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Stressed out

Foot and cart traffic affects putting green and fairway turf

Putting greens and fairways are subject to traffic stresses, which lead to wear and compaction. Creeping bentgrass is considered to be less tolerant of wear and stresses resulting from soil compaction than many other turfgrass species. However, genetic-based differences in traffic tolerance occur within and across species. Also, species compositions of swards can change in response to traffic.

Bentgrass cultivars' ability to maintain a dense turf cover and recover from traffic stresses can influence resistance to weed invasion. Annual bluegrass can invade cool-season species subjected to wear and become the dominant species on golf courses in mild temperate and subarctic climates.

James Beard, Ph.D., characterized annual bluegrass as an opportunistic grass that becomes established in nonaggressive bentgrass cultivar turfs. Reports demonstrate creeping bentgrass cultivars vary in turf density and the ability to resist annual bluegrass invasion under nontrafficked conditions. The relative dominance of bentgrasses in a sward mixture with annual bluegrass under traffic hasn't been reported.

Creeping bentgrass has been studied more extensively for golf course turf than velvet bentgrass, which produces a high-density turf but is reputed to be soft with a strong thatching tendency, characteristics that influence traffic tolerance. The release of the cultivar SR 7200 aroused interest in the use of velvet bentgrass for golf. Trials at Sports Turf Research Institute in Bingley, England, show improved wear tolerance of velvet bentgrass compared with many creeping or colonial bentgrass varieties. Other trials, such as in New Jersey, also indicate velvet bentgrass has broader adaptation for golf.

The objective of this research was to assess the performance of bentgrass cultivars in a sward mixed with annual bluegrass when subjected to wear and/or compaction on simulated putting green and fairway turf.

Table 1. Interaction effects of wear x cultivar in 2000 and cultivar main effect in 2001 on average turf density in a putting green trial grown on a sandy loam.

Bentgrass cultivar	2000 turf density, Wear x cultivar: No wear	2000 turf density, Wear x cultivar: Wear	2001 Turf density: Cultivar main effect
	1-to-9 scale†		
Vesper‡	8.6	7.7	7.9
7001‡	7.9	7.3	7.2
SR 7200‡	8.4	7.8	6.8
Penn A-4	8.1	7.6	7.2
Penn G-2	8.5	7.4	6.7
Century	7.7	7.0	6.3
L-93	6.9	5.9	5.5
SR 1119	6.5	5.9	5.2
Providence	6.4	4.4	4.3
Southshore	5.8	5.6	4.3
SR 1020	5.9	4.3	4.0
Putter	5.4	4.5	4.1
Penneagle	5.1	4.1	3.6
Pennlinks	4.7	3.4	3.0
Penncross	4.6	3.3	3.0
$LSD_{0.05}$	0.8		0.4

† 9 represents the best average turf density, and 5 represents the minimally acceptable rating.
‡ Denotes velvet bentgrass cultivar; all others are creeping bentgrass.

EXPERIMENTAL DESIGN, TREATMENTS

Two studies were conducted: One was managed as putting green turf, and the other as fairway turf. Trials were initiated on a sandy loam (fine-loamy, mixed, mesic Typic Hapludults) at a research facility in North Brunswick, N.J.

Both trials used split-plot designs with main plots (wear and compaction) arranged as two-by-two factorials. Wear at two levels (no wear and wear) and compaction at two levels (no compaction and compaction) were randomly assigned to main plots (5 feet by 56 feet). Fifteen cultivars of creeping bentgrass and velvet bentgrass were assigned randomly to subplots (5 feet by 3 feet). The 12 creeping bentgrass cultivars evaluated in the putting green study were: L-93, Penn A-4, Penn G-2, Century, SR 1119, Providence, Southshore, SR 1020, Penneagle, Putter, PennLinks and Penncross. Velvet bentgrass entries were: SR 7200, 7001 (an experimental selection) and MVB later released as Vesper. The fairway study evaluated the same cultivars except Vesper was substituted – because of a seed shortage – with Penn G-1 creeping bentgrass. The putting green study was replicated four times and the fairway study three times.

