THE EFFECTS OF SOIL REINFORCING MATERIALS ON THE TRACTION AND DIVOT RESISTANCE OF A SAND ROOT ZONE

A.S. McNitt* and P.J. Landschoot

ABSTRACT

Natural turfgrass athletic fields with high-sand root zones often lack sufficient cohesion between sand particles to provide adequate surface stability to athletes during a sporting event. Synthetic soil reinforcing materials have been mixed with athletic field root zones in an attempt to improve surface stability. The objectives of this study were to measure the effect that different synthetic soil reinforcing materials had on the traction and divot resistance of a sand root zone after the turfgrass surface was exposed to varying wear levels. Various rates of soil reinforcing materials were mixed into a high-sand root zone and evaluated for traction using Pennfoot. At the end of the study, treatments were evaluated for divot resistance of the turfgrass surface using the head of a golf pitching wedge attached to the end of weighted pendulum. The application of wear initially increased the traction values of most treatments. As wear progressed, turfgrass density decreased and traction decreased. Soil reinforcing material treatments resulted in few traction differences from the unamended control during year one and no differences from the control in year two. Soil reinforcing material treatments did not measure higher in divot resistance than the control under the no-wear level but all reinforcing material treatments measured higher in divot resistance than the control under the high-wear level. This study indicates that on high-use athletic fields with high-sand root zones, the soil reinforcing materials used in this study can increase divot resistance with little effect on traction.

Keywords

High sand athletic fields, Netlon SportGrass, sports turf, Turfgrids

INTRODUCTION

Athletic fields with high-sand root zones resist soil compaction and provide a well-drained, all-weather playing surface for many sporting activities. However, sand root zones present some problems including reduced plant-available water, low nutrient retention, poor surface stability, and susceptibility to divoting (Henderson et al., 2001).

Divoting may be thought of as the complete shearing, or removal, of the turf/root system from the remainder of the root zone. Root zones with low surface stability typically experience a high amount of divoting during an athletic event. Thus, a measure of divot resistance is a good indication of surface stability. Numerous factors may contribute to the divot resistance of a sand root zone including turfgrass rooting, amount of wear due to traffic, shoe type, athlete weight, degree of consolidation, sand physical characteristics, soil moisture content, and soil amendments. Synthetic soil reinforcing materials have been mixed with high-sand athletic field root zones in an attempt to improve divot resistance (Guise, 1995).

Baker (1997) has reviewed much of the work done on synthetic reinforcing materials for turfgrass soils and proposed two broad categories: 1) randomly-oriented fibers, filaments, or mesh elements and 2) horizontally-placed fabrics. Researchers have evaluated the effects of these soil reinforcing materials on turfgrass wear resistance, soil bulk density, moisture retention, infiltration rates, surface hardness, traction, and divot size (Baker, 1997).

Beard and Sifers (1989, 1990) reported that the presence of mesh elements in a root zone reduced divot size and improved recovery of areas damaged by divoting. The differences in divot size between reinforced and non-reinforced treatments were generally small. For instance, using their September 1988 data, divot length was 63.0 mm where no mesh elements were used and 57.5 mm where mesh elements were incorporated into the root zone. Similar results were reported for divot width where the unamended control plots had average divot widths of 37.7 mm and plots containing mesh elements had average divot widths of 34.8 mm. The plots in these studies were not exposed to wear and the presence of a strong root system may have masked the divot resistance effects of the mesh elements. The presence of roots has been shown to increase soil strength (Waldron, 1977).

The Pennsylvania State University Department of Crop and Soil Science, 116 Agriculture Science and Industries Building, University Park, PA 16801, USA. *Corresponding author: asm4@psu.edu

Few studies have been conducted to evaluate the effects of soil reinforcing materials on divot size; however, several studies have evaluated their effects on traction. The effect that reinforcing materials have on traction is important because there is evidence to suggest that the traction characteristics of athletic field surfaces are connected to surface-related injuries (Bostingl et al., 1975; Torg and Quedenfeld, 1973; Torg et al., 1974). Minner and Hudson (2000) reported that one type of soil reinforcing material (Enkamat™ increased the potential for tripping when athletes were wearing cleated shoes. Soil reinforcing materials should be evaluated for both traction and divoting potential.

Various terms have been used interchangeably to describe how a foot fitted with a cleated shoe reacts with turf. These terms include gripability, shear strength, friction, abrasion, and traction (McNitt et al., 1997). When a body slides on another body, the force tangent to the contact surface that resists the motion of one body relative to another is defined as friction (Higdon and Stiles, 1951). Traction may be thought of as the interaction between a cleated shoe as it slides across the turf surface. Unlike friction, the irregularities associated with cleated footwear and the disturbance of the turf surface created by the cleats, negate the direct application of the properties associated with friction.

