University of Arkansas Study

Summary

- 48 Bermudagrass cultivars were evaluated on the rate at which they recuperate from divot injury

Results

- Celebration showed the fastest recovery amongst all vegetatively propagated Bermudagrasses
- Celebration recovered more quickly than most seeded Bermudagrasses

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Recovery of Bermudagrass Varieties from Divot Injury

Douglas E. Karcher, Michael D. Richardson, Joshua W. Landreth, and **John H. McCalla, Jr.,** Department of Horticulture, University of Arkansas, 316 Plant Sciences Building, Fayetteville 72701

Corresponding author: Douglas E. Karcher. karcher@uark.edu

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Abstract

Intensively used turf areas in the southern United States are commonly established to bermudagrass (*Cynodon dactylon* (L.) Pers. *C. dactylon* × *C. transvaalensis* Burtt-Davy), partly due to its good recuperative potential. However, little scientific data is available regarding recuperative differences among bermudagrass varieties. The objective of the following research was to quantify differences in injury recovery among the forty-eight bermudagrass entries in the 2002 National Bermudagrass Test of the National Turfgrass Evaluation Program (NTEP). The trial was maintained under typical golf course fairway conditions and divot injury was simulated in 2003 and 2004. A digital image was collected of each divot on the day of injury and regularly thereafter until full recovery was reached. Divot images were analyzed for percent green turf cover using digital image analysis to quantify recovery percentages. Although divots recovered more quickly in 2004 than in 2003, differences among varieties remained relatively consistent across years. On average, seeded varieties reached 50% recovery one day faster than vegetatively propagated varieties. Among commercially available varieties, 'La Paloma' and 'Yukon' were fastest to recover while 'Tifsport' and 'Ashmore' were among the slowest to recover when averaged across years.

Introduction

Bermudagrass is the most commonly utilized turf species throughout the southern United States on intensive-use areas such as golf course tees and fairways, and athletic fields. Its popularity is partially due to its ability to respond well to management and form a dense, fine textured turf while tolerating moderate wear and compaction (1). However, probably the most desirable trait of bermudagrass for use in golf course and sports field situations is its high recuperative potential since these areas are consistently subjected to injury from foot traffic or divoting.

Although it is commonly accepted that bermudagrass has relatively high recuperative potential, minimal research effort has focused on differences among bermudagrass varieties regarding their recovery from injury. The National Turfgrass Evaluation Program (NTEP) has been the predominant means by which bermudagrass varieties are tested throughout North America, but evaluations have not traditionally included a measure of recuperative potential (5). If recuperative data were available in addition to the standard evaluation data resulting from NTEP trials, better choices could be made when selecting a bermudagrass variety for golf course or athletic field turf.

The objective of the following research was to determine if significant differences in recovery from divot injury are present among bermudagrass varieties in the 2002 NTEP Bermudagrass Trial.

Quantifying Divot Injury Recovery Among 48 Bermudagrass Varieties

Forty-eight bermudagrass varieties that were included in the 2002 National Bermudagrass Test (4) were planted on 2 July 2002 in a silt loam soil (Captina silt loam soil, typic hapludult) at the University of Arkansas Research and Extension Center in Fayetteville. Each variety was planted in three replicate plots measuring 2.4 by 2.4 m. Vegetative cultivars were planted as 5-cm diameter plugs on 30-cm spacings within the plots, while seeded cultivars were broadcast planted at a seeding rate of 48 kg/ha. Following establishment, plots were maintained under typical golf course fairway or sports field conditions, with a mowing height of 12 mm and monthly nitrogen applications at the rate of 48 kg/ha from mid-April through October. During months when divot recovery was evaluated, nitrogen applications were made seven days prior to divot injury. Phosphorous and potassium applications were made each March to correct deficiencies as recommended by soil test results. Irrigation was initially applied as needed to promote establishment and subsequently to prevent the development of wilt (applied twice weekly at a 1.3-cm depth during periods of no rainfall).

