# TURFGRASS RESEARCH FOR HIGH TRAFFICKED AREAS

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1998 was another busy year for turfgrass research for high trafficked areas. This year we focused our research in three major areas:

1) MANAGING POA SUPINA SCHRAD. (SUPINA BLUEGRASS) IN MICHIGAN

2) THE EFFECTS OF DIFFERENT SOCCER SHOE SOLES ON TURFGRASS

3) THE 1998 TRAVELING GOLF SPIKE STUDY

Each of these areas will be reviewed in some detail in this paper. Copies or extended versions of these reports are also available via the world wide web @ www.css.msu.edu

## MANAGING POA SUPINA SCHRAD. (SUPNA BLUEGRASS) IN MICHIGAN 1996-1998

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### Introduction

Due to the need to develop better turf systems for high wear areas on golf courses and athletic fields a research program was started at Michigan State University in 1994 to develop management practices for supina bluegrass in Michigan. A preliminary report has been published on the comparison of supina bluegrass, Kentucky bluegrass (Poa pratensis L.), and perennial ryegrass (Lolium perenne L.) sods for sand based athletic fields (Rogers et al., 1996). Although supina bluegrass has been used extensively in certain areas of Europe, little published research exists to recommend specific management practices. This is the third year for data collection from the following three experiments. Results from 1996 and 1997 data can be found in last years Annual Michigan Turfgrass Conference proceedings in addition to the internet at www.css.msu.edu. In 1995, three plot areas were established to satisfy the following research objectives: 1) Determine the appropriate mowing height range, 2) Determine the fertility requirements on sandy loam soil, and 3) Determine the effect of seeding ratios of supina bluegrass : Kentucky bluegrass on turf characteristics, with a long term objective to determine the changes in stand composition over time.

### Materials and Methods

*Experiment 1: Fertility requirements of supina bluegrass*

Supina bluegrass 'Supra' was established on a sandy loam soil at the Hancock Turfgrass Research Center, Michigan State University, MI., during summer 1995. The plot area (40 ft x 40 ft) was seeded with 1.5 lb/1000 $ft^2$ seed on 21 June 1995 using a drop spreader. Starter fertilizer (13-25-12) was applied at time of seeding to supply approximately 1 lb. N and 1 lb. P/1000 $ft^2$. The area was hydromulched and an automated irrigation system used to maintain sufficient moisture levels for germination, establishment, and subsequent maintenance. All plots were fertilized equally during 1995 with approximately 2.75 lb. additional N/1000 $ft^2$ with approximately 1 lb/1000 $ft^2$ additional P and 1.5 lb/1000 $ft^2$ additional K. On 17 Nov. 1995 a dormant application of 1 lb/1000 $ft^2$ N was applied using SCU (40-0-0). Beginning July 1995 all plots were mowed with a triplex riding mower at approximately 1.25" cutting height. Clippings were returned in each year (1995-1998).

A factorial experiment was developed to test individual fertility treatments beginning spring 1996, and was repeated beginning spring 1997 and 1998. Both total N (2, 4, and 6 lb/1000 $ft^2$/year) and N to K ratios (2:1 and 1:1) were investigated. The experimental design was a strip-plot, randomized complete block with three replications. Main plots were fertility treatments which were stripped for traffic (no traffic and simulated athletic traffic). Fertility treatment dates were as follows (Table 1), with 1 lb. N/1000 $ft^2$ and ½ (treatments 1-3) or 1 lb. K/1000 $ft^2$ (treatments 4-6) applied on each date. Urea (46-0-0) was used as the N source and sulfate of potash (0-0-50) was used as the potassium source.

*Table 1. Treatment dates and rates on supina bluegrass fertility study, East Lansing, MI, 1996 - 1998.*

| Treatment (N:K) | Application dates |
|---|---|
| 2:1 | 10 May, 16 Sept. |
| 4:2 | 10 May, 3 June, 16 Aug., 16 Sept. |
| 6:3 | 10 May, 3 June, 28 June, 16 Aug., 16 Sept., 11 Nov. |
| 2:2 | 10 May, 16 Sept. |
| 4:4 | 10 May, 3 June, 16 Aug., 16 Sept. |
| 6:6 | 10 May, 3 June, 28 June, 16 Aug., 16 Sept., 11 Nov. |

Simulated athletic traffic was applied using a Brinkman Traffic Simulator (BTS). Since 1996 a total of 79 simulated football games have been applied during the fall of each year (26, 25, and 28 games, respectively).

Turf color, density, and quality were evaluated on a regular basis. An Eijelkamp shear vane apparatus was used to determine turf shear resistance.

*Experiment II: Mowing height study*

Supina bluegrass 'Supra' was established on a sandy loam soil at the Hancock Turfgrass Research Center, Michigan State University, MI, during summer 1995. The plot area (40 ft x 40 ft) was seeded with 1.5 lb/1000 $ft^2$ seed on 21 June 1995 using a drop spreader. Starter fertilizer (13-25-12) was applied at time of seeding to supply approximately 1 lb. N and 1 lb. P/1000 $ft^2$. The area was hydromulched, and an automated irrigation system was used to maintain sufficient moisture levels for germination, establishment, and subsequent maintenance. All plots were fertilized equally during 1995 with approximately 2.75 lb. additional N/1000 $ft^2$ with approximately 1 lb/1000 $ft^2$ additional P and 1.5 lb/1000 $ft^2$ additional K. Fertilizer was applied on six dates between June through October with no more than 0.6 lb. N/1000 $ft^2$ applied at any date. On 17 November 1995 a dormant application of 1 lb/1000 $ft^2$ N was applied using SCU (40-0-0). During 1995 and early spring 1996 all plots were mowed with a triplex riding mower set at approximately 1.25" cutting height. Clippings were returned when mowed.

On 24 May 1996 a factorial experiment was started to test the effects of three mowing heights (9/16", 1.25", and 2.25") on supina bluegrass characteristics, and was continued again in 1997 and 1998. The experimental design was a randomized complete block, strip-plot, with three replications. All plots (each 10 x 10 $ft^2$) were divided into trafficked and non-trafficked areas. Simulated athletic traffic was applied using a Brinkman Traffic Simulator (BTS). Since 1996 a total of 79 simulated football games have been applied during the fall of each year (26, 25, and 28 games, respectively).

Plots were fertilized with 5 lb. N/1000 $ft^2$ and 3.5 lb. K/1000 $ft^2$ from 1996 - 1998. Fertilizer (18-3-18) was applied at 0.5 lb. N/1000 $ft^2$ on 10 May, 24 May, 14 June, 12 Aug., 3 Sept., and 24 September for 1996 - 1998. On 28 June (1996, 97, and 98), 1 lb. N/1000 $ft^2$ using sulfur coated urea (40-0-0) was applied plus 1 lb. K/1000 $ft^2$ using sulfate of potash (0-0-50). In late November of each year (1996, 97, and 98) 1 lb. N/1000 $ft^2$ was applied as a dormant application using urea (46-0-0). Plots were irrigated as needed to prevent moisture stress.

Turf color, density, and quality were evaluated on a regular basis. An Eijelkamp shear vane apparatus was used to determine turf shear resistance. Dollar spot disease ratings were collected when the disease appeared.

*Experiment 3: Competition Study*

Plots were established June 1995 on a sand based root zone (80:10:10, sand:peat:soil). Individual plots (10 x 18 ft) were seeded by hand (1.25 lb. seed/1000 $ft^2$) and the seed was raked lightly into the surface. Plots were covered with hydromulch and kept moist during the germination and establishment processes. Following establishment all plots were mowed at 1.25" height with a riding triplex mower, and clippings were returned. Plots were irrigated daily, or as needed in the spring and fall, using an automated irrigation system to prevent moisture stress. All plots were fertilized equally during 1995 with approximately 2.75 lb. additional N/1000 $ft^2$, approximately 1 lb/1000 $ft^2$ additional P, and 1.5 lb/1000 $ft^2$ additional K. Fertilizer was applied on six dates between June through October with no more than 0.6 lb. N/1000 $ft^2$ applied at any date. In late November 1995 - 98 a dormant application of 1 lb/1000 $ft^2$ N was applied using SCU (40-0-0).

A factorial experiment was used to evaluate the effect of seeding mixtures and monostands of supina bluegrass (SB) 'Supra' and Kentucky bluegrass (KB) 'Touchdown' on turf characteristics and eventually, changes in stand composition over time. The experimental design was a strip-plot, randomized complete block with three replications. Main plots were the six seeding treatments: Trt 1=100% SB, Trt 2=50%SB:50% KB, Trt 3=75% SB:25%KB, Trt 4=10% SB:90%KB, Trt 5=5% SB:95% KB, and Trt 6=100% KB. Plots were split to evaluate the effects of low (4 lb. N/1000 $ft^2$/year) and high (6 lb. N/ 1000 $ft^2$/year) fertility levels. Nitrogen was applied at approximately a 1:1 ratio with potassium on most dates (unless noted) using an 18-3-18 fertilizer (Table 1).

*Table 2. Fertility schedule and rates for supina bluegrass:Kentucky bluegrass seeding ratio study.*

| Low fertility (4 lb. N/1000 $ft^2$/year) | High fertility (6 lb. N/1000 $ft^2$/year) |
|---|---|
| 10 May 0.5 lb. N, 18-3-18 | 10 May 0.5 lb. N, 18-3-18 |
| ------------------------------ | 24 May 0.75 lb. N, 18-3-18 |
| 3 June 0.5 lb. N, 18-3-18 | 14 June 0.5 lb. N, 18-3-18 |
| 28 June 1.0 lb. N, 40-0-0 SCU | 28 June 1.0 lb. N, 40-0-0 SCU |
| ------------------------------ | 2 Aug. 0.5 lb. N, 18-3-18 |
| 16 Aug. 0.5 lb. N, 18-3-18 | 16 Aug. 0.75 lb. N, 18-3-18 |
| 5 Sept. 0.5 lb. N, 18-3-18 | 5 Sept. 0.5 lb. N, 18-3-18 |
| ------------------------------ | 1 Oct. 0.5 lb. N, 18-3-18 |
| 16 Nov. 1.0 lb. N, 46-0-0 urea | 16 Nov. 1.0 lb. N, 46-0-0 urea |
| TOTAL ANNUAL N = 4 LB/1000 $FT^2$ | TOTAL ANNUAL N = 6 LB/1000 $FT^2$ |

Simulated athletic traffic was applied using a Brinkman Traffic Simulator (BTS). Since 1996 a total of 79 simulated football games have been applied during the fall of each year (26, 25, and 28 games, respectively).

Turf color, density, and quality were evaluated on a regular basis. The Eijelkamp shear vane apparatus was used to determine turf shear resistance. Changes in stand composition were determined March 1997 and 1998, by collecting plants at random from each plot using a point quadrant and determining the percentages of supina bluegrass and Kentucky bluegrass. Plant counts will be collected again in March 1999.

## Results and Discussion

*Experiment 1: Fertility requirements of supina bluegrass*

Analysis of variance for all three years of testing are included. However, results and discussion will concentrate primarily on 1998 data, or a combination of 1996-1998 data when comparisons are warranted.

Supina bluegrass responded positively to nitrogen fertilization (Table 3 and 5). Turf color and quality were consistently greater at 4, and 6 lbs. N 1000$ft^{-2}$ $yr^{-1}$ compared to the 2 lb. N 1000$ft^{-2}$ $yr^{-1}$. The ratio of nitrogen to potassium had no significant effect on turf color, density, quality, or shear strength. Traffic treatments significantly enhanced turf color, but decreased turf density, quality, and shear strength.

Color interactions occurred in May and November of 1997, and June and November of 1998 (Table 7). No significant differences between 4, and 6 lbs. N 1000$ft^{-2}$ $yr^{-1}$ occurred regardless of the nitrogen to potassium level. However, the non trafficked plots had significantly greater color than the trafficked plots during May and November of 1997. Results from 1998 had no significant differences between traffic treatments for the 4, and 6 lbs. N 1000$ft^{-2}$ $yr^{-1}$ treatments.