Baker et al. (1988) and Baker and Richards (1995) used a traction testing device developed by Canaway and Bell (1986) to measure traction on sand and sandy loam root zones containing polypropylene fiber reinforcements at two rates (4.0 and 7.5 g kg^{-1}). The root zones were sown with 'Elka' perennial ryegrass (*Lolium perenne* L.) and exposed to simulated soccer-type wear. The researchers concluded that the effect of the fiber reinforcement at the rate of 4.0 g kg^{-1} was generally small on both soils. Baker and Richards (1995) reported an increase in traction values due to the 7.5 g kg^{-1} rate on six out of twelve assessment dates. Over the two years of study the unamended sand plots had an average traction value of 32.9 Nm compared to 35.4 Nm for the 7.5 g kg^{-1} rate. In conditions where root material was not present or substantially reduced, the range of traction values increased. Prior to grass establishment, traction values averaged 11.8 Nm in the non-reinforced root zone and 17.2 Nm at a reinforcement rate of 7.5 g kg^{-1}. Similarly, in dry conditions at the end of the trial when the remaining grass cover had been killed with a herbicide, traction values averaged 15.6 Nm on the non-reinforced sand and 20.7 Nm on the 7.5 g kg^{-1} amended sand plots.

Baker (1997) mixed mesh elements into the top 100 mm of a sand and a sandy loam soil at the rate of 3.2 kg m^{-3}. Under simulated soccer-type wear, Baker (1997) reported no significant effect of mesh elements on the retention of grass cover, or traction. In a different study, Canaway (1994) found increased traction as rates of the mesh elements increased from 0 to 5 kg m^{-3} of sandy soil.

These varying and conflicting traction results could be due to the turfgrass root systems masking the effects of the soil reinforcements. They could also be due to Canaway and Bell's traction testing device. The Canaway and Bell (1986) device consisted of a steel disc, 150 mm in diameter, into which football (soccer) cleats were secured. Cleats were arranged equidistant from the center of the disc. The disc was loaded with weights to give a total weight of 47.8 kg. The apparatus was dropped on to the turfgrass surface from 60 mm to ensure cleat penetration. The torque required to tear the turf was measured with a two-handled torque wrench.

In a review of the validity of methods used to evaluate the traction characteristics of a playing surface, Nigg (1990) stated that since friction or traction resistance depends on the characteristics of both surfaces involved, traction tests provide relevant information only when appropriate shoe soles are used, and when the actual vertical force (loading weight) applied is similar to that applied by athletes.

McNitt et al. (1997) developed and tested a device, termed Pennfoot, that meets the primary requirements for valid traction evaluation set forth by Nigg (1990). McNitt et al. (1997) compared Pennfoot to the Canaway and Bell (1986) device and found low correlation when the devices were used to measure the traction of varying species maintained at different cutting heights.

The objectives of this study were to measure the effect that different synthetic reinforcing materials amended into a sand root zone had on 1) traction measured by the Pennfoot device and 2) the resistance to divoting as measured using a golf pitching wedge attached to a weighted pendulum after the surface had been exposed to varying wear levels.

MATERIALS AND METHODS

Descriptions of Reinforcing Materials

A brief description of the reinforcing materials used in this study follows. For a more complete description of the reinforcing materials see McNitt and Landschoot (2003).

Randomly-oriented fibers, filaments, or mesh elements

DuPont Shredded Carpet - DuPont Shredded Carpet was obtained from DuPont Nylon (Chestnut Run Plaza, Wilmington, DE) and is the shredded remains of carpet fragments that include both pile and backing. Based on 100 randomly-selected carpet fibers, the average length was 135 mm, and the range was 20 to 610 mm. Fifteen carpet fibers were randomly selected and measured for width. The width of a carpet fiber averaged 2.4 mm and ranged from 0.5 mm to 4 mm. When incorporated into soil, DuPont Shredded Carpet is randomly-oriented.

Netlon - The Netlon discrete mesh elements were supplied by Netlon Ltd. (New Wellington St. Blackburn, England BB2 4PJ). The mesh is manufactured from extruded polypropylene and has a mass per unit area of 52 g m^{-2}. The filament thickness is 0.50 mm (vertical medial diameter) and 0.48 mm (horizontal medial diameter). The filaments are arranged in a grid, creating rectangular openings that are 6.7 mm by 7.1 mm. Each element is 100 mm by 50 mm.

Nike Reuse-A-Shoe Materials - The Nike Reuse-A-Shoe materials are the shredded remains of used athletic shoes. In the shredding process, the entire shoe is granulated before the components are separated by screening and floating and sinking in water. At the time of this study, Reuse-A-Shoe materials did not have a size specification. Their gradation was the result of passing granulated shoes through a 16 mm screen in the primary granulator and a 19 mm shaker screen.

