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EFFECTS OF NITROGEN FERTILITY ON THE PERFORMANCE OF PORT HARCOURT GRASS (*Chrysopogon aciculatus* (Retz.) Trin.)

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Abstract

The effects of nitrogen fertility on the performance of "Port Harcourt grass", Chrysopogon aciculatus (Retz.) Trin. were assessed with the aim of determining the optimum N rate for the turf quality features. Six fertilization regimes of 10, 20, 30, 40, 50, 60 g nitrogen/m^2/month and control were set up in three replicates each. "Port Harcourt grass" established from tillers were allowed to grow for four weeks before data collection started. Data were collected on ground cover, chlorophyll index and concentrations, total carotenoids, clipping yield and biomass at maturity. Fertility rate of 30 g N/m^2 was optimal for ground cover at weeks after planting but a lower rate (20 g N/m^2) was required after clipping. Fresh weights at second clipping and aboveground biomass were higher in the fertilizer treatments, but the corresponding dry weights were not affected. Higher N rates up to 60 g N/m^2 enhanced chlorophyll index, chlorophyll a, chlorophyll b and total carotenoids at the fourth week after second clipping. Soil N correlated positively with ground cover. Above- and below-ground biomasses also correlated positively. Chlorophyll index correlated positively with chlorophylls a and b. Chlorophyll a correlated positively with chlorophyll b and total carotenoids. The study concluded that fertility rates influence turf quality characteristics differently and the positive correlation between some of the quality characteristics shows the possibility of achieving improvement of the qualities with the same treatment.

Key Words: *Fertility, Growth, Nitrogen, Performance, Port Harcourt grass, Turf.*

Introduction

Love grass (*Chrysopogon aciculatus* (Retzius) Trinius), popularly called Port Harcourt grass in Nigeria, belongs to the family Poaceae, subfamily Panicoideae and tribe Andropogoneae (Veldkamp, 1999). It is a perennial, sword-forming grass with creeping rhizomes (Paria and Chattopadhyay, 2005). Port Harcourt grass is a warm-season species distributed in the most parts of the tropics (Ambasta and Rana, 2013) and found mostly in sunny, dry, exposed areas such as roadsides, lawns, pasture, bank of rivers, and water courses (Noltie, 2000). The grass is common in lawns and sport fields across Nigeria due to its tolerance to foot traffic (trampling stress), however, the slow growth (during the establishment stage) and poor quality in turf established with the sole stands often dictate the need for mixture with other turfgrass species such as *Cynodon dactylon* and *Axonopus compressus* (Oyedeji *et al*., 2014a). Such variations in the performance of turfgrasses have been associated with differences in nutrient requirements, especially nitrogen (Standford and Legg, 1984).

Nitrogen is a macronutrient and a vital constituent in plant components including chlorophyll which is directly associated with photosynthesis (Bojović and Marković, 2009). Brejda (2000) suggested that N requirement of native warm-season grasses largely depends on the yield potential of the site, productivity of the grass and management practices. Information on the N requirement of turfgrass and the soil nutrient status is necessary in determining the N application rate. The knowledge of the requirement of a turfgrass is needed to optimize performance while preventing over-fertilization and possible loss of N into surface and ground water via leaching (Brejda, 2000). Proper nitrogen fertility is essential for turfgrass growth and development. Nitrogen aid in turfgrass recovery from stresses such as wear, physical injury from maintenance practices, and damage from pests (Beard, 2002).

Wilson and Brown (1983) reported optimum growth rate for some warm-season turfgrass at lower N levels where cool-season grasses performed less. Previous studies have also reported higher growth rates for grasses across a range of N concentrations (Wilson, 1975; Wilson and Brown, 1983; Brown, 1985; Ahmad *et al.*, 2003). Application of N in amounts greater than the requirements of the turfgrass in question have been reported to increase above-ground growth (Christians *et al*., 1979). Contrarily, Schlossberg and Karnok (2001) reported reduced root depth and density due to excessive nitrogen rates. Therefore, identifying optimal nitrogen levels for a turfgrass performance qualities is important to managing turfs where such grass grows. The present study assess the nitrogen fertility on the performance of Port Harcourt grass (*Chrysopogon aciculatus*).

