EVALUATION OF A MODULAR TURFGRASS SYSTEM AMENDED WITH SHREDDED CARPET

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ABSTRACT

Portable modular turfgrass systems are sometimes used to provide natural turfgrass surfaces for sporting events in stadiums with synthetic surfaces. The objective of this study was to determine if shredded carpet amended into the root-zone of a modular turfgrass system can provide improvements in turfgrass density, soil physical properties, and playing surface quality. Different rates of shredded carpet were amended into a high-sand root-zone, sodded with Kentucky bluegrass, and subjected to simulated foot traffic. Treatments were evaluated for their effects on turfgrass density, soil physical properties, and playing surface quality.

The addition of 3% or 5% DuPont Shredded Carpet to the high-sand root-zone resulted in improvements in soil physical properties and playing surface quality. When modules (treatment tiles) amended with 3% or 5% shredded carpet were placed over asphalt or a sand and gravel base and subjected to wear, the most significant improvements were reductions in soil bulk density, surface hardness, and divoting. These improvements were more dramatic when treatment tiles were placed on asphalt as compared to the sand and gravel base. This study demonstrated that the 3% or 5% rates of DuPont Shredded Carpet amended into the high-sand root-zone of turfgrass modules can improve the quality of a natural turfgrass playing surface whether placed on asphalt or on a sand and gravel base.

Keywords

Soil reinforcement; athletic fields; soil amendments; portable turf; impact attenuation; traction

INTRODUCTION

Various synthetic reinforcing materials have been mixed with sand in an attempt to increase the stability of sports turf surfaces. Most reinforcing materials that have been studied in turfgrass systems consist of polypropylene fibers that are amended into the root-zone [Baker, 1997]. Some reported benefits of fiber-amended root-zones are increased traction [Baker and Richards, 1995]; improved soil physical properties [Canaway, 1994]; increased shear resistance [Adams and Gibbs, 1994]; and reduced divoting [Beard and Sifers, 1993]. Disadvantages include increased surface hardness under dry conditions [Baker and Richards, 1995] and decreased soil water content [Canaway, 1994]. Baker [1997] stated that the quality of a turf surface can be improved with the addition of reinforcing materials when there is a specific problem that can be remedied from a suitable reinforcement product.

Field studies were recently conducted at The Pennsylvania State University to determine the benefits of amending shredded carpet into sand and soil root-zones [McNitt, 2000]. When amended into a sand root-zone, shredded carpet reduced divoting, surface hardness, and soil bulk density.

Shredded carpet is currently used in a portable sand-based modular turfgrass system called GrassTiles® (Hummer Sports Turf, Lancaster, PA). The shredded carpet is mixed with the sand root-zone and placed in containers. The turfgrass is established in these containers and when mature, the turf and the root-zone are lifted from the containers and can be installed on either a synthetic surface or an existing soil.

The objective of this study was to determine if shredded carpet amended into the root-zone of a modular turfgrass system can improve turfgrass density, soil physical properties, and playing surface quality.

MATERIALS AND METHODS

Description of Shredded Carpet

The shredded carpet used in this study was obtained from DuPont Nylon (Chestnut Run Plaza, Wilmington, DE) and is the shredded remains of carpet fragments consisting of both pile and backing. The shredded carpet is currently referred to as DuPont Shredded Carpet. This product is not commercially available, but is a component of the GrassTiles sand-based modular turfgrass system. DuPont Shredded Carpet is approxi-

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mately 70% nylon, 12.2% calcium carbonate, 10.7% latex, and 7.1% polypropylene on a weight basis (V.J. Kumar, personal communication, 1998). The average filament length is 135.1 mm and the range is 20 to 610 mm. Filament width averages 2.4 mm and ranges from 0.5 mm to 4 mm. DuPont Shredded Carpet is randomly-oriented when incorporated into soil.