The materials that make up a shoe vary substantially. Most shoes have uppers, midsoles, and outsoles (Malloch, 1996). Nike supplied two materials from the Reuse-a-Shoe program for this study, Nike Lights and Nike Heavies. Samples of the materials produced at the Wilsonville, WA processing site were taken on 6 Sep. 1996 by technicians working on the project (Malloch, 1996). The Nike materials were analyzed by the technicians for purity, density and gradation. The Nike Lights contained 740 g kg^{-1} uppers, 230 g kg^{-1} midsole, and 30 g kg^{-1} outsole. The Nike Heavies contained 150 g kg^{-1} uppers, 510 g kg^{-1} midsole, and 340 g kg^{-1} outsole.

Turfgrids - Turfgrids is a commercially-available, polypropylene fiber reinforcing material manufactured by Synthetic Industries, Inc. (Chattanooga, TN). It is 99.4% polypropylene and individual fibers are 38 mm long and 5 mm wide. Each individual fiber is fibrillated to form a net-like structure of finer fibers (fibrils). When mixed with soil, each fiber expands and the net-like configuration of fine fibers is randomly-oriented throughout the root zone.

Horizontally-placed fabrics

Sportgrass. Sportgrass is a commercially-available product manufactured by Sportgrass Inc. of McLean, VA. Sportgrass consists of a polypropylene woven backing with 24 yarn strand ends per 25.4 mm in the lineal direction and 11 yarn strand ends per 25.4 mm in width. Yarn strands are 11,000 denier (1.0 denier is equal to the fineness of a yarn weighing 1.0 g for each 9000 m). The woven backing is tufted with fibrillated polypropylene tufts. In the lineal direction there are 16 tufts per 102 mm. In width, the tufts are 9.5 mm apart. The pile height is 32 mm. The individual tufts form a net-like configuration when expanded. A fibrillated tuft is 6700 denier. (W. Cook, personal communication, 1998).

Treatment Rates

Treatment rates of reinforcing materials were based on industry recommendations, previous research, and preliminary lab tests (McNitt and Landschoot, 2003). The preliminary laboratory tests included mixing different rates of reinforcing materials (except Sportgrass) with a sand and peat mixture that passed the United States Golf Association specifications (American Society for Testing and Materials, 1997). Two rates were chosen for Netlon and Turfgrids; 3 and 5 g kg^{-1}. The 3 g kg^{-1} rate of reinforcements for the Netlon and Turfgrids were based on standard industry recommendations for sports fields (Netlon Advanced Turf, Blackburn, UK; and Synthetic Industries, Chattanooga, TN). The 5 g kg^{-1} rate for both of these products is considered high for sports fields and is primarily recommended for turfgrass horse racing track installations. Rates exceeding 5 g kg^{-1} were not used in this study because of the difficulty in maintaining a homogenous blend of sand root zone and reinforcing material in preliminary studies.

Preliminary studies indicated that the DuPont Shredded Carpet could be mixed effectively at rates up to 30 g kg^{-1}. Nike Lights and Nike Heavies treatments could be mixed at rates higher than 30 g kg^{-1}, but due to a lack of available material and to make a rate comparison with the DuPont Shredded Carpet 30 g kg^{-1}, the 30 g kg^{-1} rates were chosen. Since little data exist for the DuPont Shredded Carpet, four rates were chosen. The rates were 5, 10, 20, and 30 g kg^{-1}.

Plot Construction

Field plots were established at the Joseph Valentine Turfgrass Research Center in University Park, PA in September of 1995. The plot area consisted of an under-drained gravel layer, approximately 150 mm deep, overlaid by a 65 mm intermediate layer. A 100 mm layer of the sand and sphagnum root zone mix was installed over the intermediate layer. The mix was donated by the Fertl-Soil Company, Kennett Square, PA. and was the same mix used during the preliminary testing.

A grid of 3.05 m by 3.05 m treatment plots was laid over the level root zone mix. A 300 mm border surrounded each treatment plot. The experimental design was a split block (blocks split by three levels of wear) with 12 treatments and three blocks. All of the treatments (with the exception of Sportgrass) were weighed and mixed with the root zone mix using a front end loader on an asphalt mixing pad. The sand was saturated with water during mixing. Wooden frames, 3.05 m by 3.05 m by 150 mm high, were placed on each treatment plot and leveled using a transit. After filling the frames with the mixed root zone treatments, the surface was leveled by raking and hand tamping.

The Netlon treatments were filled to within 15 mm of the surface and 15 mm of the unamended root zone mix was placed on the surface of the Netlon/root zone mixture as per industry recommendations.