Materials and Methods

Experimental design and set-up

A potted experiment was conducted in the screen house located in the Botanical Garden (N 08° 28′ 53.3″, E 04° 40′ 28.9″), University of Ilorin, Ilorin, Nigeria. Ilorin lies within the southern guinea savanna (Oyedeji *et al*., 2014b), the transition zone between the deciduous rainforest of the south and savanna of the north.

Alluvial soil typically poor in nitrogen was used for the study, as to complement its intended use with nitrogenous base fertilizer. The soil collected from the University Botanical Garden were homogenized and sieved using 2 mm mesh prior to packing into plastic pots.

The soil was analyzed for pH, organic carbon (SOC) and phosphorus concentrations, and exchangeable cations (potassium, sodium, calcium, magnesium). Soil pH was measured with a glass electrode pH meter in 1:1 water suspension. Soil particle size analysis was conducted by hydrometer method as outlined by Bouyoucos (1951).

Exchangeable cations (Ca, Mg, K and Na) were extracted using neutral 1 M NH_4OAc solution (Thomas, 1982). Na concentration in the soil extract was read with Gallenkamp flame photometer; Ca, Mg and K were determined using an atomic absorption spectrophotometer (Bulk Scientific – 210/211 VGP). Total organic carbon concentration was determined using the wet digestion method (Walkley and Black, 1934). Available P was determined by Bray P1 method (Olsen and Sommers, 1982) using a spectrophotometer (Cary 100 UV-VIS Spectrophotometer, Agilent Technologies). Total nitrogen was determined in the treatments after fertilizer application using Kjeldahl method as outlined by Bremner and Mulvaney (1982).

Twenty-one (21) pots (0.25 m length × 0.25 m breadth × 0. 15 m depth), perforated near the base for aeration, were filled with the soil and arranged in a 7 by 3 (fertilizer treatment by replicates) complete block design. The fertilizer treatments consist of urea (N:46, P:0, K:0) applied at the rate of 10, 20, 30, 40, 50 and 60 g N/m^2 and tagged respectively as T_1, T_2, T_3, T_4, T_5 and T_6. The control (unfertilized) pots tagged as T_0 were also arranged.

Nine tillers of *Chrysopogon aciculatus* (Retz.) Trin. were planted into each plastic pot one week after the fertilization. The pots were irrigated daily using double distilled water to minimize nutrient addition from the irrigation. Weeds were manually removed immediately sprouted.

Data Collection

The ground cover of the turf was measured weekly, starting from the fourth week after planting (4WAP) using a 0.0625 m^2 wooden quadrat with a regular 4 × 4 grids. Percentage ground cover was determined using the equation:

Percentage cover of grass = number of points (quadrat grids) touching grass × 100 ÷ 16

The grasses were clipped at 2 cm aboveground at 12WAP and the fresh and dry weights of the first clippings were measured. Ground cover was determined at the first and second week after the first clipping (1 and 2WFC) before the plants were again clipped. The second clipping fresh and dry weights were also determined. Ground cover was again measured from the first to the fourth week after the second clipping (1-4WSC). The above- and below-ground parts of the plants were harvested separately, weighed fresh and oven-dried to constant weight at 80 °C. The fresh and dry weights of the above- and below-ground were determined. The root/shoot ratio was calculated from the dry weight of the above- and below-ground biomasses.

