Turkish Journal of
Field Crops
2014, 19(1), 101-107

PERFORMANCE OF SOME LOCAL NIGERIAN TURFGRASSES IN SOLE AND MIXED STANDS

Stephen OYEDEJI[1], Augustine Onwuegbukiwe ISICHEI[2], Adekunle OGUNFIDODO[3]*

[1]Department of Plant Biology, University of Ilorin, Ilorin, Nigeria.
[2]Department of Botany, Obafemi Awolowo University, Ile-Ife, Nigeria.
[3]Department of Mathematics, Obafemi Awolowo University, Ile-Ife, Nigeria.
**Corresponding author: oyedeji.s@unilorin.edu.ng*

Received : 13.08.2013

ABSTRACT

The study assessed the performance of *Axonopus compressus, Chysopogon aciculatus, Sporobolus pyramidalis, Eleusine indica* and *Dactyloctenium aegyptium* in turf establishment. The five grass species planted in sole and mixed stands were varied with the legume - *Desmodium triflorum*. Ground cover differed significantly among grass species and their mixtures from 4 - 11 weeks after planting (WAP) but ground cover in the legume and no legume subplots were not significantly different from 4 – 6 WAP. *Eleusine*, *Axonopus* and *Dactyloctenium* and their mixtures had higher ground cover than those of *Sporobolus* and *Chrysopogon*. There were significant differences in ground cover among grasses and mixtures at 3 and 6 weeks after clipping (WAC), and grass-legume subplots and subplots without the legume were different at 3 and 4 WAC. Recovery weeks after trampling was faster in sole stands and mixtures with *Axonopus* and *Eleusine*, indicating they are better adapted to trampling.

Key words: ground cover, growth rate, legume, mixed stands, trampling-tolerant, warm-season turfgrasses.

INTRODUCTION

Turfgrasses serve aesthetic, recreational and environmental purposes to most landscapes; providing recreational areas, erosion control and other ecological benefits (Kir et al., 2010). The durability of recreational turfs which is the function of adaptation to the abiotic and biotic environments and the suitability to specificities of usage like trampling intensities have been given little attention in Africa. Consequently, most sports fields tend to be excessively used and proper maintenance is often lacking.

Research studies have demonstrated rapid germination and growth of turfgrass to be critical for successful establishment of athletic field turf (Murphy, 2004; Murphy and Park, 2005). Establishment and management of turf without adequate consideration of the adaptation of the sown grass to the environmental context often cause failure of the turf. Successful turf management often begins with proper selection of species that are adapted to the climatic conditions to be experienced (Busey, 2003).

There are several studies on the performance of turfgrasses under Mediterranean (Volterrani et al., 2001; Geren et al., 2009; Demiroglu et al., 2010; Kir et al., 2010; Salman et al., 2011) and temperate climates (Gaussoin, 1994; Steir and Koeritz, 2008) but far less is known about the performance and response of tropical turfgrasses to trampling. Although trampling-tolerant turfgrasses have been the focus of many research efforts over the past three decades (Shearman and Beard, 1975; Hacker, 1987; Taivalmaa et al., 1998; Park et al., 2005) and the performance of some tropical species and cultivars have been studied (Wood and Law, 1972; Evans, 1988; Minner et al., 1993), surprisingly none of these studies have investigated the performances of warm season turfgrasses and their response to trampling. Even in well-established turf, intensive use is a major factor which reduces turf density, particularly use in rainy weather in finer-textured soils with poor drainage (Murphy, 2004).

Differences in trampling tolerance among plant species have been viewed by some authors from the morphological point of view (Bates, 1938; Tachibana, 1976; Sun and Liddle, 1993). Species in trampled habitats are believed to have prostrate growth in which most of their growing point is in contact with the ground surface. The strength of aerial organs in some grass species has been reported to favour trampling tolerance (Kobayashi and Hori, 2000).

In this study, the performance of five grasses; three creepers and two bunch- type (tussock) grasses, at different combinations under the low-mowing (clipping) and the trampling conditions in a tropical climate was assessed.

MATERIALS AND METHODS

The study area

The field study was carried out at the Teaching and Research Farm (T&RF), Obafemi Awolowo University Campus, Ile-Ife, Nigeria: latitude 7˚23' N and longitude 4˚ 37' E. The vegetation of the area falls within the rain forest belt where there are two prominent seasons, the rainy season and the dry season. The dry season is short, usually from November to March while the rainy season lasts the remaining seven months. The rainfal1 pattern is bimodal with peaks in July and September/October, and total annual precipitation is between 1200 mm and 1500 mm with over 1800 mm in some very rainy years. Daily temperatures do not fluctuate considerably with a maximum between 27 ˚C and 35 ˚C and a minimum between 18.9 ˚C and 23.3 °C.

Soil characteristics of the experimental site

The study area is associated with rolling topography with slope range of 3-6 % and lies within the basement complex with the underlying rock consisting of granites, gneisses, and undifferentiated schists that were mapped and grouped as Iwo Association by Smyth and Montgomery (1962), and classified as ferruginous tropical soils.

