

# Wear Tolerance, Growth, and Quality of Seashore Paspalum in Response to Nitrogen and Potassium

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**Abstract.** Damage from traffic can seriously injure athletic field turfgrass, although fertility regimes can influence wear tolerance. While excess nitrogen (N) can reduce wear tolerance, moderate N has improved tolerance and hastened recovery from injury. Potassium (K) may enhance wear tolerance through regulation of turgor potential. This research was undertaken to determine shoot growth and wear tolerance of seashore paspalum (*Paspalum vaginatum* Swartz) to N and K application. Field studies were conducted in 1998 at the Univ. of Georgia Experiment Station, Griffin. Grasses were established on U.S. Golf Association specification greens in 1996. Fertility treatments were applied at annual N rates of 196 and 392 kg-ha<sup>-1</sup> and K rates of 92 and 392 kg-ha<sup>-1</sup>. The higher N rate increased wear tolerance, shoot growth, shoot density, visual quality, and color of the two ecotypes, AP 10 and AP 14, but reduced their visible range spectral reflectance, indicating greater absorption of photosynthetically active radiation (PAR). Measured responses to K were minimal and no enhancement of wear tolerance in response to K treatment was noted.

Traffic can impose two distinct forms of injury on turf. Wear injury to shoot tissue is manifested by abrasion or tearing of leaf tissue, resulting in chlorophyll degradation and reduced photosynthesis. The second type of traffic damage, soil compaction, is initially expressed in the root zone. The overall effects of either injury is inhibition of turf growth, loss of shoot density, and premature senescence of shoot or root tissue. Rates of recovery vary based on inherent growth rate and degree of severity of the injury.

The two elements required in greatest quantity for turfgrass growth and quality are N and K, and can also influence turfgrass tolerance to environmental stresses. While enhanced shoot growth following N applications can reduce tolerance to wear injury (Beard, 1973), moderate N fertility can increase wear tolerance in cool-season grasses (Carroll and Petrovic, 1991; Shearman and Beard, 1975).

The influence of K on wear tolerance is less distinct. Beard (1973) stated that high K levels increased wear tolerance by increasing turgidity and reducing tissue succulence. Creeping bentgrass (*Agrostis palustris* Huds.) cv. Toronto had significantly improved wear tolerance following application of K at 270 or 360 kg-ha<sup>-1</sup> (Shearman and Beard, 1975). In contrast, Hawes and Decker (1977) and Carroll and Petrovic (1991) found no influence of K on wear tolerance or recovery from wear in Kentucky bluegrass (*Poa pratensis* L.) and creeping bentgrass. Likewise, recovery of bermudagrass (*Cynodon dactylon* × *C. transvaalensis* Burt-Davy) from coring and verticutting was not enhanced by K (Carrow et al., 1987).

Seashore paspalum is a prostrate-growing, salt-tolerant warm-season turfgrass native to tropical and coastal environments. A diverse species, it displays a wide range of tolerance to multiple environmental stresses, particularly salinity (Dudeck and Peacock, 1985; Harivandi et al., 1984; Marcum and Murdoch, 1990, 1994), drought (Beard et al., 1991), and flooding (Malcolm, 1969).

Although the literature contains multiple reports of the influence of N and K on wear tolerance of cool-season turfgrass species (Canaway, 1984; Carroll and Petrovic, 1991; Hawes and Decker, 1977; Shearman and Beard, 1975), reports of wear tolerance in warm-season species are limited. Additionally, nutritional requirements of new turfgrass introductions may differ from requirements of grasses currently in use. This research was

undertaken to: 1) provide guidelines for judicious use of N and K on seashore paspalum; and 2) evaluate the influence of N and K on wear tolerance of this species.

## Materials and Methods

This research was conducted at the Univ. of Georgia Experiment Station in Griffin, and was repeated twice during the 1998 growing season with very similar results. Only results of the first trial are presented here.

Two seashore paspalum ecotypes, AP 10 and AP 14 (selections from Alden Pines Golf Club, Ft. Myers, Fla.), were established on U.S. Golf Association (USGA)-specification, sand-based greens in Summer 1996. Plots were mowed three times weekly with a greens reel mower at 4 mm and clippings were removed. Plots were verticut and topdressed at the start of the growing season. Topdressing material was identical to the sand-based mix in which the grasses were growing. Irrigation was provided as needed throughout the test period to prevent wilting.

