EFFECTS OF INTENSE, SHORT-TERM TRAFFIC ON SOIL PHYSICAL PROPERTIES AND TURFGRASS GROWTH

by

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Effects of Intense, Short-term Traffic on Soil Physical Properties and Turfgrass Growth

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ABSTRACT

Most turfgrass areas are subjected to some degree of traffic resulting in wear and compaction placing stress on the plant. Along with physical abrasion caused by wear, traffic causes compaction which presses soil particles together altering soil physical parameters. With a constant force, the degree of compaction is a function of soil water content. Maximum compaction occurs at some time after the large soil pores start to drain.

Five treatments were applied to a 2.5 year old tall fescue (*Festuca arundinacea* Schreb. 'Kentucky 31') stand on a Chase silty clay loam. A one-time compaction treatment of 35 passes with a water filled, smooth, power roller exerting 1.0 kg/cm^2 static pressure, was applied to a soil with four soil moisture levels. Soil moisture treatments were established by irrigating the area until water was standing and then applying the compaction treatment 0, 4, 24, and 72 hours after the standing water condition, respectively. The fifth treatment was a non-compacted check. The effects of treatments on soil physical factors and plant growth were monitored. The study took place from 3 May to 11 July 1979.

Of the compacted treatments, bulk density was 1.41 g/cm^3 for the 24-hour treatment and 1.31 g/cm^3 for both the 0-hour treatment and the check. Aeration porosity at -0.1 bar matric potential was reduced by 20% for the soil compacted at saturation compared to the check. After

6 weeks, differences in moisture retention were not evident.

Two and six weeks after treatment date, visual ratings were reduced in all compacted plots. The 4 weeks between ratings had high temperatures and no rain. A correlation coefficient of 0.82 occured between visual quality and aeration porosity at -0.1 bar matric potential. No differences at alpha = .10 were found between treatments for verdure and shoot density. Four weeks after treatment, root weights at the 0-10 cm level were reduced by 61% in the saturated treatment compared to the uncompacted check.

Total nonstructural carbohydrates (TNC) levels 4 weeks after compaction, were higher than the check for the 0, 4, and 24-hour treatments indicating a slower growth rate. All treatments showed a steady increase in TNC except for the 24-hour treatment which showed a 35% decrease in TNC level 7 weeks after compaction. By 9 weeks after compaction, all treatments exhibited similar TNC levels.

Additional index words: Tall fescue, soil moisture content, compaction, grass.

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Most turfgrass areas are subjected to some degree of traffic which is a stress on the turfgrass plant. Even routine maintenance practices. such as mowing, impose traffic stresses. Recreational turfs are often subjected to heavy traffic when environmental and soil conditions are unfavorable. As a result, the turf stand may deteriorate.

The two major traffic related problems are wear and soil compaction. Wear is the injurious effects of concentrated traffic on a turf due to physical abrasion and tearing (1). Compaction is the pressing together of soil particles into a more dense soil mass (1,7). Soil compaction influences air, water, and soil strength factors. These paramenters in turn affect growth and persistance of the turf.

With a constant applied force, there is an optimum moisture content at which soil compacts to the greatest extent (4). Due to the imcompressability of water, in a saturated soil maximum compaction will occur at some point after the larger pores start to drain and fill with air. At that time, water will act as a lubricant allowing soil particles to pack closer together (7).

Due to the stresses imposed on the turfgrass plant from compaction, it is important for the turfgrass manager to restrict traffic on excessively wet turfs. Knowledge of the resultant effects on the turfgrass plant may provide the turfgrass manager with a better basis for controlling use of a turf area when unfavorable soil conditions are present.

The objective of this study was to observe the effects of intense, short-term traffic on soil physical properties and turfgrass growth.

