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Effects of Biomass Accumulation on the Playing Quality of a Kentucky Bluegrass Stabilizer System Used for Sports Fields

P. J. Sherratt,* J. R. Street, and D. S. Gardner

ABSTRACT

Sand-based sports fields can deteriorate rapidly under intense sports traffic due to poor surface stability. Natural grass stabilizer systems have been developed as one option to improve sand-based field stability and therefore provide a more consistent playing surface. Accumulation of biomass above the stabilizer system may form a layer between the grass plants and the stabilizer that causes the grass to shear off under sports traffic. A study was established in August 2000 at The Ohio State University to evaluate aeration, verticutting, and topdressing practices that may reduce biomass accumulation on a stabilizer system. The study examined playability characteristics of the stabilizer system and the relationship between biomass accumulation and playing quality by measuring traction, divot resistance, surface hardness, and ball rebound. The stabilizer had no effect on traction at 12.7-mm depth but did increase traction at 18.8- and 31.3-mm depths where shearing and physical displacement of underlying soil can occur on sand rootzones. The stabilizer increased divot resistance. Biomass accumulation reduced both traction at 18.8- and 31.3-mm stabilizer profile depths and divot resistance. Biomass management on stabilizer carpet is thus necessary for long-term performance. Sand topdressing increased biomass depth while verticutting reduced biomass depth. Verticutting one time per month increased divot resistance. Verticutting, however, increased both surface hardness and ball rebound. Solid tining reduced surface hardness but resulted in stabilizer deterioration. Thus, verticutting programs could be adopted to manage biomass accumulation on natural grass stabilizers. However, research into the prevention of biomass accumulation on sand-based stabilized sports fields needs further investigation.

SAND ROOTZONES are used to improve the drainage potential of athletic fields and consequently encourage healthy turfgrass growth. However, sand-based rootzones can become unstable, particularly when turfgrass cover is lost. Stabilizing natural turf is a relatively new technology.

Most natural grass stabilizers are polypropylene based and can be broadly categorized into one of the following categories: (i) intact carpets or fabrics; (ii) fragments of interlocking mesh, typically 100 by 50 mm, mixed randomly into the rootzone; (iii) individual fibers, typically of 30- to 40-mm length, mixed randomly into the rootzone; and (iv) fibers, typically 200 mm in length, sown vertically into the rootzone. The means by which these stabilizers improve wear tolerance and turf quality are summarized as load spreading, crown protection, and increased traction between stabilizer fibers and athlete's footwear (Baker, 1997).

Whether carpet-type stabilizers improve grass retention during periods of intense traffic is an issue that has been debated. Baker's 1997 review cites reports that suggest an increase in ground cover when Enkamat (Colbond Geosynthetics, Arnhem, The Netherlands) was used. However, the same review cites research in which no differences in ground cover or root mass were observed. Baker et al. (1988a, 1988b, 1988c) and Baker (1990) found that retention of grass cover on soil was considerably greater with Vertical Horizontal and Angular Fibers (VHAF—a carpet-type stabilizer no longer in production), but there was evidence of lower grass cover on sand with or without VHAF.

Several research trials have been conducted on stabilizer materials since the review by Baker in 1997. McNitt and Landschoot (2000) compared several stabilizer materials, including a carpet type called SportGrass (Sportgrass Inc., McLean, VA). They concluded that most stabilizers reduced divot length when compared with nonstabilized turf, with SportGrass showing the greatest reduction. Further studies on SportGrass have suggested that traction/stability levels remain the same or increase slightly compared with nonreinforced systems. The SportGrass system, however, increased surface hardness, and hardness values further increased as the biomass on the carpet was reduced (Minner and Hudson, 2000). In addition, they reported that solid tining decreased hardness, and verticutting increased hardness on the stabilizer.

Carpet-type stabilizers separate the turfgrass and thatch layer from the underlying soil profile, thus reducing the likelihood of thatch biodegradation. With SportGrass, thatch accumulation was greater than in nonstabilized or culturally treated plots (Minner and Hudson, 2000). In addition, the biomass layer created a wet, spongy playing surface.

This study, conducted at The Ohio State University, examined the effects of a carpet stabilizer (TS-II) on turf playing quality. TS-II has been commercially available since 1998 and has been used on several high-profile fields, including the Sydney Olympics, World Cup Rugby in Australia, The Ohio State University's Ohio Stadium, and Raymond James Stadium during the Super Bowl. The objectives of the study were to (i) assess the rate of biomass (plant tissue, thatch, and soil mineral matter) accumulation on the TS-II stabilizer, (ii) determine how the accumulated biomass affected playing quality, (iii) evaluate cultural practices best suited to aid the degra-

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Dep. of Hortic. and Crop Sci., 2021 Coffey Rd., The Ohio State Univ., Columbus, OH 43210-1086. Salaries and research support provided in part by State and Federal funds appropriated to the Ohio Agricultural Research and Development Center, The Ohio State University. HCS 04-01. Received 6 July 2004. *Corresponding author (sherratt.1@osu.edu).