Evaluations included turf quality, turf density, and percentage of shoot tissue injury. Visual quality ratings were based on color, shoot density, and uniformity of stand, where 1 = no live grass and 9 = dark-green, dense, uniform grass. Turf density ratings were based only on shoot density, where 1 = no grass and 9 = uniform dense grass. Shoot tissue injury (STI), which was taken on wear-treated plots only, was defined as the percentage of leaves visually seen as injured (chlorotic) or killed (necrotic) because of wear. Wear tolerance was defined as 100-STI.

Treatments were arranged in a factorial combination of two N and two K rates with four replications and were applied every 10 to 12 d. Nitrogen was applied as ammonium nitrate at 19.6 or 39.2 kg-ha<sup>-1</sup> for 10 applications, for total annual rates of either 196 or 392 kg-ha<sup>-1</sup>. Potassium was applied as potassium chloride at 9.2 or 39.2 kg-ha<sup>-1</sup> for annual rates of either 92 or 392 kg-ha<sup>-1</sup>. A single wear treatment, sufficient to cause adequate shoot tissue injury for data collection, was applied on 25 June. The wear treatment was applied in a strip within replications as 74 multiple passes at one time. A differential slip wear device with rubber-covered rollers was used for applying wear at 0.90 kg-cm<sup>-1</sup> of force. The differential slip arrangement allowed the rollers to turn at different speeds so that abrasion and scuffing actions were created.

A greens reel mower set at a mowing height of 4 mm was used to collect shoot growth clippings from a 0.5-m<sup>2</sup> area from the center of the plots. Shoot tissue was analyzed for percentage of cell wall components (total cell wall, cellulose, hemicellulose, lignocellulose, and lignin) following the methodology of Goering and Van Soest (1970). Quantity of verdure tissue was measured by pulling three 5.7-cm-diameter cores per plot following mowing. All tissue was removed from cores with shears, collectively dried in a forced air drier at 70 °C, and weighed. Counts were taken on number of shoots per core.

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Table 1. Average quality, color, density, and shoot tissue injury scores (STI) of two seashore paspalum ecotypes as influenced by N and K at 7 and 14 d after wear treatment (DAWT).

Ecotype	N -- kg-ha <sup>-1</sup> --	K	7 DAWT							14 DAWT						
			Quality		Color		Density		STI (%)	Quality		Color		Density		STI (%)
			Wear	No Wear	Wear	No Wear	Wear	No Wear	Wear	Wear	No Wear	Wear	No Wear	Wear	No Wear	Wear
AP-10	196	92	6.7	7.4	7.1	7.7	7.4	7.9	5.0	7.3	7.4	7.4	7.6	7.5	7.9	2.8
		392	6.5	7.5	7.2	7.8	7.3	7.9	7.5	7.2	7.4	7.5	7.7	7.6	7.9	2.0
	392	92	7.6	8.1	8.1	8.5	8.0	8.6	2.5	8.1	8.2	8.3	8.7	8.4	8.7	0
		392	7.8	7.9	8.2	8.3	8.1	8.4	2.5	8.1	8.3	8.4	8.7	8.5	8.8	0.8
	cv (%)		6	2	4	2	4	2	63	7	3	8	3	7	4	109
AP-14	196	92	4.8	6.3	5.3	6.5	5.3	6.7	23.8	5.0	6.0	5.4	6.2	5.6	6.4	7.5
		392	5.1	6.1	5.6	6.3	5.7	6.7	15.0	5.3	6.1	5.5	6.1	5.7	6.5	8.8
	392	92	6.9	7.7	7.3	8.0	7.1	8.1	2.5	7.3	7.7	7.6	8.0	7.6	8.1	0
		392	6.9	7.5	7.5	7.9	7.2	8.0	5.0	7.2	7.6	7.4	7.8	7.8	8.0	0
	cv (%)		9	5	8	4	8	6	65	8	6	8	5	7	5	99
<i>P</i>																
AP-10	N		0.001	0.001	0.001	0.001	0.001	0.001	0.02	0.01	0.001	0.04	0.001	0.01	0.001	0.03
	K		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	N*K		NS	NS	NS	0.10	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
AP-14	N		0.001	0.001	0.001	0.001	0.001	0.001	0.02	0.001	0.001	0.001	0.001	0.001	0.001	0.02
	K		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	N*K		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

<sup>NS</sup>Nonsignificant at  $P > 0.10$ .