MATERIALS AND METHODS

To observe the effects of heavy traffic on an established turf at different soil moisture levels, five treatments were applied to a 2.5 year old tall fescue (Festuca arundinacea Schreb., 'Kentucky 31') stand. The soil was a Chase silty clay loam of the fine, montmorillonitic, mesic Aquic Arguidolls at the Kansas State Univeristy Turf Research Plots in Manhattan, Kansas. The study took place from 3 May to 11 July 1979. Each plot measured 2.44 X 1.13 m and was seperated by .61 m alleys. Experimental design was completely randomized with three replications for each treatment.

All compaction treatments were initiated on 3 May. Four of the treatments were compacted at: 0 (saturation); 4 (partially saturated); 24 (field capacity); and 72 (below field capacity) hours after irrigating the total area to a standing water condition. The fifth treatment received no compaction and served as a check.

All compaction treatments were applied by using 35 passes per area with a water filled, smooth power roller. Static pressure was 1.0 kg/cm^2.

Soil samples, three from each plot, were taken immediately before each compaction treatment to determine soil water content for each moisture level treatment. Soil moisture contents for all samples were determined gravemetrically. (Table 1).

Normal mowing practices with a three-gang self-propelled reel mower were continued. Two weeks prior to treatment, all plots received 0.48 kg N/100 m^2. No irrigation was applied, while rainfall over the period of the study totaled 16.2 cm.

Three undisturbed soil cores (5.4 cm I.D. X 3 cm) per plot, were taken 2 and 6 weeks after the last treatment. These cores were used to determine bulk density (2), porosity (12), and moisture retention (9).

Samples for percent total nonstructural carbohydrates (TNC), were taken from each plot before 10 a.m. with a 5.7 cm I.D. plugger. Live shoot tissue was excised from the plugs, combined, and dried at 100°C for 1 hour, then 60°C for 24 hours. TNC was determined with Dreywood's anthrone reagent (8).

Verdure (6) and shoot density were determined at the same time as the second and third TNC samples. Shoot density was obtained by removing two 5.7 cm I.D. plugs from each plot and counting the number of actively growing shoots.

Root weight samples were taken 6 and 9 weeks after the last treatment with four cores (2 cm I.D. X 20 cm) per plot. Samples from each plot were combined, washed, dried at 60°C for 24 hours and weighed.

RESULTS AND DISCUSSION

Soil Physical Properties

Moisture content at treatment. Based on the moisture retention curve for the uncompacted check, moisture retention at the time of compaction were -0.07, -0.09, -0.16, and -2.0 bar matric potential for the 0, 4, 24, and 72-hour treatments, respectively. While the saturation (0-hour) treatment was apparently not saturated to a depth of 3 cm, the surface was saturated as evidenced by standing water. This treatment also exhibited the lowest bulk density for all compacted treatments. (Table 1).

Bulk density. Harris (4) and Madison (7) noted that the degree of compaction, as expressed by bulk density, was a function of moisture content at a constant pressure. Maximum compaction occurs near field capacity when air filled pores can be compressed and sufficient moisture acts as a lubricant. This trend was apparent with the greatest increase in bulk density occuring at the 24-hour treatment followed by the 72, 4, and 0-hour treatments. (Table 1). Bulk densities were 1.31 and 1.41 g/cm^3 for the check and 24-hour treatment, respectively.

Porosity and moisture retention. Compaction may alter the pore-size distribution of a soil. As a result aeration and moisture relationships are affected (13). When compaction was applied to the saturated soil, reductions of 3.7% in total porosity (Table 2) and 20% in aeration at -0.1 bar (Table 1) compared to the check were observed.

Hillel (5) noted that soil structure affects the soil moisture characteristic curve in the low-suction range and that compaction decreases total porosity and the large interaggregate pores. The reduction of aeration porosity of the compacted saturated soil indicates that porosity was affected by changes in soil structure.

Moisture rentention for the 0-hour treatment was lower than the check at the 0 bar matric potential on 20 May. The saturated treatment also showed a higher moisture retention at -1.0 bar than the check. (Table 2). The decrease at the 0 bar with an increase at -1.0 bar matric potential indicates a change in pore-size distribution.