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Abbreviations: G_{max}, peak deceleration in gravities; OM, organic matter; OTF, Ohio Turfgrass Foundation; TST, turf shear tester.

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dation or reduction of biomass, and (iv) document playability characteristics of the stabilized turf. The hypothesis was that playing quality would be compromised as biomass levels increased.

MATERIALS AND METHODS

A study was initiated August 2000 at The Ohio Turfgrass Foundation (OTF) Research and Education Facility in Columbus, OH. The rootzone blend was comprised of 87.5% sand (Table 1), with a fineness modulus index of 1.88 and a coefficient uniformity (D60:D10) index of 2.2. The textural analysis of the soil component was 5.8% silt, 5.4% clay, and 1.3% gravel (USGA Green Section Staff, 1993b).

The Motz TS-II carpet stabilizer (The Motz Group Inc., Cincinnati, OH) had biodegradable and nondegradable components. The biodegradable component of the carpet backing was a natural jute of a plain weave, with a face weight of 283 g m^{-2} and manufactured in 3.6- or 4.5-m widths. The nondegradable backing component was a woven polypropylene mesh. Synthetic tufts of 100% polypropylene fibers (minimum 7000 denier, minimum 623 g m^{-2}) were stitched in a chevron pattern into the woven backing. The polypropylene fibers were tufted into the backing such that they extended 38 mm above the surface in a vertical orientation. In Brooksville, IN, in August 1999, TS-II was laid down on plastic, filled with rootzone sand to a 20-mm depth, and broadcast-seeded at 100 kg ha^{-1} with a five-way blend consisting of equal parts Blacksburg (Pure Seed Testing, Inc., Hubbard, OR), NuGlade (Jacklin Seed/Simplot, Post Falls, ID), Midnight (Turf Seed, Inc., Hubbard, OR), Liberator (Jacklin Seed/Simplot), and Award (Jacklin Seed/Simplot).

Stabilized and nonstabilized sod, 1-m width, 7.6-m length, and 57-mm thick (38 mm from base of mat to top of fibers), with a weight of ≈45 kg m^{-2}, was harvested in August 2000 and established at the OTF facility. Having been grown on plastic, the sod had no roots, so harvesting was performed by removing the cutting blade from the sod machine and rolling the sod onto the machine's rolling mechanism. Plot size was 2 by 4 m. Plots were irrigated throughout the growing season to maintain the turf in good growing condition. All plots were mowed three times per week at a height of 31.25 mm during the growing season, and grass clippings were removed. Starter fertilizer was applied at 50 kg N ha^{-1} in August 2000. Complete 50% slow-release fertilizer (ratio 4–1–2) applications were subsequently made every 3 to 6 wk between April and October to supply 100 kg N ha^{-1} per year.

A standard Brouwer TR224 turf roller was used to create simulated wear on the plots (Brouwer Turf Equipment, Dalton, OH). The roller was modified by the Agricultural Engineering Department at The Ohio State University to produce differential slip-type wear similar to the Brinkman Traffic Simulator developed by Cockerham and Brinkman (1989). The wear simulator was equipped with four hundred 12.7-mm-long NCAA football cleats donated by The Ohio State University Athletics. Simulated traffic was applied on 0.3-m centers across the plots with 16 passes in May and 16 passes in October in both 2001 and 2002 to simulate spring and fall athletic activity. No traffic was applied during the summer to allow for grass recovery.

The experimental design was a randomized complete block, with three replications. Each replication contained six cultural treatments: (i) verticutting once per month with a single pass of the SISIS Autorotorake Mk4 (SISIS Turf Equipment, Sandy Springs, SC) with the unit depth set to the top of the stabilizer fibers (verticut 1×/M); (ii) verticutting with a single pass of the SISIS Autorotorake with the unit depth set to the top of the stabilizer fibers plus solid tining with a John Deere Aercore 800 with 15-mm-diam. solid tines, 100 mm long at 50-mm tine spacing, three times per season (verticut + ST); (iii) solid tining with a John Deere Aercore 800 (John Deere, Moline, IL) with 15-mm-diam. solid tines at 50-mm tine spacing and followed with a rootzone sand topdressing application at 6.25-mm depth per application (ST + topdress); (iv) scarifying with eight passes of the SISIS Autorotorake with the unit depth set into the immediate top of the stabilizer fibers in spring 2001 and spring 2002 (scarify 1×/S); (v) nonstabilized sand sod with the same Kentucky bluegrass (*Poa pratensis* L.) cultivars; and (vi) stabilized control. Solid tining and topdressing treatments were applied 21 Apr., 5 Aug., and 16 Nov. in 2001 and 15 Apr., 20 Aug., and 28 Nov. 2002.

Treatment areas received a 24-h dry down before field sampling to encourage uniform moisture before sampling. A time domain reflectometer (Soil Moisture Equipment Inc., Goleta, CA) was used to determine average soil moisture to a 15-cm depth before sampling. Soil moisture varied by ±3% between plots. No sampling took place until surface moisture had completely dried.