Before seeding the bentgrasses in each trial, the entire plot area was topdressed with soil cores taken from putting greens at Plainfield Country Club that contained seeds of annual bluegrass. The cores were stockpiled for one year to kill bentgrass vegetation, spread onto the soil surface, and hollow-tine cultivated and verticut to incorporate them into the soil. Creeping bentgrass cultivars were seeded at 3.6 $g\ m^{-2}$ and velvet bentgrass at 2.1 $g\ m^{-2}$ based on number of seeds per unit area. An unseeded subplot was included. Volunteer establishment of bentgrass in unseeded subplots was negligible. The initial soil pH value was 6, and available phosphorus and potassium were 22.2 and 36.5 $g\ m^{-2}$, respectively. Irrigation was applied only when wilt stress was imminent to maintain relatively dry soil conditions and to wash-in fertilizer. Fungicides were applied as

Table 2. Interaction effects of wear x compaction (comp) x cultivar in 2000 and compaction x cultivar in 2001 on average annual turf quality in a putting green trial grown on a sandy loam.

Bentgrass cultivar	2000 turf quality				2001 turf quality	
	No wear No comp	No wear Comp	Wear No comp	Wear Comp	No comp	Comp
	1-to-9 scale†					
Vesper‡	8.2	8.1	7.3	7.4	7.7	7.5
7001‡	7.5	7.0	6.9	7.0	7.2	7.0
SR 7200‡	7.5	7.5	7.3	6.4	6.5	6.0
Penn A-4	8.5	8.5	7.6	7.8	6.8	7.0
Penn G-2	8.3	8.7	7.2	7.4	6.1	6.5
Century	7.5	7.6	6.6	6.6	6.1	5.7
L-93	7.3	6.6	6.3	5.6	5.4	5.0
SR 1119	6.5	6.8	5.4	6.0	4.6	4.7
Providence	6.8	5.5	5.0	4.0	4.6	3.7
Southshore	5.8	5.3	5.6	5.0	4.1	3.7
SR 1020	5.6	6.0	4.3	4.9	3.9	4.1
Putter	5.3	4.9	3.8	3.8	4.2	3.9
Penneagle	5.1	4.5	4.3	4.0	3.4	3.3
Pennlinks	4.5	4.5	3.6	2.9	3.2	3.0
Penncross	4.2	3.9	3.1	3.4	2.8	2.8
$LSD_{0.05}$	0.7				0.8	

† 9 represents the best turf quality, and 5 represents the minimally acceptable rating. ‡ Denotes velvet bentgrass cultivar; all others are creeping bentgrass.

needed to avoid disease stress.

The putting green trial, which was seeded Sept. 30, 1998, was fertilized with 4.9, 2.1, 4.1 g m^{-2} of nitrogen, phosphorus and potassium on Sept. 30, 1998. Two postplant fertilizations applied 7.5, 2.4, and 5.2 g m^{-2} of nitrogen, phosphorus and potassium, respectively. Fertilizer treatments (19 times) applied a total of 26.1, 7.1 and 12.7 g m^{-2} of nitrogen, phosphorus and potassium in 1999; 6.4, 1.1, and 2.0 g m^{-2} of nitrogen, phosphorus and potassium in 2000 (four times); and 14.1, 4.5, 9.3 g m^{-2} of nitrogen, phosphorus and potassium in 2001 (nine times).

Mowing the green was initiated Nov. 7, 1998, at 0.62 inch. The height was lowered to 0.14 inch on June 12, 1999, and 0.12 inch on March 23, 2000. The green was mowed six times a week, and clippings were removed.

The study was topdressed eight times from April to December 1999 for a total of 10.9 L m^{-2} with medium-sized sand conforming to USGA guidelines. Two topdressings were applied each in 2000 and 2001, totaling 1.7 L m^{-2} and 1.9 L m^{-2}. Solid-tine cultivation was performed before topdressing on Dec. 10, 1999, and vertical mowing (0.18-inch depth) was performed before and after topdressing in July 2001. Traffic treatments were initiated on July 21, 1999.

The fairway trial was seeded Nov. 10, 1998. It was fertilized with 3.2, 0.4 and 1.3 g m^{-2} of nitrogen, phosphorus and potassium Nov. 10, 1998. Two postplant fertilizations applied 5.9, 0.8, and 3.4 g m^{-2} of nitrogen, phosphorus and potassium. Fertilization applied (14 times) a total of 34.1, 5.3, and 17.2 g m^{-2} of nitrogen, phosphorus and potassium in 1999; 2.4 g m^{-2} of nitrogen in 2000 (once) and 8.0, 2.3, 4.5 g m^{-2} of nitrogen, phosphorus and potassium in 2001(five times).