Plant Growth

Visual ratings. Prior to compaction, all plots demonstrated similar visual quality. (Table 3). Two weeks after treatment, compacted plots exhibited decreased visual quality, particularly the 0-hour treatment. Part of the reduction in quality for the 0-hour plots was due to mud collected on the leaves after the power roller treatment.

During the first half of June, weather conditions were moist with generally moderated temperatures favorable for tall fescue growth. Similar visual quality ratings were noted for this period. By 20 June, after a week of high temperatures, visual quality differences were apparent. Plots receiving the 0, 4, and 24-hour treatments demonstrated reduced quality.

Verdure and shoot density. No differences between treatments at either sampling date were evident for verdure and shoot density.(Table 4). These are often related to visual quality which is based on shoot density, color and uniformity. However, in this study, they were not related as correlation coefficeints were 0.34, 0.17, and 0.37 for quality-density, quality-verdure, and density-verdure relationships, respectively. Turf quality was a good indicator of compaction effects as illustrated by a correlation coefficient of 0.82 for quality versus aeration porosity at -0.1 bar.

Root weights. At 4 weeks after compaction, root density at the 0-10 cm level for the 0-hour treatment was only 61% of the uncompacted check. (Table 5). Even though differences were not significant, the turf in the 2, 24, and 72-hour treatments exhibited a trend of decreased rooting. By 10 weeks, no significant differences in root density were evident among treatments.

Tall fescue is a cool season grass which exhibits root growth primarily in the spring and fall. Restriction of new root initiation in the spring by compaction could result in a shallow root system during the hot summer months when drought stress is severe.

Other investigators have noted that a relationship exists between degree of compaction, aeration porosity, bulk density and root growth (3, 10,11,14). However, correlation analyses were not given indicating the degree of correlation and significance among thses parameters. Correlation analysis revealed correlations of 0.70 and -0.46 for aeration porosity at -1.0 bar matric potential and bulk density versus root density at the 0-10 cm level, respectively.

Total nonstructural carbohydrates. TNC levels are an indicator of reserve carbohydrates necessary for regrowth and recovery should the turf be injured by environmental stresses, pests, or human activities. Also, carbohydrate reserves are utilized by the plant for growth. TNC levels are normally highest during periods of limited shoot growth (1).

At 4 weeks after compaction (6 June), the 0, 4, and 24-hour treatments exhibited higher TNC levels than the check. (Table 6). Possibly this was due to a slower growth rate, which would result in increased storage of carbohydrates (1).

From 6 June until 20 June, TNC levels increased, except for the 24-hour treatment which had a 35% decrease. The reason for this was not apparent from the data in this study. By 9 July TNC levels were similar for all plots.

CONCLUSION

Many recreational turf stands are subjected to repeated, heavy traffic. In this study intense traffic was applied only for a short period and wear was minimized. Thus, much greater influence on soil physical properties and turf growth would be expected under normal recreational use. This study does illustrate that turf sites receiving heavy traffic for short periods are adversely affected. The degree of influence on soil physical parameters and turf growth was related to soil moisture content at the time of compaction. Detrimental responses were most evident at the saturated (0-hour) treatment and the field capactiy (24-hour) treatment. Turf deterioration from these treatments were still evident 9 weeks after compaction.

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Table 1. Water content at treatment, bulk density, and aeration porosity

Soil moisture treatment by time	Moisture content at treatment: % by vol.	Moisture content at treatment: matric potent.	Bulk density: 20May	Bulk density: 20June	Aeration porosity -0.10 bar: 20May	Aeration porosity -0.10 bar: 20June	Aeration porosity -0.33 bar: 20May	Aeration porosity -0.33 bar: 20June
		bar	gm/cm^3		%			
0-hour (saturation)	46.2a*	-.07	1.33ab	1.31c	16.1b	18.4a	19.2b	23.2b
4-hour (part. sat.)	42.6b	-.09	1.35a	1.34bc	19.0a	21.7a	22.5a	26.9a
24-hour (field cap.)	40.0c	-.12	1.35a	1.41a	18.8a	19.8a	22.4a	24.4ab
72-hour (below f.c.)	31.9d	-2.00	1.34a	1.37ab	19.4a	21.9a	23.1a	26.5ab
Check (uncompacted)	—	—	1.28ab	1.31c	20.3a	21.5a	24.0a	25.1ab

*Numbers within columns not followed by the same letter differ at the 0.10 level of probability using Duncan's Multiple Range Test.