The experimental site has a slightly acidic (pH = 6.4), well-drained sandy-loam soil with the sand, silt and clay in the proportions 72.8: 15.1: 12.1. Soil organic carbon, total N and available P were 19.8 g/kg, 0.18 g/kg and 3.35 mg/kg, respectively. The soil exchangeable cations Na^+, K^+, Ca^{2+} and Mg^{2+} were 0.09, 0.29, 1.65 and 0.11 $cmol.kg^{-1}$ respectively.

Experimental design and protocol

The five perennial turfgrasses, *Axonopus compressus* (Sw.) P. Beauv., *Chrysopogon aciculatus* (Retz.) Trin., *Dactyloctenium aegyptium* (L.) Willd., *Eleusine indica* (L.) Gaertn., and *Sporobolus pyramidalis* (P. Beauv.), with their mixtures tested, made fifteen entries. The former three grass species are creeping while the latter two species are tussocks. The entries were tested with and without the association with *Desmodium triflorum* (Linn.) DC. The fifteen entries of grass species and their mixtures are the whole-plot levels, whereas the legume versus no legume factor is the sub-plot factor. The set-up consisted of 90 subplots of 0.5 m × 0.5 m each separated by a 0.2 m alley and arranged in a 15 by 2 factorial treatment fitted in a split-plot design and was replicated three times. The grass species and *Desmodium* in all the treatments were established on 15th June by planting tillers. Grass ground cover was measured weekly, starting from 14th July using a 0.04 m^2 quadrat with a regular 4 × 4 grid and placed at two different points selected using random numbers, each point corresponds to positions along x and y axis for each subplot. The grid nodes of the quadrats touching grass species in each sub-plot were counted from the two selected points weekly at the same points in all the subplots. Percentage ground cover was calculated by dividing the number of points touching grass species by thirty-two (16 nodes x 2) and multiplied by 100. Eleven weeks after planting (11 WAP), the grasses in each subplot were clipped 2 cm above ground and left to re-grow for another 3 weeks after which ground cover measurement resumed. Starting from seven weeks after clipping (7 WAC), the grasses were trampled daily by a 66 kg man wearing soccer boots for two weeks. The trampling consisted of pressing the foot 30 times on top of the plants at different positions within each subplot. Weekly assessment of ground cover of green turfs in each subplot weeks after trampling (WAT) was done for 6 weeks.

Data processing and statistical analyses

The effects of grass species or mixture and presence/absence of legume on percentage ground cover were examined using three-way ANOVA model performed with the Proc ANOVA in SAS for Windows (SAS, 2003). Means were separated using least significant difference (LSD) at α = 0.05. The linear model for the ANOVA procedure is represented by:

$$Y_{ijk} = \mu + R_i + G_j + RG_{(ij)} + L_k + (GL)_{jk} + e_{(ijk)}$$

Where $i = 1, 2, \ldots, 3$; $j = 1, 2, \ldots, 15$; $k = 1, 2$

R_i is the replicated block factor (random); G_j is the grass species/combinations effect or whole-plots factor (fixed); L_k is the legume effect or subplot factor (fixed); $RG_{(ij)}$ is the whole-plot error (random); $(GL)_{jk}$ is the grass species-legume interaction effect (fixed); and $e_{(ijk)}$ is the sub-plot error (random).

RESULTS

During the period of establishment of the turf (4 – 11 WAP), there were significant differences in ground cover of the grass species and their mixtures (Table 1a). Sole stand of *Eleusine* had the highest ground cover except at 9 WAP (96.35%) and 10 WAP (98.44%). Most grass species and their mixtures had 100% ground cover at 11 WAP except the sole stands of *Chrysopogon* (88.54%), *Sporobolus* (95.31%), and grass mixture of *Chrysopogon* + *Sporobolus* (93.75%) (Table 1b). There were significant differences due to the presence of the legume (*Desmodium*) from 7 - 11 WAP, but not from 4 - 6 WAP (Table 1a). The interaction between grass species/mixtures and *Desmodium* was significant from 7 - 11 WAP.

Weeks after clipping (WAC), there were significant differences in ground cover in grass species and their mixtures at 3 WAC and 6 WAC (Table 2). Although, the sole stands *Axonopus* and *Dactyloctenium*, with *Axonopus* + *Dactyloctenium* had 100% ground cover at 4 WAC, the ground cover in these sole stands were not consistent from our observations at 5 WAC. Ground-cover in subplots with *Chrysopogon* + *Sporobolus* and *Chrysopogon* + *Dactyloctenium* reduced by about 6.5% at 5 WAC. All grass species with their mixtures had 100% ground cover at 7 WAC, except *Chrysopogon* + *Sporobolus* with 99.48% ground cover (Table 2). There was significant difference in the ground cover of grass species and their mixtures between subplots with *Desmodium* and those without the legume at 3 WAC and 4 WAC and average ground cover was 100% in subplots with legume at 7 WAC (Table 3). The interaction between the grass species/mixtures and legume was significant only at 6 WAC (Table 2).