*Table 3. Analysis of variance for color† on supina bluegrass at different fertility‡ and traffic§ levels, East Lansing, MI. 1996-98.*

| 1996 | June | July | August | September | October | November |
|---|---|---|---|---|---|---|
| Fertility (F) | Ns | * | * | * | * | * |
| Traffic (T) | * | * | Ns | * | * | * |
| F * T | Ns | Ns | Ns | Ns | Ns | Ns |
| **1997** | **May** | **June** | **July** | **September** | **October** | **November** |
| Fertility (F) | * | Ns | * | * | * | * |
| Traffic (T) | * | * | * | Ns | Ns | * |
| F * T | * | Ns | Ns | Ns | Ns | * |
| **1998** | **May** | **June** | **July** | **August** | **September** | **November** |
| Fertility (F) | Ns | * | * | * | * | * |
| Traffic (T) | * | * | Ns | Ns | Ns | Ns |
| F * T | Ns | * | Ns | Ns | Ns | * |

† Color was rated visually on a 1-9 scale where 1=dead or brown turf, and 9=dark green turf.

‡ Fertility consisted of 2, 4, and 6 lbs. N 1000 $ft^{-2}$ $yr^{-1}$ at both a 1:1 and 2:1 ratio of N:K.

§ Traffic was simulated using the Brinkman Traffic Simulator.

* Significant at the 0.05 probability level.

Ns Not significant at the 0.05 probability level.

*Table 4. Analysis of variance for density† on supina bluegrass at different fertility‡ and traffic§ levels, East Lansing, MI. 1996-98.*

| 1996 | June | July | August | September | October | November |
|---|---|---|---|---|---|---|
| Fertility (F) | Ns | Ns | * | * | Ns | Ns |
| Traffic (T) | Ns | * | Ns | Ns | Ns | * |
| F * T | Ns | Ns | Ns | * | Ns | * |
| **1997** | **May** | **June** | **July** | **September** | **October** | **November** |
| Fertility (F) | Ns | Ns | * | Ns | Ns | * |
| Traffic (T) | * | Ns | * | Ns | * | * |
| F * T | * | Ns | Ns | Ns | Ns | Ns |
| **1998** | **May** | **June** | **July** | **August** | **September** | **November** |
| Fertility (F) | Ns | Ns | Ns | Ns | Ns | Ns |
| Traffic (T) | Ns | Ns | Ns | Ns | Ns | * |
| F * T | Ns | Ns | Ns | Ns | Ns | Ns |

† Density was rated visually on a percent turfgrass cover (0-100%).

‡ Fertility consisted of 2, 4, and 6 lbs. N 1000 $ft^{-2}$ $yr^{-1}$ at both a 1:1 and 2:1 ratio of N:K.

§ Traffic was simulated using the Brinkman Traffic Simulator.

* Significant at the 0.05 probability level.

Ns Not significant at the 0.05 probability level.

*Table 5. Analysis of variance for quality† on supina bluegrass at different fertility‡ and traffic§ levels, East Lansing, MI. 1996-98.*

| 1996 | June | July | August | September | October | November |
|---|---|---|---|---|---|---|
| Fertility (F) | Ns | * | Ns | * | * | * |
| Traffic (T) | Ns | * | * | Ns | * | * |
| F * T | Ns | Ns | Ns | Ns | Ns | Ns |
| **1997** | **May** | **June** | **July** | **September** | **October** | **November** |
| Fertility (F) | Ns | Ns | * | * | * | * |
| Traffic (T) | * | * | * | * | * | * |
| F * T | Ns | Ns | Ns | * | Ns | * |
| **1998** | **May** | **June** | **July** | **August** | **September** | **November** |
| Fertility (F) | Ns | * | * | * | * | * |
| Traffic (T) | * | * | * | Ns | Ns | * |
| F * T | Ns | Ns | Ns | Ns | Ns | Ns |

† Quality was rated visually on a 1-9 scale where 1=dead and/or bare turf, and 9=uniform dark green turf.

‡ Fertility consisted of 2, 4, and 6 lbs. N 1000 $ft^{-2}$ $yr^{-1}$ at both a 1:1 and 2:1 ratio of N:K.

§ Traffic was simulated using the Brinkman Traffic Simulator.

* Significant at the 0.05 probability level.

Ns Not significant at the 0.05 probability level.

*Table 6. Analysis of variance for shear vane† on supina bluegrass at different fertility‡ and traffic§ levels, East Lansing, MI. 1996-98.*

| | September 1996 | November 1996 | November 1997 | August 1998 | December 1998 |
|---|---|---|---|---|---|
| Fertility (F) | * | Ns | Ns | * | Ns |
| Traffic (T) | * | * | * | Ns | * |
| F * T | Ns | Ns | Ns | Ns | Ns |

† Shear strength was collected using the Eijelkamp Shear Vane in Newton meters.

‡ Fertility consisted of 2, 4, and 6 lbs. N 1000 $ft^{-2}$ $yr^{-1}$ at both a 1:1 and 2:1 ratio of N:K.

§ Traffic was simulated using the Brinkman Traffic Simulator.

* Significant at the 0.05 probability level.

Ns Not significant at the 0.05 probability level.

*Table 7. Interaction of fertility and traffic† for color‡ on supina bluegrass, East Lansing, MI. 1997-98.*

| | May 1997 | | November 1997 | | June 1998 | | November 1998 | |
|---|---|---|---|---|---|---|---|---|
| | None | 26 games | None | 25 games | None | 25 games | None | 28 games |
| Fertility rate | | | | Color | | | | |
| 2:1 | 6.8 | 6.0 | 5.1 | 5.0 | 7.0 | 7.4 | 6.0 | 5.9 |
| 4:2 | 7.3 | 6.0 | 6.0 | 4.9 | 8.5 | 8.5 | 6.4 | 6.0 |
| 6:3 | 7.4 | 5.9 | 6.0 | 5.0 | 8.5 | 8.5 | 6.5 | 6.1 |
| 2:2 | 6.6 | 6.0 | 4.8 | 4.6 | 7.1 | 7.6 | 5.5 | 5.5 |
| 4:4 | 6.8 | 6.0 | 5.9 | 4.6 | 8.5 | 8.5 | 6.5 | 6.5 |
| 6:6 | 7.5 | 5.9 | 6.0 | 5.0 | 8.5 | 8.5 | 6.4 | 6.0 |
| LSD§ (0.05) | 0.5 | | 1.7 | | 0.5 | | 0.3 | |
| LSD¶ (0.05) | 0.6 | | 0.9 | | 0.8 | | 0.5 | |

† Traffic was simulated using the Brinkman Traffic Simulator.

‡ Color was rated visually on a 1-9 scale where 1=dead or brown turf, and 9=dark green turf.

§ Between traffic treatments at same fertility level.

¶ Between fertility levels at same or different traffic.

*Experiment 2: Mowing height study*

Analysis of variance for all three years of testing are included. However, results and discussion will concentrate primarily on 1998 data, or a combination of 1996-1998 data when comparisons are warranted.

Mowing height and traffic interactions occurred for color at the end of each season after traffic treatments were applied (Table 12). Color ratings differed greatly for each year regardless of mowing height or traffic. The vast differences between each rating date and treatments, may be a result of the different temperatures during the late fall of each season. The fall of 1996 was much cooler than the fall of 1997, and especially 1998. This is noticeable by the low turf color for the 2.25" mowing height in December 1996.

Mowing height and traffic interactions also occurred for turfgrass density at the end of each season (Table 13). As mowing height decreased from, 2.25" to 1.25" to 9/16" respectively, turf density also decreased proportionally. However, unlike the December 1996 and November 1997 ratings, there was no significant difference between the 1.25" and 2.25" mowing heights plus traffic for the November 1998 rating. This is likely a result of the turf having three full seasons of growth to mature. During the winter of 1997-98 the ground never froze, and in turn the growing season was lengthened. As a result, all grasses were able to grow longer enabling thatch to accumulate, and possibly providing more wear resistance.

Finally, mowing height and traffic interactions occurred for turfgrass quality at the end of each season (Table 14). Without traffic, the 1.25" mowing height typically had the greatest turfgrass quality. At the 2.25" mowing height, particularly without traffic, the overall appearance of the turf was not uniform giving it a lower quality rating. The appearance of the 9/16" mowing height without traffic was very dense and uniform in texture; however, quality was decreased as a result of creeping bentgrass encroachment. The lower quality ratings for the trafficked plots is mostly attributed to the level of decline in turfgrass density.

*Table 8. Analysis of variance for color† on supina bluegrass at different mowing heights‡ and traffic§ levels, East Lansing, MI. 1996-98.*

| **1996** | **June** | **July** | **August** | **September** | **October** | **November** |
|---|---|---|---|---|---|---|
| Height (H) | * | Ns | Ns | * | - | * |
| Traffic (T) | Ns | Ns | Ns | Ns | - | Ns |
| H * T | Ns | Ns | Ns | Ns | - | * |
| **1997** | **May** | **June** | **July** | **September** | **October** | **November** |
| Height (H) | * | Ns | * | Ns | Ns | Ns |
| Traffic (T) | Ns | Ns | Ns | Ns | Ns | * |
| H * T | * | Ns | Ns | Ns | Ns | * |
| **1998** | **May** | **June** | **July** | **August** | **September** | **November** |
| Height (H) | * | * | Ns | * | * | Ns |
| Traffic (T) | * | Ns | Ns | Ns | Ns | * |
| H * T | * | Ns | Ns | Ns | Ns | * |

† Color was rated visually on a 1-9 scale where 1=dead or brown turf, and 9=dark green turf.

‡ Mowing was done three times a week using reel mowers returning clippings.

§ Traffic was simulated using the Brinkman Traffic Simulator.

* Significant at the 0.05 probability level.

Ns Not significant at the 0.05 probability level.

\- Data was not collected during this period.

*Table 9. Analysis of variance for density† on supina bluegrass at different mowing heights‡ and traffic§ levels, East Lansing, MI. 1996-98.*

| 1996 | June | July | August | September | October | November |
|---|---|---|---|---|---|---|
| Height (H) | * | Ns | Ns | Ns | - | Ns |
| Traffic (T) | Ns | Ns | Ns | Ns | - | * |
| H * T | Ns | Ns | Ns | Ns | - | * |
| **1997** | **May** | **June** | **July** | **September** | **October** | **November** |
| Height (H) | * | * | Ns | Ns | * | * |
| Traffic (T) | * | * | Ns | Ns | * | * |
| H * T | * | * | Ns | Ns | * | * |
| **1998** | **May** | **June** | **July** | **August** | **September** | **November** |
| Height (H) | * | * | Ns | * | * | Ns |
| Traffic (T) | * | Ns | Ns | Ns | Ns | * |
| H * T | * | Ns | Ns | Ns | Ns | * |

† Density was rated visually on a percent turfgrass cover (0-100%).
‡ Mowing was done three times a week using reel mowers returning clippings.
§ Traffic was simulated using the Brinkman Traffic Simulator.
* Significant at the 0.05 probability level.
Ns Not significant at the 0.05 probability level.

*Table 10. Analysis of variance for quality† on supina bluegrass at different mowing heights‡ and traffic§ levels, East Lansing, MI. 1996-98.*

| 1996 | June | July | August | September | October | November |
|---|---|---|---|---|---|---|
| Height (H) | * | * | * | Ns | - | Ns |
| Traffic (T) | Ns | Ns | Ns | Ns | - | * |
| H * T | Ns | Ns | Ns | Ns | - | * |
| **1997** | **May** | **June** | **July** | **September** | **October** | **November** |
| Height (H) | * | * | Ns | Ns | * | * |
| Traffic (T) | * | * | * | * | * | * |
| H * T | * | * | * | * | * | * |
| **1998** | **May** | **June** | **July** | **August** | **September** | **November** |
| Height (H) | * | Ns | Ns | Ns | * | Ns |
| Traffic (T) | Ns | Ns | Ns | Ns | Ns | * |
| H * T | Ns | Ns | Ns | Ns | Ns | * |

† Quality was rated visually on a 1-9 scale where 1=dead and/or bare turf, and 9=uniform dark green turf.
‡ Mowing was done three times a week using reel mowers returning clippings.
§ Traffic was simulated using the Brinkman Traffic Simulator.
* Significant at the 0.05 probability level.
Ns Not significant at the 0.05 probability level.

*Table 11. Analysis of variance for shear vane† on supina bluegrass at different mowing heights‡ and traffic§ levels, East Lansing, MI. 1996-98.*

| | November 1996 | November 1997 | December 1998 |
|---|---|---|---|
| Height (H) | * | * | Ns |
| Traffic (T) | * | * | * |
| H * T | Ns | * | Ns |

† Shear strength was collected using the Eijelkamp Shear Vane in Newton meters.
‡ Mowing was done three times a week using reel mowers returning clippings.
§ Traffic was simulated using the Brinkman Traffic Simulator.
* Significant at the 0.05 probability level.
Ns Not significant at the 0.05 probability level.