Mowing was initiated Dec. 14, 1998, at 0.62 inch and was lowered to 0.53 inch Oct. 21, 1999, and 0.41 inch March 23, 2000. Mowing was performed three to four times a week with clippings removed. Traffic treatments were initiated July 22, 1999.

Wear was applied using a 2.6-foot-wide wear simulator constructed from a modified walk-behind power broom. Compaction treatments were applied using a 2-foot-wide, 952-pound water-filled turf roller or a 2.6-foot-wide, 2,586-pound vibratory pavement roller. Wear and compaction treatment consisted of two passes of the wear simulator and/or compaction roller applied twice per week (four passes a week) from mid-May through September. Once every two weeks, the 2,586-pound vibratory pavement roller was used in replacement of the water-filled roller to apply two passes to ensure adequate compactive force was applied.

Figure 1. Bulk densities of 0-to-51-mm surface depth as affected by traffic on a putting green grown on a sandy loam in 2001.

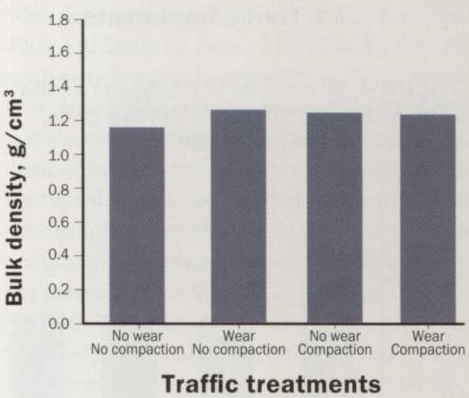
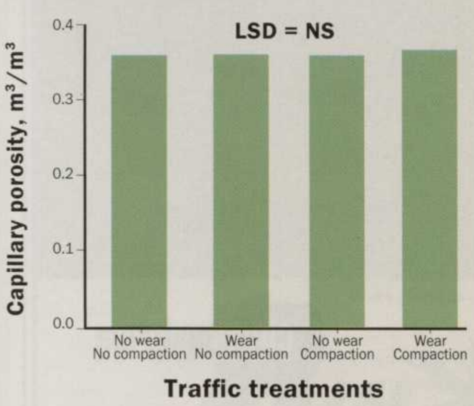


Figure 2. Capillary porosities of 0-to-51-mm surface depth as affected by traffic on a putting green grown on a sandy loam in 2001.



OBSERVATIONS, DATA COLLECTION, ANALYSIS

Plots were evaluated in early spring, late spring, summer and fall for quality during 1999, 2000 and 2001, and in spring and late summer for density using a 1-to-9 scale (1 representing poorest quality turf, 9 the best quality turf, and 5 the minimally acceptable rating). A line-intersect grid count method provided 209 observations per plot for determining the bentgrass population in spring, summer and fall of 1999, 2000 and 2001.

Four 76-mm-diameter undisturbed core samples were taken randomly from the 0-to-51-mm surface soil depth of unseeded subplots of main (traffic) plots in October 2001 for assessment of physical properties. The turf's composition was predominantly annual bluegrass. Saturated water conductivity of each core sample was determined from a 0.5-h flow period after 4-h of constant-head flow. Air-filled porosity was determined by subtracting capillary porosity measured at -10 kPa water potential from the calculated total porosity.

Data were analyzed using the analysis of variance procedures of SAS (version 9.1). Soil physical properties data were analyzed using a 2-by-2 factorial arrangement of wear and compaction factors in a randomized complete block design for both trials. All other data were analyzed using a split-plot design with main plots arranged as a 2-by-2 factorial and 15 cultivars as subplots. Turf quality and density ratings were averaged for a given year.

RESULTS: SOIL PHYSICAL PROPERTIES

In the putting green study, bulk densities of the surface 0 to 51 mm of the plots were relatively low (Figure 1) because of the large organic matter content in the thatch-mat layer where biomass was accumulated in the form of crowns, roots and stolons. This organic matter added resiliency, which limited the damaging effects of compaction from bi-weekly and weekly treatments using 2,586-pound and 952-pound rollers. Bulk densities of all traffic plots were higher than the nontraffic plots, and traffic treatments didn't affect capillary porosity or K_{sat} (Figures 2 and 3).