For the Sportgrass treatment, frames were installed and filled with the root zone mix to within 25 mm of the top. The Sportgrass was then cut to fit the frames. Next, small amounts of the root zone mix was applied over the surface and worked into the pile using brooms. The plots were watered and allowed to dry, then more of the mix was broomed into the pile. This process was repeated until approximately 3 mm of pile protruded above the settled mix.

After the borders were filled with root zone mix, the frames were removed and plots were seeded with 'SR 4200' perennial ryegrass at a rate of 200 kg ha^{-1}. Nutrients and water were applied as needed to prevent nutritional deficiency and drought stress. The plot area received five N applications equaling 50 kg N ha^{-1} during each growing season (April-October). The turf was mowed twice per week with a reel mower at a height of 38 mm and clippings were not collected.

Wear level treatments were applied with a Brinkman Traffic Simulator (Cockerham and Brinkman, 1989). The Brinkman Traffic Simulator weighs 410 kg and consists of a frame housing two 1.2 m long rollers. Each roller has steel dowels or sprigs (12.7 mm diameter by 12.7 mm length) welded to the outside of the rollers, at an average of 150 dowels m^{-2}. These dowels are the approximate length and width of the cleats on the shoe of an American football lineman at the collegiate level. The Brinkman Traffic Simulator produces wear, compaction, and turf/soil lateral shear. The drive thrust yielding lateral shear is produced by different sprocket sizes turning the rollers at unequal speeds. The Brinkman Traffic Simulator was pulled with a model 420 tractor (Steiner Turf Equipment Inc., Dalton, OH) equipped with a dual turf tire package.

Blocks were split with three levels of wear. The wear levels were no-wear, medium-wear (three passes with the Brinkman Traffic Simulator three times per week), and high-wear (five passes three times per week). According to Cockerham and Brinkman (1989), two passes of the Brinkman Traffic Simulator produces the equivalent number of cleat dents created at the 40 yard line during one National Football League game. Thus, 15 passes per week are equivalent to the cleat dents sustained from 7.5 games per week.

In 1996, wear began on 1 June and ended on 17 October. In 1997, wear began on 2 June and ended 17 October. Typically, wear was applied regardless of weather conditions or soil water content. Numerous wear applications occurred when the soil water content was at or near saturation. Occasionally, due to heavy precipitation or schedule conflicts, wear was not applied on the scheduled day. In these cases, wear was applied on the following day.

Data Collection

The criteria used for comparing treatments were traction, divot size, and turfgrass density. Traction was measured using the Pennfoot device. For a thorough description of design rationale and construction details of Pennfoot see McNitt et al. (1997). Pennfoot consists of a frame which supports a steel player leg with a cast aluminum foot pinned on the lower end. The simulated foot was cast from a size 10 foot mould and it can be fitted with different athletic footwear. Two holes located on top of the foot are used for connection with the leg. The first hole located toward the toe allows for raising the heel off the ground and distributing the weight on the ball of the foot. All traction measurements in this study were taken with the forefoot in contact with the surface and the heel of the foot raised off the ground.

In this study, Pennfoot was configured to measure linear traction with a loading weight of 121.8 kg and a high-top moulded shoe. The shoe contained 18 triangular studs (12 mm long) around the perimeter of the sole and 35 smaller studs (9 mm long) in the center (Nike, Inc., 150 Ocean Dr., Greenland, NH). The linear force was created by a single pulling piston that is connected to the heel of the foot. The pressure being applied to the pistons was created with a hand pump and monitored with a liquid filled pressure gauge that was connected directly to the pump. The pressure readings were converted to Newtons (N) by multiplying the effective area of the pulling piston and the amount of pressure read from the gauge. The average of three measurements taken in different locations on each sub-plot was used to represent the traction value of the sub-plot.

At the end of the study, divot size was measured on each treatment. Divots were created using the head of a golf club pitching wedge attached at the end of a weighted pendulum. The pendulum was weighted with a 76 kg weight consisting of a 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 can be set at different heights and when the three point hitch is lowered the pad rests on the soil surface. During this experiment the depth of the head was set to 30 mm.

To make a divot, the pendulum was released from a horizontal position. After the head of the pitching wedge cut through the soil surface, the maximum length, width and depth of each divot was measured. Three divots were created and measured on each treatment sub-plot.

Turfgrass density was rated visually and served as an estimate of number of tillers per unit area. Density was rated using a scale of 0 to 5 with half units. A plot with no turfgrass present was rated as 0, and 5 indicated maximum tiller density.

The turfgrass density ratings, and the means of the three traction and three divot size measurements were analyzed using analysis of variance and Fisher's 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.

Table 1. Treatment and wear level main effects and interactions for linear traction and divot size.