Biomass (mineral plus organic) depth and organic matter (OM) accumulation were determined by taking sample cores from each plot in April, August, and November in both 2001 and 2002. Biomass herein is defined as the total organic and mineral matter accumulation above the stabilizer fibers. Cores were removed with a 50- by 50-mm hole saw. Biomass depth was determined by visually measuring the depth of the biomass between the top of the vertical stabilizer fibers and the grass plant crown. Three measurements were taken per core and averaged to give a single replication value. All biomass above the polypropylene vertical fibers was then removed for organic and mineral matter composition determination. Organic matter accumulation was determined using the loss on ignition procedure of ASTM D2974-87 Method C (USGA Green Section Staff, 1993a). The effect of biomass accumulation on the playing quality was determined by comparing the rotational shear resistance, divot resistance, surface hardness, and ball rebound resilience.

The criteria for playing quality were originally written specifically for association football (soccer) by Canaway et al. (1990). There are currently no criteria for American football, so a criterion for rugby football was used because the sports are analogous. The exception was ball rebound resilience, which was based on association football preferred and acceptable ranges because ball rebound resiliency testing has traditionally been done with a soccer ball. Playing quality criteria

Table 1. Sieve size/sand fraction analysis (performed November 2000) of rootzone and topdressing sand used in the study. Analysis Method ASTM F-1632 (USGA Green Section Staff, 1993b).

Sieve size and sand particle diameter					
No. 18 very coarse 1 mm	**No. 35 coarse 0.5 mm**	**No. 60 medium 0.25 mm**	**No. 100 fine 0.15 mm**	**No. 140 fine/very fine 0.10 mm**	**No. 270 very fine 0.05 mm**
			Retained, %		
7.0	32.8	34.8	10.2	1.6	1.1

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used in this study was developed by McClements and Baker (1994b) and published by Aldous (1999).

The measuring process for surface stability consisted of two pieces of apparatus. The first measured traction (Canaway et al., 1990), and the second measured shear strength (Model CCB1A, Baden Clegg PTY Ltd., Wembley DC, WA, Australia) in the form of divot resistance (Fig. 1). The Ohio State University's traction device consisted of a 150-mm-diam. steel disc containing six 12.7-mm-long NCAA football cleats spaced at 60° intervals at a radius of 46 mm. Canaway's apparatus consisted of cleats 15 mm in length. The disc (weighted with a mass of 45.36 kg) was dropped from a 50-mm height so that the studs penetrated the surface. The torque required for the studs to tear the surface layer was then measured in Newton meters (N·m) using a torque wrench. Three readings were taken within each test area in random locations and averaged providing a single replication value. The preferred range was ≥35 N·m, and the acceptable range was ≥25 N·m (Aldous, 1999). There was no recommended upper limit; however, Baker et al. (1988c) have suggested that recorded values in excess of 80 N·m may cause possible injuries to knees and ankles induced by torsion. The traction test was repeated using additional steel disks made at The Ohio State University that contained 18.8-mm-long tines and 31.3-mm-long tines. There were no preferred or acceptable ranges for these tine lengths. The three lengths provided a vertical assessment of traction with depth within the carpet stabilizer. The apparatus had a maximum reading of 160 N·m.