*Table 12. Interaction of mowing and traffic† for color‡ on supina bluegrass, East Lansing, MI. 1997-98.*

| | December 1996 | | November 1997 | | November 1998 | |
|---|---|---|---|---|---|---|
| | None | 26 games | None | 25 games | None | 28 games |
| 9/16 | 5.3 | 5.8 | 3.8 | 4.0 | 3.8 | 4.0 |
| 1.25 | 3.0 | 5.3 | 4.0 | 3.2 | 4.0 | 3.2 |
| 2.25 | 1.0 | 3.8 | 3.0 | 2.3 | 3.0 | 2.3 |
| LSD(0.05) | 0.8 | | 1.0 | | 0.6 | |
| | 0.7 | | 0.8 | | 0.6 | |

† Traffic was simulated using the Brinkman Traffic Simulator.
‡ Color was rated visually on a 1-9 scale where 1=dead or brown turf, and 9=dark green turf.
§ Between traffic treatments at same mowing height.
¶ Between mowing heights at same or different traffic.

*Table 13. Interaction of mowing and traffic† for density‡ on supina bluegrass, East Lansing, MI. 1997-98.*

| | December 1996 | | November 1997 | | November 1998 | |
|---|---|---|---|---|---|---|
| | None | 26 games | None | 25 games | None | 28 games |
| 9/16 | 99.0 | 60.0 | 96.3 | 41.7 | 100 | 46.7 |
| 1.25 | 99.0 | 78.3 | 100 | 65.0 | 100 | 86.7 |
| 2.25 | 99.0 | 94.0 | 100 | 97.7 | 100 | 91.7 |
| LSD(0.05) | 2.6 | | 14.8 | | 7.0 | |
| | 2.3 | | 15.0 | | 7.5 | |

† Traffic was simulated using the Brinkman Traffic Simulator.
‡ Density was rated visually on a percent turfgrass cover (0-100%).
§ Between traffic treatments at same mowing height.
¶ Between mowing heights at same or different traffic.

*Table 14. Interaction of mowing and traffic† for quality‡ on supina bluegrass, East Lansing, MI. 1997-98.*

| | December 1996 | | November 1997 | | November 19-98 | |
|---|---|---|---|---|---|---|
| | None | 26 games | None | 25 games | None | 28 games |
| 9/16 | 7.3 | 2.2 | 4.2 | 2.0 | 6.8 | 3.7 |
| 1.25 | 6.3 | 2.7 | 5.7 | 3.7 | 7.0 | 5.5 |
| 2.25 | 5.0 | 5.5 | 4.5 | 3.8 | 7.0 | 6.2 |
| LSD(0.05) | 0.7 | | 0.6 | | 0.6 | |
| | 0.7 | | 0.6 | | 1.3 | |

† Traffic was simulated using the Brinkman Traffic Simulator.
‡ Quality was rated visually on a 1-9 scale where 1=dead and/or bare turf, and 9=uniform dark green turf.
§ Between traffic treatments at same mowing height.
¶ Between mowing heights at same or different traffic.

*Experiment three: Competition study*

For the purpose of this study, color and quality ratings will not be presented, because of the vast differences in normal physiological characteristics (i.e. color), the color and quality ratings would be somewhat skewed as a result of the mixing of the two turf species.

No significant differences occurred between the different seeding ratios in turfgrass density since the first fall of traffic (Table 15). However, significant differences occurred during the spring and fall ratings for turfgrass density, as a result of fertility treatments. With the exception of the fall 1996 rating, the November 1997 and 1998 density ratings were greater for the 6 lbs. N $1000ft^{-2}$ $yr.^{-1}$ than the 4 lbs. N $1000ft^{-2}$ $yr^{-1}$ treatment. The drastic improvement in turfgrass density at the end of the 1997 and 1998 season compared to the 1996 season, for the high fertility treatments, may be a result of increased turfgrass maturity. It is interesting to note that the May 1998 density ratings reversed from the previous fall even though no more traffic had been applied. For the high fertility treatment, the percent turfgrass cover declined from the previous fall; while, the low fertility treatment increased in density. These results may be a result of pink snow mold that occurs on the supina bluegrass every winter, particularly on the high fertility treatments.

Applying 6 lbs. N $1000ft^{-2}$ $yr.^{-1}$ compared to 4 lbs. N $1000ft^{-2}$ $yr.^{-1}$ decreases turfgrass shear strength (Table 16). Even though the low fertility treatments had greater shear strength results, the average shear values for the high fertility treatments, for November 1997 and December 1998, are still at acceptable values for turfgrass shear strength. Since the first fall of treatments (October 1996), turfgrass shear strength greatly increased overall for both fertility levels, and different seeding ratios. This is a result of the turfgrass maturing, and developing more extensive stolons and rhizomes.

Results from Figure 1 show the increase in supina bluegrass competition as a result of traffic and increased fertility (spring 1997 sampling date). Applying traffic significantly increases the percent supina bluegrass. In addition, high fertility treatments further increase supina bluegrass encroachment. Simply seeding at 5 or 10% supina bluegrass, and applying traffic is enough to increase the percent supina bluegrass to about 50%. Seeding at 10 and 25% supina bluegrass, and applying high fertility and traffic is enough to increase their stand to almost 80%.

Figure 2 shows the same results for percent supina encroachment, but for spring the spring 1998 sampling date one year later. Unlike Figure 1 results from Figure 2 show the increase in percent supina bluegrass, for the 5 and 10% seeding rates, is not increased any further by a combination of high versus low fertility in addition to traffic, but only by traffic alone. After two seasons of traffic, seeding at 5 and 10% supina bluegrass the percent supina bluegrass increased to about 70%. This is the same for the 25% seeding rate for supina bluegrass with traffic and low fertility. With high fertility and traffic, seeding at 25% supina bluegrass the percent supina present after two years of testing is about 85%.

Finally, Figure 3 shows the number of actual seed stalks counted in a given area for each treatment. This figure simply reinforces the results from Figures 1 and 2. The aggressiveness of supina bluegrass is evident by the similar number of seed stalks recorded for the 5, 10, and 25% seeding rates with the 50 and 100% supina seeding rates.

*Table 15. Effects of seeding ratios and fertility on supina bluegrass and Kentucky bluegrass mixes for turfgrass density†, East Lansing, MI. 1996-98.*

| % supina seeded | December 1996 | May 1997 | November 1997 | May 1998 | November 1998 |
|---|---|---|---|---|---|
| 0 | 84.8 | 95.8 | 91.8 | 95.8 | 100 |
| 5 | 84.8 | 95.6 | 93.8 | 95.6 | 94.0 |
| 10 | 81.2 | 96.0 | 94.0 | 96.0 | 98.4 |
| 25 | 80.3 | 95.1 | 92.3 | 95.2 | 98.7 |
| 50 | 79.8 | 94.9 | 94.8 | 94.9 | 96.9 |
| 100 | 65.0 | 89.8 | 93.6 | 89.8 | 94.5 |
| LSD(0.05) | 11.8 | Ns | Ns | Ns | Ns |
| **Fertility** | **26 games** | **26 games** | **25 games** | **25 games** | **28 games** |
| 3 lbs. N year-=1 | 92.4 | 96.8 | 90.2 | 96.8 | 95.8 |
| 6 lbs. N year-=1 | 76.3* | 92.3* | 96.6* | 92.3* | 98.4* |

† Density was rated visually on a percent turfgrass cover (0-100%).

* Significant at the 0.05 probability level.

*Table 15. Effects of seeding ratios and fertility on supina bluegrass and Kentucky bluegrass mixes for turfgrass shear vane†, East Lansing, MI. 1996-98.*

| % supina seeded | October 1996 | November 1997 | December 1998 |
|---|---|---|---|
| 0 | 9.9 | 23.0 | 19.5 |
| 5 | 11.6 | 20.3 | 20.4 |
| 10 | 12.0 | 18.9 | 20.3 |
| 25 | 13.3 | 19.1 | 19.1 |
| 50 | 13.7 | 18.5 | 20.9 |
| 100 | 14.9 | 16.5 | 21.0 |
| LSD(0.05) | Ns | 2.8 | Ns |
| **Fertility** | | | |
| 3 lbs. N year-=1 | 14.3 | 20.0 | 21.5 |
| 6 lbs. N year-=1 | 10.8* | 18.8* | 18.9* |

†. Shear strength was collected using the Eijelkamp Shear Vane in Newton meters. * Significant at the 0.05 probability level.

**Figure 1. The effects of supina bluegrass (SB) seeding (S) rate, fertility level (F), and traffic (T) on % SB in a supina / Kentucky bluegrass stand, East Lansing, MI. 1997.**

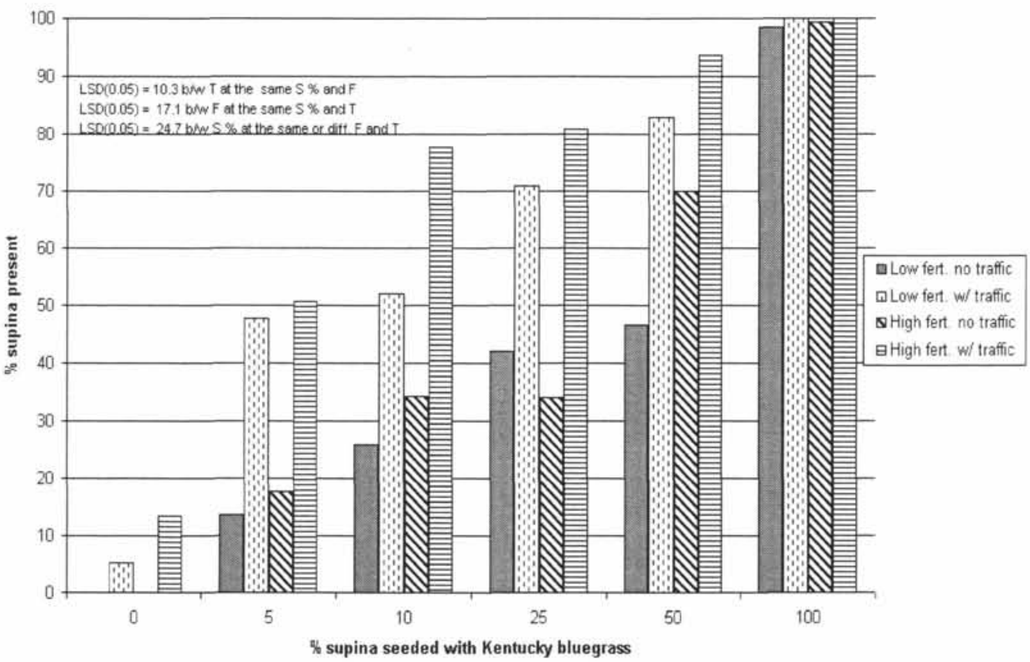


Figure 2. The effects of supina bluegrass (SB) seeding (S) rate, fertility level (F), and traffic (T) on % SB in a supina / Kentucky bluegrass stand, East Lansing, MI. 1998