		1996			1997		
Source	df	18 June	23 Aug.	18 Oct.	11 June	19 Aug.	15 Oct.
		Linear Traction (Newtons)					
Blocks (R)	2	**†	**	**	*	**	**
Wear (W)	2	**	**	**	**	**	*
Error (a) (RW)	4						
Treatment (T)	11	NS	**	*	NS	NS	NS
Error (b) (RT)	22						
WT	22	NS	NS	**	NS	*	NS
Error (c) (RWT)	44						
		Turfgrass Density (0 - 5‡)					
Blocks (R)	2	NS	NS	NS	NS	NS	NS
Wear (W)	2	**	**	**	**	**	**
Error (a) (RW)	4						
Treatment (T)	11	**	**	**	**	**	**
Error (b) (RT)	22						
WT	22	*	**	**	**	NS	NS
Error (c) (RWT)	44						
		Divot Size					
		Divot width		Divot depth		Divot length	
		(mm)					
Blocks (R)	2	NS		NS		NS	
Wear (W)	2	**		**		**	
Error (a) (RW)	4						
Treatment (T)	11	**		**		**	
Error (b) (RT)	22						
WT	22	NS		*		**	
Error (c) (RWT)	44						

†NS = not significant, * = significant at 0.05 level, ** = significant at 0.01 level

‡Visual estimate of number of tillers per unit area. Zero represents bare ground and five represents maximum turfgrass density considering species and mowing height.

RESULTS AND DISCUSSION

Traction

Traction differences due to wear levels were significant on all rating dates (Table 1). On the first two rating dates in 1996 and on the first rating date in 1997, the high-wear level plots measured higher in traction than the no-wear level plots, with the medium-wear level plots being intermediate (Table 2). On the remaining rating dates, the medium-wear plots measured highest in traction. Initially, as the level of wear increased, traction increased. This was probably due to surface firming. As wear progressed through each year, the high-wear level plots lost significant turfgrass density and traction decreased (Tables 1 and 2).

Significant traction differences due to soil reinforcing material treatments were found on the 23 Aug. and 18 Oct. rating dates in 1996, and no differences were detected in 1997 (Table 1). Turfgrids 3 g kg^{-1}, Turfgrids 5 g kg^{-1}, Nike Heavies 30 g kg^{-1}, Nike Lights 30 g kg^{-1}, and DuPont Shredded Carpet 20 g kg^{-1} had lower traction values than the control on 23 Aug. 1996. On the 18 Oct. 1996 rating date, only Sportgrass had a traction value higher than the control. The lack of traction differences in 1997 (two years after establishment) could indicate that a more mature turf masks the effect of the soil reinforcements.

Table 2. Mean linear traction, turfgrass density, and divot size values for wear levels.

	1996			1997		
Wear Level	18 June	23 Aug.	18 Oct.	11 June	19 Aug.	15 Oct.
	Linear Traction (Newtons)					
No wear	1131	1283	1304	1245	1204	1345
Medium wear	1189	1461	1459	1315	1315	1413
High wear	1252	1474	1272	1384	1290	1363
LSD (0.05)	39	42	39	28	19	48
	Turfgrass Density (0 - 5†)					
No wear	4.9	4.9	5.0	5.0	5.0	5.0
Medium wear	4.2	3.5	3.2	4.9	3.4	3.4
High wear	3.8	2.5	2.2	4.7	2.5	2.4
LSD (0.05)	0.1	0.1	0.1	0.1	0.1	0.1
	Divot Size					
	Divot width		Divot depth		Divot length	
			(mm)			
No wear	76		25		153	
Medium wear	78		24		241	
High wear	85		28		247	
LSD (0.05)	3		2		15	

†Visual estimate of number of tillers per unit area; 0 represents bare ground and 5 represents maximum turfgrass density considering species and mowing height.

One treatment by wear level interaction for traction occurred during each year (18 Oct. 1996 and 19 Aug. 1997) (Table 1). The traction values for the wear by treatment interactions are shown in Table 4. As described in the previous paragraph, the high-wear plots measured highest in traction early in the growing season. As wear progressed, the high-wear level plots measured lower in traction, presumably due to a reduction in turfgrass density. The interactions illustrate that on two rating dates, the high-wear level traction values for some reinforcing material treatments dropped below the medium-wear level traction value for those treatments; while for other treatments, the high-wear level traction values remained higher than the medium-wear level.

Sportgrass was the only reinforcing material treatment that produced higher traction values than the control in the high-wear level plots on both the 18 Oct. 1996 and 19 Aug. 1997. Although the Netlon 3 g kg^{-1}, Turfgrids 3 g kg^{-1}, and Nike Heavies 30 g kg^{-1} treatments had lower traction values than the control in the high-wear level plots on 18 Oct. 1996, this interaction did not occur on any other rating date. In contrast, the 19 Aug. 1997 findings showed that under high-wear, Nike Lights 30 g kg^{-1}, Turfgrids 3 g kg^{-1}, Netlon 5 g kg^{-1}, and DuPont Shredded Carpet 20 and 5 g kg^{-1} treatments had higher traction values than the control. These results indicate that the influence of most reinforcing materials on traction was inconsistent among rating dates and wear levels. The only possible exception to this was Sportgrass, which produced higher traction values under high-wear levels later in the season.