Experiment 1 – Asphalt Overlay

This two-year field experiment was conducted at the Joseph Valentine Turfgrass Research Center in University Park, PA. The experiment included four treatments consisting of three rates of DuPont Shredded Carpet amended into a high-sand root-zone and a non-amended control. The three rates of shredded carpet were 1% (0.01 kg kg^{-1} carpet and root-zone mix), 3% (0.03 kg kg^{-1} carpet and root-zone mix), and 5% (0.05 kg kg^{-1} carpet and root-zone mix). The root-zone mix consisted of 65% USGA specified sand [Green Section Staff, 1993], 15% loam soil, 10% sphagnum peat, and 10% diatomaceous earth mixed on a volume basis. Each combination of shredded carpet and root-zone mix and the non-amended control were placed into wooden containers (2130 mm by 2130 mm by 57 mm), filled to the top, and graded. After grading, Kentucky bluegrass (*Poa pratensis*, L.) sod , washed free of soil, was placed onto the shredded carpet and root-zone mixes and the control. The sod was grown from a seed blend consisting of 33% 'Touchdown', 33% 'Ram I', and 33% 'Glade' on a weight basis and was 18 months old when harvested. After installing the sod on 2 June 1997, it was allowed to root into the treatment mixtures for 91 days before wear treatments were imposed. During this time, the sod was watered and fertilized frequently to encourage rooting. The sod was mowed at 38 mm.

On 2 Sep. 1997, the sod and shredded carpet/root-zone mixtures and the controls (hereafter referred to as treatment tiles) were lifted from each container and installed on a 6.3 mm drainage mat (Terradrain 50, WEB TEC Inc., Charlotte, NC) that was laid over a level asphalt road. The treatment tiles were arranged in a randomized complete block design with three replications. The exposed areas surrounding the treatment tiles were filled with silt loam soil to limit soil water loss. The plot area was watered only to prevent wilting. The turf was cut with a reel mower twice per week at a height of 38 mm and the clippings were not collected.

On 3 Sep. 1997 we began to impose wear on the treatment tiles. Wear was applied with a Brinkman Traffic Simulator [Cockerham and Brinkman, 1989]. McNitt [2001] gives a more detailed description of the traffic simulator used in this experiment.

Wear was imposed on entire plots as five passes with the Brinkman Traffic Simulator three times per week (15 passes per week). According to Cockerham and Brinkman [1989], two passes of the Brinkman Traffic Simulator is equivalent to turfgrass wear at the 40 yard line resulting from one National Football League (NFL) game. Thus, 15 passes per week is equivalent to the wear sustained from 7.5 games per week. Wear treatments were terminated for the season on 18 Nov. 1997. In 1998, we began wear on 15 Apr. and ended on 17 Aug. Typically, wear was applied regardless of weather conditions. However, due to heavy precipitation or schedule conflicts wear was sometimes not applied on the scheduled day. In these cases, wear was applied on the following day.

The criteria used for comparing treatments were turfgrass density, soil physical properties (bulk density and water content), and playing surface quality (hardness, traction, and divoting). A description of the methods used to evaluate turfgrass density, soil bulk density, soil water content, surface hardness, and traction can be found in McNitt [2001].

At the end of the experiment, divot size was measured on each plot. Divots were created using the head of a pitching wedge golf club attached to the end of a pendulum weighted with a 76 kg steel cylinder filled with lead. The pitching wedge and pendulum were fastened to the three-point hitch of a tractor. The height of the head, relative to the treatment surface, was controlled with an adjustable metal pad. The pad could be set at different heights and when the three-point hitch was lowered the pad rested on the soil surface. During this experiment, the depth of the head was set at 15 mm.

To make a divot, the pendulum was released from a horizontal position. After the pitching wedge club head cut through the soil surface, the maximum length and width of each divot was measured.

The turfgrass density ratings and the means of the three soil bulk densities, three soil water contents, six surface hardness measurements, three traction measurements, and three divot sizes were subjected to analysis of variance and means were separated using Fisher's Protected Least Significant Difference (LSD) test at the 0.05 level. A LSD was not calculated when the F ratio was not significant at the 0.05 level.