Turf colour was assessed biweekly starting from 4WAP using chlorophyll index (CI) and concentrations of chlorophyll a, chlorophyll b and total carotenoids in the leaf blades of the grass. Chlorophyll index (CI) was measured using Atleaf chlorophyll meter (FT Green LLC, USA). Chlorophyll a, chlorophyll b and total carotenoids content were analyzed according to the protocol published by Lichtenthaler (1987). Fresh leaves (25 mg) were soaked in 7 ml of 100% acetone for 72 hours in the dark. The samples were centrifuged at 5000 rpm and the absorbance of the supernatant was read at 470.0 nm, 644.8 nm and 661.6 nm with a spectrophotometer (Cary 100 UV-VIS

Spectrophotometer, Agilent Technologies). Chlorophyll a, chlorophyll b, and total carotenoids (xanthophyll + β-carotene) concentrations in the leaf extracts were calculated using the equations:

Chlorophyll a = $11.24 \times A_{661.6\ nm} - 2.04 \times A_{644.8\ nm}$

Chlorophyll b = $20.13 \times A_{644.8\ nm} - 4.19 \times A_{661.6\ nm}$

Total carotenoids = $1000 \times A_{470\ nm} - (1.9$ Chl. a – 63.14 Chl. b) ÷ 214

Data Analyses

Data on ground cover, clipping yields and biomasses were analysed using ANOVA in SAS PROC ONE-WAY (version 9.1.3; SAS Institute, Cary, NC). Means were separated using Fisher's protected LSD test at 0.05 α level. Correlation coefficients between soil N and performance variables were determined using SAS PROC CORR. Ground cover readings were normalized using arcsine transformation before statistical analyses and retransformed to percentages thereafter.

Results and Discussion

Soil Chemical Properties

The distribution of sand, silt and clay in the alluvial soil was 95.9%, 4.0% and 0.1% respectively. Soil pH was 7.62 (slightly alkaline). SOC and phosphorus concentrations were 1.21% and 0.81% respectively. Exchangeable Na, K, Ca and Mg were 0.81 cmol/kg, 2.26 cmol/kg, 0.76 cmol/kg and 0.26 cmol/kg respectively. Total nitrogen concentration was 0.11% in T_0, 5.23% in T_1, 5.35% in T_2, 6.45% in T_3, 6.94% in T_4, 8.40% in T_5 and 9.45% in T_6.

Ground cover

The ground cover of *Chrysopogon aciculatus* turf established with varying nitrogen fertilizer regimes were not significantly different ($P > 0.05$) at 4 weeks after planting (WAP) until 7WAP. The slow establishment of the unfertilized control (T_0) supports the claim that turfgrass cannot function properly without nitrogen as the nutrient impact a number of processes including shoot growth and density (Ebdon *et al.*, 1999).

There were significant differences in the ground cover of the turf from 8 – 12WAP. The control (T_0) had the least ground cover in the weeks after planting. T_2 had the highest ground cover at 8 and 9WAP. T_2 and T_3 had equal ground cover at 10WAP (94.9%) but T_3 outperformed the other treatments at 11 WAP and 12WAP (Table 1). The order of ground cover from the eighth to twelfth week after planting (8 -12WAP) in the present study corroborates the report of Rosen *et al.* (2008) "that too little fertilizer leads to poor plant growth, and too much fertilizer can also reduce plant growth and quality".

The ground cover of turf at one week after first clipping (1WFC) varied significantly ($P < 0.05$) among the treatments. T_5 had the highest ground cover (81.5%) while T_0 had the least (40.7%). There was improvement in percentage ground cover at 2WFC, but the treatments were not different significantly (Table 2). N fertilization improved regrowth of the turf compared with the unfertilized control. Beard (2016) reported that growth, recuperative potential and rate are dependent on soil nitrogen level. The fertilizer treatments had significantly high ground cover at 3WSC and 4WSC, except T_1 at 4WSC (Table 2). The faster regrowth (ground cover after clipping) after the second clipping is attributed to increase in tillering induced by the clipping. This corroborates the report of Hull (1998) that mowing is beneficial to turf as it remove apical meristem and flower culms while inducing vegetative growth of basal tillers that result in thicker turf with increased shoots per square foot.