Table 1a. F-statistics to determine the effect of treatment and their interactions on ground cover (%) in grasses and their mixtures weeks after planting (WAP)

		4 WAP		**5 WAP**		**6 WAP**		**7 WAP**	
Source	*df*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Grass	14	2.25	0.0333	5.38	<.0001	6.18	<.0001	13.58	<.0001
Grass × Rep.	28								
Legume	1	2.22	0.1470	0.39	0.5361	2.63	0.1152	6.95	0.0131
Grass × Legume	14	1.48	0.1789	0.86	0.6073	1.36	0.2336	2.05	0.0489
Grass × Legume × Rep.	30								
Total	89								
		8 WAP		9 WAP		10 WAP		11 WAP	
Grass	14	15.21	<.0001	9.70	<.0001	6.77	<.0001	10.36	<.0001
Grass × Rep.	28								
Legume	1	22.15	<.0001	20.22	<.0001	10.67	0.0027	20.51	<.0001
Grass × Legume	14	5.16	<.0001	4.71	0.0002	3.78	0.0011	8.23	<.0001
Grass × Legume × Rep.	30								
Total	89								

Table 1b. Percentage ground cover in grass species and their mixtures weeks after planting (WAP) in trial plots. $LSD_{0.05}$ is least significant difference at α=0.05 and means with the same letter(s) down the column are not significant.

	Grass species/Grass combination	**4WAP (%)**	**5WAP (%)**	**6WAP (%)**	**7WAP (%)**	**8WAP (%)**	**9WAP (%)**	**10WAP (%)**	**11WAP (%)**
1	*Axonopus compressus*	15.63^{bcde}	23.44^{cdef}	53.65^{bcd}	76.56^{bcde}	87.50^{bcd}	90.62^{abc}	100.00^{a}	100.00^{a}
2	*Chrysopogon aciculatus*	11.46^{bcde}	13.54^{ef}	23.44^{f}	38.54^{f}	54.17^{e}	68.23^{d}	88.02^{cd}	88.54^{c}
3	*Sporobolus pyramidalis*	5.21^{e}	15.10^{ef}	26.04^{ef}	50.52^{f}	61.46^{e}	65.10^{d}	93.23^{bc}	95.31^{b}
4	*Eleusine indica*	29.69^{a}	53.65^{a}	75.00^{a}	93.23^{a}	98.44^{a}	96.35^{ab}	98.44^{ab}	100.00^{a}
5	*Dactyloctenium aegyptium*	13.02^{bcde}	29.17^{bcde}	58.85^{abc}	84.90^{abcd}	94.27^{abc}	95.83^{abc}	100.00^{a}	100.00^{a}
6	*Axonopus + Chrysopogon*	10.42^{bcde}	19.27^{def}	38.54^{cdef}	72.40^{de}	84.37^{cd}	94.79^{abc}	100.00^{a}	100.00^{a}
7	*Axonopus + Sporobolus*	8.85^{cde}	15.10^{ef}	34.90^{def}	66.15^{e}	82.29^{d}	84.90^{c}	98.96^{a}	100.00^{a}
8	*Axonopus + Eleusine*	20.31^{abc}	44.79^{ab}	67.52^{ab}	89.58^{ab}	92.19^{abcd}	96.87^{a}	100.00^{a}	100.00^{a}
9	*Axonopus + Dactyloctenium*	9.90^{bcde}	22.92^{cdef}	45.31^{cde}	75.00^{cde}	87.00^{bcd}	87.50^{abc}	100.00^{a}	100.00^{a}
10	*Chrysopogon + Sporobolus*	12.50^{bcde}	12.50^{f}	20.83^{f}	43.23^{f}	58.33^{e}	60.94^{d}	84.90^{d}	93.75^{b}
11	*Chrysopogon + Eleusine*	21.87^{ab}	38.54^{abc}	56.25^{abc}	82.29^{abcd}	90.62^{abcd}	93.23^{abc}	96.87^{ab}	99.48^{a}
12	*Chrysopogon + Dactyloctenium*	9.37^{cde}	22.40^{def}	40.10^{cdef}	65.62^{e}	84.37^{cd}	89.06^{abc}	100.00^{a}	99.48^{a}
13	*Sporobolus + Eleusine*	17.71^{abcd}	41.15^{ab}	67.71^{ab}	85.94^{abc}	92.71^{abcd}	93.23^{abc}	100.00^{a}	100.00^{a}
14	*Sporobolus + Dactyloctenium*	7.81^{de}	18.23^{def}	44.79^{cde}	66.67^{e}	86.46^{cd}	85.42^{bc}	100.00^{a}	100.00^{a}
15	*Eleusine + Dactyloctenium*	18.23^{abcd}	33.33^{bcd}	75.52^{a}	91.15^{a}	97.40^{ab}	97.92^{a}	100.00^{a}	100.00^{a}
	$LSD_{0.05}$	12.49	15.89	21.19	13.51	10.43	11.27	5.38	3.00

There were significant differences in ground cover among the grass species and their mixtures in all the weeks after trampling (1 – 6 WAT). Subplots with *Desmodium* had significantly higher ground cover of grass species/mixtures except at 1 WAT. There were no significant interactions between grass species/mixtures and presence or absence of *Desmodium* at 1, 2 and 6 WAT (Table 4a). Sole stand of *Dactyloctenium* and *Chrysopogon* + *Dactyloctenium* had below 50% ground cover after trampling. Regrowth was fast in stands of *Axonopus* (sole and mixed) but only the sole stand had 100% cover at 6 WAT (Table 4b). Ground cover of grasses and their mixtures in both subplots with *Desmodium* and those without were below 100% at 6 WAT (Table 2).