Table 2. Moisture retention by volume.

	Percent water content by volume at four matric potentials							
	0 bar		-0.10 bar		-0.33 bar		-1.0 bar	
Treatment	20May	20June	20May	20June	20May	20June	20May	20June
	%							
0-hour	59.2b*	62.0a	43.1a	43.6a	40.0a	38.8a	38.4a	36.2a
4-hour	61.8a	64.9a	42.8a	43.2ab	39.3a	38.0a	37.8a	35.2ab
24-hour	61.3a	63.1a	42.5a	43.3ab	39.0ab	38.6a	37.4a	35.8ab
72-hour	61.9a	64.3a	42.4a	42.4ab	38.7ab	37.9a	37.1ab	34.9b
Check	61.5a	63.6a	41.2a	42.1b	37.5b	38.5a	35.6b	34.9b

*Numbers within columns not followed by the same letter differ at the 0.10 level of probability using Duncan's Multiple Range Test.

Table 3. Visual quality ratings.

	Visual quality ratings+				
Treatment	4 May	20 May	6 June	20 June	9 July
0-hour	7.2a	5.3d	6.3a	5.7b	5.7b
4-hour	6.7a	6.3bc	6.0a	5.7b	6.2ab
24-hour	6.8a	6.0c	6.2a	5.7b	6.0b
72-hour	6.7a	6.5b	6.0a	5.8ab	6.3ab
Check	7.0a	7.0a	6.5a	6.3a	6.8a

*Numbers within columns not followed by the same letter differ at the 0.10 level of probability using Duncan's Multiple Range Test.

+Visual quality ratings are based on shoot density, color, and uniformity with 9 = ideal turf, 1 = no live turf.

Table 4. Verdure and shoot density.

Treatment	Verdure		Shoot density	
	6 June	20 June	6 June	20 June
	—— mg/100 cm^2 ——		—— no./100 cm^2 ——	
0-hour	1326.1a*	1426.6a	15.4a	14.4a
4-hour	1400.0a	1526.6a	21.6a	20.4a
24-hour	1173.4a	1293.4a	15.8a	14.6a
72-hour	1386.6a	1606.6a	16.6a	23.2a
Check	1440.0a	1380.0a	22.6a	19.6a

*Numbers within columns not followed by the same letter differ at the 0.10 level of probability using Duncan's Multiple Range Test.

Table 5. Root Weights.

	Root weights by depth			
	6 June		9 July	
Treatment	0-10 cm	10-20 cm	0-10 cm	10-20 cm
	mg/100 cm^3			
0-hour	508.0b*	201.0a	649.6a	169.2a
4-hour	644.6ab	256.0a	684.2a	203.8a
24-hour	713.4a	250.0a	612.4a	169.2a
72-hour	727.0a	191.8a	705.6a	177.4a
Check	831.4a	284.6a	744.6a	186.8a

*Numbers within columns not followed by the same letter differ at the 0.10 level of probability using Duncan's Multiple Range Test.

Table 6. Total nonstructural carbohydrates.

Treatment	16 May	6 June	20 June	9 July
	%			
0-hour	7.7b*	19.0b	25.7a	24.7a
4-hour	11.3ab	20.0b	26.3a	27.3a
24-hour	12.7a	25.7a	17.7b	20.7a
72-hour	10.3ab	13.0c	17.7b	24.0a
Check	13.4a	17.0bc	25.0a	22.3a

*Numbers within columns not followed by the same letter differ at the 0.10 level of probability using Duncan's Multiple Range Test.

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