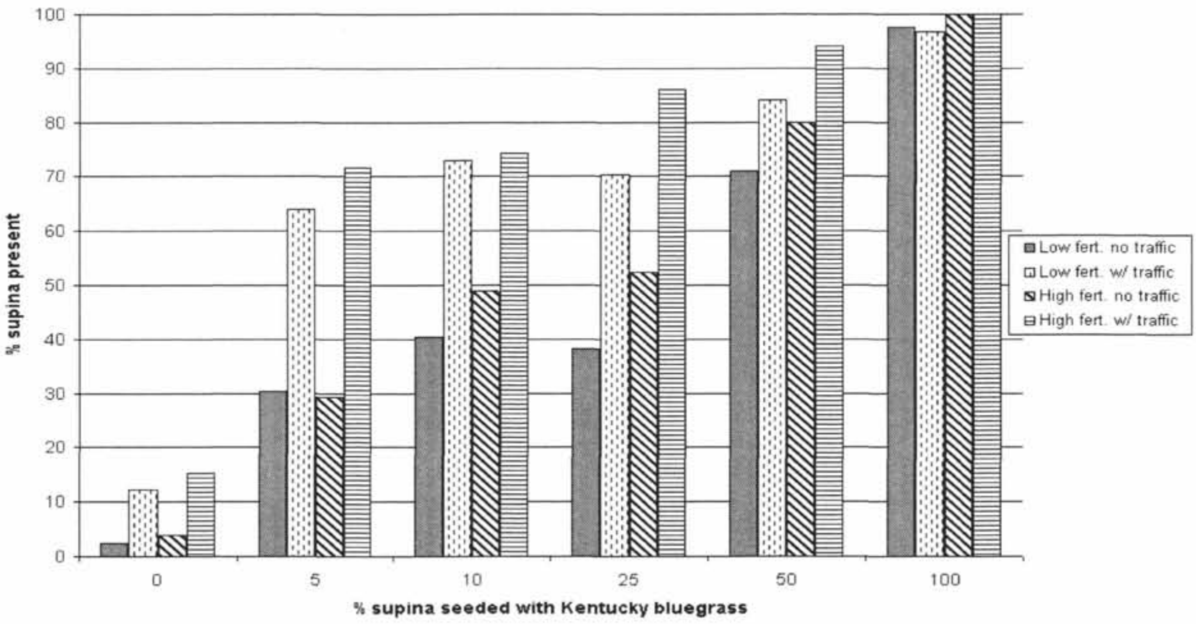
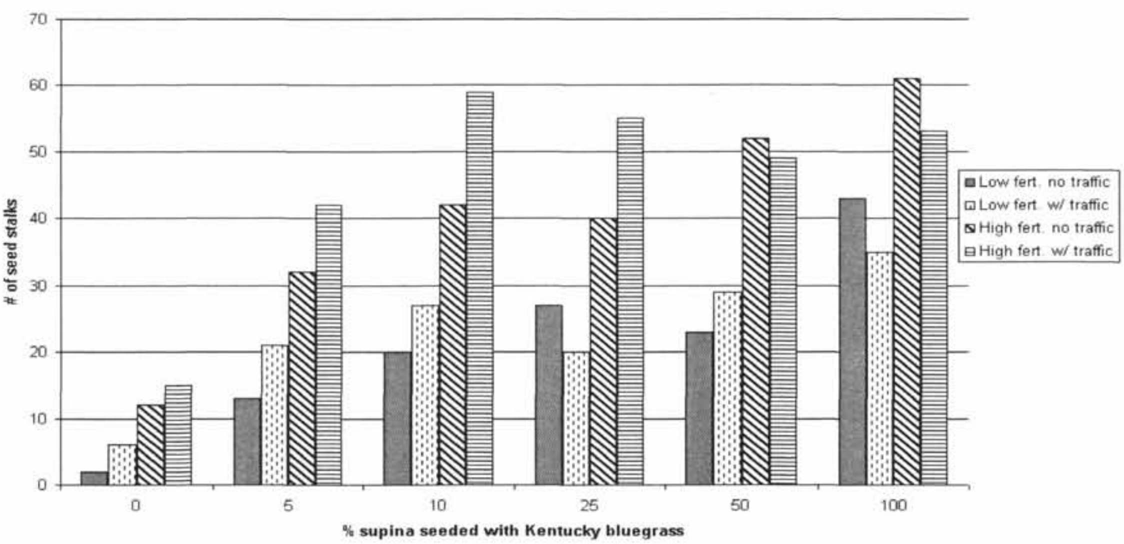



Figure 3. The effects of supina bluegrass (SB) seeding (S) rate, fertility level (F), and traffic (T) on the number of SB seed stalks in a supina / Kentucky bluegrass stand, East Lansing, MI. 1998



**Conclusions**

*Experiment 1: Fertility requirements of supina bluegrass*

Fertilizing at 4, or 6 lbs. N $1000ft^{-2}$ $yr^{-1}$ compared to the 2 lb. N $1000ft^{-2}$ $yr^{-1}$ resulted in superior turfgrass color, and to an extent density quality. The ratio of nitrogen to potassium, whether it was 1:1 or 2:1, had no significant effect on turf color, density, quality, or shear strength. Shear resistance, indicative of the degree of rooting and turf strength, was occasionally decreased by high N fertility. Traffic treatments significantly enhanced turf color, but decreased turf density, quality, and shear strength. Thus, one could conclude that fertilizing at 4 lbs. N $1000ft^{-2}$ $yr^{-1}$ would provide the highest overall quality of turf at the most efficient cost.

*Experiment 2: Mowing study*

Supina bluegrass provided acceptable turfgrass stand for all three mowing heights tested (9/16", 1.25", and 2.25") on non trafficked plots. Supina bluegrass has demonstrated the ability to thrive at a fairway mowing height of 9/16". However, it would not provide a suitable turf surface at the 9/16" mowing height for athletic field conditions. One example of its ability to thrive at this mowing height is its ability to recover from as low as 50% cover to 100% cover within a few growing months after traffic has ceased. Mowing at 2.25", supina bluegrass is very tolerable to traffic, but it does exhibit a lack of uniformity in growth at this increased mowing height. The appearance of the supina appears to accumulate a lot of thatch causing the lack of uniformity at the 2.25" mowing height. Overall, mowing at 1.25" provided the greatest all around turf stand. Supina bluegrass, mowed at 1.25", is very tolerable to athletic field traffic, while maintaining a uniform, high quality appearance.

*Experiment 3: Competition study*

Supina bluegrass has demonstrated the ability to encroach into or out compete Kentucky bluegrass when seeded as a mixture. Only 5 or 10% supina bluegrass is needed to aggressively compete with Kentucky bluegrass. When seeded at 5 or 10%, supina bluegrass will become the dominant species (about 70%) in the turf stand after two seasons of simulated football traffic (26, and 25 games, respectively). Ultimately, it would be optimal to achieve a turf stand that is predominantly supina bluegrass for its quick recuperative potential via stolons, while maintaining a lesser stand of Kentucky bluegrass to utilize its ability to increase stability and shear strength via rhizomes. A combination of a supina bluegrass and Kentucky bluegrass may in a sense mimic a cool season version of bermudagrass, which, is a turfgrass that provides superior turf conditions for high wear athletic fields, as a result of its aggressive stoloniferous and rhizomatous growth habit.

# THE EFFECTS OF DIFFERENT SOCCER SHOE SOLES ON TURFGRASS

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## Introduction

High use of athletic fields, particularly at the grade school level has created an ongoing challenge for field managers to maintain an acceptable playing surface. Heavy traffic applied to the turfgrass during game and practice situations decreases turfgrass density and overall quality. This causes the playing surface to become uneven. For instance, when a turfgrass area is worn down to bare soil, the soil becomes unstable and develops ruts; thus, increasing the opportunity for a player to lose their footing. The lack of a consistent playing surface increases the potential for player injury to occur; therefore, making the field unsafe. The implementation of any component that demonstrates the potential for preserving turfgrass density is desirable. Improving the type of spikes used on the soles of soccer shoes is one component that has the potential to limit the rate of wear applied to the turfgrass area. The objective of this study was to compare different types of spikes for the soles of soccer shoes, and their effect on turfgrass density. A second analysis compared the performance or stability of the different soles themselves. A total of four different spikes were compared. All four shoe soles were tested using Lanzera soccer shoes (PO Box 442, Tingsboro, MA., 01879). The first shoe sole tested was a traditional thirteen stud molded soccer cleat. The molded soccer shoe had thirteen spikes. It is the most common cleat used for games and practices. The length of the studs in the molded cleat consists of 10, 12, and 15 mm studs. The 10 mm spikes are in the forefront of the shoe, the 12 mm studs are in the center, and the 15 mm studs are in the heel. The second shoe sole tested was a traditional six stud screw-in type soccer cleat. The six stud soccer cleat has four 15 mm spikes in the forefront, and two 18 mm spikes in the heel. This cleat is typically used in games and practices where the field conditions are very wet, and normal footing is an issue. The next two shoe soles tested were experimental studs. The first experimental sole was the molded TX sole. This shoe was similar to the traditional molded soccer cleat has 10, 12, and 15 mm spikes which are part of the actual shoe sole itself. However, these spikes differ from the traditional spikes in that they are not the traditional round spike. The molded TX cleats are designed to improve traction during acceleration and stopping. This was done by elongating the surface of the stud from front to back, while maintaining the same width at the traditional stud. The final shoe sole tested was the Flat Spike. The Flat Spike is a stud that is designed so as not to not penetrate the turfgrass surface, but to use the actual blades of turfgrass for traction and footing. The Flat Spikes have circular 24 mm in diameter studs which are serrated to have four wing type edges for traction. When they are folded down they are 9 mm in length. The primary intention of these spikes is to perform on top or within the turfgrass canopy. This would be best suited for younger children who are unable to penetrate the ground surface to gain traction.

## Materials and Methods

A study to compare four different soccer shoe soles on turfgrass was conducted at the Hancock Turfgrass Research Center on the campus of Michigan State University in August 1998. Four different shoe soles were compared in a randomized complete block design with three replications on an established Poa pratensis (Kentucky bluegrass) and Lolium perenne (perennial ryegrass) turf stand. The four shoe soles tested were traditional molded cleats, traditional screw-in cleats, molded TX cleats, and a Flat Spike cleat in a screw-in type sole. Testing consisted of kicking soccer balls on a designated area of the turfgrass, with the different types of soccer shoes. A total of 100 kicks were applied to each plot by ten different people (4 females » 114 lbs. per person, and 6 males » 174 lbs. per person) There were ten kicks per person, per plot. Turfgrass analysis for density and shear strength was evaluated prior to and after the kicking traffic was applied in order to assess the damage caused by each shoe type. All 100 kicks were done with the right foot of each person, and the turfgrass was assessed for density and shear strength where the left foot was planted prior to the right foot making contact with the soccer ball. This was the area of greatest wear applied to the turf during the approach to kick the soccer balls. Percent turfgrass cover was determined on a visual estimate bases, using a 0 to 100% scale. Shear strength was measured using the Eijelkamp Shear Vane in Newton meters (Nm).

## Results

Results in Figure 1.0 show the traditional screw-in spikes had significantly less turf density after 100 soccer kicks were applied (63% cover); where, there was no significant difference between the Flat Spikes, traditional molded spike, and the molded TX spike (97, 95, and 94% cover, respectively). However, the molded TX spike had significantly less turfgrass density after the 100 kicks were applied compared to the original 100% turfgrass cover prior to the kicking traffic was applied.

Interpreting Figure 1.1 correctly, the effect of individual shoes prior to and after the soccer kicks were applied need to be compared. These results indicate that the molded TX spikes reduced the shear strength the least (3.3 Nm) after 100 soccer kicks were applied to the turfgrass. However, the other three spikes decreased turfgrass shear strength, with the traditional molded spikes causing the least significant decrease followed by the FlatSpikes, and then the screw-in spikes (4.3, 6.8 and 12.5 Nm respectively). The screw-in spikes showed the greatest change in turfgrass shear strength after the soccer kicks were applied, and this could be directly attributed to the large decrease in turfgrass density which occurred as a result of the soccer kicks (fig. 1.0). The significant changes in turfgrass shear strength for the FlatSpikes is likely a result of the actual spikes weakening the turfgrass canopy as the wings of the spikes gripped the turfgrass, when the person kicking the ball would plant their foot as they kicked the ball. It appears the FlatSpikes performed as they were intended to, because the actual strength of the turfgrass was weakened; while the turfgrass density did not change significantly.

Figure 2.0 shows the significance of individual ratings for the performance of the different shoe soles tested. Results are averages of the ten different people who tested the shoes and how they felt the shoes performed. The screw-in spikes had significantly higher ratings then the other three spikes, with the traditional molded spikes having a significantly higher rating than the molded TX and FlatSpike. The performance of the shoe is related to the traction provided as a result of the specific sole type, and the higher the rating the greater the traction. While the screw-in spikes and traditional molded spike had relatively high ratings, the molded TX and FlatSpikes were still considered more than adequate in terms of traction.

## Conclusion

From this experiment, conclusions can be made that the use of alternative spikes, such as the FlatSpikes, have demonstrated potential to sustain greater turfgrass densities. However, it should be noted that the testing for this experiment was applied by men and women between the ages of 19 and 50 years of age, and no children were represented in the experiment. With this in mind, and the greater potential for the use of FlatSpikes with young children and/or teenagers, warrants the need for continued research in this area.

