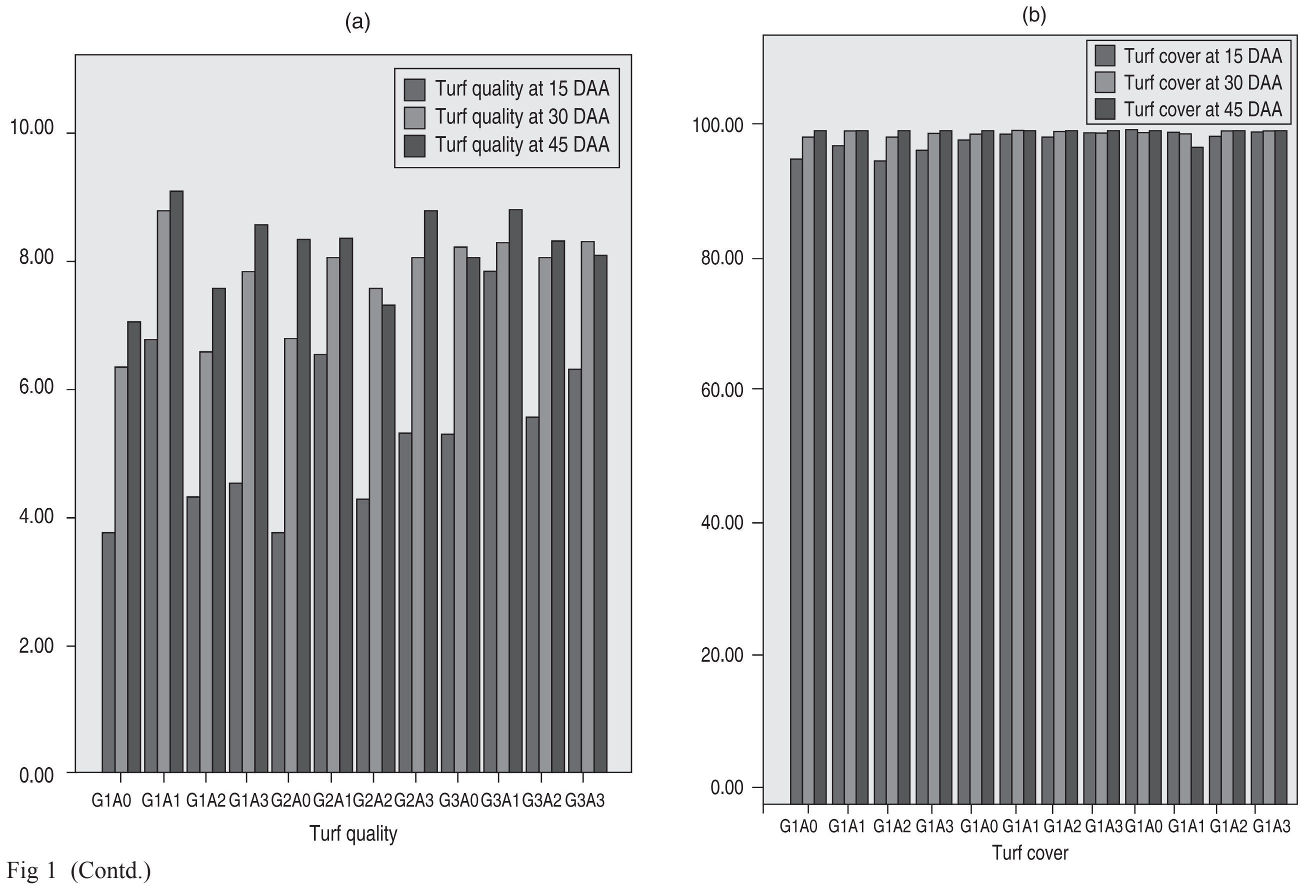

Fig 1 (Contd.)