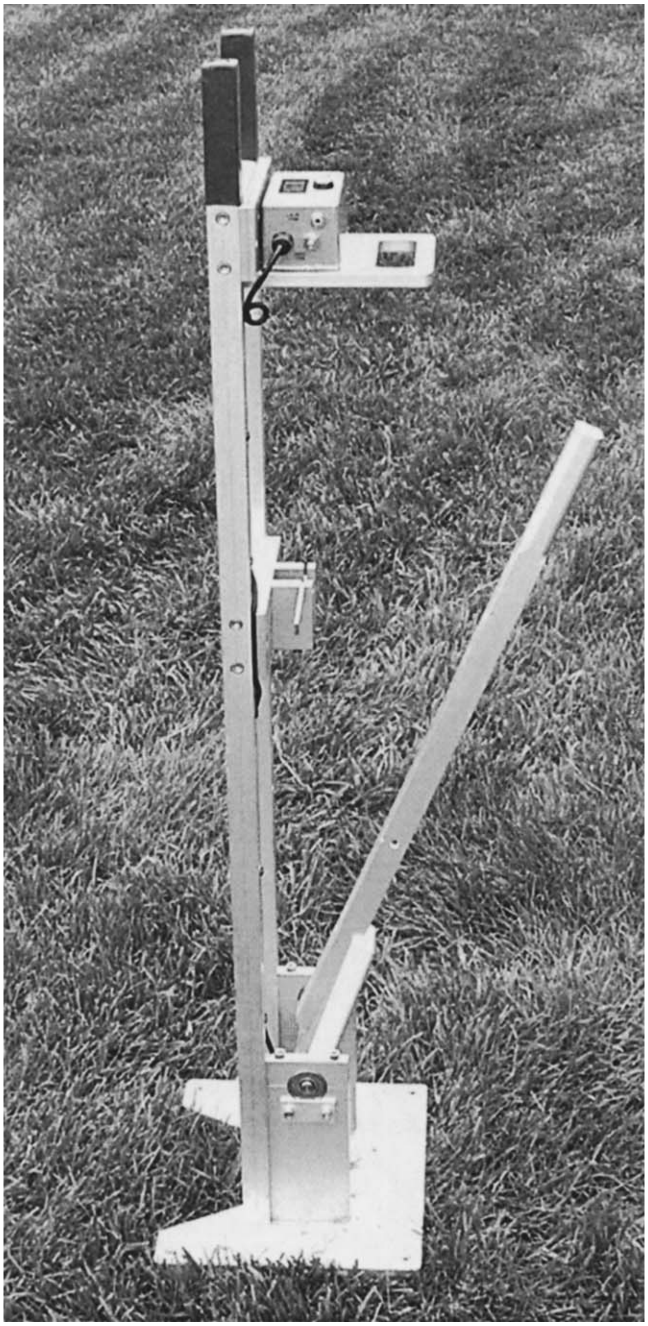

Fig. 1. Turf shear tester (TST) Model CCB1B 50 mm wide by 30 mm long. Pulling down on the lever causes major surface displacement in a horizontal direction. Readings are in Newton meters (N·m).

Divot resistance was determined by the turf shear tester (TST). A shearing plate 50 mm wide by 30 mm deep was used to represent typical shearing/divot forces exerted on a football field. The TST is a recent addition to shear test apparatus that causes surface displacement and generates an index of shear strength at the surface in a horizontal direction. The index is calibrated in units of kilograms force needed to tear the turf. The unit was converted to N·m so that comparisons could be made with the traction apparatus. Three random readings were taken on each test replicate and averaged providing a single replicated value.

Surface hardness was measured using both ball rebound resilience and impact absorption. Ball rebound resilience was determined by dropping a soccer ball inflated to 70 kPa from a height of 3 m and its rebound height measured as a percentage of the release height. To accurately determine rebound height, rebounds were recorded with a digital video camera and played back in slow motion. The background scale was made at The Ohio State University. Three random readings were taken within each test replicate and averaged. The preferred range was 20 to 50% rebound, and the acceptable range was 15 to 55% rebound (Aldous, 1999)

Impact absorption was determined by dropping a cylindrical Clegg (1976) impact soil tester (Lafayette Instrument Company, Lafayette, IN) with a hammer mass of 0.5 kg from a height of 0.55 m. An accelerometer attached to the hammer gave a peak deceleration in gravities (G_{max}). This test was conducted in 10 random locations within each plot and averaged to provide a single replicated value. The preferred range was 50 to 100 G_{max}, and the acceptable range was 30 to 180 G_{max} (Aldous, 1999)

Measurements were taken three times per year beginning in April 2001. Measurements of TST were only taken in 2002. All playing quality measurements were subjected to analysis of variance using the General Linear Model and correlation procedures in the Statistical Analysis System (SAS Inst., 1990).

RESULTS

Biomass Thickness and Organic Matter Accumulation

Verticut 1×/M and verticut + ST reduced biomass thickness compared with the stabilized control. The ST + topdressing and nonstabilized treatments increased biomass thickness (Fig. 2). By the end of the study, verticutting treatments had reduced biomass thickness by up to 33%. The topdressing treatment had increased biomass thickness by 31%, and the nonstabilized treatment had increased biomass thickness by 26%. There were no differences in OM accumulation

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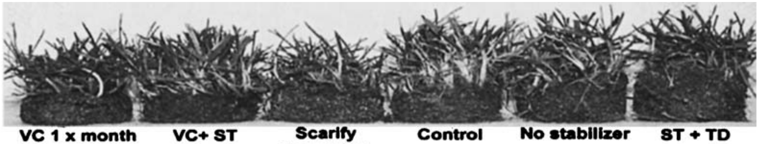

	VC 1 x month	VC+ ST	Scarify 1 x spring	Control	No stabilizer	ST + TD
Biomass Depth (mm)	11.0c	12.3c	14.0bc	16.3b	20.6a	21.3a
Percent of Control (increase or decrease)	- 33	- 25	- 14	0	26	31

Fig. 2. Representative cores in ascending order, showing mean treatment effects on biomass depth. Photograph taken at the end of the study period, November 2002. Treatments include verticutting once per month (VC 1 × month), verticutting plus solid tining three times per year (VC + ST), solid tine plus topdress three times per year (ST + TD), scarifying once in spring (scarify 1 × spring), nonstabilized, and stabilized control. Means followed by the same letter are not significantly different at $P = 0.05$ according to Fisher's protected LSD.

among treatments in April and August 2001 and August 2002 (Table 2). In November 2001 and April and November 2002, verticutting and scarifying treatments reduced OM accumulation. After 2 yr, only verticut 1×/M and verticut + ST had resulted in reduced OM accumulation.