**Figure 1.0 The effect of different shoe soles for soccer cleats on turfgrass density, August 1998, East Lansing, MI. 48824**

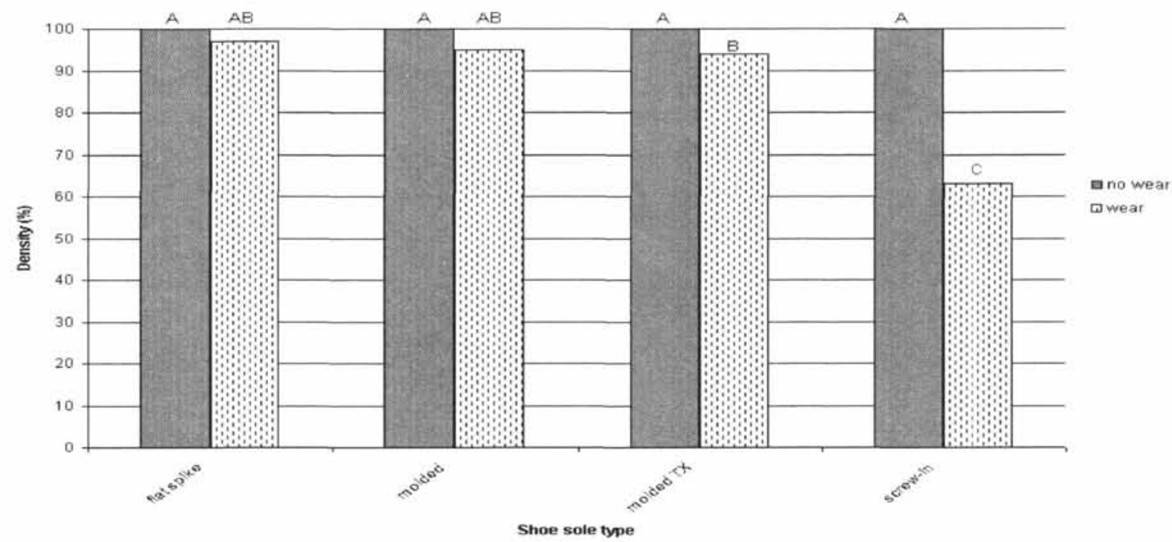



**Figure 1.1 The effect of different shoe soles for soccer cleats on loss of tufgrass shear strength, August 1998, East Lansing, MI. 48824**

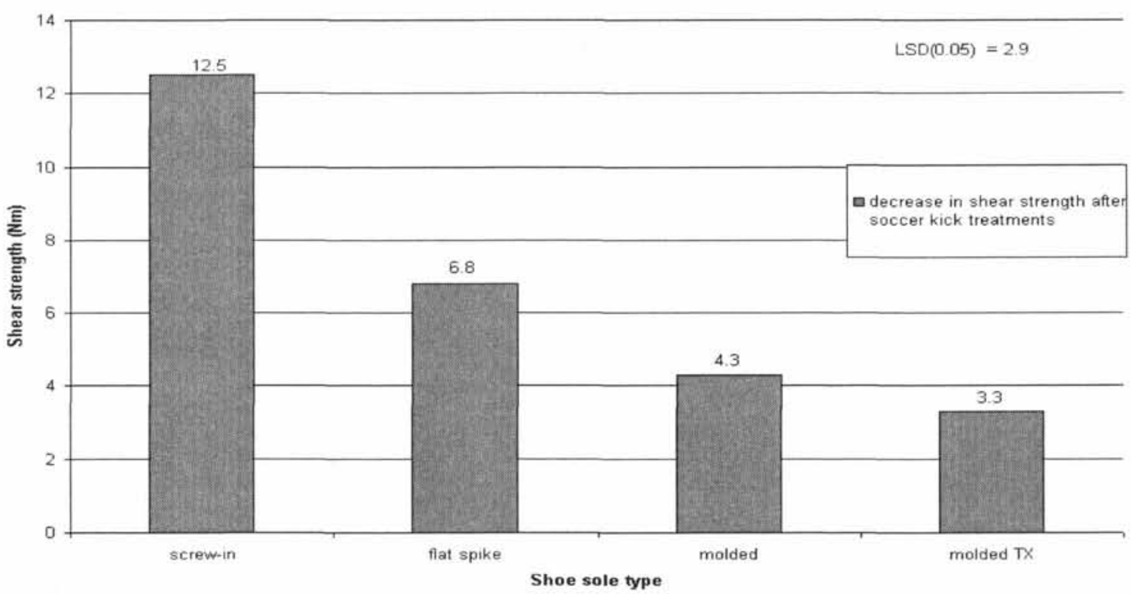
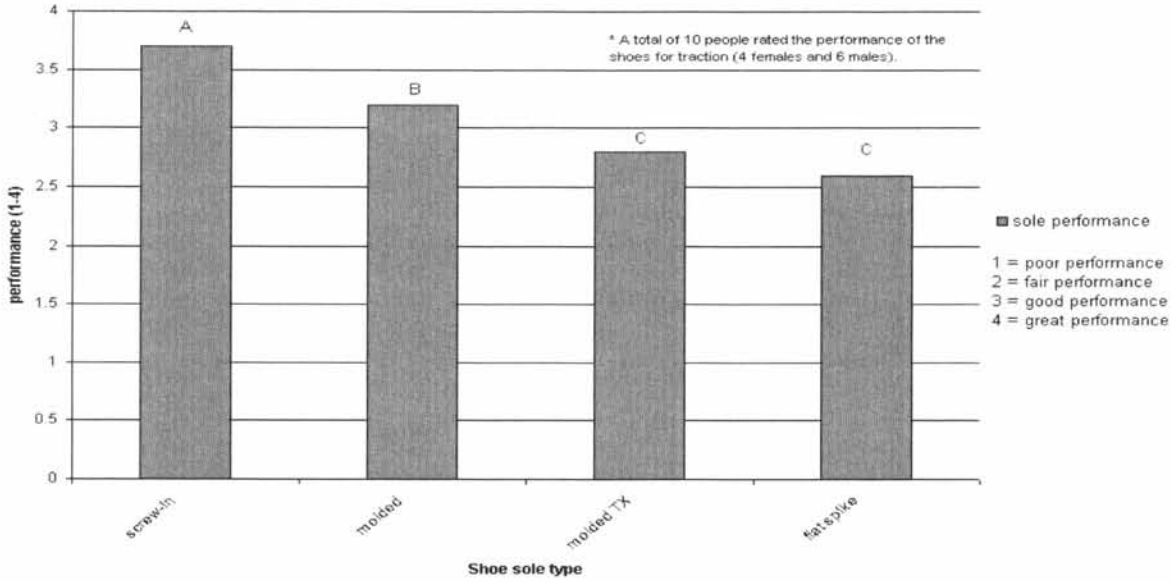


**Figure 2.0 Comparison of shoe soles for soccer cleats on traction performance, August 1998, East Lansing, MI. 48824**



# 1998 TRAVELING GOLF SPIKE STUDY

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## Introduction

Golf is a game that has undergone tremendous technological changes in the 1990's. One of these dramatic changes has been the banning of the 8mm metal golf spike on shoes at numerous golf courses. In 1995 there were less than 100 golf courses worldwide (1) that had banned the traditional 8mm metal spike. At this time Michigan State University (MSU) began its involvement in alternative spike research (2). Our scientific commitment to concerns brought forth with changes in golfers footwear has been cautious and calculated. Through literature reviews we uncovered a conflict in opinions between turf-researchers and golf course managers and superintendents in 1959(3,4). There have been numerous changes in turf management since that time including: standards for green root-zone construction, thinner bedknives allowing tighter mowing heights, light frequent sand-topdressing, and the banning of insecticides that killed soil microorganisms that alleviated the development of thatch. Each of these probably had some bearing on the acceptance of today's alternative spike/sole. MSU was cognizant of the fact that rating wear caused by the 8mm spike (uplifting of the turf plant) and alternative spike designs (indentations on the putting surface) was similar to comparing apples and oranges. Not wanting to release results that might differ from public opinion led MSU to conduct a golf sole/spike traffic survey in 1997(5). Prior to this survey, MSU never attributed a qualitative rating to any of the alternative spike research it conducted. Among the 1997 survey results was the fact that, regardless of the occupation of the surveyor, the uplifting of turf caused by 8mm spikes was perceived more damaging to a research putting green than indentations made by any of the alternative spikes. However, concerns and doubts persisted regarding the plethora of alternative soles and spikes available in today's market. These doubts led to MSU conducting the 1998 Traveling Golf Spike Study.

## Materials and Methods

In winter and early spring 1998, various non-metal golf shoe spike manufacturers were asked to submit entries for the study. The different contributions from each company and their respective codes used in this data reporting are represented in Table 1.

The experiment was a randomized block design with 27 shoe/spike entries and 3 replications. It was conducted at 6 different locations (golf courses) thus providing an ability to evaluate and analyze a spike by location interaction. The golf courses were chosen to represent the various types of putting greens that are managed on Midwestern golf courses. Each course is currently under a ban of metal spikes or under pressure to do so soon. Details of each golf course and its management characteristics are shown in Table 2. This study was conducted between 6 July and 30 July 1998. Each golf course was visited one day during this period. The weather on each day that the golf courses were visited was very similar. Temperatures averaged 80°F and rain was not a factor before or during data collection.

*Table 1. 1998 Traveling Golf Spike Study Treatment List- Michigan State University.*

| Treatment | Code | Shoe | Spike |
|---|---|---|---|
| 1 | DJ8mm | DryJoys | 8mm |
| 2 | DJ6mm | DryJoys | 6mm |
| 3 | DJds | DryJoys | Duraspike |
| 4 | DJgk | DryJoys | GreenKeepers |
| 5 | DJgs | DryJoys | Greenspike |
| 6 | DJfs | DryJoys | Flatspikes |
| 7 | DJfg | DryJoys | FlexiGrip |
| 8 | DJgpr | DryJoys | Gripper |
| 9 | DJssxp | DryJoys | Softspike XP |
| 10 | FJCssxp | Foot-Joy Classics | Softspike XP |
| 11 | FJC | Foot-Joy Classics | ———— |
| 12 | DJGXssxp | DryJoysGX | Softspike XP |
| 13 | DJSSssxp | DryJoys(studded sole) | Softspike XP |
| 14 | DJS | DryJoys | ———— |
| 15 | TMssxp | Turfmaster | Softspike XP |
| 16 | SJTssxp | Soft-Joy Terrain | Softspike XP |
| 17 | GJssxp | Green-Joy | Softspike XP |
| 18 | U2tg | Ultimate 2000 | TurfGrips |
| 19 | DTtg | Difference Tour | TurfGrips |
| 20 | Dtg | Difference | Turfgrips |
| 21 | AP | All-Performance | ———— |
| 22 | STGtg | Stabilite TurfGrips | TurfGrips |
| 23 | SS | Stabilite Softspikes | ———— |
| 24 | NAtg | Nike Air Zoom | TurfGrips |
| 25 | NAZws | Nike Air Zoom | Waffle Spike |
| 26 | NAA | Nike Air Access II | ———— |
| 27 | Control | ———————— | ———— |

*Table 2. Participating golf courses and specific putting green information for 1998 Traveling Golf Spike Study- Michigan State University.*

| Golf Course | Forest Akers | CC Detroit | Oakland Hills | Red Run | Pine View | Inverness |
|---|---|---|---|---|---|---|
| Location | E. Lansing, MI | Grosse Pointe, MI | Bloomfield Hills, MI | Royal Oak, MI | Ypsilanti, MI | Toledo, OH |
| Test Green | Pract./Putt | Pract./Chip | Pract./Putt | Pract./Putt | 18th | Pract./Putt |
| Date of visit | 6 July | 13 July | 15 July | 16 July | 27 July | 30 July |
| Supt. | Ron Foote | Mark Jackson | Steve Cook | Gary Thommes | Charles Gaige | Tom Walker |
| Mowing Ht. (inch) | 0.157 | 0.130 | 0.130 | 0.095 | .145 | .130 |
| Turf Species | Penncross | Penn A-4 | *Poa/Agrostis* | *Poa annua* | Penncross | Pennlinks |
| Construction (Sand/Peat) | 85/15 | 90/10 | Push up | Push up | 80/20 | Push up |
| Age of Green | 2 years | 2 years | 70 years | 90 years | 9 years | 11 years |
| Topdressing depth (inch) | 0.25 | 0.19 | 3.0 | 4.9 | 0.5 | 2.0 |
| Topdressing frequency | 3 weeks | 2-3 weeks | 3 weeks | 2 weeks | 6 weeks | 1-2 weeks |
| Topdressing material | 100 % sand | 100 % sand | 100 % sand | 100 % sand | 100 % sand | 100 % sand |
| Days since last topdressing at time of visit | 14 | 10 | 8 | 7 | 30 | 10 |
| Thatch Characteristics | minimal | < 0.25 inch | minimal | minimal | 0.5 inch | 0.25 inch |

Traffic was applied to each treatment to represent 200 foot steps around the cupping area of a putting green. 6-10 people (all wore approximately size11 shoe) were responsible for applying traffic at each course. Each person applying traffic treatments wore every pair of shoes in the study and applied the same number of footsteps in the same pattern for each plot.