DISCUSSION

The consistent dominance of *Eleusine* during the establishment period could be ascribed to its high tiller density, combined with higher leaf conductance and greater net photosynthesis especially in areas with abundant rainfall (Kobayashi and Hori, 2000). Increased tillering will not only favour ground cover but also enhances the visual quality and the overall performance of the turf (Park et al., 2005). This is achieved as increase in aboveground parts cover up the bare ground rapidly. Murphy and Park (2005) emphasized fast germination and rapid establishment in turfgrass species, as necessary to provide a dense turf within the shortest period. The other tussock species (*Sporobolus*) as well as the three creeping species (*Chrysopogon*, *Axonopus* and *Dactyloctenium*) had low ground cover. The tall slender stems, narrower leaves and fewer tillers in *Sporobolus* probably accounted for the lower ground cover. This is in conformity with the report by Sharma (1984). The low ground cover in *Chrysopogon* was due to its uneven spread resulting from the continued apical dominance. By contrast, the other creepers (*Axonopus* and *Dactyloctenium*) lost apical dominance sooner and their axillary buds spread out and covered the ground fast. The lower ground cover in the *Chrysopogon* and *Sporobolus* also affected the ground cover of their mixed stands were poorest among the mixed grass species. This corroborates Austin's (1982) report that performance of species in mixed stands can be modelled from their individual performance in monoculture.

Table 2. F-statistics to determine the effect of treatment and their interactions on ground cover (%) in grasses and their mixtures weeks after clipping (WAC). Bottom part table shows **g**round cover (%) in grasses and their mixtures from 3 – 7 WAC in trial plots. $LSD_{0.05}$ is least significant difference at α=0.05 and means with the same letter(s) down the column are not significant.

		3 WAC		4 WAC		5 WAC		6 WAC		7 WAC	
Source	*df*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Grass	14	2.70	0.0123	1.64	0.1275	1.63	0.1308	2.10	0.0459	1.00	0.4793
Grass × Rep.	28										
Legume	1	10.81	0.0026	6.99	0.0129	0.84	0.3674	1.47	0.2347	1.00	0.3253
Grass × Legume	14	0.92	0.5535	1.15	0.3627	1.18	0.3415	2.95	0.0063	1.00	0.4777
Grass × Legume × Rep.	30										
Total	89										
		Ground cover (%)									
Grasses and mixtures											
Axonopus compressus		98.96^{a}		100.00^{a}		98.96^{a}		100.00^{a}		100.00^{a}	
Chrysopogon aciculatus		86.98^{de}		83.85^{c}		88.54^{ab}		97.40^{a}		100.00^{a}	
Sporobolus pyramidalis		85.94^{e}		89.06^{bc}		90.10^{ab}		95.83^{ab}		100.00^{a}	
Eleusine indica		89.06^{bcde}		97.40^{ab}		99.48^{a}		98.44^{a}		100.00^{a}	
Dactyloctenium aegyptium		95.83^{abc}		100.00^{a}		99.48^{a}		100.00^{a}		100.00^{a}	
Axonopus + Chrysopogon		94.79^{abcd}		97.92^{ab}		99.48^{a}		100.00^{a}		100.00^{a}	
Axonopus + Sporobolus		98.44^{a}		96.87^{ab}		91.15^{ab}		100.00^{a}		100.00^{a}	
Axonopus + Eleusine		98.44^{a}		98.96^{ab}		95.83^{a}		98.96^{a}		100.00^{a}	
Axonopus + Dactyloctenium		97.92^{a}		100.00^{a}		100.00^{a}		100.00^{a}		100.00^{a}	
Chrysopogon + Sporobolus		92.71^{abcde}		90.10^{abc}		83.85^{b}		92.19^{b}		99.48^{b}	
Chrysopogon + Eleusine		88.90^{bcde}		96.87^{ab}		98.95^{a}		98.44^{a}		100.00^{a}	
Chrysopogon + Dactyloctenium		96.35^{ab}		95.83^{ab}		89.06^{ab}		96.35^{ab}		100.00^{a}	
Sporobolus + Eleusine		92.19^{abcde}		92.19^{abc}		96.35^{a}		97.92^{a}		100.00^{a}	
Sporobolus + Dactyloctenium		96.35^{ab}		97.92^{ab}		97.92^{a}		100.00^{a}		100.00^{a}	
Eleusine + Dactyloctenium		88.02^{cde}		96.35^{ab}		97.92^{a}		99.48^{a}		100.00^{a}	
$LSD_{0.05}$		8.09		10.62		11.69		4.38		0.39	

Table 3. Ground cover (%) of grasses and their mixtures in subplots with *Desmodium* (Legume) and without the legume (No Legume) weeks after planting, clipping and trampling. $LSD_{0.05}$ is least significant difference at α=0.05 and means with the same letter(s) down the column at WAP, WAC and WAT are not significant.