Playing Quality

Traction

All treatments at all cleat/tine lengths exceeded the preferred (≥35 N·m) and acceptable (≥25 N·m) ranges for traction (Table 3). Using a 12.7-mm cleat length, ST + topdressing increased traction compared with the stabilized control on every test date and resulted in the highest traction value of 70.3 N·m. Verticut + ST resulted in increased traction on three of the six test dates with the 12.7-mm cleat length, whereas verticut 1×/M only increased traction on one test date. The nonstabilized treatment provided greater traction on four test dates relative to the stabilized control.

Using a 18.8-mm tine length, verticutting 1×/M increased traction in May and November 2001 and May and September 2002. Verticut + ST and scarify 1×/S both resulted in increased traction on two test dates and a trend for higher traction on all dates. Traction between the nonstabilized and stabilized control treatments was similar, except for September 2002 when the nonstabilized treatment increased traction.

Using a 31.3-mm tine length, both solid-tining treatments and the nonstabilized treatment reduced traction in September and December 2002.

Table 2. Effects of cultivation and topdressing treatments on Kentucky bluegrass organic matter accumulation over a Motz TS-II carpet stabilizer at Columbus, OH, in 2001 and 2002.

	Sampling date					
	2001			2002		
Treatment†	Apr.	Aug.	Nov.	Apr.	Aug.	Nov.
	organic matter, g‡					
Verticut 1×/M	2.4a§	2.3a	2.2c	2.5d	2.3a	2.2c
Verticut + ST	2.3a	2.3a	2.3b	2.6cd	2.5a	2.3bc
ST + topdress	2.8a	2.8a	2.8a	3.2ab	2.9a	2.6ab
Scarify 1×/S	2.2a	2.6a	2.6ab	3.0bc	2.5a	2.6ab
Nonstabilized	2.8a	2.7a	2.8a	3.3ab	3.0a	3.2a
Stabilized control	2.3a	2.6a	2.7ab	3.5a	3.0a	2.9a

† Treatments applied April, August, and November in both 2001 and 2002. Treatments include verticutting once per month (verticut 1×/M), verticutting plus solid tining three times per year (verticut + ST), solid tine plus topdress three times per year (ST + topdress), scarifying once in spring (scarify 1×/S), nonstabilized, and stabilized control.

‡ Organic matter accumulation, as determined by loss on ignition ASTM D2974-87 Method C (USGA Green Section Staff, 1993a). Accumulation is presented as total grams of organic matter.

§ Means within columns followed by the same letter are not significantly different at $P = 0.05$ according to Fishers protected LSD.

Divot Resistance

Using the TST with the 30-mm plate depth, the TST results were comparable to the traction device at the 31.3-mm cleat depth. The stabilized control was seldom different than any other treatments; however, both solid-tining treatments reduced divot resistance, and the nonstabilized treatment displayed lower divot resistance compared with the stabilized control on three out of the four testing dates: August, October, and December 2002 (Fig. 3).

Ball Rebound Resilience

No treatment fell outside the preferred (20–50%) or acceptable (15–55%) limits for ball rebound resilience (Table 4). Verticutting 1×/M increased ball rebound resilience compared with the stabilized control on all testing dates. Scarify 1×/S also increased ball rebound resilience in October 2001 and June and October 2002. The nonstabilized treatment resulted in greater ball rebound resilience in November 2001 and September 2002 in both cases following simulated traffic, but in neither case did the value fall outside the preferred or acceptable ranges.

Surface Hardness (Impact Absorption)

All treatments had higher surface hardness readings in 2001 than in 2002 (Fig. 4). Both solid-tining treatments reduced surface hardness compared with the stabilized control in September and November 2001 and December 2002. Verticutting 1×/M increased surface

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Table 3. Effects of cultivation and topdressing treatments on the traction of a Kentucky bluegrass Motz TS-II carpet stabilizer system at Columbus, OH, in 2001 and 2002.

	2001			2002		
Treatment†	May	Sept.	Nov.	May	Sept.	Dec.
	12.7-mm regulation plastic cleat, N.m‡					
Verticut 1×/M	55.0ab§	59.6bc	62.6b	55.3bc	59.6cd	57.0ab
Verticut + ST	56.0ab	64.0ab	63.3ab	61.0ab	65.0b	55.3b
ST + topdress	60.0a	68.0a	68.3a	65.6a	70.3a	62.6a
Scarify 1×/S	56.3ab	55.3c	62.3b	57.3bc	56.0de	54.6b
Nonstabilized	67.0a	67.3a	63.0ab	51.6c	60.6c	59.6ab
Stabilized control	54.3b	59.0c	58.6b	54.0bc	53.6e	55.6b
	18.8-mm metal tine, N.m					
Verticut 1×/M	114.3ab	100.6a	111.3a	98.0a	81.6c	88.0a
Verticut + ST	108.6b	96.0a	101.0b	89.6ab	95.6b	86.0a
ST + topdress	99.0c	98.3a	97.6b	98.0a	95.0b	83.6a
Scarify 1×/S	119.6a	100.6a	102.0b	97.0ab	103.3a	83.0a
Nonstabilized	92.6c	95.0a	101.0b	93.0ab	93.3b	77.0a
Stabilized control	97.3c	90.3a	94.3b	85.6b	79.0d	84.0a
	31.3-mm metal tine, N.m					
Verticut 1×/M	160.0a¶	160.0a	160.0a	160.0a	140.0b	159.6a
Verticut + ST	160.0a	159.3a	158.0a	154.3a	140.0b	134.3b
ST + topdress	160.0a	156.0a	158.0a	154.0a	127.3c	133.3b
Scarify 1×/S	160.0a	160.0a	160.0a	160.0a	155.0a	158.6a
Nonstabilized	123.0a	123.0a	143.3a	151.3a	106.0d	103.3c
Stabilized control	160.0a	160.0a	160.0a	160.0a	150.0a	160.0a