At the end of the traffic period the plots were rated using the scale found in the Survey Data Analysis section of this report. Ratings were done by MSU staff, golf course superintendents, and golfers at the golf course.

**Survey Data Analysis**

Plots were rated using a turf damage severity scale (1 = *Severe*, 2 = *Significant*, 3 = *Moderate*, 4 = *Minimal*, and 5 = *None*) immediately following 200 simulated rounds of golf. For this study, a plot is one replication of a single spike/shoe traffic treatment and an observation is a single rating for one plot. The product of the number of spike/shoe treatments, spike/shoe replications, and raters is the number of observations taken from each golf course. Table 3 summarizes the number of plots and rating observations taken at each golf course.

Table 3. Summary of rating observations at each golf course.

| | C. C. Detroit | Forest Akers | Inverness | Oakland Hills | Pine View | Red Run |
|---|---|---|---|---|---|---|
| Spikes/Soles | 26 | 26 | 27 | 27 | 27 | 27 |
| Replications | 3 | 3 | 3 | 3 | 3 | 3 |
| Plots | 78 | 78 | 81 | 81 | 81 | 81 |
| Raters | 13 | 20 | 8 | 14 | 6 | 11 |
| Observations | 1014 | 1560 | 648 | 1134 | 486 | 891 |

The survey categories imply a ranking of turf damage severity, but not quantifiable differences among plots. These data, called ordinal data, arise when a continuous characteristic (turf damage) is measured on a discrete scale with a finite, countable number of categories (severe, significant, moderate, minimal, and none). The assigned scores, 1 = *Severe*, 2 = *Significant*, 3 = *Moderate*, 4 = *Minimal*, and 5 = *None* to the categories for purpose of analysis is arbitrary. Assigning other scores to the categories that preserve their ranking order are equally appropriate, e.g. 1 = *Severe*, 10 = *Significant*, 100 = *Moderate*, 1000 = *Minimal*, and 10000 = *None* or a = *Severe*, b = *Significant*, c = *Moderate*, d = *Minimal*, and e = *None*. It is apparent that a proper analysis of ordered outcomes must not depend on the labeling system for categories.

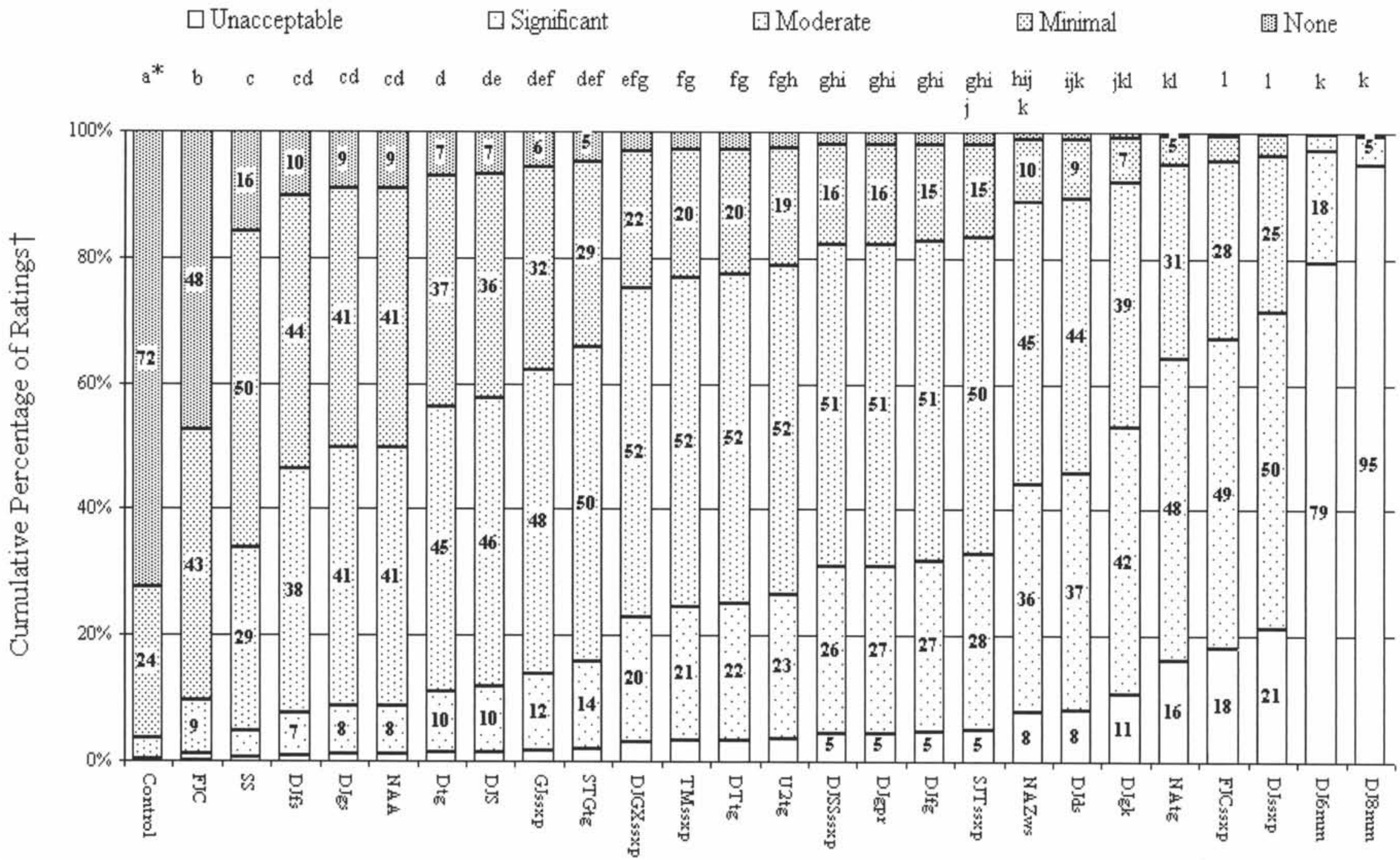
Ordinal data are discrete multivariate and follow the multinomial distribution law. Appropriate hypotheses for comparing treatments with an ordinal response are phrased in terms of equality of the category probabilities. Representing ordinal data should **never** include mean rating scores, but rather probabilities to observe a particular category. Recently, statistical techniques have been developed for ordinal data that permit treatment comparisons, statistical tests, and results similar to analysis of variance but take into account the distributional properties of ordinal data. These analyses are independent of category labeling or numbering, adding an element of objectivity. Parameters of ordinal data models are statistically estimated by maximum likelihood techniques. Reliability of estimates increases with increasing sample size.

A proportional odds model with the logit transform was used to analyze the turf damage rating data and to test for shoe/spike effects, golf course effects, and their interaction. Results are given in terms of probability distributions rather than mean rating scores. Calculating a chi-square value for pairwise comparisons of parameter estimates separates treatment probability distributions.

**Results and Discussion**

The results from our work and surveys reflect a strong spike x location interaction. The results can be viewed by examining spikes among different locations (Figures 1-6) or spikes across different locations (Table 4). The six figures allow easy examination of various spikes within a specific golf course putting surface. Table 4 provides a format to evaluate individual spikes and their response across all putting surfaces. Both the figures and the tables provide the same information, the presentation formats are diametrically oriented.

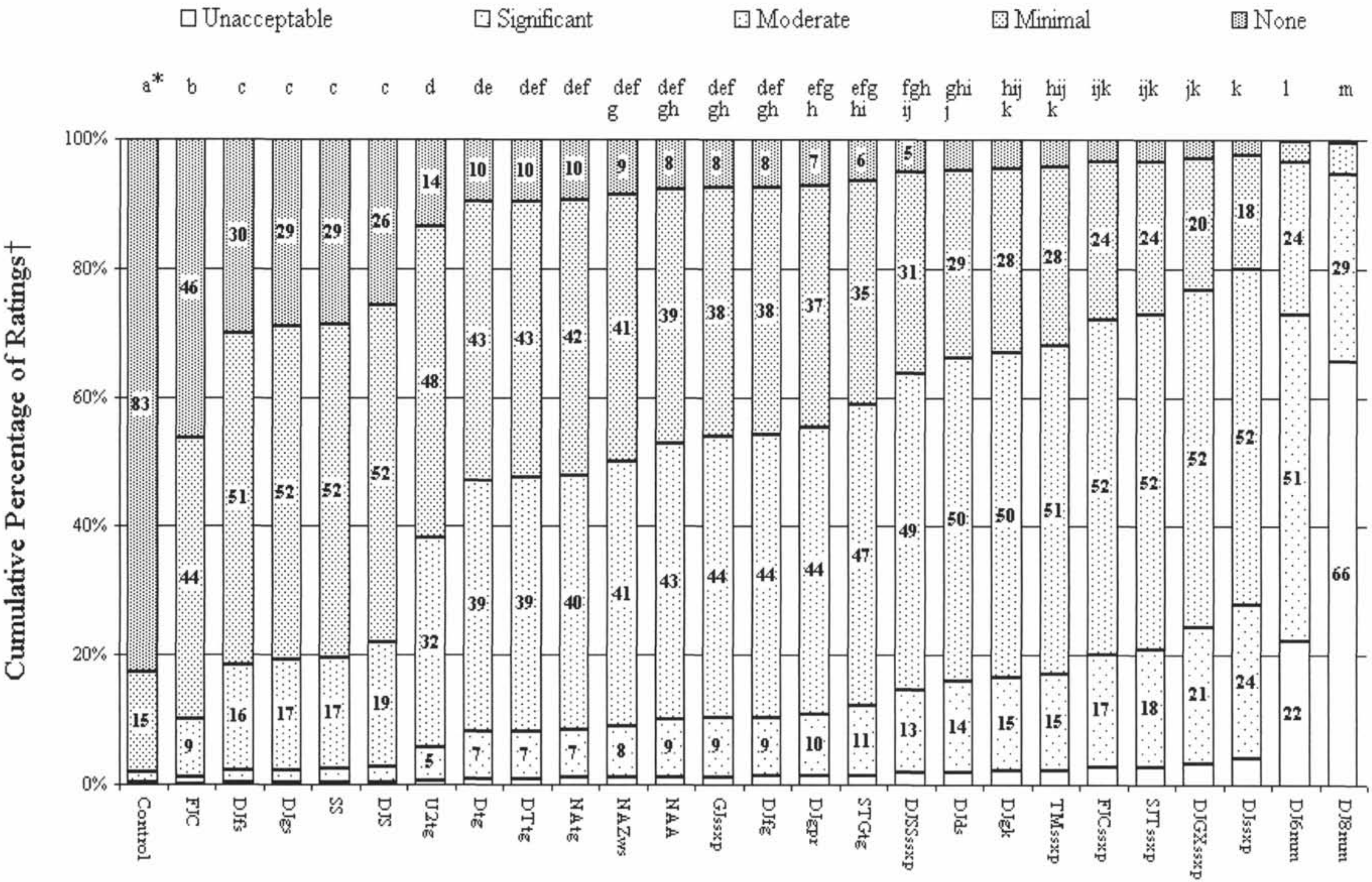
# Figure 1. Effects of Spike/Sole on Wear Rating, Country Club of Detroit (July 1998)




*Shoe soles sharing a letter are not significantly different (P < 0.05).

†Numbers within the bars represent percentage of ratings for individual categories.