	Ground Cover of Grass (%)							
Subplot	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP	9 WAP	10 WAP	11 WAP
Legume	15.07 ± 1.67^{a}	26.18 ± 2.42^{a}	50.95 ± 3.34^{a}	75.00 ± 2.66^{a}	87.15 ± 1.72^{a}	90.07 ± 1.50^{a}	98.75 ± 0.47^{a}	99.44 ± 0.23^{a}
No Legume	13.19 ± 1.59^{a}	27.57 ± 2.56^{a}	46.18 ± 3.65^{a}	69.24 ± 3.28^{b}	79.72 ± 3.07^{b}	83.26 ± 2.79^{b}	95.97 ± 1.33^{b}	97.43 ± 0.93^{b}
$LSD_{0.05}$	4.56	5.80	7.74	4.93	3.81	4.11	1.96	1.09
	3 WAC	4 WAC	5 WAC	6 WAC	7 WAC			
Legume	96.89 ± 0.70^{a}	97.36 ± 0.96^{a}	95.76 ± 1.36^{a}	98.68 ± 0.58^{a}	100.00 ± 0.00^{a}			
No Legume	89.91 ± 1.84^{b}	93.75 ± 1.51^{a}	94.44 ± 1.36^{a}	97.99 ± 0.57^{a}	99.93 ± 0.07^{a}			
$LSD_{0.05}$	8.09	3.88	4.27	1.60	0.14			
	1 WAT	2 WAT	3 WAT	4 WAT	5 WAT	6 WAT		
Legume	61.11 ± 2.87^{a}	85.62 ± 1.25^{a}	88.18 ± 1.02^{a}	93.20 ± 0.70^{a}	96.46 ± 0.59^{a}	95.90 ± 0.79^{a}		
No Legume	60.62 ± 3.21^{a}	81.62 ± 1.81^{b}	85.21 ± 1.61^{b}	88.82 ± 1.40^{b}	92.15 ± 1.45^{b}	93.40 ± 1.19^{b}		
$LSD_{0.05}$	2.05	3.40	2.82	1.25	1.58	1.64		

The mixed stand of *Axonopus* with either *Eleusine* or *Sporobolus* had the highest ground cover (98.44%) at 3WAC despite the low value in the sole stand of *Eleusine* and *Sporobolus* (Table 3), because clipping did not have much effect on ground cover of *Axonopus* unlike tussock species which were quite affected by clipping. The long sub-crown internodes and coarse nature of the leaves in *Eleusine* and *Sporobolus* contributed to the losses of ground cover after clipping. This reduction in aboveground growth over time with regular clippings has previously been documented by other defoliation studies (Savelle and Heady, 1970; Heady, 1975) which is in agreement with Hawes' (1980) report, that creeping grasses are better adapted to low mowing. This explains why combinations of either *Axonopus* or *Dactyloctenium* with *Sporobolus* resulted in a high ground cover. Although *Chrysopogon* possesses some features such as fine short leaf blades and short internodes that enhance adaptability to low mowing, its slow growth and uneven spread of the aerial parts accounted for the fluctuations in ground cover at 5 WAC in mixtures with *Sporobolus* and *Dactyloctenium*, and the low performance during this experiment. Unlike sole *Axonopus* and *Dactyloctenium* which reached 100% ground cover at 4 WAC, the turf of sole *Chrysopogon* require about 7 weeks to reach full ground-cover if mowed low to about 2 cm to the ground.

Table 4a. F-statistics to determine the effect of treatment and their interactions on ground cover (%) in grasses and their mixtures weeks after trampling (WAT).

		1 WAT		**2 WAT**		**3 WAT**	
Source	*df*	*F*	*P*	*F*	*P*	*F*	*P*
Grass	14	9.88	<0.0001	5.84	<0.0001	6.21	<0.0001
Grass × Rep.	28						
Legume	1	0.04	0.8376	6.36	0.0172	6.47	0.0163
Grass × Legume	14	1.56	0.1490	1.19	0.3302	2.91	0.0068
Grass × Legume × Rep.	30						
Total	89						
		4 WAT		**5 WAT**		**6 WAT**	
Grass	14	25.67	<0.0001	17.09	<0.0001	14.56	<0.0001
Grass × Rep.	28						
Legume	1	24.85	<0.0001	30.27	<0.0001	8.53	0.0066
Grass × Legume	14	4.22	0.0005	4.30	0.0004	0.72	0.7419
Grass × Legume × Rep.	30						
Total	89						

Table 4b Ground cover (%) in grass species and their mixtures weeks after trampling (WAT) in trial plots. $LSD_{0.05}$ is least significant difference at α = 0.05 and means with the same letter(s) down the column are not significant.