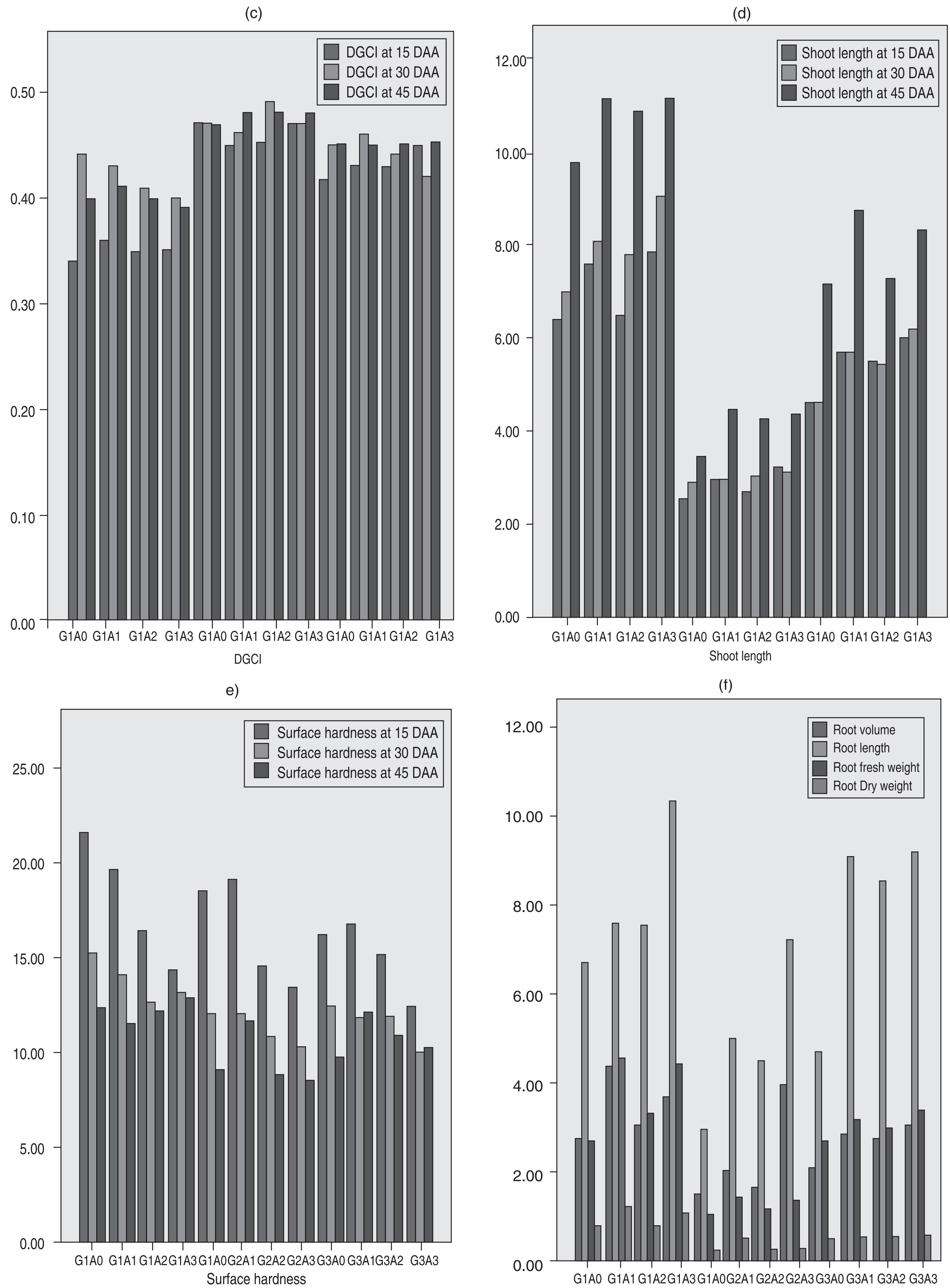

Fig 1 Effect of aerification techniques on a) turf quality, b) turf cover, c) DGCI content d) shoot length, e) surface hardness and f) root, parameters of trafficked turf grasses.

was on par with Seashore paspalum in WI and HTA (8.25) and lowest was observed with Cowgrass in ZA treatment (6.25). The Cowgrass in WI treatment (9.00) was found to be best and also on par with Seashore paspalum in WI treatment and Manilagrass in HTA (8.75). The least turf quality was observed with Cowgrass in ZA treatment (7.00) at 45 DAA. The turf cover differed significantly at 45 DAA for interaction between turfgrass and aerification treatment. Both in WI and HTA, Seashore paspalum recorded 100 % turf cover recovery at 45 DAA. Manilagrass also recorded 100 % turf cover recovery and the highest turf cover which was on par with Cowgrass in WI treatment (99.98 %). The least turf cover was observed with Cowgrass in ZA treatment (99.74 %) at 45 DAA (Fig 1b).