Divot injury was simulated on the bermudagrass varieties on 30 July in 2003 and 3 August in 2004. Standardized divots, each measuring 5 cm wide by 10 cm long by 1.25 cm deep, were cut from each plot using a modified edger (3) and then completely backfilled with topdressing sand. The particle size of the sand was predominately in the ‘medium’ size class (0.25 to 0.50 mm). Recovery was monitored for each divot by collecting digital images semiweekly, beginning on the day of injury and continuing until full recovery was reached. A red metal frame with a 10-by-15-cm opening was placed around each divot when collecting images so that for every divot, the same area of turf was measured each time an image was collected. The frame interior of each image was analyzed for percent green turf cover using SigmaScan Pro (9) software and techniques described by Richardson et al. (8). Percent recovery for an individual divot was calculated from the following equation:

$$\% \text{ recovery} = (\%\text{cover}_{(x)} - \%\text{cover}_{(o)}) / (100\% - \%\text{cover}_{(o)}),$$

where $\%\text{cover}_{(x)}$ is the percent green cover of the frame interior on the day the image was collected and $\%\text{cover}_{(o)}$ is the percent green cover of the frame interior on the day of divot injury. Recovery evaluation methods are summarized in Fig. 1.

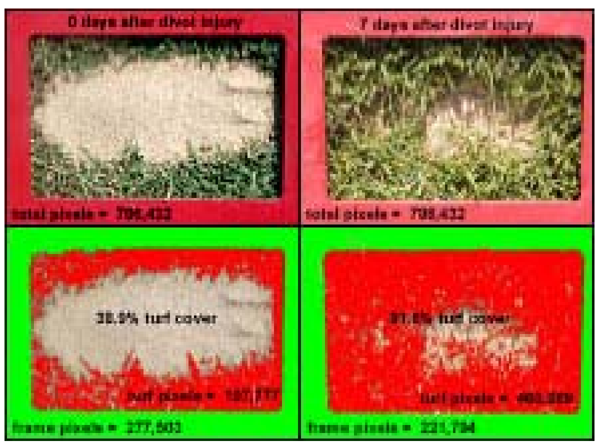

Fig. 1. Image analysis results for a specific bermudagrass divot at zero and seven days after injury. Image analysis software selects image pixels associated with a frame and green turf as shown highlighted in bright green and red, respectively. Percent turf cover within each frame was calculated as [turf pixels / (total pixels – frame pixels)]. At seven days after injury, recovery for this divot was calculated as (81.6% – 38.9%) / (100% – 38.9%) = 69.9%.

A scatter plot of the recovery data versus days after injury (DAI) revealed a strong nonlinear relationship. Moreover, the data fit well to the one-phase exponential association model:

$$\text{recovery} = 1 - \exp(-K * \text{DAI}),$$

where DAI equals the number of days after divot injury and K is an estimated model parameter such that recovery equals 50% when DAI equals (0.6932 / K) (6). With this model, recovery begins at zero and increases rapidly initially, but progresses asymptotically towards 100%. A sum of squares reduction F-test was used to determine if bermudagrass varieties significantly affected recovery (6). The F-test compared the sum of squares from a global model (all varieties share a K value) against the cumulative sum of squares from models where K values were determined separately for each variety. If the sum of squares were reduced significantly ($P < 0.05$) using separate K values, variety effects were determined to be significant. Pairs of varieties were determined to be significantly different if the 95% confidence intervals associated with their predicted K values did not overlap. Nonlinear regression analysis of the recovery data was performed using GraphPad Prism version 4.0 for Windows, (GraphPad Software, San Diego, CA).

Divot Injury Recovery Among Bermudagrass Varieties

In both years, bermudagrass effects were significant regarding recovery time (Table 1). The single phase exponential association model described the data well as R^2 values ranged from 0.88 to 0.99 in 2003 and from 0.88 to 0.98 in 2004 (Table 2). Higher K values translate to more rapid recovery, thus among commercially available varieties, 'La Paloma' had the most rapid recovery while 'Tifsport' was the slowest to recover (Table 2). Seven of the ten varieties with the fastest recovery time were experimental lines and are not currently commercially available.

Table 1. Hypothesis test summaries for 2003 and 2004 bermudagrass variety and propagation effects on recovery from injury.