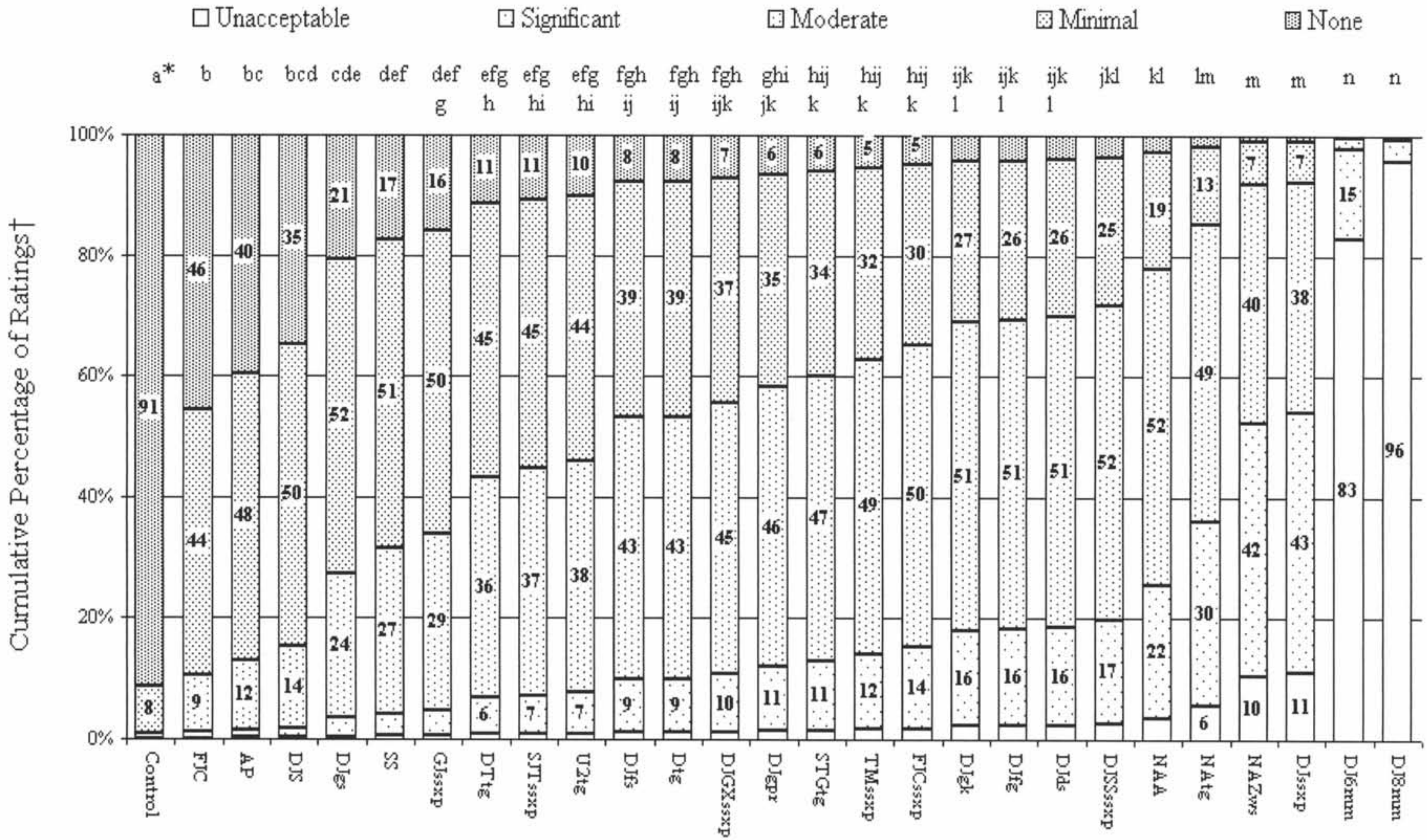
**Figure 2. Effects of Spike/Sole on Wear Rating, Forest Akers Golf Course (July 1998)**




*Shoe soles sharing a letter are not significantly different (P < 0.05).

†Numbers within the bars represent percentage of ratings for individual categories.

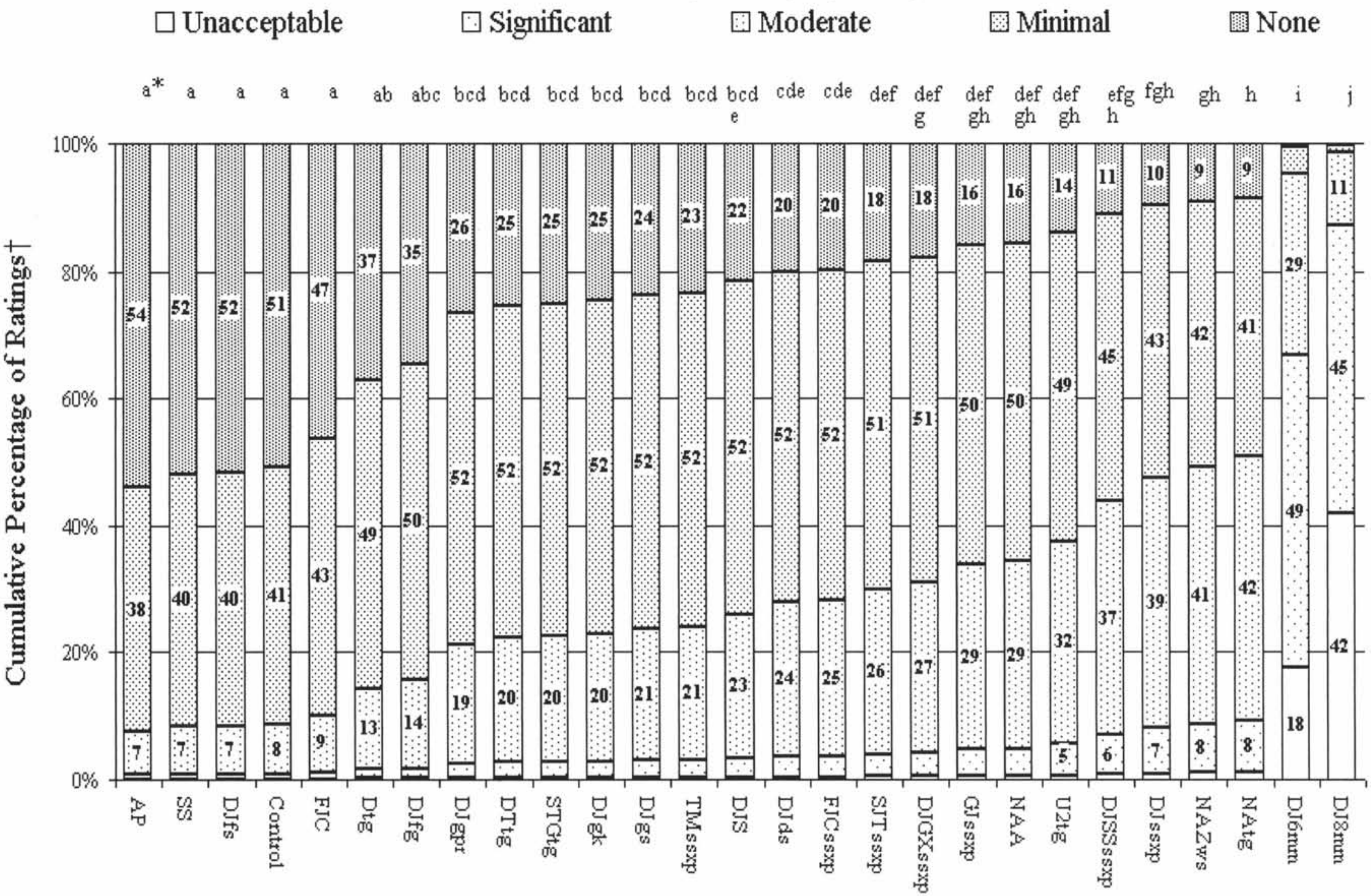
**Figure 3. Effects of Spike/Sole on Wear Rating, Inverness Club (July 1998)**




*Shoe soles sharing a letter are not significantly different (P < 0.05).

†Numbers within the bars represent percentage of ratings for individual categories.

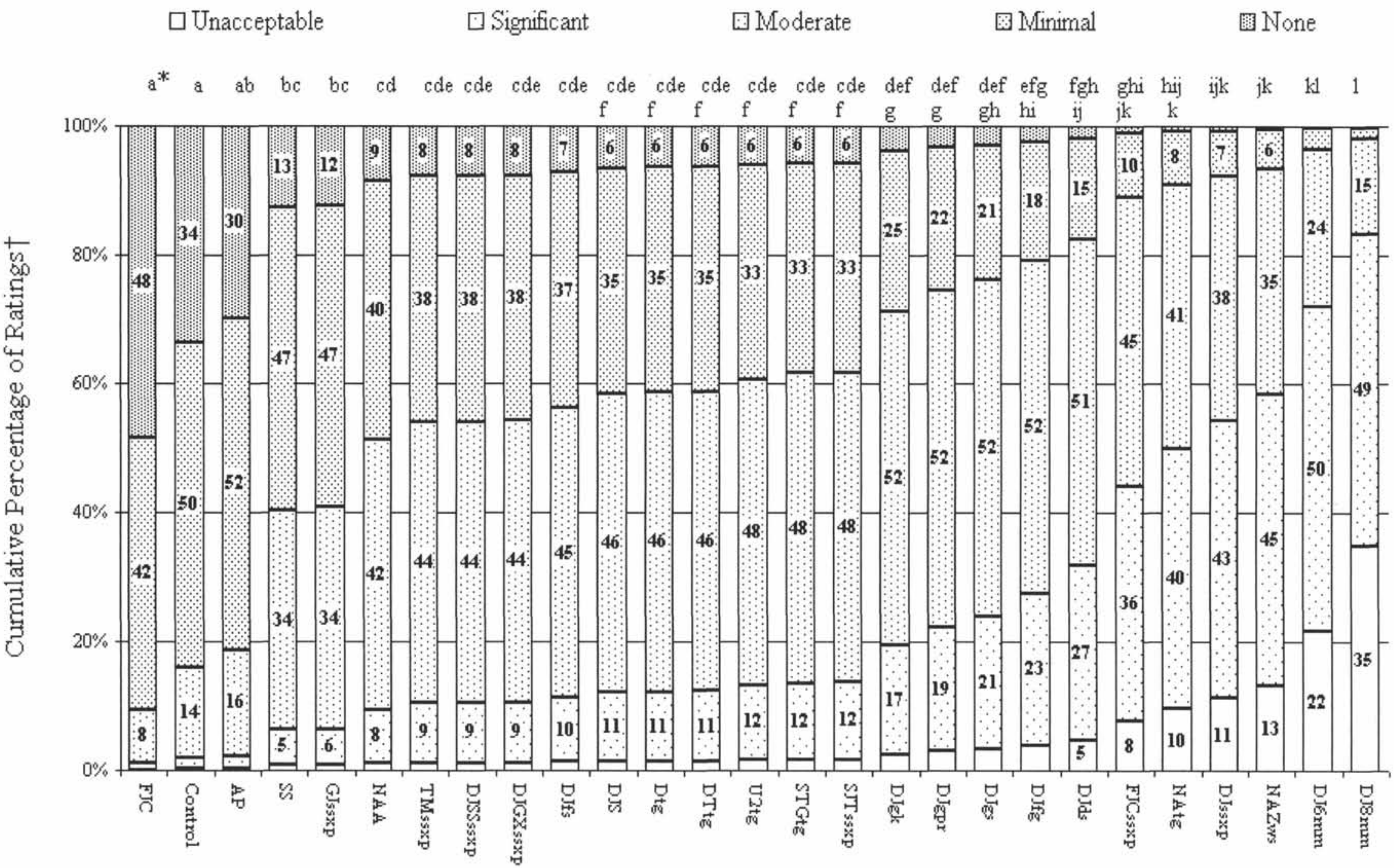
**Figure 4. Effects of Spike/Sole on Wear Rating, Oakland Hills Country Club (July 1998)**




*Shoe soles sharing a letter are not significantly different (P < 0.05).

†Numbers within the bars represent percentage of ratings for individual categories.