† Treatments applied April, August, and November in both 2001 and 2002. Treatments include verticutting once per month (verticut 1×/M), verticutting plus solid tining three times per year (verticut + ST), solid tine plus topdress three times per year (ST + topdress), scarifying once in spring (scarify 1×/S), nonstabilized, and stabilized control.

‡ Traction at 12.70-, 18.75-, and 31.25-mm cleat/tine lengths. At the 12.70-mm cleat length, preferred range was ≥35 N·m, and the acceptable range was ≥25 N.m. There is no range for 18.75 and 31.25 mm.

§ Means within columns followed by the same letter are not significantly different at $P = 0.05$ according to Fishers protected LSD.

¶ Recorded value exceeded the limit of the measuring device.

hardness in May and November 2001 and October 2002 and produced the highest surface hardness values (160 G_{max}). Scarify 1×/S provided higher surface hardness in May 2001 and October and December 2002. The nonstabilized treatment provided greater surface hardness on all test dates in 2001 and October 2002 compared with the stabilized control and exceeded the preferred hardness range (50–100 G_{max}) on every testing date, except May and December 2002. The stabilized control exceeded the preferred range for surface hardness in September and November 2001.

DISCUSSION

Physically removing biomass by verticutting and/or scarifying could be an effective cultural practice to con-

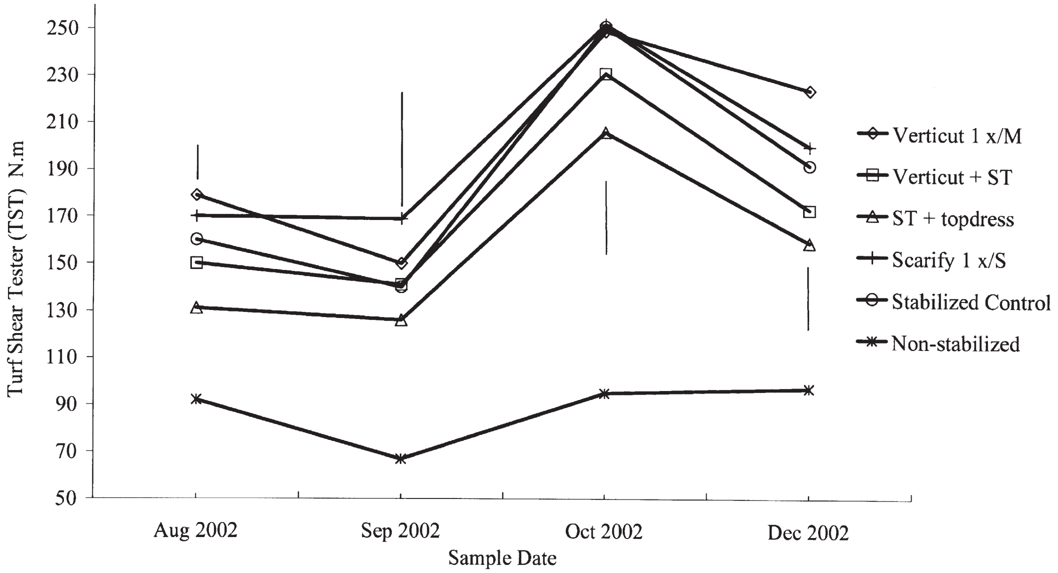

Fig. 3. Turf shear strength (divot resistance). Torque required for the apparatus to tear the surface layer measured in Newton meters (N·m) with turf shear tester (TST) Model CCB1B 50 mm wide by 30 mm long. Vertical lines denote LSD at the 0.05 probability level. Treatments include verticutting once per month (verticut 1×/M), verticutting plus solid tining three times per year (verticut + ST), solid tine plus topdress three times per year (ST + topdress), scarifying once in spring (scarify 1×/S), nonstabilized, and stabilized control. Vertical lines denote LSD at the 0.05 probability level.

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Table 4. Effects of cultivation and topdressing treatments on the percentage ball rebound resilience of a Kentucky bluegrass Motz TS-II carpet stabilizer system at Columbus, OH, in 2001 and 2002.