Table 1: Percentage ground cover of *Chrysopogon aciculatus* turf established on soil amended with varying nitrogen fertilizer rates at weeks after planting

Treatment	Percentage ground cover at WAP								
	4	5	6	7	8	9	10	11	12
T_0	21.5^{ab}	24.9^{b}	44.0^{b}	44.0^{b}	48.1^{b}	48.1^{c}	48.1^{b}	48.1^{c}	52.0^{c}
T_1	14.5^{b}	29.4^{b}	44.3^{ab}	48.1^{b}	59.8^{ab}	$63.5b^{c}$	71.7^{ab}	71.7^{bc}	71.7^{bc}
T_2	36.2^{ab}	78.2^{a}	78.2^{a}	87.8^{a}	92.5^{a}	92.5^{a}	94.9^{a}	94.9^{ab}	94.9^{ab}
T_3	25.7^{ab}	48.1^{ab}	67.0^{ab}	67.0^{ab}	70.6^{ab}	82.5^{ab}	94.9^{a}	98.7^{a}	98.7^{a}
T_4	29.4^{ab}	59.8^{ab}	70.9^{ab}	70.9^{ab}	70.9^{ab}	75.3^{abc}	75.3^{ab}	79.5^{abc}	79.5^{bc}
T_5	44.3^{a}	55.7^{ab}	59.8^{ab}	63.5^{ab}	70.6^{ab}	75.1^{abc}	75.1^{ab}	75.1^{bc}	81.8^{abc}
T_6	48.1^{a}	64.6^{ab}	71.7^{ab}	71.7^{ab}	75.1^{ab}	75.1^{abc}	78.5^{ab}	78.5^{bc}	81.8^{abc}
P-value	0.074	0.088	0.196	0.062	0.023	0.046	0.041	0.019	0.016

Means with the same superscripted letter(s) are not significantly different at $P>0.05$.

Table 2: Percentage ground cover of *Chrysopogon aciculatus* turf established on soil amended with varying nitrogen fertilizer rates at weeks after the first and second clippings

Fertilizer Treatment	1WFC	2WFC	1WSC	2WSC	3WSC	4WSC
T_0	40.7^{c}	59.3^{a}	51.8^{a}	63.0^{a}	63.0^{b}	70.4^{b}
T_1	59.3^{bc}	74.1^{a}	66.7^{a}	77.8^{a}	81.5^{a}	88.9^{ab}
T_2	74.1^{ab}	81.5^{a}	70.4^{a}	85.2^{a}	88.9^{a}	92.6^{a}
T_3	77.8^{ab}	88.9^{a}	70.4^{a}	81.5^{a}	88.9^{a}	92.6^{a}
T_4	70.4^{ab}	81.5^{a}	66.7^{a}	81.5^{a}	92.6^{a}	96.3^{a}
T_5	81.5^{a}	88.9^{a}	66.7^{a}	85.2^{a}	88.9^{a}	92.6^{a}
T_6	66.7^{ab}	81.5^{a}	62.9^{a}	77.8^{a}	96.3^{a}	100.0^{a}
P-value	0.003	0.163	0.677	0.254	0.008	0.030

WFC – weeks after first clipping; WSC – weeks after second clipping.
Means with the same superscripted letter(s) are not significantly different at $P>0.05$

Yield

The fresh and dry weights of the first clippings (FCFW and FCDW) of the treatments were not significantly different ($P > 0.05$) (Fig. 1). The fresh weights of the second clipping (SCFW) was significantly different ($P < 0.05$) among treatments. T_3 had the highest SCFW (78.56 g m^{-2}) while the Control (T_0) had the least (33.6 g m^{-2}). The dry weights of the second clipping (SCDW) was not significantly different ($P > 0.05$) for the treatments (Fig. 2). The lack of significant variation in the first and second clipping yields suggests nitrogen requirements may vary for turf quality parameters. This observation is consistent with the report of Bilgili and Açikgöz (2011) that variation exists in the relative effectiveness of fertilizers in improving turf quality. The application of nitrogen fertilizer has resulted in variable effects on plant establishment and productivity in rangeland revegetation studies (Holechek, 1982). The significant variation in SCFW is attributed to the moisture contents in the clippings as the result was not consistent with SCDW. This observation is consistent with the report of Noer (1945) that variation between the fresh and dry turf clippings may be influenced by moisture level in the clippings.