Table 3. Mean linear traction and turfgrass density values for treatments across all wear levels.

Treatment Reinforcing Material	Rate	1996 June 18	1996 Aug. 23	1996 Oct. 18	1997 June 11	1997 Aug. 19	1997 Oct. 15
	(g kg^{-1})	Linear Traction (Newtons)					
Control	-	1199	1455	1360	1331	1257	1359
DuPont Shredded Carpet	5	1207	1384	1320	1325	1303	1382
DuPont Shredded Carpet	10	1250	1463	1377	1299	1268	1403
DuPont Shredded Carpet	20	1241	1356	1341	1321	1277	1384
DuPont Shredded Carpet	30	1155	1435	1331	1327	1261	1395
Netlon	3	1191	1518	1331	1327	1286	1366
Netlon	5	1164	1379	1363	1317	1290	1365
Nike Lights	30	1202	1354	1345	1322	1282	1363
Nike Heavies	30	1178	1364	1323	1304	1246	1367
Sportgrass	-	1184	1445	1447	1322	1243	1380
Turfgrids	3	1130	1366	1268	1274	1257	1356
Turfgrids	5	1183	1356	1331	1306	1266	1368
LSD (0.05)		NS	84	78	NS	NS	NS
		Turfgrass Density (0-5†)					
Control	-	4.3	3.6	3.5	4.8	3.4	3.3
DuPont Shredded Carpet	5	4.4	3.8	3.6	5.0	3.5	3.7
DuPont Shredded Carpet	10	4.4	3.6	3.4	4.9	3.7	3.6
DuPont Shredded Carpet	20	4.3	3.7	3.6	5.0	3.8	3.7
DuPont Shredded Carpet	30	4.4	3.7	3.6	4.9	3.7	3.6
Netlon	3	4.2	3.6	3.3	4.7	3.6	3.5
Netlon	5	4.3	3.6	3.4	4.9	3.5	3.6
Nike Lights	30	4.7	4.0	3.7	5.0	3.7	3.8
Nike Heavies	30	4.8	3.9	3.6	5.0	3.9	3.9
Sportgrass	-	3.8	3.3	3.2	4.7	3.4	3.3
Turfgrids	3	4.1	3.5	3.3	4.8	3.6	3.6
Turfgrids	5	4.2	3.4	3.4	4.7	3.5	3.6
LSD (0.05)		0.3	0.2	0.2	0.2	0.3	0.3

†Visual estimate of number of tillers per unit area. Zero represents bare ground and five represents maximum turfgrass density considering species and mowing height.

Table 4. Turfgrass linear traction values for the treatment by wear interactions.

Treatment ReinforcingMaterial	Rate (g kg^{-1})	No wear	Medium wear	High wear
		(Gmax)		
		18 October 1996		
Control	-	1284	1457	1339
DuPont Shredded Carpet	5	1331	1416	1215
DuPont Shredded Carpet	10	1281	1493	1358
DuPont Shredded Carpet	20	1288	1447	1288
DuPont Shredded Carpet	30	1238	1432	1323
Netlon	3	1335	1471	1187
Netlon	5	1378	1498	1215
Nike Lights	30	1339	1475	1222
Nike Heavies	30	1335	1475	1160
Sportgrass	-	1284	1459	1596
Turfgrids	3	1257	1413	1133
Turfgrids	5	1296	1471	1226
LSD (0.05)		136	NS	136
		19 August 1997		
Control	-	1238	1313	1218
DuPont Shredded Carpet	5	1253	1343	1312
DuPont Shredded Carpet	10	1238	1331	1234
DuPont Shredded Carpet	20	1187	1323	1319
DuPont Shredded Carpet	30	1191	1312	1281
Netlon	3	1218	1354	1285
Netlon	5	1195	1354	1390
Nike Lights	30	1199	1323	1323
Nike Heavies	30	1156	1273	1308
Sportgrass	-	1203	1238	1288
Turfgrids	3	1168	1288	1316
Turfgrids	5	1199	1327	1273
LSD (0.05)		NS	93	93

On the 19 Aug. 1997 rating date, Sportgrass had a traction value intermediate to the other treatments under the high-wear level (Table 4). Under the medium-wear level, the Sportgrass measured lowest in traction and was significantly lower than the DuPont Shredded Carpet 5 g kg^{-1} and 20 g kg^{-1}, the Nike Lights 30 g kg^{-1}, and the Turfgrids 3 g kg^{-1} treatments. While most treatments had lower traction values under high-wear than under medium-wear, on 19 Aug. 1997 four treatments had higher traction values under the high-wear level (Netlon 5 g kg^{-1}, Nike Heavies 30 g kg^{-1}, Sportgrass, and Turfgrids 3 g kg^{-1}). The Nike Lights 30 g kg^{-1} had equal traction values under high and medium-wear. Overall, traction differences between treatments varied less in 1997 than in 1996. Although a different traction measuring device was used, these results are in general agreement with the results reported by Baker (1997).