Experiment 2 – Grow-in

This single-season field experiment was also conducted at the Joseph Valentine Turfgrass Research Center in University Park, PA. The treatments in Experiment 2 included a non-amended control and two rates of DuPont Shredded Carpet 3% (0.03 kg kg^{-1} carpet and root-zone mix), and 5% (0.05 kg kg^{-1} carpet and root-zone mix) amended into the same high-sand root-zone as described in Experiment 1. The shredded carpet/root-zone mixture and non-amended control mix were placed into wooden containers of the same dimension as those described in Experiment 1. The Kentucky bluegrass sod described in Experiment 1 was washed and placed onto the mixes on 2 June 1997. The treatment tiles in this experiment were managed according to the procedures listed in Experiment 1.

On 2 Oct. 1997, the tiles were lifted from each container and installed over 200 mm of a 90% sand:10% sphagnum peat (v:v) USGA specified root-zone [Green Section Staff, 1993]. This mix was installed on top of 150 mm of USGA specified drainage gravel [Green Section Staff, 1993] that included corrugated PVC drainage pipes.

The tiles were arranged in a randomized complete block design with three replications. The plot area was watered only to prevent wilting and the turf was cut with a reel mower twice per week at a height of 38 mm and the clippings were not collected.

Beginning on 1 June 1998 (240 days after installation), blocks were split with two wear levels. Wear was applied with the Brinkman Traffic Simulator described in Experiment 1. The wear levels imposed on the treatment tiles were no-wear and wear equaling five passes of the Brinkman Traffic Simulator three times per week. Wear ended on 15 Oct. 1998. Sometimes, due to heavy precipitation or schedule conflicts, wear could not be applied on the scheduled day. In these cases wear was applied on the next day.

The same criteria used to evaluate treatments in Experiment 1 were used in Experiment 2 (turfgrass density, bulk density, water content, hardness, traction, and divoting). Data collection for each of these criteria followed the procedures described in Experiment 1. Bulk density, water content, hardness, and traction data were collected on two rating dates (3 Jul. 1998 and 14 Oct. 1998). Divot data were collected on 15 Oct. 1998.

The turfgrass density rating and the means of the three soil bulk densities, three soil water contents, six surface hardness measurements, three traction measurements, and three divot lengths and widths were analyzed using the analysis of variance and Fisher's Protected Least Significant Difference (LSD) test at the 0.05 level. A LSD was not calculated when the F ratio was not significant at the 0.05 level.

RESULTS AND DISCUSSION

Experiment 1 – Asphalt Overlay

Turfgrass Density. No differences in turfgrass density were found among treatments on either rating date of this experiment (Table 1). Results indicated no significant advantage with respect to turfgrass density in amending DuPont Shredded Carpet into the treatment tile root-zones. This is consistent with the findings of other researchers in which fiber incorporation into sand root-zones did not increase grass cover retention during wear [Baker et al., 1988; Baker and Richards, 1995].

Table 1. Mean turfgrass density, soil bulk density, surface hardness, linear traction, and divot dimensions for treatments in Experiment 1.

Treatment	14 Nov. 1997	3 Jul. 1998
	Turfgrass Density (0-5 †)	
Control	4.2	2.6
DuPont Shredded Carpet 1%	3.8	2.9
DuPont Shredded Carpet 3%	4.0	3.0
Dupont Shredded Carpet 5%	3.9	3.1
LSD ‡ (0.05)	NS	NS
	Soil Bulk Density (t m^{-3})	
Control	1.22	1.37
DuPont Shredded Carpet 1%	1.21	1.35
DuPont Shredded Carpet 3%	1.12	1.21
Dupont Shredded Carpet 5%	1.09	1.15
LSD (0.05)	0.11	0.04
	Soil Water Content (m^3 m^{-3})	
Control	0.288	0.092
DuPont Shredded Carpet 1%	0.294	0.098
DuPont Shredded Carpet 3%	0.271	0.090
Dupont Shredded Carpet 5%	0.272	0.107
LSD (0.05)	NS	NS
	Surface Hardness (Gmax)	
Control	76	101
DuPont Shredded Carpet 1%	74	114
DuPont Shredded Carpet 3%	67	86
Dupont Shredded Carpet 5%	62	87
LSD (0.05)	6	13
	Linear Traction (Newtons)	
Control	1419	1405
DuPont Shredded Carpet 1%	1360	1459
DuPont Shredded Carpet 3%	1336	1373
Dupont Shredded Carpet 5%	1356	1349
LSD (0.05)	48	81

† Visual estimate turf cover and tillers per unit area, 0 represents no turfgrass present and 5 represents maximum turfgrass cover and density.
‡ Fisher's protected least significant difference test.