Sum of squares reduction test	**2003**	**2004**
Variety effect		
Null hypothesis	Shared K† for all varieities	
Alternative hypothesis	Different K for each varitey	
Numerator df	41	41
Denominator df	714	996
F-value	6.273	4.454
P-value	<0.001	<0.001
Propagation effect		
Null hypothesis	Shared K for both propagation types	
Alternative hypothesis	Different K for each propagation type	
Numerator df	1	1
Denominator df	628	1006
F-value	33.09	59.040
P-value	<0.001	<0.001

† K values determine recovery percentage according to the formula: 1 - exp(-K * DAI), where DAI = days after injury. Higher K values indicate faster recovery from injury.

It is often assumed that the recuperative potential of a variety is directly related to its establishment vigor. Although this may be true for vegetatively propagated varieties where establishment vigor is determined primarily by lateral growth rate, the establishment vigor of seeded varieties is more related to germination and seedling vigor than lateral growth rate. For example, the vegetative varieties 'Tifway' and 'Tifsport' have consistently ranked low in establishment vigor (4,7) and were also among the slowest varieties to recover from injury (Table 2). Conversely, 'Arizona Common', 'Riviera', and 'NuMex Sahara' were among the fastest to recover from injury but have the slowest reported establishment vigor among seeded varieties (4).

Table 2. Nonlinear regression results for predicting bermudagrass variety recovery from injury. Varieties are sorted by average K value (fastest to slowest recovery).

Variety	Comm-ercially available	Propa-gation†	2003			2004		
			K‡	(SE)	R^2	K	(SE)	R^2
SW1-1012		S	0.153	(0.0064)	0.98	0.170	(0.0095)	0.97
SW1-1044		S	0.157	(0.0076)	0.98	0.162	(0.0089)	0.96
La Paloma	✔	S	0.115	(0.0071)	0.96	0.201	(0.0125)	0.96
Yukon	✔	S	0.122	(0.0078)	0.96	0.193	(0.0112)	0.97
SR 9554	✔	S	0.130	(0.0111)	0.93	0.179	(0.0143)	0.93
CIS-CD7		S	0.124	(0.0080)	0.96	0.185	(0.0085)	0.98
SW1-1041		S	0.142	(0.0060)	0.98	0.166	(0.0080)	0.97
SW1-1045		S	0.143	(0.0062)	0.98	0.160	(0.0126)	0.93
PST-R68A		S	0.121	(0.0063)	0.97	0.179	(0.0136)	0.94
SW1-1014		S	0.150	(0.0079)	0.98	0.149	(0.0107)	0.94
Celebration	✔	V	0.121	(0.0066)	0.97	0.177	(0.0107)	0.96
Arizona Common	✔	S	0.119	(0.0117)	0.91	0.178	(0.0101)	0.96
Panama	✔	S	0.122	(0.0100)	0.93	0.173	(0.0078)	0.98
NuMex Sahara	✔	S	0.141	(0.0047)	0.99	0.152	(0.0114)	0.93
Princess 77	✔	S	0.129	(0.0064)	0.98	0.160	(0.0155)	0.89
Sunstar	✔	S	0.117	(0.0134)	0.88	0.170	(0.0124)	0.94
CIS-CD6		S	0.122	(0.0080)	0.96	0.164	(0.0090)	0.97
Transcontinental	✔	S	0.114	(0.0075)	0.96	0.169	(0.0082)	0.97
Riviera	✔	S	0.132	(0.0067)	0.98	0.151	(0.0108)	0.94
OKC 70-18		V	0.144	(0.0062)	0.98	0.136	(0.0060)	0.97
Mohawk	✔	S	0.120	(0.0090)	0.94	0.159	(0.0091)	0.96
SW1-1001		S	0.144	(0.0075)	0.98	0.128	(0.0080)	0.95
B-14		S	0.122	(0.0117)	0.91	0.150	(0.0078)	0.97
Sundevil	✔	S	0.117	(0.0045)	0.99	0.148	(0.0087)	0.96
Tift No. 2		S	0.116	(0.0074)	0.96	0.143	(0.0131)	0.88
Southern Star	✔	S	0.097	(0.0052)	0.97	0.162	(0.0074)	0.97
FMC-6		S	0.107	(0.0102)	0.91	0.150	(0.0088)	0.96
SW1-1003		S	0.109	(0.0075)	0.96	0.144	(0.0080)	0.96
Aussie Green	✔	V	0.108	(0.0049)	0.98	0.143	(0.0114)	0.91
GN-1	✔	V	0.092	(0.0038)	0.98	0.158	(0.0101)	0.95
Patriot	✔	V	0.125	(0.0073)	0.97	0.121	(0.0087)	0.93
Midlawn	✔	V	0.114	(0.0059)	0.98	0.130	(0.0075)	0.95
Tift No. 1		S	0.093	(0.0066)	0.95	0.151	(0.0126)	0.91
Tift No. 4		V	0.106	(0.0058)	0.97	0.139	(0.0118)	0.89
MS-Choice	✔	V	0.111	(0.0083)	0.95	0.131	(0.0098)	0.93
Tift No. 3		V	0.096	(0.0050)	0.97	0.146	(0.0111)	0.92
CIS-CD5		S	0.104	(0.0087)	0.93	0.137	(0.0063)	0.97
Tifway	✔	V	0.096	(0.0062)	0.96	0.139	(0.0072)	0.96
SW1-1046		S	0.092	(0.0049)	0.97	0.141	(0.0109)	0.92
OR 2002		V	0.114	(0.0066)	0.97	0.100	(0.0066)	0.92