Turfgrass quality and turf cover are the prime indicators for turf assessment. Among three methods of aerification techniques applied in the present study WI outperformed the remaining techniques with respect to turf quality and turf cover. The results are in accordance with the observations of Murphy *et al.* (1994) who reported high-pressure water injection was much more effective in relieving the compaction and improving the turf quality. This might due to minimum surface disruption, proper aeration to roots with more pore space, less damage to crown and root tissue of the turf and also improved physical soil properties were another reason for increase in turf quality as suggested by White and Dickens (1984).

The highest DGCI being with Manilagrass in HTA treatment (0.47) was on par with ZA treatment (0.47) in the same turfgrass, whereas the lowest DGCI was observed with Cowgrass in ZA treatment (0.34) at 15 DAA. At 30 DAA, STA in Manilagrass recorded highest (0.49) while the lowest was recorded with Cowgrass in STA treatment (0.41) (Fig 1c). Shoot length did not differ significantly for interaction between turfgrass and aerification treatment (Fig 1d). Digital Image Analysis (DIA) provides an accurate, non-destructive, and objective assessment of turf colour. Karcher and Richardson (2003) have developed an index known as the dark green colour index (DGCI) via DIA as an indicator of turf colour and turf cover (and this index was used in the present study). The results revealed the highest dark green colour index in Manilagrass in accord once with the findings of Ihab (2012), the increase in colour index of a turfgrass species after aerification revealed an increased in the overall green turf coverage.

The highest clipping yield was observed with seashore paspalum in WI treatment (80.00 g) and the lowest was observed with Manilagrass in ZA treatment (8.75g) at 15 DAA. At 30 DAA, WI treatment in seashore paspalum (120.00g) recorded the highest clipping yield which was on par with HTA in the same turfgrass (118.75g) and lowest was observed with Manilagrass in ZA treatment (34.75g). The Cowgrass in WI treatment (185g) recorded the highest clipping yield which was on par with seashore paspalum in the same treatment (120g) and the lowest was recorded in Manilagrass with ZA treatment (33.75g) at 45 DAA (Table 1).

The root length for cowgrass under HTA was highest (10.25cm) and was on par with seashore paspalum turfgrass (9.25cm). The highest root volume was observed with cowgrass in WI treatment (4.33cm^3) and was on par with Manilagrass in HTA (3.95cm^3) and lowest was observed with Manilagrass in ZA treatment (1.48cm^3). Cowgrass in WI treatment recorded the highest (4.51g) root fresh weight which was on par with HTA in same turfgrass (4.39g) and the lowest was recorded with Manilagrass in ZA treatment (1.03g). The highest root dry weight was observed with cowgrass in WI treatment (1.22g) followed by HTA with the same turfgrass (1.03 g) and lowest was observed with Manilagrass in ZA treatment (0.21g) (Fig 1f).In the present study, the root length differed significantly and in all three turfgrasses HTA resulted in increased root length. These observations are in line with the earlier findings of Carrow (1980), increase in root length in all the turfgrass species can be ascribed to the fact that aerification relieves the compaction stress leads to increased soil oxygen, decreased soil strength, availability and proper uptake of nutrients.

The highest relative water content (RWC) was observed with WI treatment in cowgrass (94.33%) which was on par with HTA in the same turfgrass (90.11%) and lowest RWC was observed in Manilagrass with ZA treatment (63.23%). The seashore paspalum turfgrass in HTA recorded the

Table 1 Effect of aerification techniques on clipping yield (g/m^2) of turfgrasses

Treatment	15th DAA					30th DAA					45th DAA				
	A0 (ZA)	A1 (WI)	A2 (STA)	A3 (HTA)	Mean	A0 (ZA)	A1 (WI)	A2 (STA)	A3 (HTA)	Mean	A0 (ZA)	A1 (WI)	A2 (STA)	A3 (HTA)	Mean
G1	20.00	45.00	28.75	42.50	34.06	61.25	106.25	62.50	88.75	79.69	70.00	185.00	76.25	128.75	115.00
G2	8.75	17.50	13.75	16.75	14.19	34.75	66.25	38.75	51.25	47.75	33.75	72.00	43.75	62.50	53.00
G3	23.75	80.00	33.75	40.00	44.38	86.25	120.00	90.00	118.75	103.75	90.00	120.00	100.00	115.00	106.25
Mean	17.50	47.50	25.42	33.08		60.75	97.50	63.75	86.25		64.58	125.67	73.33	102.08	