All treatments showed relatively high turfgrass density on 14 Nov. 1997, following the equivalent of 80 NFL games on the treatment tiles. However, by 3 July 1998 plots had thinned significantly, probably due to the simulated wear of 167 NFL games. These data indicate that this modular system placed over asphalt can sustain high amounts of wear for short periods without serious thinning, but that thinning will eventually occur with increased wear over several months.

Soil Bulk Density. Differences in soil bulk density due to treatments were detected during this experiment (Table 1). The DuPont Shredded Carpet 5% treatment had a significantly lower soil bulk density than the control and the DuPont Shredded Carpet 1% treatment on both rating dates. The DuPont Shredded Carpet 3% treatment had a significantly lower soil bulk density than the control and the DuPont Shredded Carpet 1% treatment only on 3 July 1998.

All soil bulk density values were higher on 3 July 1998 compared to 14 Nov. 1997. This was likely due to the effects of 167 NFL games of wear with the Brinkman Traffic Simulator over the two-year test period. The range of soil bulk density values was greater on 3 July 1998. Whereas the soil bulk density of the control increased from 1.22 t m^{-3} in 1997 to 1.37 t m^{-3} in 1998 (an increase of 0.15 t m^{-3}), the DuPont Shredded Carpet 5% treatment increased only from 1.09 t m-3 to 1.15 t m^{-3} (an increase of 0.06 t m^{-3}) during the same period. As the rate of DuPont Shredded Carpet increased, its moderating effect on soil bulk density under high traffic was more pronounced.

Soil Water Content. No differences in soil water content due to treatments were found on either rating date of this experiment (Table 1). The fact that no soil water content differences were found could be considered an advantage with shredded carpet given that some reinforcing materials have decreased soil water contents when mixed with sand [Canaway, 1994; Richards, 1994].

Surface Hardness. On both rating dates, the DuPont Shredded Carpet 3% and 5% treatments had surface hardness values lower than the control and the DuPont Shredded Carpet 1% treatment. On 3 July 1998, the surface hardness values of all treatments were higher than those recorded on 14 Nov. 1997. Some of this increase may have been due to the Brinkman Traffic Simulator, but it can also be attributed to the low soil water contents measured on 3 July 1998. Previous studies have shown a correlation between low soil water content and high surface hardness [Rogers et al., 1988; Canaway, 1994].

On the first rating date, after imposing traffic that approximates 80 NFL games, all treatment tiles installed over asphalt had surface hardness values similar to those reported by Rogers et al. [1988] for artificial turf (60-91 Gmax). After imposing traffic that approximates 167 NFL games, the DuPont Shredded Carpet 3% and 5% treatments remained in the 60-91 Gmax range, but the control and DuPont Shredded Carpet 1% treatment had surface hardness values above 91 Gmax. These data indicate that the DuPont Shredded Carpet 3% and 5% treatments had a moderating effect on surface hardness under high traffic conditions. This is especially noteworthy considering that surface hardness measurements in 1998 were taken under low soil water contents.

Table 2. Mean divot dimensions for treatments in Experiment 1.

Treatment	Divot Dimensions Width	Divot Dimensions Length
	(mm)	
Control	94	272
DuPont Shredded Carpet 1%	81	132
DuPont Shredded Carpet 3%	79	119
Dupont Shredded Carpet 5%	74	107
LSD † (0.05)	8	56

† Fisher's protected least significant difference test.