	Grasses and mixtures	**1WAT (%)**	**2WAT (%)**	**3WAT (%)**	**4WAT (%)**	**5WAT (%)**	**6WAT (%)**
1	*Axonopus compressus*	76.04^{ab}	89.58^{ab}	94.79^{a}	97.92^{a}	100.00^{a}	100.00^{a}
2	*Chrysopogon aciculatus*	51.56^{d}	82.29^{bcd}	84.37^{cde}	88.02^{fg}	93.75^{bcd}	94.27^{cdef}
3	*Sporobolus pyramidalis*	70.31^{abc}	87.58^{ab}	91.67^{abc}	94.79^{abc}	97.92^{ab}	95.83^{abcde}
4	*Eleusine indica*	66.15^{abcd}	77.77^{cd}	89.06^{abcd}	93.23^{bcd}	98.44^{a}	96.87^{abcde}
5	*Dactyloctenium aegyptium*	13.02^{f}	61.46^{e}	67.62^{f}	72.92^{h}	76.56^{f}	75.00^{g}
6	*Axonopus + Chrysopogon*	64.06^{bcd}	90.10^{ab}	89.58^{abcd}	94.79^{abc}	97.40^{ab}	96.87^{abcde}
7	*Axonopus + Sporobolus*	80.21^{a}	93.23^{a}	88.54^{abcd}	93.75^{bc}	96.87^{ab}	96.87^{abcde}
8	*Axonopus + Eleusine*	75.00^{ab}	87.00^{abc}	89.58^{abcd}	95.33^{ab}	98.96^{a}	98.96^{ab}
9	*Axonopus + Dactyloctenium*	67.19^{abcd}	85.94^{abc}	87.50^{abcd}	90.10^{def}	91.15^{d}	92.71^{ef}
10	*Chrysopogon + Sporobolus*	68.75^{abc}	82.29^{bcd}	82.29^{de}	88.54^{efg}	92.19^{cd}	93.75^{def}
11	*Chrysopogon + Eleusine*	57.29^{cd}	85.42^{abc}	89.06^{abcd}	94.27^{bc}	98.96^{a}	98.44^{ab}
12	*Chrysopogon + Dactyloctenium*	34.37^{e}	73.96^{d}	78.65^{e}	85.42^{g}	86.46^{e}	91.15^{f}
13	*Sporobolus + Eleusine*	65.10^{abcd}	84.38^{abc}	86.98^{bcd}	91.68^{def}	96.35^{abc}	96.87^{abcde}
14	*Sporobolus + Dactyloctenium*	66.67^{abcd}	86.98^{abc}	87.50^{abcd}	90.10^{def}	91.67^{d}	94.79^{bcdef}
15	*Eleusine + Dactyloctenium*	57.29^{cd}	85.94^{abc}	93.23^{ab}	94.27^{bc}	97.92^{ab}	97.40^{abcd}
	$LSD_{0.05}$	15.94	2.05	7.73	1.25	4.34	4.51

The percentage ground cover one week after trampling (1 WAT) was an indication of resistance of the turfgrass species to trampling pressure as suggested by Minner and Valverde (2005) for cool-season turfgrasses. Subsequent weeks were used to assess the grass' inherent recuperative potential. The greatest reduction in cover due to trampling was in the sole stand of *Dactyloctenium* due to its soft tender stems and leaves (i.e. low tensile strength). There was loss of verdure in the other grasses but their recovery rate (recuperative potential) was high. Despite its increase in ground cover from 13.02% to 61.46% at 2 WAT (Table 4b), *Dactyloctenium* would not be recommended for use in athletic turf or heavily trampled sites since it will result to bare ground if intensive trampling, such as in this experiment, would last for three weeks or more.

Apart from wear and divots removal on the grasses, other impacts of trampling include soil compaction and soil displacement (Park et al., 2010). Wear injury, defined by the immediate result of the crushing, tearing, and shearing actions of foot and vehicular traffic (Park et al., 2007), affects aboveground plant parts (stems, leaves, inflorescences). Only the sole *Axonopus* had 100% cover at 6 WAT but the performance of other grasses and their mixtures was also high except for sole stand of *Dactyloctenium* (Table 4b). The performance of mixed stands of *Dactyloctenium* with *Eleusine* and *Sporobolus* was better possibly due to positive interactions of these tussock species with *Dactyloctenium*. The tall and flexible stems of the tussocks, could enable cushioning of *Dactyloctenium*, potentially reducing direct trampling impacts such as bruising and shearing of the vegetative parts in the mixed stands.

The lack of significant effect of the legume species (*Desmodium*) on ground cover of the grasses and their mixtures during the early stages (4 - 6 WAP) could be due to abundance of soil nutrients, such as nitrogen and phosphorus, required for carbon uptake in both grass and legume during this period. However at 7 WAP when most of the grasses and their mixtures have covered above 50% of the ground, the demand for mineral nutrients to sustain this vegetative cover increases with enhanced competition for soil N up to 11 WAP. It is possible that the grass-legume subplots had significantly higher ground cover than the no legume grass subplots from 7 - 11 WAP due to the contribution from the legume. Most species of *Desmodium* have been reported to fix nitrogen (Dzowela, 1986; Amudavi et al., 2007) thus reducing the dependence of grass fields on inorganic fertilizers (Vendramini et al., 2010; Caddel et al., 2012). Biological nitrogen fixation is a symbiotic process in which rhizobium bacteria change inert atmospheric N_2 to NH_3 biologically useful to the legume species. Legume nitrogen fixation starts with the formation of nodule, which can be seen 2 - 3 weeks after planting, depending on the legume species and germination conditions (Lindermann and Glover, 2011). Some legume species are inoculated with *Rhizobium* to stimulate nodulation. But an uninoculated legume such as *Leucaena leucocephala* is able to form as much as 36 nodules per plant at 12 WAP (Khonje, 2012). The number of nodules per plant varies among species and their shapes depend on the life cycle of the legume (Caddel et al., 2012; Lindermann and Glover, 2012).

The clipping in the grasses resulted in active meristematic growth which induces an increase in nutrient demand. The grass-legume subplots will benefit from soil nitrogen enrichment from the legume and reduced evaporative loss of water due to closed mat formed by the legume underneath the grasses at early stage after clipping. Conversely, in pure grass stands, clipping will uncover more soil surface. Since growth is sigmoidal in nature, this difference in ground cover at later stages (4 – 7 WAC) between the subplots with legume and those without the legume were insignificant. Response of plants to defoliation, even within a single species, is a variable that is sensitive to timing, nutrient availability, and plant associations (Maschinski and Whitham, 1989).