Ashmore	✔	V	0.093	(0.0070)	0.95	0.119	(0.0068)	0.95
Tifsport	✔	V	0.074	(0.0072)	0.91	0.128	(0.0096)	0.92

† S = seeded, V = vegetative.

‡ K values determine recovery percentage according to the formula:
1 - exp(-K * DAI), where DAI = days after injury. Higher K values indicate faster recovery from injury.

In both years, propagation type significantly affected recovery (Table 1) as the coarser textured seeded varieties recovered faster than finer-textured, vegetatively propagated varieties. An exception to this trend was that 'Celebration', a vegetatively propagated variety, recovered more quickly on average than many seeded varieties (Table 2). However, 'Celebration' was rated as the coarsest textured of the vegetative varieties at the Fayetteville, AR NTEP site, and when averaged across all NTEP locations, 'Celebration' was statistically among the coarsest textured varieties together with 'MS Choice' and 'GN-1' (4). Within bermudagrass and other turfgrass species, leaf texture is often a function of turfgrass density, where more dense cultivars produce narrow leaves that are better able to compete for available light. Density in bermudagrass is dictated primarily by stolon and rhizome internode length. As internode length decreases, more crowns are produced per unit area and these result in more growing points for leaves. However, as internode length decreases, the growth rate of lateral stems is also decreased (1). This can have a significant impact on recovery from divot injury, as recovery is primarily a function of lateral growth. It is noteworthy that 'Ashmore', which was among the slowest varieties to recover, is a very fine-textured *C. transvaalensis* species.

Predicted recovery curves for commercial varieties in 2003 and 2004 are shown in Fig. 2 and 3, respectively. In 2003, the differences between the fastest ('NuMex Sahara') and slowest ('Tifsport') varieties to reach 25, 50, and 75% recovery were 2, 4, and 9 days, respectively. In 2004 the differences between the fastest ('La Paloma') and slowest ('Ashmore') varieties to reach 25, 50, and 75% recovery were smaller at 1, 2, and 5 days, respectively.

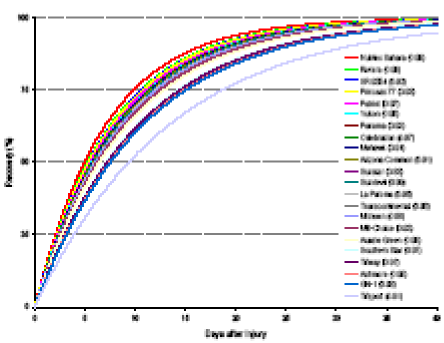

Fig. 2. 2003 predicted recovery curves for commercially available bermudagrass varieties. R^2 value for each variety is listed in parentheses.