Table 3. Mean turfgrass density, soil bulk density, surface hardness, and linear traction for treatments in Experiment 2.

Treatment	3 Jul. 1998 No Wear	3 Jul. 1998 High Wear	14 Oct. 1998 No Wear	14 Oct. 1998 High Wear
	Turfgrass Density (0-5 †)			
Control	5.0	3.1	5.0	2.0
DuPont Shredded Carpet 3%	5.0	3.1	5.0	2.5
Dupont Shredded Carpet 5%	5.0	3.3	5.0	2.0
LSD ‡ (0.05)	NS	NS	NS	0.3
	Soil Bulk Density (t m^{-3})			
Control	1.21	1.30	1.25	1.55
DuPont Shredded Carpet 3%	1.08	1.13	1.08	1.32
Dupont Shredded Carpet 5%	1.03	1.08	1.04	1.25
LSD (0.05)	0.03	0.03	0.03	0.03
	Soil Water Content (m^3 m^{-3})			
Control	0.148	0.148	0.062	0.073
DuPont Shredded Carpet 3%	0.127	0.127	0.071	0.077
Dupont Shredded Carpet 5%	0.118	0.118	0.070	0.076
LSD (0.05)	0.013	0.013	NS	NS
	Surface Hardness (Gmax)			
Control	66	86	74	87
DuPont Shredded Carpet 3%	64	84	74	85
Dupont Shredded Carpet 5%	63	70	70	79
LSD (0.05)	NS	3	NS	4
	Linear Traction (Newtons)			
Control	1495	1343	1433	1370
DuPont Shredded Carpet 3%	1465	1290	1460	1370
Dupont Shredded Carpet 5%	1414	1349	1486	1405
LSD (0.05)	NS	NS	36	NS

† Visual estimate turf cover and tillers per unit area, 0 represents no turfgrass present and 5 represents maximum turfgrass cover and density.
‡ Fisher's protected least significant difference test.

Traction. Traction differences due to treatments are shown in Table 1. All treatments containing DuPont Shredded Carpet measured lower in linear traction than the control on the 14 Nov. 1997 rating date. Zebarth and Sheard [1985] reported lower traction values on soil with lower bulk densities. The lower traction values in this study may in part be due to the lower soil bulk density values.

On the 3 Jul. 1998 rating date, no treatments containing DuPont Shredded Carpet were different than the control, although the 5% treatment had a lower traction value than the 1% treatment. The data show a trend towards decreased traction for treatments with lower soil bulk densities.

Divoting. Due to the destructive nature of the divoting procedure, the divoting test was conducted only

Table 4. Mean divot dimensions for treatments in Experiment 2.

Treatment	Width		Length	
	No Wear	High Wear	No Wear	High Wear
	Divot Dimensions (mm)			
Control	92	114	203	227
DuPont Shredded Carpet 3%	84	76	200	205
Dupont Shredded Carpet 5%	91	71	211	195
LSD † (0.05)	NS	25	11	11

† Fisher's protected least significant difference test.

once at the end of the experiment. The control had longer divots than any treatment containing DuPont Shredded Carpet (Table 2). No divot length differences were found among the DuPont Shredded Carpet treatments. Differences in divot width were not as great as differences in divot length because width is controlled to some degree by the width of the club head. Divot widths in DuPont Shredded Carpet treatments were slightly less than divot widths in the control plots.

These data suggest that shredded carpet fragments had a beneficial effect in increasing resistance to divoting. Numerous researchers have demonstrated that fibers incorporated into sand soils increase shear strength [Vidal, 1969; Gray and Ohashi, 1983; Tumay et al., 1979].

Experiment 2 – Grow-In

Turfgrass Density. The only differences in turfgrass density in Experiment 2 occurred on 14 October on the high-wear treatments (Table 3). In this case, the DuPont Shredded Carpet 3% had slightly higher turfgrass density than either the control or the DuPont Shredded Carpet 5% treatment.