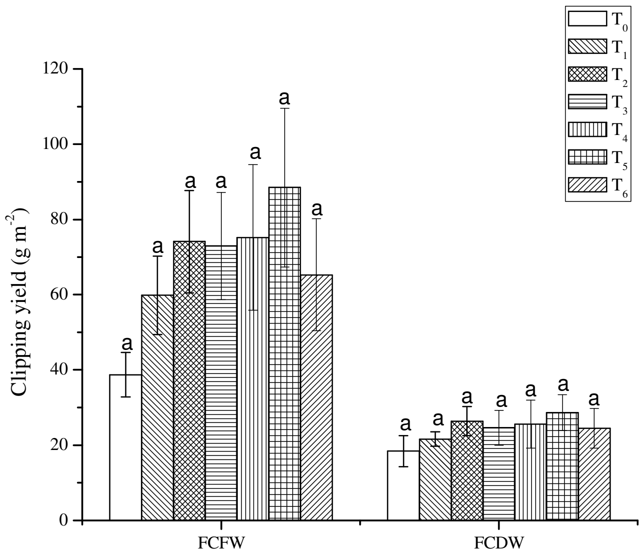

Fig. 1: Fresh and dry weights of first clippings from C. aciculatus turf established with varying nitrogen rates.

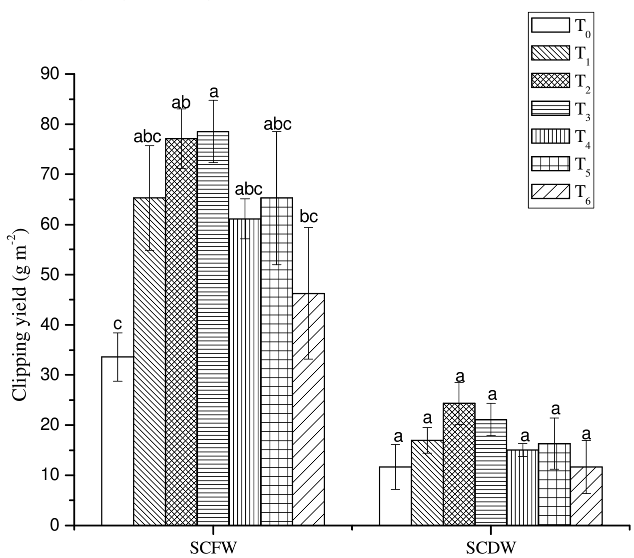

Fig. 2: Fresh and dry weights of second clippings from *C. aciculatus* turf established with varying nitrogen rates.

There was significant difference ($P < 0.05$) in the fresh weights of the aboveground biomass (AGB_f). T_4 had the highest AGB_f (312 g m^{-2}) while T_0 had the least (124.8 g m^{-2}). The dry weights of the aboveground biomass (AGB_d) were not statistically different ($P > 0.05$). There were no significant variation in the fresh weights and dry weights of belowground biomass (BGB_f and BGB_d). The total biomass was not significantly different ($P > 0.05$) and ranged from 145.6 g m^{-2} (T_6) to 448.0 g m^{-2} (T_2) (Table 3). The connexion of the aboveground, belowground and total biomasses to the first and second clipping yields also link to the results of the variables to insufficient fertilizer rates. The root-shoot ratio was also not significantly different ($P > 0.05$) and ranged from 2.0 to 5.0 (Table 3) indicating that *C. aciculatus* naturally allocates greater biomass to the root than shoot – an adaptive feature against environmental stress. Chapin *et al.* (1993) and Sage and Kubien (2003) reported that high root-shoot ratio in grasses is a strategy for water uptake in drought environment.