Compaction increased bulk density and decreased air-filled porosity of nonwear plots without affecting wear plots (data not shown). Similarly, wear treatments didn't affect bulk density and air-filled porosity on the plots that also received compaction treatments but increased bulk density on noncompacted plots. It's possible the repeated wear thinned out the turf and the resiliency of the turf was reduced and allowed compaction of the surface from the rotating flexible paddles on the wear simulator. Bulk density changes were a result of decreased air-filled porosity, yet K_{sat} wasn't affected, which further illustrated the resiliency of this sand topdressed turf grown on sandy loam (Figures 3 and 4).

In the fairway study, the surface layer of 0 to 51 mm indicated lower bulk densities than the putting green trial (Table 3) because of the sand topdressing practice that added sand (high particle density material) to the thatch-mat layer of the putting green. Surface bulk density of fairway plots was increased by compaction and wear treatments (Table 3). Air-filled porosity and K_{sat} levels were higher than the soil green trial, especially under the no traffic and wear-only treatment plots.

Compaction decreased air-filled porosity and increased capillary porosity, while wear only decreased air-filled porosity (Table 3) compared to plots receiving no nontraffic treatments. This structural change at the surface of wear plots wasn't large enough to reduce K_{sat}, whereas compaction treatments reduced K_{sat} (Table 3). Despite lower bulk densities, other physical properties in the fairway trial indicated the fairway turf cover wasn't as resilient to traffic as turf cover in the putting green that received sand topdressing.

CULTIVAR RESPONSES TO TRAFFIC

While traffic and cultivar effects explained much of the variation in turf responses, significant

Figure 3. Saturated hydraulic conductivities of 0-to-51-mm surface depth as affected by traffic on a putting green grown on a sandy loam in 2001.

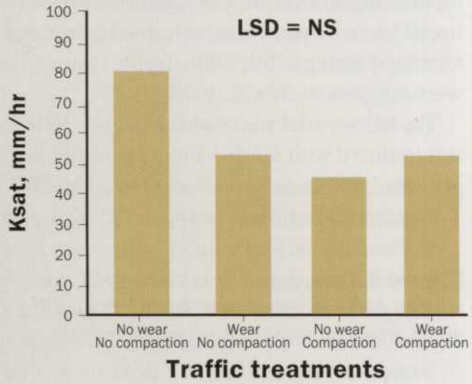
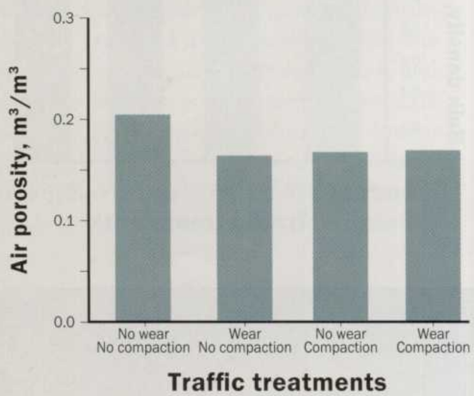


Figure 4. Air porosities of 0-to-51-mm surface depth as affected by traffic on a putting green grown on a sandy loam in 2001.



interactions were observed. Interactions involving the cultivars indicated the cultivars that were affected under wear and/or compaction levels were more noteworthy than any change in the ranking of cultivars under wear and compaction. Thus, discussion of the interactive effects involving the cultivar factor on the effect of wear and/or compaction factors within cultivars is appropriate.

In the putting green study, turf quality generally decreased because of wear treatment, but response to compaction treatment was relatively small in 2000 (Table 2). Wear decreased turf quality of almost all cultivars at one or both levels of compaction except 7001, which didn't respond to wear in 2000 (Table 2). Also, wear didn't affect turf quality of SR 7200 and Southshore in uncompacted plots and Penncross in compacted plots. Compaction didn't affect turf quality of most cultivars; however, compaction decreased turf quality of Providence in no-wear plots and SR 7200, Providence and Southshore in plots receiving wear treatments.

In 2001, compaction decreased turf quality of only Providence (Table 2). Wear decreased turf quality of compacted and uncompacted plots, whereas compaction only reduced quality in the presence of wear. Vesper, 7001 and Penn A-4 had the best turf quality during the last year of the trial (2001) while Penneagle, Pennlinks and Penncross had the poorest turf quality (Table 2). Velvet bentgrass cultivars had better turf quality than most of the creeping bentgrass cultivars studied regardless of whether they received wear or compaction treatments.