	2001		2002		
Treatment†	Oct.	Nov.	June	Oct.	Nov.
	ball rebound, %‡				
Verticut 1×/M	45a§	43a	46a	46a	37a
Verticut + ST	42abc	39ab	44ab	46a	35ab
ST + topdress	41bc	39ab	45a	44ab	33b
Scarify 1×/S	43ab	37bc	45a	46a	34b
Nonstabilized	41bc	44a	43ab	47a	36ab
Stabilized control	39c	36bc	41b	41b	34b

† Treatments include verticutting once per month (verticut 1×/M), verticutting plus solid tining three times per year (verticut + ST), solid tine plus topdress three times per year (ST + topdress), scarifying once in spring (scarify 1×/S), nonstabilized, and stabilized control. Treatments applied April, August, and November in both 2001 and 2002.

‡ Percentage ball rebound resilience. The preferred range was 20 to 50% rebound, and the acceptable range was 15 to 55% rebound.

§ Means within columns followed by the same letter are not significantly different at $P = 0.05$ according to Fishers protected LSD.

trol biomass accumulation. Nonstabilized treatments appeared to have greater biomass thickness, possibly due to the presence of more rhizome and shoot matter in the sample compared with the stabilized treatments that had rhizomes and crowns situated in or below the stabilizer. When stabilized samples were taken, only biomass above the stabilizer layer was measured. Sand topdressing diluted the OM on top of the stabilizer, thereby increasing biomass thickness without increasing the actual amount of OM accumulation.

The stabilizer carpet did not increase traction at the regulation cleat depth (12.7 mm), presumably because biomass depth was greater than cleat depth; therefore, the cleats did not come into contact with the stabilizer fibers. Topdressing appeared to increase traction, possibly by increasing thatch bulk density and/or by the physical properties of the sand mineral particles increasing the compression strength of the immediate surface. Thus, at regulation cleat depth (12.7 mm), the deciding factor on traction would appear to be the immediate surface components, not the underlying synthetic material. Canaway et al. (1990) found that most traction readings on natural grass at 15.0-mm cleat length were around 60 N·m. Higher traction values as reported in this study would suggest that the use of stabilizers can increase traction.

At the 18.8-mm tine length, verticutting 1×/M was the only treatment providing higher traction than the stabilized control on most testing dates. Verticutting 1×/M also provided the greatest TST values at 30-mm shearing plate depth. Long tines (31.3 mm) had higher traction values because the tines were forced into the stabilizer fibers by the weight of the apparatus and were therefore in closer proximity to the polypropylene backing. The tines lodged in the backing or close to the backing and, in most cases, could not tear the stabilizer polypropylene material, resulting in maximum traction values that exceeded the 160 N·m capacity of the rotational torque wrench. This is further supported by the higher traction values for the stabilized carpet compared with the nonstabilized control with longer tine depth and the effect of verticutting 1×/M on traction. It appears that less biomass allows the tine to penetrate closer to the backing or actually lodge in the backing.

Solid-tining treatments reduced traction because the coring tines pushed the polypropylene vertical fibers of the stabilizer vertically downward into the underlying soil. This physical displacement of the fibers downward broke apart and destroyed the integrity of the backing