Table 3: Above and below-ground biomass (fresh and dry) of *Chrysopogon aciculatus* established with varying nitrogen rates

Fertilizer Treatment	AGB_f	AGB_d	BGB_f	BGB_d	TB	root/shoot
T_0	124.8^c	52.8^a	713.6^a	132.8^a	185.6^a	2.5^a
T_1	219.2^b	40.0^a	1192.0^a	182.4^a	222.4^a	5.0^a
T_2	296.0^{ab}	91.2^a	1574.4^a	356.8^a	448.0^a	3.3^a
T_3	222.4^{ab}	83.2^a	1627.2^a	345.6^a	430.4^a	5.0^a
T_4	312.0^a	86.4^a	1566.4^a	259.2^a	347.2^a	3.3^a
T_5	275.2^{ab}	52.8^a	1420.8^a	246.4^a	299.2^a	5.0^a
T_6	211.2^{bc}	46.4^a	979.2^a	97.6^a	145.6^a	2.0^a
P-value	0.003	0.180	0.079	0.140	0.099	0.429

KEY: AGB_f - Aboveground biomass (fresh weight); AGB_d – Aboveground biomass (dry weight); BGB_f – Belowground biomass (fresh weight); BGB_d – Belowground biomass (dry weight); root/shoot – root-shoot ratio; TB – Total biomass. Means with the same superscripted letter(s) are not significantly different at $P>0.05$.

Photosynthetic Pigments

Foliar chlorophyll index (CI) varied significantly among the treatments at 4, 8, 12WAP and 4WSC. All the treatments had low CI at 4 and 6 WAP, except T_5 (36.2). Generally, CI <35 reflect poor health of the grass. CI for all the treatments decreased at 2 WSC and 4 WSC except for T_6 (Table 4). There was no significant variation ($P > 0.05$) in the concentrations of chlorophyll a, b and total carotenoids, except at 4WSC (Tables 5 and 6). *Chl. a* concentrations in T_0 decreased from 2WFC until 4WSC. T_0 also had the least *Chl. a* concentration at 4WSC (4.2 mg g^{-1}) while T_6 had the highest (9.0 mg g^{-1}) (Table 5). T_0 had the least *Chl. b* at 4WSC (Table 6). Generally, *Chl. b* and total carotenoids concentrations also wavered in all the stages of growth (Table 6 and 7). The results of CI, chlorophylls a, b and total carotenoids suggest nitrogen fertilization enhanced photosynthetic pigments in *C. aciculatus* compared with the unfertilized control. Although the order of improvement by nitrogen was erratic, nitrogen rates up to 60 g N/m^2 (T_2) optimally improved photosynthetic pigments in the grass. The improvement of chlorophyll in this study is logical since nitrogen is a structural element of chlorophyll and protein molecules, and thereby affects formation of chloroplasts and consequent accumulation of chlorophyll in them (Bojović and Marković, 2009).

Table 4: Foliar chlorophyll index of *Chrysopogon aciculatus* turf established with varying nitrogen rates

Fertilizer treatment	4WAP	6WAP	8WAP	10WAP	12WAP	2WFC	2WSC	4WSC
T_0	31.3^{ab}	32.4^{a}	37.8^{c}	36.4^{a}	37.0^{c}	37.7^{a}	33.4^{a}	31.9^{c}
T_1	25.6^{b}	31.1^{a}	38.3^{c}	41.0^{a}	42.2^{bc}	43.2^{a}	36.0^{a}	36.0^{b}
T_2	30.4^{ab}	30.1^{a}	40.8^{bc}	39.3^{a}	44.8^{ab}	41.6^{a}	37.9^{a}	37.5^{ab}
T_3	35.2^{a}	32.1^{a}	37.4^{c}	36.9^{a}	44.8^{ab}	40.3^{a}	37.7^{a}	37.2^{ab}
T_4	32.1^{a}	34.0^{a}	43.6^{ab}	41.0^{a}	44.7^{ab}	41.1^{a}	36.3^{a}	36.3^{b}
T_5	32.9^{a}	36.2^{a}	46.8^{a}	42.3^{a}	47.6^{a}	40.6^{a}	37.6^{a}	37.6^{ab}
T_6	30.5^{ab}	35.0^{a}	44.2^{ab}	41.9^{a}	47.7^{a}	37.6^{a}	40.7^{a}	40.7^{a}
P value	0.041	0.507	0.001	0.420	0.003	0.404	0.118	0.003