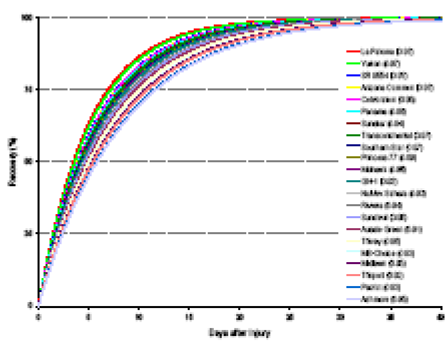

Fig. 3. 2004 predicted recovery curves for commercially available bermudagrass varieties. R^2 value for each variety is listed in parentheses.

Variety confidence intervals (95%) of the mean DAI to reach 50% recovery are illustrated in Fig. 4 and 5, for 2003 and 2004, respectively. Varieties with non-overlapping confidence interval bars were significantly different ($P < 0.05$). On average, varieties took approximately one more DAI to reach 50% recovery in 2003 compared to 2004. However, weather conditions were more favorable for bermudagrass growth in August 2003 when the average daily temperature was 26.0°C, compared to August 2004 when the average daily temperature was 22.2°C. The faster recovery time in 2004 may have been the result of more mature turf stands with better developed lateral stems from which to recover compared to 2003. On average, seeded varieties reached 50% recovery about one full day faster than vegetative varieties in both years (Fig. 6).

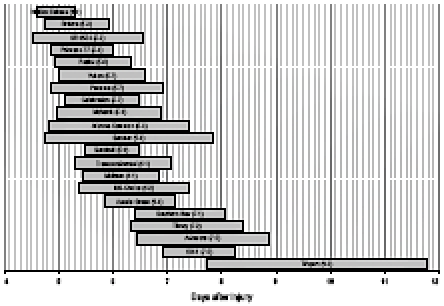

Fig. 4. 2003 bermudagrass variety confidence intervals (95%) for the mean number days to reach 50% recovery following divot injury. Pairs of means are significantly different (*P* = 0.05) if their confidence interval bars do not overlap. Means are listed in parentheses following variety labels.

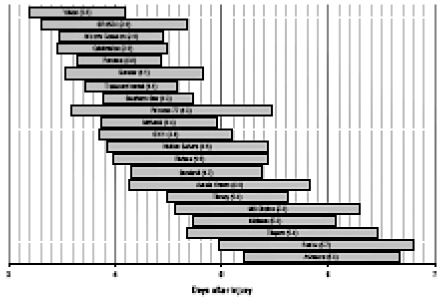

Fig. 5. 2004 bermudagrass variety confidence intervals (95%) for the mean number days to reach 50% recovery following divot injury. Pairs of means are significantly different (*P* = 0.05) if their confidence interval bars do not overlap. Means are listed in parentheses following variety labels.

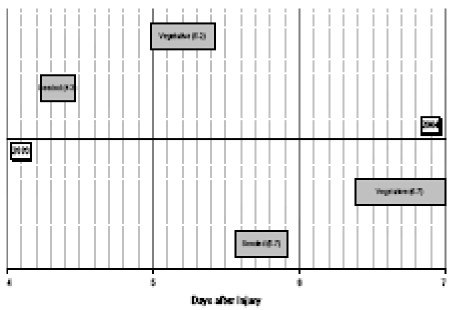

Fig. 6 2003 and 2004 propagation type confidence intervals (95%) for the mean number days to reach 50% recovery following divot injury. Within each year, propagation means are significantly different (*P* = 0.05) since their confidence interval bars do not overlap. Means are listed in parentheses following variety labels.

Although recuperative potential is an important trait when selecting a variety for intensively used turf areas, it is important that other criteria are also considered. This is especially true in the northern boundary areas of bermudagrass adaptation where winter kill is a persistent threat and variety cold tolerance is imperative. Characteristics such as genetic color, density, leaf texture, and overall quality should also weigh into variety selection, with their relative importance dependent on clientele expectations.

Acknowledgments

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