Compaction didn't affect turf density in 2000. Wear decreased turf density of all cultivars except 7001, SR 7200 and Penn A- 4 (Table 1). An immediate reduction of turf density in 2000 caused by wear would be expected because wear damage is acute, causing immediate thinning of turf while compaction is a chronic stress. In 2001, wear continued to decrease turf density regardless of whether plots received compaction or not, while compaction treatments only reduced density in the presence of wear.

In 2001, Vesper was the most dense cultivar, followed by 7001 and Penn A-4. Pennlinks and Penncross were the least dense (Table 1). S.I. Sifers et al studied 12 bentgrass cultivars and reported similar observations for shoot density. They noted Penn G-2 had the highest shoot density at 3,547 shoots dm^{-2}, and Pennlinks and Penncross had the lowest at 1,353 and 1,369 shoots dm^{-2}. Beard et al reported Penn G-2 had the second highest density among the 13 creeping bentgrass cultivars studied, while Putter, Penneagle and Penncross had the lowest. Our data indicated cultivar differences in turf density exhibited under nontraffic conditions should also be evident under trafficked conditions.

In the fairway study, turf quality response was more varied than the putting green trial. Also, more cultivars were responsive to the compac-

Table 3. Soil physical properties of the 0-to-51-mm surface depth as affected by wear and compaction in a fairway trial grown on sandy loam; sampled in October 2001.

Main effects	Bulk density	Air-filled porosity†	Capillary porosity	K_{sat}
	$Mg\ m^{-3}$	---- $m^3\ m^{-3}$ ---		$mm\ h^{-1}$
No wear	0.97	0.229	0.404	92
Wear	1.07	0.197	0.401	74
No compaction	0.99	0.239	0.386	126
Compaction	1.04	0.188	0.419	40
Source of variation				
Wear	***	*	NS	NS
Compaction	**	**	**	**
Wear x compaction	NS	NS	NS	NS
CV (%)	1.9	7.5	3.6	38.5

* Significant at the 0.05 probability level. ** Significant at the 0.01 probability level. *** Significant at the 0.001 probability level. † Air-filled porosity was determined by subtraction of capillary porosity (measured as water retention at -10 kPa water potential) from total porosity. Total porosity was calculated from bulk density assuming a particle density of 2.65 $Mg\ m^{-3}$.

tion treatment as would be expected based on the greater extent of detrimental soil physical properties responses observed in the fairway trial (Table 3). Wear reduced turf quality of 10 cultivars in no-compaction plots and 12 cultivars in compaction plots in 2000. Pennlinks and Penncross were the only cultivars not affected by wear in compacted or noncompacted plots.

Compaction didn't alter turf quality of 12 cultivars in no-wear plots and nine cultivars in wear plots during 2000. However, compaction decreased turf quality of SR 7200 in plots receiving wear treatments and those receiving no wear treatments. Wear decreased turf quality of almost all cultivars in 2001. Only SR 7200 wasn't affected at both levels of compaction. Compaction didn't alter turf quality of 12 cultivars in no-wear plots and nine cultivars in wear plots in 2001. However, compaction reduced quality of SR 7200 at both levels of wear.

Wear reduced turf density of fewer cultivars (nine cultivars in no-compaction plots and seven in compaction plots) in 2000 than observed in the putting green trial (Table 1). Wear reduced density of Penn G-2, Penn G-1, Providence and SR 1020 in plots receiving compaction or not, whereas wear didn't affect SR 7200, Pennlinks, and Penncross at both levels of compaction.

Compaction decreased turf density of six cultivars in no-wear and wear plots in 2000. Compaction reduced density of Penn G-1 and SR 1020 at both levels of wear. Wear reduced turf density of nine cultivars in no-compaction plots and eleven cultivars in compaction plots in

IMPACT ON THE BUSINESS

Redirection, aerification help prevent traffic woes

By John Walsh

Superintendents who have a mix of *Poa annua* and bentgrass on their courses know *Poa* withstands foot and cart traffic better than bentgrass. Nonetheless, redirection and aerification help Ken Flisek, CGCS, prevent turf from taking a beating from golfers at the private, 18-hole Club at Nevillewood in Pennsylvania.

Flisek maintains *Poa* and bentgrass on the fairways, greens and tees with a $1.4 million budget. He tries to control the traffic on the greens as best he can by spreading it out via hole locations, which are rotated around the green daily.