WAP-weeks after planting; WFC-weeks after the first clipping; WSC-weeks after the second clipping. Means with the same superscripted letter(s) are not significant at P>0.05

Table 5: Foliar chlorophyll **a** concentrations (in mg g^{-1} fresh weight) for *Chrysopogon aciculatus* turf established with varying nitrogen rates

Fertilizer Treatment	4WAP	6WAP	8WAP	10WAP	12WAP	2WFC	2WSC	4WSC
T_0	9.3^{a}	8.6^{a}	7.8^{a}	6.0^{a}	8.5^{a}	7.9^{a}	6.4^{a}	4.2^{c}
T_1	10.0^{a}	8.0^{a}	8.8^{a}	7.1^{a}	7.8^{a}	7.9^{a}	8.1^{a}	5.5^{bc}
T_2	9.1^{a}	7.3^{a}	9.0^{a}	7.4^{a}	8.9^{a}	8.8^{a}	8.5^{a}	7.9^{ab}
T_3	11.3^{a}	6.8^{a}	9.7^{a}	6.5^{a}	7.0^{a}	9.0^{a}	10.3^{a}	5.7^{bc}
T_4	8.8$^{\mathbf{a}}$	9.0^{a}	10.8^{a}	7.3^{a}	5.9^{a}	7.7^{a}	7.0^{a}	5.8^{bc}
T_5	9.8^{a}	9.0^{a}	11.0^{a}	7.4^{a}	9.6^{a}	8.5^{a}	7.1^{a}	7.3^{ab}
T_6	10.1^{a}	9.5^{a}	9.3^{a}	8.1^{a}	7.2^{a}	6.5^{a}	8.2^{a}	9.0^{a}
P-value	0.724	0.119	0.388	0.571	0.414	0.307	0.174	0.019

WAP-weeks after planting; WFC-weeks after the first clipping; WSC-weeks after the second clipping. Means with the same superscripted letter(s) are not significant at P>0.05

Table 6: Foliar chlorophyll **b** concentrations (in mg g^{-1} fresh weight) for *Chrysopogon aciculatus* turf established on soils amended with varying nitrogen rates

Fertilizer Treatment	4WAP	6WAP	8WAP	10WAP	12WAP	2WFC	2WSC	4WSC
T_0	3.0^a	2.6^a	2.2^a	1.9^a	2.6^a	2.9^a	1.5^a	1.4^c
T_1	3.2^a	2.3^a	2.6^a	1.8^a	2.2^a	2.2^a	2.1^a	2.7^{ab}
T_2	2.8^a	2.1^a	2.6^a	1.9^a	1.9^a	2.7^a	3.2^a	2.6^{abc}
T_3	3.6^a	1.9^a	3.0^a	1.8^a	2.1^a	2.7^a	2.6^a	1.6^{bc}
T_4	2.7^a	2.6^a	3.3^a	1.9^a	1.7^a	2.3^a	2.0^a	1.9^{bc}
T_5	3.0^a	2.6^a	3.3^a	2.1^a	3.2^a	2.5^a	2.1^a	2.3^{abc}
T_6	3.2^a	2.8^a	4.0^a	2.2^a	2.3^a	2.2^a	2.6^a	3.2^a
P-value	0.615	0.057	0.545	0.952	0.454	0.346	0.252	0.030

WAP-weeks after planting; WFC–weeks after the first clipping; WSC–weeks after the second clipping. Means with the same superscripted letter(s) are not significant at $P>0.05$