Reflectance measurements were taken with a hand-held Cropscan multispectral model MSR16 radiometer (Cropscan, Rochester, Minn.) fitted with filters to measure reflectance at 507, 559, 661, 706, 760, 813, and 935 nm. In addition, the following growth and stress indices were evaluated: 1) NDVI (normalized difference vegetation index) growth index computed as  $[R_{935} - R_{661}] / [(R_{935} + R_{661})]$ ; 2) IR/R (leaf area index) growth index computed as  $R_{935} / R_{661}$ ; 3) Stress1 index computed as  $R_{706} / R_{760}$ ; and 4) Stress2 index computed as  $R_{706} / R_{813}$ .

The radiometer was held at a height of 2 m and measured a plot area of  $\approx 1$  m<sup>2</sup>. Reflectance readings were taken within a time period from 1100 to 1300 HR under conditions of minimal cloud cover.

Both of the greens ecotypes evaluated in this project were established in separate blocks; therefore, data for each were analyzed separately, using a randomized complete-block design with four replications. The wear treatment represented a strip plot within each replication of each test. General linear model analysis (SAS Institute, 1987) was used to determine significant ( $P < 0.05$ ) differences due to fertility and wear treatments.

### Results and Discussion

Nitrogen had a highly significant influence on visual turf quality scores of both ecotypes under both wear and nonwear conditions (Table 1). Application of N at 392 kg-ha<sup>-1</sup> increased turf quality, color, and density more than did N at 196 kg-ha<sup>-1</sup>, regardless of K rate. Turf color and density of both grasses at 7 and 14 days after wear treatment (DAWT) were also enhanced by the higher N rate.

In contrast with data of Beard, (1973), who stated that higher N decreased wear tolerance due to reduced thickness of cell walls and greater succulence of shoot tissue, we found that STI was reduced by the higher N rate at both 7 and 14 DAWT. Similarly, Carroll and

Petrovic (1991) and Shearman and Beard (1975) reported better wear tolerance in response to moderate N fertility in creeping bentgrass. Moderate N should produce these results, since it would yield more shoot tissue to absorb the injury, and faster regrowth of turf following wear injury.

Shoot density and verdure of both ecotypes also increased with N (Table 2). As with the visual ratings, no shoot responses to K were evident.

Cell wall components differed in response to fertility treatments only in AP-14 (Table 3), where high N reduced leaf total cell wall

(TCW), lignocellulose, and cellulose, and increased hemicellulose contents. Greater shoot growth resulting from the higher N rate produced thinner cell walls, resulting in lower TCW. In some cases, TCW and wear tolerance were negatively correlated ( $r = -0.53$  for AP 10 and  $r = -0.81$  for AP 14). This was consistent with the results of Trenholm et al. (2000a), who reported that lower leaf TCW was associated with greater wear tolerance in this species. This response was attributed to greater cell elasticity under lower TCW content. Beard (1973) reported that thinner cell walls in response to N fertilization could reduce wear

Table 2. Effects of N and K application on shoot growth, density, and verdure of 2 seashore paspalum ecotypes.<sup>z</sup>

Ecotype	N --- (kg-ha <sup>-1</sup> )---	K	Shoot growth (kg-ha <sup>-1</sup> )	Shoot density (no. cm <sup>-2</sup> )	Verdure (kg-ha <sup>-1</sup> )
AP-10	196	92	46.8	5.0	43.6
		392	63.4	5.3	46.7
	392	92	54.7	5.9	59.6
		392	68.6	5.9	52.7
	Wear		62.6	5.3	40.4
	No wear		54.1	5.8	60.9
	cv (%)		27	13	26
AP-14	196	92	38.4	4.4	48.7
		392	48.2	4.5	48.2
	392	92	39.7	5.3	57.4
		392	51.4	5.7	66.4
	Wear		45.8	4.7	48.6
	No wear		43.0	5.2	61.7
	cv (%)		35	7	31
<i>P</i>					
AP-10	N		NS	0.05	0.01
	K		NS	NS	NS
	N*K		NS	NS	NS
	Wear		NS	NS	0.03
AP-14	Wear*N*K		NS	NS	NS
	N		NS	0.001	0.01
	K		NS	NS	NS
	N*K		NS	NS	NS
	Wear		NS	0.05	0.07
Wear*N*K		NS	NS	0.05	

<sup>z</sup>Shoot growth taken at 6 DAWT. Shoot density and verdure measured at 6 and 9 DAWT.