The 400-member club generates about 24,000 rounds a year, 23,000 of which are with carts. The course features continuous cart paths. There also are signs that say "please park here" to help spread the traffic wear on turf. In particular, Flisek struggles with – and nurses – six greens that lack desired air movement. They sit low and are surrounded by trees.

"On two of those greens, we extended the cart path and brought it behind the green to give golfers two or three options to park and walk on and off the greens," he says.

Flisek is resurfacing the cart paths and widened them to 12 feet with curbs near the greens. Still, it's tricky to prevent traffic from negatively affecting the health of the turf.

"Golfers are creatures of habit," he says. "Some people park in the same spot no matter where the hole is. But our $15 'please park here' signs are worth their weight in gold because they help distribute foot traffic."

Flisek's crew members move the signs when they move the hole locations but the course doesn't have a sign on every green, just the six babied greens.

Compaction is another problem caused by traffic. All greens have it, and it's one reason why Flisek aerifies. He needle-tines the greens every three weeks throughout the summer (four to six times a year) and needle-tines some greens every two weeks. He core aerifies twice a year and might aerify additionally where carts exit and enter the fairway.

Flisek doesn't have traffic problems in the fairways. Rather, they're in the areas between the cart path and fairway – the rough areas, which tend to get concentrated traffic the most.

"We converted bentgrass to *Poa* because it withstood traffic better," he says. "The stands with a larger percentage of *Poa* withstand traffic better and are healthier."

Flisek distributes traffic in the fairways with the help of one-inch-diameter PVC posts painted black with white tops. The posts are moved every day to designate where golfers should exit the fairways.

"The effect of traffic is a huge issue in the rough," he says. "The turf would be down to dirt if we didn't direct the traffic with the posts. Ninety percent of golfers exit where they're supposed to."

Golfers at Nevillewood have a 50-yard area where they're asked to scatter carts. When the weather is dry and hot, the posts are moved closer to the greens.

"If it had a rope, everyone would drive right up to the rope," Flisek says. "With the post, everyone scatters naturally."

For Flisek, it's a simple matter of being proactive.

"We're trying to move traffic around before a problem develops," he says. **GCI**

2001. Penncross and 7001 weren't affected by wear at both levels of compaction. Compaction decreased turf density of seven cultivars in no-wear plots and only three cultivars in wear plots in 2001. SR 7200 and SR 1020 were affected by compaction at both levels of wear.

BENTGRASS POPULATION

Bentgrass population data (Table 4) for mid-season were presented because this time represents a key time of the growing season for golf course turf. Data were representative of populations measured at other times of the year. Generally, bentgrass population decreased as the study progressed and annual bluegrass encroached. Decreased bentgrass population was particularly evident for lower-density cultivars, as well as plots that received wear treatment (Table 4).

In the putting green study, wear decreased bentgrass population of five cultivars in no-compaction plots and seven cultivars in compaction plots measured on July 28, 2000. Wear decreased bentgrass population of Penn G-2, SR 1020 and Pennlinks at both levels of compaction (Table 4). Compaction decreased bentgrass population of only two cultivars: Putter in no-wear plots and SR 7200 in wear plots. Unexpectedly, compaction increased bentgrass population of Putter in wear plots. However, this response was not evident in 2001 (Table 4). Bentgrass populations in Vesper, 7001, Penn A-4 and L-93 didn't change regardless of the level of wear or compaction in 2000. And Vesper, 7001 and Penn A-4 maintained bentgrass populations of 92 percent or more over all levels of wear and compaction.

Bentgrass populations ranged from 48 to 99 percent on Aug. 13, 2001 (Table 4). Wear decreased bentgrass population of nine cultivars in no-compaction plots and seven cultivars in compaction plots and wear decreased bentgrass of Penn G-2, SR 1119, Southshore and SR 1020 at both levels of compaction (Table 4). Compaction decreased bentgrass population of only four cultivars: Southshore in no-wear plots and SR 1119, SR 1020 and Penneagle in wear plots. Interestingly, compaction increased bentgrass population of Pennlinks from 53 to 64 percent in wear plots in 2001 (Table 4). However, turf quality and density data didn't provide insight to explain this response in Pennlinks plots. Moreover, the practical significance of the increased bentgrass population of Pennlinks appeared to be limited since the bentgrass population (64 percent) was low compared to the best performing creeping

Table 4. Interaction effects of wear x compaction (comp) x cultivar on bentgrass populations (% area of plot) in a putting green trial grown on a sandy loam in 2000 and 2001.