Table 7: Foliar concentrations of total carotenoids (in mg g^{-1}fresh weight) for *Chrysopogon aciculatus* turf established on soils amended with varying nitrogen fertilizer rates

Fertilizer Treatment	4WAP	6WAP	8WAP	10WAP	12WAP	2WFC	2WSC	4WSC
T_0	1.5^a	1.5^a	1.4^a	1.0^a	1.5^a	1.2^a	1.4^a	0.7^{cd}
T_1	1.6^a	1.3^a	1.5^a	1.5^a	1.5^a	1.4^a	1.6^a	0.3^d
T_2	1.5^a	1.5^a	1.5^a	1.5^a	1.9^a	1.6^a	1.4^a	1.4^{ab}
T_3	1.8^a	1.3^a	1.6^a	1.4^a	1.2^a	1.5^a	2.3^a	1.3^{ab}
T_4	1.5^a	1.6^a	1.9^a	1.5^a	1.1^a	1.3^a	1.4^a	1.0^{bc}
T_5	1.7^a	1.7^a	1.8^a	1.4^a	1.6^a	1.4^a	1.5^a	1.3^{ab}
T_6	1.7^a	1.6^a	1.2^a	1.5^a	1.2^a	1.0^a	1.6^a	1.7^a
P-value	0.752	0.238	0.446	0.317	0.169	0.287	0.463	<0.001

WAP-weeks after planting; WFC-weeks after the first clipping; WSC-weeks after the second clipping. Means with the same superscripted letter(s) are not significant at $P>0.05$

Relationship between Performance Variables and Soil N

There was significant positive correlation between ground cover and soil N ($P < 0.05$) (Table 8). The significant positive correlation of ground cover with soil N indicates that ground cover increase with increasing soil N. The observed increase in ground cover was consistent up to 30 g N per m^2. The optimum N fertilizer rate in the present study is consistent with optimum rate of rate 30 g N per m^2 reported by Ahmad *et al.* (2003) for coverage rate in *Cynodon dactylon* var. 'Dacca' and *Zoysia* spp. var 'Chinese' turfs. ABG correlated positively with BGB. *Chl. a* and *Chl. b* correlated positively with CI. *Chl. a* also correlated positively with *Chl. b* and total carotenoids. The correlation of chlorophyll a with chlorophyll b and total carotenoids depict that improvement of these photosynthetic pigments can be achieved with the same treatment. The positive correlation of chlorophylls a and b concentrations with CI in this study establish the possibility of determining chlorophyll concentrations in *C. aciculatus* from CI readings obtained from ATLeaf chlorophyll meter.

Table 8: Pearson correlation for soil N and performance variables of *C. aciculatus* turf established in varying nitrogen fertilizer regimes

	Soil N	Ground cover	AGB	BGB	CI	*Chl. a*	*Chl. b*
Soil N							
Ground cover	0.800*						
AGB	-0.229	0.131					
BGB	-0.294	-0.220	0.835*				
CI	0.739	0.707	0.047	0.082			
Chl. a	0.694	0.673	0.019	0.018	0.900*		
Chl. b	0.463	0.415	-0.354	-0.271	0.761*	0.812*	
Total carotenoids	0.696	0.750	0.340	0.209	0.726	0.795*	0.312

*. Correlation is significant at the 0.05 level.

Conclusion

Fertility rates influence turf characteristics differently. The data from this study indicate nitrogen fertilization rate up to 30 g N/m^2 enhance ground coverage in *C. aciculatus*. Improvement in ground cover may not necessarily translate to increased clipping yields. Higher nitrogen rates (60 g N/m^2) was sufficient to optimize chlorophylls a, b, and total carotenoid concentrations. The established relationship between chlorophylls a, b and total carotenoids highlights the possibility of improving these qualities with the same treatment. The study also showed the possibility of ascertaining chlorophyll concentrations from chlorophyll index readings using non-destructive ATLeaf chlorophyll meter.

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