	15th DAA G	15th DAA A	15th DAA G × A	30th DAA G	30th DAA A	30th DAA G × A	45th DAA G	45th DAA A	45th DAA G × A
F test	*	*	*	*	*	*	*	*	*
SEm	0.690	0.796	1.38	0.875	1.010	1.75	1.653	1.909	3.31
CD	1.983	2.290	3.97	2.514	2.903	5.03	4.752	5.487	9.50
CV	8.94			4.54			7.23		

Table 2 Effect of aerification treatments on trafficked warm season turf grasses with regard to relative water content (%), thatch content (g), their bulk density and infiltration rate (mm/s)

Turf grasses	Aerification techniques	Relative water content (RWC) (%)	Thatch content (g)	Bulk density (BD)	Infiltration rate (IR) (mm/s)
Cowgrass	A0(ZA)	72.52	0.39	1.74	0.98
	A1 (WI)	94.33	1.82	1.69	0.50
	A2(STA)	86.15	1.90	1.57	1.33
	A3 (HTA)	90.11	1.41	1.43	1.60
Manilagrass	A0(ZA)	63.23	7.65	1.80	0.85
	A1 (WI)	82.56	14.25	1.61	0.98
	A2(STA)	76.54	16.06	1.50	3.83
	A3 (HTA)	78.76	8.87	1.44	1.35
Seashore paspalum grass	A0(ZA)	82.19	7.86	1.87	2.18
	A1 (WI)	88.84	13.39	1.60	4.05
	A2(STA)	84.13	15.95	1.59	1.95
	A3 (HTA)	85.34	10.47	1.45	5.13
F test		**	*	NS	*
SEm		4.03	0.17	0.06	0.15
CD at (P=0.05)		11.58	0.48	0.18	0.44

highest (5.13 mm/s) infiltration rate and the lowest were recorded with cowgrass in WI treatment (0.5 mm/s) (Table 2). Hollow tine aerification is associated with lower bulk density and higher infiltration rate. The above results are in conformity with findings of Bryne *et al.* (1965), Morghan *et al*. (1965) and Canaway *et al*. (1986), this might be due to the removal of cores which was subsequently top dressed with coarse sand which ultimately enhanced the infiltration rate by alleviating soil compaction.

The highest thatch content was observed with Manilagrass in STA treatment (16.06 g/m^2) on par with seashore paspalum with the same treatment (15.95 g/m^2) and lowest was observed with cowgrass in ZA treatment (0.39g/m^2) (Table 2). Thatch is a tightly intermingled layer of living and dead plant tissue that develops between the green vegetation and soil surface. Thatch is formed from periodically sloughed roots, horizontal stems (stolons and rhizomes), stubble and mature leaf sheaths and blades (Engel 1954). In the present study, the thatch content differed significantly in all the turfgrasses and was found least in HTA. These results are consistent with earlier reports of Stier and Hollman (2003). HTA works to reduce thatch, this can be ascribed to the fact that HTA reduces thatch by physically removing pieces of thatch and opens up the thatch layer providing a better environment for microorganisms to decompose organic matter (Brauen *et al*. 1998).

Among interaction between turfgrass and aerification treatment, surface hardness did not differed significantly. The highest surface hardness was observed with cowgrass in ZA treatment (21.30 and 15.13 gmax, respectively) and the lowest was observed with seashore paspalum in HTA treatment (12.33 and 10.00 gmax, respectively) at 15 DAA and 30 DAA. At 45 DAA, HTA treatment in cowgrass (12.78 gmax) recorded the maximum surface hardness and lowest was observed with Manilagrass in HTA treatment (8.48 gmax) (Fig 1e).The highest surface hardness was recorded in cowgrass and lowest surface hardness was recorded with seashore paspalum. Surface hardness as influenced by treatment also showed significant difference, with ZA recorded the highest surface hardness and HTA recording the lowest in Manilagrass. The results are in accordance with those of McCarty *et al*. (2007) who observed that core cultivation reduced the surface hardness compared to ZA treatment. This can be ascribed to the fact that surface hardness decreases with increase in shoot density and turf cover by relieving soil compaction.

The present study revealed that seashore paspalum has good recuperative potential to traffic stress compared to Manilagrass. Further, results indicated water injection as the best aerification technique for quick relief from soil compaction, while hollow tine aerification as a long-term relief technique to improve turf quality and turf cover by way of reducing the thatch, bulk density and increasing the infiltration rate.

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