	July 28, 2000				Aug. 13, 2001			
Bentgrass	No wear	No wear	Wear	Wear	No wear	No wear	Wear	Wear
cultivar	No comp	Comp	No comp	Comp	No comp	Comp	No comp	Comp
	(% cover)†							
Vesper‡	95.7	94.1	94.3	92.6	99.0	96.9	97.7	94.7
7001‡	95.3	95.6	93.5	93.1	99.0	96.7	96.2	93.7
SR 7200‡	94.3	93.3	92.7	89.3	96.7	93.7	92.9	85.2
Penn A-4	95.3	94.6	92.3	93.5	91.5	91.6	79.4	81.2
Penn G-2	95.6	95.6	91.7	90.2	90.3	90.8	75.9	79.8
Century	91.5	93.7	92.7	89.2	86.7	84.6	84.1	73.6
L-93	91.0	90.1	87.9	87.7	81.5	73.4	64.4	69.5
SR 1119	91.9	90.0	82.8	86.5	77.6	71.5	60.4	47.8
Providence	89.2	88.9	86.8	83.3	73.0	76.1	60.9	67.5
Southshore	89.6	91.5	87.4	85.4	81.5	70.7	53.1	55.4
SR 1020	89.5	90.0	84.8	83.3	80.1	70.7	65.0	54.1
Putter	92.7	85.9	85.9	90.7	82.7	74.6	64.7	68.4
Penneagle	89.5	88.6	85.8	83.3	78.0	74.6	68.9	53.1
Pennlinks	90.4	89.6	85.4	84.9	68.3	73.6	53.1	64.4
Penncross	88.8	86.1	86.4	84.1	64.0	66.1	54.1	48.4
LSD $_{0.05}$		3.8				10.7		

† Cover measured as the percent of 209 line-intersect observations of bentgrass (remainder was annual blue grass) over 1.35 m² of each plot. ‡ Denotes velvet bentgrass; all others are creeping bentgrass.

bentgrass (81 percent bentgrass for Penn A-4) at that level of traffic. Bentgrass population in Vesper and 7001 plots were 93 percent or greater and weren't significantly affected by the level of wear or compaction.

Beard et al reported Penncross creeping bentgrass had low shoot density (1,369 shoots dm^{-2}) and was less competitive against annual bluegrass encroachment in established nontrafficked turf compared to Penn G-2 and Penn A-1 that had shoot densities above 2,000 shoots dm-2. R.H. Cashel et al found that denser cultivars tolerated traffic stresses on a sand-based root zone and resisted infestation by annual bluegrass overseeding better than older, less dense cultivars.

More cultivars in the fairway trial responded to wear and compaction than in the putting green study with respect to bentgrass populations.

In the fairway study, wear decreased bentgrass populations of most cultivars measured on Aug. 7, 2000. Only 7001 and SR 7200 in no-compaction plots and SR 7200, Penn G-1 and Pennlinks in compaction plots didn't respond to wear. Compaction decreased bentgrass population of eleven cultivars in no-wear plots and five cultivars in wear plots. Compaction decreased bentgrass population of Penn G-2, L-93, Providence and Penneagle at both levels of wear. While all cultivars decreased in bentgrass population because of some level of wear and/or compaction, by Aug. 7, 2000, bentgrass population didn't fall below 90 percent for 7001, 89 percent for SR 7200, 88 percent for Penn G-1 and 87 percent for Penn A-4.

Wear decreased bentgrass populations of almost all cultivars by Aug. 22, 2001, except 7001 and SR 7200 in no-compaction plots and 7001 and Pennlinks in compaction plots. Compaction decreased bentgrass populations of 10 cultivars in no-wear plots and 12 cultivars in wear plots. Compaction decreased bentgrass in eight cultivars regardless of the level of wear: Penn G-2, Century, L-93, SR 1119, Providence, SR 1020, Penneagle and Penncross. 7001 was the only cultivar that didn't lose bentgrass population because of compaction at both levels of wear and maintained a population range of 93 to 99.8 percent across all traffic treatments. Of the creeping bentgrass cultivars, Penn A-4 and Penn G-1 maintained the greatest bentgrass population (83 and 79 percent, respectively) under the most stressful traffic level of wear plus compaction. **GCI**

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