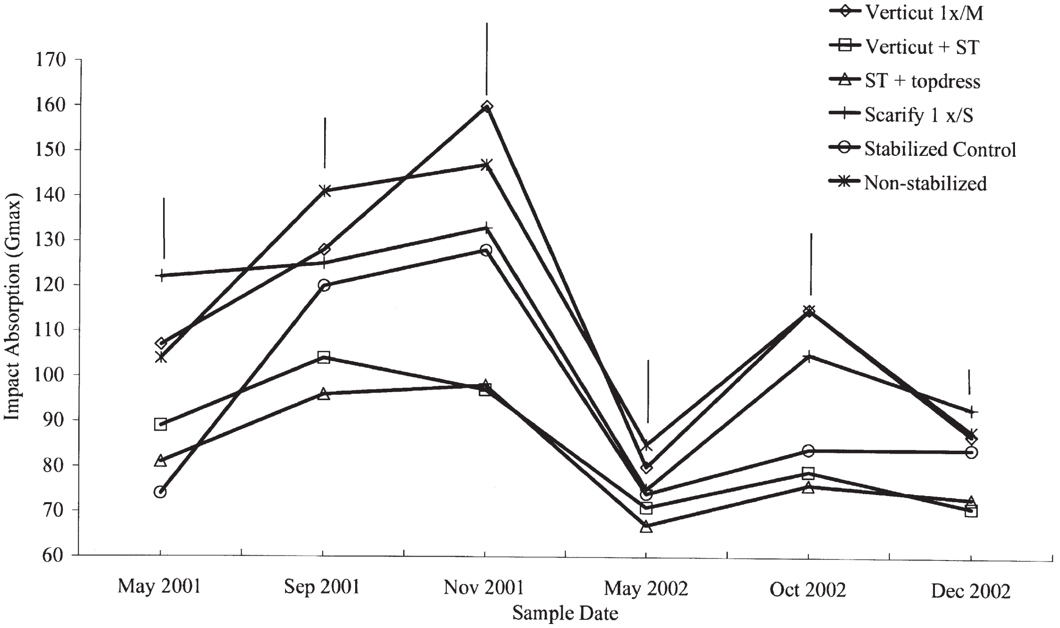

Fig. 4. Surface hardness (G_{max}). The peak deceleration in gravities caused by impact of a cylindrical hammer with a mass of 0.5 kg dropped from a height of 0.55 m. Vertical lines denote LSD at the 0.05 probability level. Treatments include verticutting once per month (verticut 1×/M), verticutting plus solid tining three times per year (verticut + ST), solid tine plus topdress three times per year (ST + topdress), scarifying once in spring (scarify 1×/S), nonstabilized, and stabilized control. The preferred range was 50 to 100 G_{max}, and the acceptable range was 30 to 180 G_{max}. Vertical lines denote LSD at the 0.05 probability level.

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and stabilizer carpet. One observation made during sampling confirms this since it was difficult to separate biomass from the verticutting treatment synthetic fibers. The crowns of the grass plant were embedded in the stabilizer treatments compared with the solid tine samples that were very easily separated or pulled apart.

The verticutting 1×/M treatment increased traction at the intermediate and long tine lengths because biomass depth was reduced and the cleats more readily penetrated the stabilizer fibers. Thus, for all cleat/tine lengths, the governing factor for traction is more dependent on the interaction of the cleat/tine and the stabilizer layer. Maintaining the stabilizer close to the surface by verticutting or possibly scarifying (i.e., reducing biomass depth) will increase traction and make the surface more stable.

Reduced biomass thickness in the verticutting treatments increased ball rebound resilience, possibly because the stabilizer fibers were closer to the surface. Simulated traffic also increased surface hardness across all treatments each year, possibly due to surface compaction or a reduction in surface ground cover due to wear. Surface hardness was much greater in 2001 than 2002, which may be attributed to the increase in biomass across treatments.

In November 2001, verticutting 1×/M exceeded the preferred limit for surface hardness due to shallow biomass depth. The close proximity of the stabilizer fibers to the surface appears to result in increased surface hardness. McNitt and Landshoot (2003) measured Sportgrass hardness values with a 2.25-kg missile, which produced lower G_{max} values than the 0.5-kg missile used in this study. However, they concluded that Sportgrass resulted in hardness values that were probably greater than the preferred upper limit of 80 G_{max} suggested for association football by Canaway et al. (1990). Solid-tining treatments reduced surface hardness because even though the tines forced the stabilizer fibers into the underlying rootzone, the tines gently lifted the stabilizer as they exited the carpet and soil surface. This heaving of the soil surface and stabilizer layer created a soft surface that was immediately apparent following treatment. However, solid tining also destroyed the integrity of the stabilizer material, reducing the shear strength/stability benefit.

CONCLUSIONS

The presence of a carpet stabilizer does not appear to significantly influence traction with regulation American football cleats (12.7 mm) where rotational shear forces are involved. Traction was increased by over 100% at a greater depth within the stabilizer profile as measured with longer cleats/tines. This increased traction should translate into enhanced surface stability and reduced physical displacement of sod and underlying soil. This may affect those sports that are played with longer cleats, e.g., soccer. Divot resistance reflecting lateral shear strength increased with all the stabilizer treatments. Verticutting 1×/M resulted in the greatest divot resistance. Biomass accumulation on the stabilizer was also best controlled by verticutting and would be the recommended practice for carpet stabilizer management.

Verticutting 1×/M increased surface hardness and ball rebound. The surface hardness and ball rebound increase associated with vertical mowing may be related to a decrease in biomass cushion over the reinforced surface. Surface hardness could be controlled by periodic solid tining if the ranges exceeded the preferred or acceptable limits. Ultimately though, continued solid tining will result in reduced traction and a loss of stabilizer efficacy and performance.

Topdressing improved traction at the regulation cleat depth but reduced traction at 18.8- and 31.3-mm depths. This implies that regular topdressing applications may eventually reduce playing quality and bury the stabilizer. In the preparation stages of the stabilizer surface for establishment, less sand topdressing in the stabilizer carpet itself, before seeding, may assist in slowing down the biomass accumulation process. In addition, biomass accumulation could be reduced by seeding the stabilizer with a grass that does not produce excessive thatch, e.g., nonaggressive Kentucky bluegrass cultivars, perennial ryegrass (*Lolium perenne* L.), or tall fescue (*Festuca arundinacea* Schreb.).

Thus, stabilized playing surfaces require a biomass depth that limits surface hardness and excessive traction but is not so great that it reduces divot and shear resistance. Mechanically managing biomass can be achieved through judicious use of verticutting and scarification; however, topdressing and aerification programs can lead to excessive biomass accumulation and ultimate destruction of the stabilizer over time. Research into the prevention and control of biomass accumulation on sand-based stabilized sports fields needs further investigation.

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