The presence of *Desmodium* did not confer additional strength on the grasses thus grasses grown with or without the legume were recuperating from the same effect at 1 WAT and ground cover were not significantly different. This observation in ground cover at 1 WAT could also result from that fact that the non-exclusive nature of the trampling affected both grasses and the legume in the grass-legume subplots, thereby reducing their activity. Lindermann and Glover (2011) asserted that any stress that reduces legume activity will ultimately reduce nitrogen fixation. This is because nitrogen fixation is a symbiotic process that requires the plant to contribute some amount of photosynthates and other nutritional factors to the bacteria and this contribution is often compromised when the plant (legume) is stressed. However, when such stress is corrected the legume responds directly and normal physiological process is resumed (Lindermann and Glover, 2011) as observed from 2 – 6 WAT in our result.

CONCLUSION

Fast establishment and high ground cover in turf grasses does not necessarily express resistance to trampling. Tough aerial organs with increased growth have proved a better tool to adjudging resistance to trampling than increased ground cover alone. The individual performance of the grasses in the sole stands correlated with their performances in the mixed stands. Fast recovery after trampling, a function of the growth of the grass species, was facilitated by the presence of *Desmodium*. We recommend the use of grass mixes in turfs composed of species that should have been previously identified to perform well in sole stands (e.g. *Axonopus* and *Eleusine*). Features like rapid leaf elongation, fast growth and leaf toughness in *Axonopus* and *Eleusine* should be used to breed trampling-resistant turfgrass cultivars. Inconspicuous legumes such as *Desmodium* should be planted in turfs to reduce dependence on organic fertilizers and to improve technical quality of the turf swards.

LITERATURE CITED

Amudavi, D., Z. Khan and J. Pickett, 2007. Enhancing the push-pull strategy. *LEISA Magazine*, 23(4): 8-10

Austin, M.P., 1982. Use of relative physiological performance value in the prediction of performance of multispecies mixtures from monoculture performance. *J. Ecol.*, 70: 559-570

Bates, G.H., 1938. Life forms of pasture plants in relation to treading. *J. Ecol*., 26: 452-454

Busey, P., 2003. Cultural management of weeds in turfgrass: a review. *Crop Sci.*, 43: 1899-1911

Caddel, J., D. Redfearn, H. Zhang, J. Edwards and S. Deng, 2012. *Forage Legumes and Nitrogen Production*. Oklahoma Cooperative Extension Fact Sheets PSS-2590. Division of Agricultural Sciences and Natural Resources, Oklahoma State University. Available at http://osufacts.okstate.edu

Demiroglu, G., H. Geren, B. Kir and R. Avcioglu, 2010. Performances of some cool season turfgrass cultivars in Mediterranean environment: II. *Festuca arundinacea* Screb., *Festuca ovina* L., *Festuca rubra* spp. *rubra* L., *Festuca rubra* spp. *trichophylla* Gaud and *Festuca rubra* spp. *commutate* Guad. *Turk J Field Crops.*, 15: 180-187

Dzowela, B.H., 1986. Value of a forage legume component in summer beef fattening systems in Malawi. *In*: Haque, I., S. Jutzi, and P.J.H. Neate (eds.), *Potentials of Forage Resumes in Farming Systems of Sub-Saharan Africa*. Proceedings of a Workshop held at ILCA, Addis Ababa, Ethiopia, 16 -19 September 1985. ILCA, Addis Ababa, Ethiopia.

Evans, G.E., 1988. Tolerance of selected Bluegrass and Fescue taxa to simulated human foot traffic. *J. Environ. Hort.*, 6: 10-14

Gaussoin, R.E., 1994. Choosing traffic-tolerant turfgrass varieties. *Sports Turf*, 10: 25-26

Geren, H., R. Avcioglu and M. Curaoglu, 2009. Performance of some warm-season turfgrasses under Mediterranean conditions. *Afr. J. Biotech.*, 8: 4469-4474

Hacker, J.W., 1987. Wear tolerance in amenity and sports turf: A review 1980-1985. *Acta Hort.*, 195: 35-41

Hawes, D.T., 1980. Response of warm- and cool-season turfgrass polystands to nitrogen and topdressing. *In*: *Proceedings of the Third International Turfgrass Research Conference*, Munich, Germany. July 11-13, 1977. International Turfgrass Society, ASA, CSSA and SSSA, Madison, WI, USA.

Heady, H.F., 1975. Physical effects of grazing animals. *In*: Heady, H.F. (Ed.), *Rangeland Management*. McGraw-Hill, USA.