Divoting

Due to the destructive nature of the divot test, it was performed only once at the end of the study. Divot length, width, and depth due to wear levels and treatment main effects were significant (Table 1). The average divot width and depth were greater for the high-wear level than the medium-wear and no-wear levels, which were not different from on another. For divot length, the high-wear and medium-wear levels did not reveal significant differences (247 and 241 mm) but were significantly greater than the no-wear treatment (153 mm). These data indicate that the more wear imposed on a perennial ryegrass turf growing in a high sand root zone, the larger the divots. Generally, lower turf density resulted in lower soil strength as evidenced by greater divot sizes, even when soil reinforcing material treatments were present.

Divot size due to soil reinforcing material treatments was significant for all three divot dimensions measured (Table 1). Sportgrass had smaller divots than any other treatment for all divot size dimensions measured (Table 5). For treatments other than Sportgrass, the range in divot length was greater than the range in divot width and depth. All reinforcing material treatments had an average divot length that was less than the control.

The data for the treatment by wear interaction for divot length are shown in Table 6. The reduced turfgrass density under the high-wear level resulted in an increase in divot length. Turfgrids 5 g kg^{-1} was the only treatment to have shorter divot length than the control under the no-wear level. Under medium-wear, all treatments except Nike Heavies 30 g kg^{-1} had shorter divot length than the control and under high-wear all treatments reduced divot length compared to the control. Overall, there were greater differences among treatments as wear levels increased and turfgrass density decreased, indicating that at 100% turf cover, the perennial ryegrass root system probably masked the divot resistance effect of the soil reinforcements. The soil reinforcing treatments resulted in smaller divot size than the control only after turfgrass cover was significantly reduced. The rate effect of DuPont Shredded Carpet, Netlon, and Turfgrids is

Table 5. Average divot size for treatments across wear levels.

Treatment		Divot Size		
Reinforcing Material	Rate	Depth	Width	Length
	(g kg^{-1})		(mm)	
Control	-	29	83	294
DuPont Shredded Carpet	5	24	79	244
DuPont Shredded Carpet	10	30	78	225
DuPont Shredded Carpet	20	26	81	200
DuPont Shredded Carpet	30	24	78	182
Netlon	3	28	82	233
Netlon	5	29	79	208
Nike Lights	30	28	85	234
Nike Heavies	30	25	81	245
Sportgrass	-	12	68	152
Turfgrids	3	30	81	186
Turfgrids	5	24	81	166
LSD (0.05)		4	6	30

Table 6. Divot length for the treatment by wear level interaction.

Reinforcing Material	Treatment Rate	Divot Length		
		No-wear	Medium-wear	High-wear
	(g kg^{-1})		(mm)	
Control	-	170	327	385
DuPont Shredded Carpet	5	167	260	306
DuPont Shredded Carpet	10	159	259	255
DuPont Shredded Carpet	20	174	224	202
DuPont Shredded Carpet	30	169	198	180
Netlon	3	151	270	277
Netlon	5	157	237	231
Nike Lights	30	128	262	312
Nike Heavies	30	155	275	303
Sportgrass	-	150	182	123
Turfgrids	3	147	191	220
Turfgrids	5	114	207	176
LSD (0.05)		53	53	53

evident in the interaction data, as increasing rates of the soil reinforcing materials resulted in smaller divot sizes under the high-wear level. The reduction in divot size due to soil reinforcing materials is in general agreement with the trends reported by Beard and Sifers (1989, 1990), although the range in divot size in this experiment is greater, probably due to the simulated foot traffic.

CONCLUSIONS

The imposition of wear using the traffic simulator initially increased traction, presumably due to an increase in surface firming. If the wear level was high enough or long enough to significantly reduce turfgrass density, traction was reduced regardless of the presence of soil reinforcements. The presence of soil reinforcing materials had a small and inconsistent effect on traction in year one and produced no measurable effect in year two.

Under the conditions of this study, the soil reinforcing materials tested did not help to reduce divots if the turfgrass had experienced little or no-wear. It is presumed that the mature healthy root system of the turfgrass provided adequate stabilization to mask the effect of the reinforcing materials under the no-wear level. As increased wear levels decreased turfgrass density and presumably turfgrass rooting, divot size generally increased for all treatments. However, the treatments containing soil reinforcements had significantly smaller divots than the unamended control. Under conditions where there was a significant reduction in turfgrass cover, a soil reinforcement rate effect was evident, with increasing amounts of a particular reinforcement resulting in a decrease in divot size.