<sup>NS</sup>Nonsignificant at  $P > 0.10$ .

tolerance, and Trenholm et al. (2000a) found that greater TCW reduced wear tolerance in coarse-leaved paspalum ecotypes, with no differences in wear tolerance among the fine-leaved ecotypes such as those evaluated in this study.

Spectral reflectance values varied primarily due to N rate and wear (Table 4). These values are indicative of the quantity of PAR absorbed by plant tissue for photochemical processes; in a turf canopy, the amount of light not reflected is generally that absorbed by the plant. Throughout the visible range wavelengths ( $R_{507}$ ,  $R_{559}$ ,  $R_{661}$ , and  $R_{706}$ ), reflectance was significantly lower at the higher N rate,

indicating greater absorption of PAR at higher N rates. Trenholm et al. (2000b) found that reflectance values in these wavelengths were inversely correlated with N rate in creeping bentgrass (Trenholm et al., 2000b). Growth (NDVI and IR/R) and stress (Stress1 and Stress2) ratios were also highly responsive to N rate. Higher values of growth ratios, indicating greater growth, and reduced stress values likewise support previous spectral research (Trenholm et al., 1999, 2000b).

Reflectance at 661 and 813 nm and the growth and stress ratios have reliably distinguished between wear-treated and nontreated plots and have shown strong associations ( $r^2 =$

0.76) with turf visual quality and density scores (Trenholm et al., 1999). Reflectance is reduced on stressed plots because of tissue senescence, loss of leaf area, or chlorophyll degradation (Carter, 1994; Carter and Miller, 1994). As in previous research, significant increases were observed in reflectance at 661 and 813 nm because of senescence and damage to shoot tissue caused by wear. The increase in reflectance suggests reduced photosynthetic capacity resulting from the injury.

Responses to K were minimal for all variables. No response of turf quality, density, color, or STI to K application was noted on wear-treated plots (Tables 1 and 2). Reports in the literature are inconsistent with regard to effects of K on wear tolerance. Similar to our results, Kentucky bluegrass and creeping bentgrass exhibited neither greater wear tolerance nor recovery from wear in response to K (Carroll and Petrovic, 1991; Hawes and Decker, 1977). Likewise, recovery of bermudagrass from coring and verticutting was not enhanced by K (Carrow et al., 1987). In contrast, applied K increased wear tolerance in seashore paspalum on a clay soil (Trenholm et al., 2001). Higher K leaf concentration has also been identified as an important nutrient mechanism involved in enhancing wear tolerance of both seashore paspalum and bermudagrass (Trenholm et al., 2000a). Potassium has been cited as enhancing wear tolerance because of greater turgidity and reduced tissue succulence (Beard, 1973), as well as effects on stomatal control and cell turgidity (Carrow, 1995).

The K amendments did not affect reflectance values in AP 10; AP 14 had slightly higher reflectance values ( $P = 0.07$  and  $0.09$ ) at 559 and 706 nm, respectively, in both stud-

Table 3. Cell wall analysis of two seashore paspalum ecotypes as influenced by N and K.

Ecotype	Treatments		Cell wall concn				
	N	K	TCW	Lignocellulose	Lignin	Hemicellulose	Cellulose
	--- kg·ha <sup>-1</sup> ---		----- g·kg <sup>-1</sup> -----				
AP-10	196	92	716.2	362.8	53.1	353.4	309.7
	196	392	688.5	319.3	64.4	369.2	254.9
	392	92	706.0	351.2	55.8	354.8	295.4
	392	392	699.0	344.8	55.5	354.2	289.3
	cv (%)		6	26	16	13	34
AP-14	196	92	709.9	391.2	61.2	318.7	330.1
	196	392	670.3	328.9	55.9	341.4	273.0
	392	92	639.3	252.1	67.6	387.2	184.5
	392	392	642.7	287.0	64.5	355.7	222.5
	cv (%)		3	14	17	8	19
			<i>P</i>				
AP-10	N		NS	NS	NS	NS	NS
	K		NS	NS	NS	NS	NS
	N*K		NS	NS	NS	NS	NS
AP-14	N		0.001	0.01	NS	0.01	0.01
	K		NS	NS	NS	NS	NS
	N*K		0.08	0.04	NS	0.06	0.06

<sup>NS</sup>Nonsignificant at  $P > 0.10$ .