Soil Bulk Density. Substantial differences in bulk densities occurred among the different rates of DuPont Shredded Carpet under both wear levels during July and October (Table 3). In all cases, as the amount of shredded carpet increased, bulk density decreased. These results are similar to those obtained in Experiment 1 where treatment tiles were placed over asphalt.

Soil Water Content. Differences in soil water content were found among treatments under both wear levels on 3 July, but no differences were detected on 14 October (Table 3). On 3 July, the treatments containing DuPont Shredded Carpet contained less water than the control. While these differences are statistically significant, they are probably of minor practical importance since they varied by only 2 to 3 percent. The fact that no water content differences were found among treatments on 14 October may indicate that as water content decreases overall, the effect of the shredded carpet on soil water is less pronounced.

Surface Hardness. Results showed that only the DuPont Shredded Carpet 5% treatment lowered surface hardness and this occurred only when treatment tiles were exposed to high-wear (Table 3). Although the DuPont Shredded Carpet 3% treatment did not show an effect on surface hardness relative to the control in this experiment, it did moderate surface hardness in Experiment 1. This was especially noticeable when the Gmax values in the control and DuPont Shredded Carpet 1% treatment exceeded 100. All treatment tiles installed over 200 mm of sand in this experiment had surface hardness values similar to those reported by Rogers et al. [1988] for artificial turf (60-91 Gmax). The difference between experiments may be due to the turfgrass being older, and presumably having more thatch in Experiment 2, prior to initiation of wear treatments. Although thatch thickness was not measured in this study, it may have had a moderating effect on surface hardness [Rogers and Waddington, 1990].

The smaller range of surface hardness values found in Experiment 2 may also be due to the moderating effect of the sand root-zone under the treatment modules. Henderson et al. [1990] reported that shallow soils increased surface hardness values compared to a greater depth of the same soil and that differences due to depth were greatest when there was no turfgrass present. When compared to Experiment 1, the reduced range in surface hardness values found in Experiment 2 is most likely due to the moderating effect of both soil depth and turfgrass maturity.

Traction. Differences in traction were found among treatments on only one occasion in Experiment 2 (Table 3). In contrast to the Asphalt Overlay study, in which traction decreased with higher rates of shredded carpet, traction increased on one occasion with shredded carpet additions in Experiment 2. Traction results from this experiment are in general agreement with McNitt [2000] who reported minor effects on traction due to the presence of DuPont Shredded Carpet in both a sand and a silt loam soil.

Divoting. The divot test was done only once at the end of this experiment. The addition of shredded carpet to the root-zone mix caused a reduction in divot length and width, especially in the high-wear plots (Table 4). Although these differences were significant, the differences were smaller than those found in Experiment 1. This may be due to the moderating effect of thatch. Compared to Experiment 1, the modules in Experiment 2 were more mature prior to the initiation of wear.

SUMMARY AND CONCLUSIONS

Improvements in soil physical properties and playing surface quality resulted from the addition of 3% or 5% DuPont Shredded Carpet to the high-sand root-zone used in this modular turfgrass system. When treatment tiles amended with 3% or 5% shredded carpet were placed over asphalt and subjected to wear, the most significant improvements were reductions in soil bulk density, surface hardness, and divoting. One possible detrimental effect with these treatments is a slight reduction in traction. Under the conditions of the Asphalt Overlay study, shredded carpet additions did not have a significant influence on soil water content of the root-zone or turfgrass density.

Improvements from DuPont Shredded Carpet-amended root-zone mixtures placed over sand and gravel and split with wear included reduced bulk density, reduced surface hardness (at the 5% rate only under high-wear), and a slight reduction in divoting under high-wear. These improvements were generally less dramatic in the Grow-in study than in the Asphalt Overlay study. This may have been due to older sod (more thatch), less overall wear, and greater soil depth. Effects on the other parameters measured in this test were either minor or variable.

This study demonstrated that 3% or 5% rates of DuPont Shredded Carpet amended into the high-sand root-zone of the turfgrass modules can improve the quality of a natural turfgrass playing surface, whether placed over asphalt or on a sand and gravel base. The benefits were more pronounced when placed on asphalt.

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