Khonje, D.J., 2012. Adoption of the rhizobium inoculation technology for pasture improvement in sub-Saharan Africa. *In*: *FAO Corporate Document Repository* available at http://www.fao.org/wairdocs/ILRI/x5536E/x5536e1g.htm

Kir, B., R. Avcioglu, G. Demiroglu and A. Simic, 2010. Performances of some cool season turfgrass species in Mediterranean environment: I. *Lolium perenne* L., *Festuca arundinacea* Schreb., *Poa pratensis* L., and *Agrostis tenuis* Sibth. *Turkish J. Field Crop*., 15: 174-179

Kobayashi, T. and Y. Hori, 2000. Photosynthesis and water-relation traits of the summer annual C_4 grasses, *Eleusine indica* and *Digitaria adscendens*, with contrasting trampling tolerance. *Ecol. Res.* 15: 165-174

Lindermann, W.C. and C.R. Glover, 2011. Nitrogen Fixation by Legumes. New Mexico University Extension Guide A-129. New Mexico State University, New Mexico. Available at http://aces.nmsu.edu/pubs/_a/A-129/welcome.html

Maschinski, J. and T.G. Whitham, 1989. The continuum of plant response to herbivory: The influence of plant-association, nutrient availability, and timing. *Amer. Nat.*, 134: 1-19

Minner, D.D. and F.J. Valverde, 2005. Performance of established cool-season grass species under simulated traffic. *Int. Turfgrass Soc. Res. J.*, 10: 393-397

Minner, D.D., J.H. Dunn, S.S. Burghrara and B.S. Fresenburg, 1993. Traffic tolerance among cultivars of Kentucky bluegrass, tall fescue, and perennial ryegrass. *Int. Turfgrass Soc. Res. J.*, **7**: 687-694

Murphy, J.A. and B.S. Park, 2005. Turfgrass establishment procedures for sports fields. Rutgers Cooperative Research and Extension, New Jersey Agricultural Experiment Station, Bulletin E300.

Murphy, J.A. 2004. Maintaining athletic fields. Rutgers Cooperative Research and Extension, New Jersey Agricultural Experimental Station, Fact Sheet FS105. The State University of New Jersey, New Brunswick.

Park, B.S., T.J. Lawson, H. Samaranayake, and J.A. Murphy, 2010. Tolerance and recovery of Kentucky bluegrass subjected to seasonal wear. *Crop Sci.*, 50: 1526-1536

Park, B.S., J.A. Murphy, T.J. Lawson, W.K. Dickson and B. Clark, 2007. Did Kentucky bluegrass and tall fescue cultivars and selections differ in response to traffic stress in 2007? *In*: *2007 Rutgers Turfgrass Proceedings of the New Jersey Turfgrass Association*, December 4-6, 2007.

Park, B.S., J.A. Murphy, W.A. Meyer, S.A. Bonos, J. den Haan, D.A. Smith and T.J. Lawson, 2005. Performance of Kentucky bluegrass within phenotypic classifications as affected by traffic. *Int. Turfgrass Soc. Res. J.*, 10: 618-626

Salman, A., R. Avcioglu, H. Oztarhan, A.C. Cevheri and H. Okkaoglu, 2011. Performances of different cool season turf grasses and some mixtures under Mediterranean environmental condition. *Int. J. Agric. Biol.*, 13: 529-534

SAS Institute, 2003. *SAS/STAT 9 Users Guide*. SAS Institute Inc., Cary, NC, USA.

Savelle, G.D. and H.F. Heady, 1970. Mediterranean annual species: Their response to defoliation. Process XI International Grassland Congress.

Sharma, B.M., 1984. Ecophysiological studies of *Eleusine indica* (L.) Gaertn.and *Sporobolus pyramidalis* P. Beauv. at Ibadan, Nigeria. *J. Range Managmt.*, 37: 275-276

Shearman, R.C. and J.B. Beard, 1975. Turfgrass wear tolerance mechanisms: I. Wear tolerance of seven turfgrass species and quantitative methods for determining wear tolerance. *Agron. J.* 67: 208-211

Smyth, A.J. and R.F. Montgomery, 1962. *Soils and Land Use in Central Western Nigeria*. Ibadan Government Printers.

Steir, J.C. and E.J. Koeritz, 2008. Seeding dates for tall fescue (*Festuca arundinacea* Schreb.) athletic fields established in a temperate continental climate. *Acta Hort.*, 783: 49-56

Sun, D. and M.J. Liddle, 1993. The morphological responses of some Australian tussock grasses and the importance of tiller number in their resistance to trampling. *Biol. Cons.*, 65: 43-49.

Tachibana, H., 1976. Changes and revegetation in sphagnum moors destroyed by human treading. *Ecol. Rev.*, 18: 133-210.

Taivalmaa, S.L., H. Talvitie, L. Jauhiainen and O. Niemelainen, 1998. Influence of wear-stress on turfgrass species and cultivars in Finland. *J. Turf. Sci.* 74: 52-62

Vendramini, J., M.B. Adjei, and A.E. Kretschmer Jr., 2010. Florida Carpon Desmodium. *Florida Forage Handbook Document SS-AGR-11*, Institute of Food and Agricultural Sciences (IFAS), University of Florida. Available at http://edis.ifas.ufl.edu/pdf/pdffiles/AG/ AG24900.pdf

Volterrani, M., S. Miele, S. Magni, M. Gaetani and G. Pardini, 2001. Bermudagrass and seashore paspalum overseeded with seven cool-season turfgrasses. *Int. Turfgrass Soc. Res. J.*, 9: 957-961

Wood, G.M. and A.G. Law, 1972. Evaluating bluegrass cultivars for wear resistance. In: *1972 Agronomy Abstracts*. ASA, Madison, WI. pp.65.