This study indicates that on high-use athletic fields with high-sand root zones, the soil reinforcing materials used in this study can provide a decrease in divoting with little effect on traction.

REFERENCES

American Society for Testing and Materials. 1997. Annual Book of ASTM Standards; Vol. 15.07. End Use Products. Standard test method for saturated hydraulic conductivity, water retention, porosity, particle density, and bulk density of putting green and sports turf rootzone mixes. F1815-97. American Society for Testing and Materials, West Conshohocken, PA.

Baker, S.W. 1997. The reinforcement of turfgrass areas using plastic and other synthetic materials: A review. Int. Turfgrass Soc. Res. J. 8:3-13.

Baker, S.W., A.R. Cole, and S.L. Thornton. 1988. The effect of reinforcement materials on the performance of turf grown on soil and sand rootzones under simulated football-type wear. J. Sports Turf Res. Inst. 64:107-119.

Baker, S.W., and C.W. Richards. 1995. The effect of fibre reinforcement on the quality of sand rootzones used for winter games pitches. J. Sports Turf Res. Inst. 71:107-117.

Beard, J.B., and S.I. Sifers. 1989. A randomly oriented, interlocking mesh element matrices system for sports turf root zone construction. p. 253-257. *In* H. Takatoh (ed.) Proc. International Turfgrass Research Conference, 6th, Tokyo, Japan. 31 July-5 Aug. International Turfgrass Society and Japanese Society of Turfgrass Science, Tokyo, Japan.

Beard, J.B., and S.I. Sifers. 1990. Feasibility assessment of randomly oriented interlocking mesh element matrices for turfed root zones. p. 154-165. *In* R.C. Schmidt et al. (ed.) Natural and artificial playing fields: Characteristics and safety features. American Society for Testing and Materials, Standard Technical Publication 1073, West Conshohocken, PA.

Bonstingl, R.W., C.A. Morehouse, and B. Niebel. 1975. Torques developed by different types of shoes on various playing surfaces. Med. Sci. Sport. Exer. 7:127-131.

Canaway, P.M. 1994. A field trial on isotropic stabilisation of sand rootzones for football using Netlon mesh elements. J. Sports Turf Res. Inst. 70:100-109.

Canaway, P.M., and M.J. Bell. 1986. Technical note: an apparatus for measuring traction and friction on natural and artificial playing surfaces. J. Sports Turf Res. Inst. 62:211-214.

Cockerham, S.T., and D.J. Brinkman. 1989. A simulator for cleated-shoe sports traffic on turfgrass research plots. California Turfgrass Culture 39(3&4):9-10.

Guise, S. 1995. An alternative to mechanical aeration. Sports Turf 10(9):10-13.

Henderson, J.J., Crum, J.R. Wolff, T.F., and Rogers, J.N. III. 2001. Athletic field root zone mixes: What is the best mix for your field? p. 96-99. *In* Annual Michigan Turfgrass Conference Proceedings, 71st, E. Lansing, MI. Jan. Michigan Turfgrass Foundation, E. Lansing, MI.

Higdon, A., and W.B. Stiles. 1951. Engineering Mechanics. 3rd ed. Prentice-Hall, Inc., New York.

Malloch, W. 1996. Reuse-A-Shoe material specifications. Internal research report, Nike Inc., Beaverton, Oregon.

McNitt, A.S., and P.J. Landschoot. 2003. The effects of soil reinforcing materials on the surface hardness, soil bulk density, and water content of a sand root-zone. Crop Sci. 43:957-966.

McNitt, A.S., R.O. Middour, and D.V. Waddington. 1997. Development and evaluation of a method to measure traction on turfgrass surfaces. J. Test. Eval. 25(1):99-107.

Minner, D.D., and Hudson, J.S. 2000. Managing cool-season grasses as part of a SportGrass® system. Iowa Turfgrass Research Report 21:1-5. Iowa State Univ., Ames, IA.

Nigg, B.M. 1990. The validity and relevance of tests used for the assessment of sports surfaces. Med. Sci. Sport. Exer. 22:131-139.

Torg, J.S., and T.C. Quedenfeld. 1973. Knee and ankle injuries traced to shoes and cleats. Physician SportsMed. 1:39-43.

Torg, J.S., T.C. Quendenfeld, and S. Landau. 1974. The shoe-surface interface and its relationship to football knee injuries. J. Sports Med. Phys. Fit. 2:261-269.

Waldron, L.J. 1977. The shear resistance of root-permeated homogeneous and stratified soil. Soil Sci. Soc. Am. J. 41:843-849.