Table 4. Spectral reflectance values of two seashore paspalum cultivars as influenced by N and K at 7 DAWT. Measurements taken with a Cropscan model MSR16 radiometer.

Ecotype	N	K	Wavelength (nm)											
			507	559	661	706	760	813	935	NDVI <sup>2</sup>	IR/R	Stress1	Stress2	
	--- kg·ha <sup>-1</sup> ---													
AP 10	196	92	5.3	9.6	5.3	15.0	57.2	49.8	55.7	0.82	10.6	0.26	0.30	
	196	392	5.3	9.6	5.2	15.1	58.1	50.2	56.1	0.83	10.8	0.26	0.30	
	392	92	5.0	8.8	4.8	13.9	57.9	50.1	55.8	0.84	12.0	0.24	0.28	
	392	392	5.0	8.9	4.7	14.0	59.4	51.4	57.1	0.85	12.3	0.24	0.28	
	Wear			5.2	9.2	5.5	14.5	52.2	45.1	51.4	0.81	9.5	0.28	0.32
	No wear			5.1	9.3	4.6	14.5	64.1	55.7	61.0	0.86	13.4	0.23	0.26
	cv (%)			2	2	3	2	2	4	4	1	5	3	5
AP 14	196	92	6.0	10.4	6.7	16.2	46.8	44.9	51.8	0.77	7.9	0.35	0.37	
	196	392	6.0	10.5	6.8	16.4	47.9	45.8	53.1	0.77	8.1	0.35	0.36	
	392	92	5.4	9.4	5.7	14.8	47.8	45.8	53.3	0.80	9.6	0.32	0.33	
	392	392	5.5	9.6	5.7	15.0	48.2	46.5	53.8	0.81	9.7	0.31	0.33	
	Wear			5.8	9.8	6.9	15.6	42.6	40.6	48.2	0.75	7.0	0.37	0.39
	No wear			5.6	10.1	5.5	15.6	52.7	50.9	57.7	0.83	10.6	0.30	0.31
	cv (%)			3	3	5	3	3	3	2	2	6	3	4
P	N		0.001	0.001	0.001	0.001	NS	NS	NS	0.01	0.01	0.01	0.01	
	K		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
	N*K		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
	Wear		NS	NS	0.01	NS	0.001	0.001	0.001	0.001	0.001	0.001	0.001	
	Wear*N*K		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
AP 14	N		0.001	0.001	0.001	0.001	NS	NS	NS	0.001	0.001	0.001	0.001	
	K		NS	0.07	NS	0.09	NS	NS	NS	NS	NS	NS	NS	
	N*K		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
	Wear		NS	NS	0.001	NS	0.001	0.001	0.001	0.001	0.001	0.001	0.001	
	Wear*N*K		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

<sup>2</sup>NDVI, IR/R: highest values = best. Stress1 and Stress2: lowest values = best.

<sup>NS</sup>Nonsignificant at  $P > 0.10$ .

ies. We found no previous reports of an effect of K on spectral reflectance in the literature.

Both ecotypes in this study were strongly influenced by N, with greater shoot growth, shoot density, visual turf quality, color, and density following application of N at 392 kg-ha<sup>-1</sup> than at the lower rate. Shoot tissue injury resulting from wear was significantly reduced at the higher rate. Cell wall components that may influence wear tolerance exhibited inconsistent responses to fertility treatments, but when differences did occur, the higher rate of N reduced leaf TCW, lignocellulose, and cellulose, and increased hemicellulose contents.

Wear tolerance increases with reduced leaf TCW content (Trenholm et al., 2000a), and the current results support the observation that higher N rates reduce wear injury through this mechanism.

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