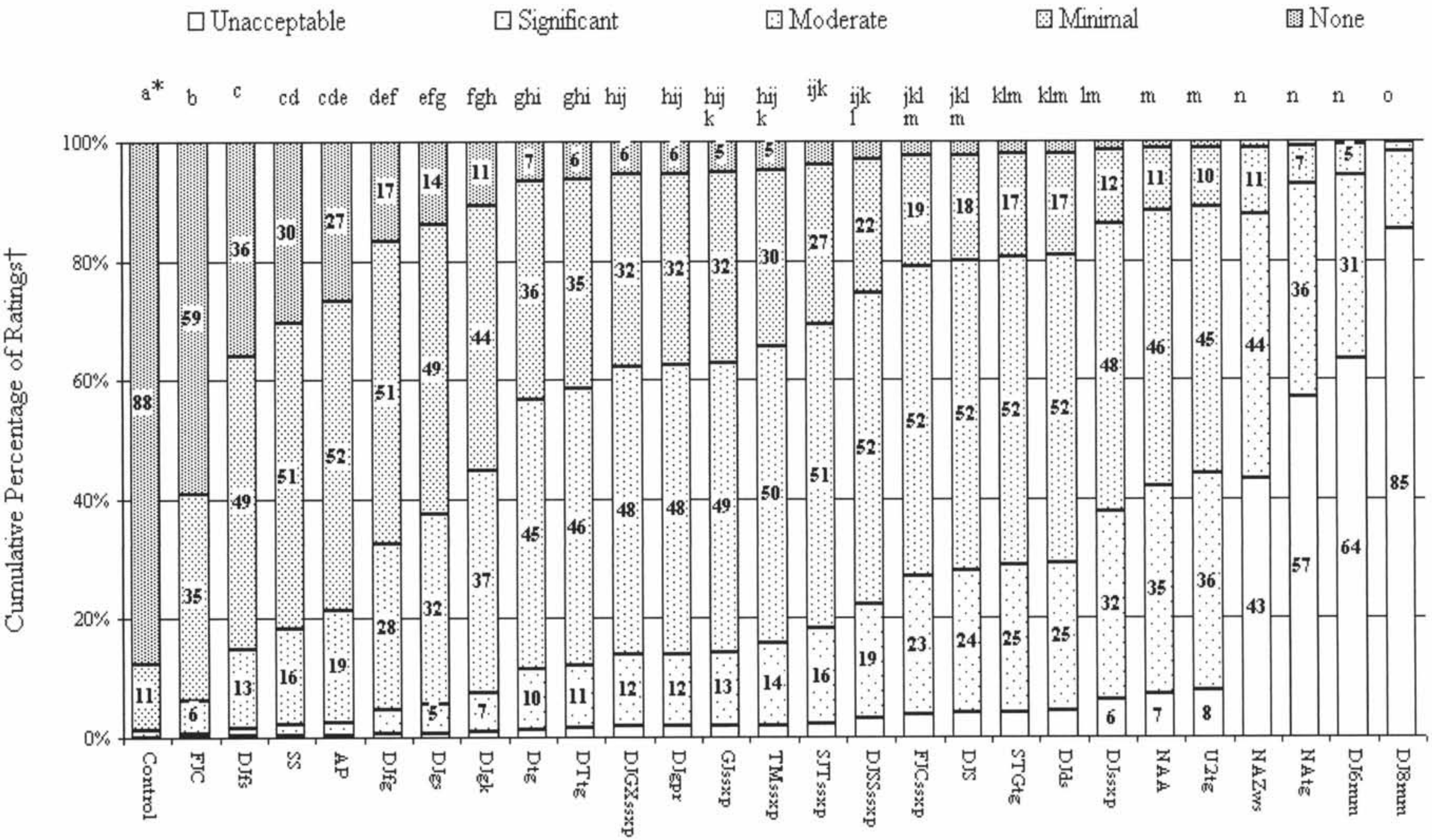
## Figure 5. Effects of Spike/Sole on Wear Rating, Pine View Golf Course (July 1998)




*Shoe soles sharing a letter are not significantly different (P < 0.05).

†Numbers within the bars represent percentage of ratings for individual categories.

## Figure 6. Effects of Spike/Sole on Wear Rating, Red Run Golf Club (July 1998)




*Shoe soles sharing a letter are not significantly different (P < 0.05).

†Numbers within the bars represent percentage of ratings for individual categories.

*Table 4. Effects of Spike/Sole on Wear Ratings, Sliced by Spike/Sole. 1998 Traveling Golf Spike Study - Michigan State University*

| Spike/Sole | Rating Category | OHCC | MSU | IC | PV | RRGC | CCD |
|---|---|---|---|---|---|---|---|
| | | — % of ratings at each golf course — | | | | | |
| **All-Performance†** | Unacceptable | 0.1 | na | 0.2 | 0.2 | 0.3 | na |
| *spikeless* | Significant | 0.7 | na | 1.3 | 1.9 | 2.3 | na |
| | Moderate | 6.9 | na | 11.5 | 16.4 | 18.6 | na |
| | Minimial | 38.4 | na | 47.5 | 51.5 | 52.2 | na |
| | None | 54.0 | na | 39.5 | 29.9 | 26.6 | na |
| | ***Significance**** | ***a*** | ***na*** | ***ab*** | ***ab*** | ***b*** | ***na*** |
| | ***Rank‡*** | ***1*** | ***na*** | ***3*** | ***3*** | ***5*** | ***na*** |
| **Control** | Unacceptable | 0.1 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 |
| | Significant | 0.8 | 0.2 | 0.1 | 1.6 | 0.1 | 0.3 |
| | Moderate | 7.7 | 1.8 | 0.8 | 14.2 | 1.2 | 3.2 |
| | Minimial | 40.6 | 15.3 | 7.7 | 50.2 | 11.0 | 24.2 |
| | None | 50.7 | 82.7 | 91.4 | 33.8 | 87.6 | 72.2 |
| | ***Significance**** | ***b*** | ***a*** | ***a*** | ***b*** | ***a*** | ***a*** |
| | ***Rank‡*** | ***4*** | ***1*** | ***1*** | ***2*** | ***1*** | ***1*** |
| **DryJoys** | Unacceptable | 17.7 | 22.3 | 82.9 | 21.6 | 63.6 | 79.4 |
| *6 mm metal spike* | Significant | 49.0 | 50.5 | 14.9 | 50.4 | 30.6 | 17.9 |
| | Moderate | 28.6 | 23.7 | 1.9 | 24.4 | 5.2 | 2.4 |
| | Minimial | 4.2 | 3.2 | 0.2 | 3.3 | 0.5 | 0.2 |
| | None | 0.5 | 0.4 | 0.0 | 0.4 | 0.1 | 0.0 |
| | ***Significance**** | ***a*** | ***a*** | ***b*** | ***a*** | ***b*** | ***b*** |
| | ***Rank‡*** | ***26*** | ***25*** | ***26*** | ***26*** | ***26*** | ***25*** |
| **DryJoys** | Unacceptable | 41.9 | 65.7 | 95.9 | 34.7 | 85.1 | 94.9 |
| *8 mm metal spike* | Significant | 45.1 | 29.0 | 3.7 | 48.5 | 13.0 | 4.5 |
| | Moderate | 11.5 | 4.8 | 0.4 | 14.9 | 1.7 | 0.5 |
| | Minimial | 1.3 | 0.5 | 0.0 | 1.7 | 0.2 | 0.1 |
| | None | 0.1 | 0.1 | 0.0 | 0.2 | 0.0 | 0.0 |
| | ***Significance**** | ***a*** | ***b*** | ***c*** | ***a*** | ***c*** | ***c*** |
| | ***Rank‡*** | ***27*** | ***26*** | ***27*** | ***27*** | ***27*** | ***26*** |
| **DryJoy** | Unacceptable | 0.4 | 2.0 | 2.4 | 4.7 | 4.2 | 8.3 |
| *duraspike* | Significant | 3.3 | 14.0 | 16.2 | 26.9 | 25.0 | 37.4 |
| | Moderate | 24.3 | 50.1 | 51.4 | 50.9 | 51.6 | 43.9 |
| | Minimial | 52.0 | 29.2 | 26.0 | 15.4 | 16.9 | 9.3 |
| | None | 20.0 | 4.8 | 4.0 | 2.0 | 2.3 | 1.1 |
| | ***Significance**** | ***a*** | ***b*** | ***b*** | ***bc*** | ***bc*** | ***c*** |
| | ***Rank‡*** | ***15*** | ***18*** | ***20*** | ***21*** | ***20*** | ***20*** |
| **DryJoy** | Unacceptable | 0.2 | 1.2 | 2.3 | 3.9 | 0.5 | 4.8 |
| *flexigrip* | Significant | 1.6 | 9.2 | 15.9 | 23.4 | 4.0 | 27.1 |
| | Moderate | 13.8 | 43.9 | 51.3 | 52.0 | 28.0 | 50.8 |
| | Minimial | 49.9 | 38.1 | 26.4 | 18.2 | 50.7 | 15.3 |
| | None | 34.6 | 7.6 | 4.1 | 2.5 | 16.8 | 2.0 |
| | ***Significance**** | ***a*** | ***c*** | ***cd*** | ***d*** | ***b*** | ***d*** |
| | ***Rank‡*** | ***7*** | ***14*** | ***19*** | ***20*** | ***6*** | ***17*** |

*Table 4. (continued)*

| Spike/Sole | Rating Category | OHCC | MSU | IC | PV | RRGC | CCD |
|---|---|---|---|---|---|---|---|
| | | — % of ratings at each golf course — | | | | | |
| **DryJoy** | Unacceptable | 0.1 | 0.2 | 1.2 | 1.3 | 0.2 | 0.9 |
| *flatspike* | Significant | 0.8 | 1.9 | 8.8 | 9.8 | 1.5 | 6.9 |
| | Moderate | 7.5 | 16.2 | 43.2 | 45.0 | 13.2 | 38.5 |
| | Minimial | 40.1 | 51.4 | 38.9 | 36.8 | 49.3 | 43.6 |
| | None | 51.6 | 30.2 | 7.9 | 7.1 | 35.8 | 10.2 |
| | ***Significance**** | ***a*** | ***b*** | ***c*** | ***c*** | ***ab*** | ***c*** |
| | ***Rank‡*** | ***3*** | ***3*** | ***11*** | ***10*** | ***3*** | ***4*** |
| **DryJoy** | Unacceptable | 0.3 | 2.1 | 2.3 | 2.5 | 0.8 | 10.8 |
| *greenkeepers* | Significant | 2.5 | 14.5 | 15.7 | 16.9 | 6.5 | 42.2 |
| | Moderate | 20.1 | 50.4 | 51.2 | 51.7 | 37.4 | 39.0 |
| | Minimial | 52.4 | 28.4 | 26.7 | 25.1 | 44.5 | 7.2 |
| | None | 24.7 | 4.6 | 4.2 | 3.8 | 10.7 | 0.8 |
| | ***Significance**** | ***a*** | ***c*** | ***c*** | ***c*** | ***b*** | ***d*** |
| | ***Rank‡*** | ***11*** | ***19*** | ***18*** | ***17*** | ***8*** | ***21*** |
| **DryJoy** | Unacceptable | 0.3 | 1.3 | 1.4 | 3.0 | 1.7 | 4.6 |
| *gripper* | Significant | 2.3 | 9.5 | 10.6 | 19.3 | 12.3 | 26.5 |
| | Moderate | 18.8 | 44.5 | 46.3 | 52.3 | 48.5 | 51.1 |
| | Minimial | 52.3 | 37.5 | 35.1 | 22.3 | 32.0 | 15.7 |
| | None | 26.4 | 7.3 | 6.5 | 3.2 | 5.5 | 2.1 |
| | ***Significance**** | ***a*** | ***b*** | ***b*** | ***bc*** | ***b*** | ***c*** |
| | ***Rank‡*** | ***8*** | ***15*** | ***14*** | ***18*** | ***12*** | ***16*** |
| **DryJoy** | Unacceptable | 0.3 | 0.3 | 0.4 | 3.2 | 0.6 | 1.0 |
| *greenspike* | Significant | 2.6 | 2.0 | 3.2 | 20.6 | 4.9 | 7.8 |
| | Moderate | 20.7 | 17.1 | 23.8 | 52.3 | 31.9 | 40.9 |
| | Minimial | 52.4 | 51.8 | 52.1 | 20.9 | 48.6 | 41.3 |
| | None | 23.9 | 28.9 | 20.6 | 3.0 | 14.0 | 8.9 |
| | ***Significance**** | ***ab*** | ***a*** | ***ab*** | ***d*** | ***bc*** | ***c*** |
| | ***Rank‡*** | ***12*** | ***4*** | ***5*** | ***19*** | ***7*** | ***5*** |
| **DryJoyGX** | Unacceptable | 0.5 | 3.3 | 1.3 | 1.2 | 1.7 | 3.1 |
| *softspike xp* | Significant | 3.7 | 21.0 | 9.6 | 9.1 | 12.2 | 19.8 |
| | Moderate | 26.8 | 52.3 | 44.6 | 43.8 | 48.4 | 52.3 |
| | Minimial | 51.2 | 20.4 | 37.3 | 38.2 | 32.1 | 21.7 |
| | None | 17.8 | 2.9 | 7.3 | 7.6 | 5.6 | 3.1 |
| | ***Significance**** | ***a*** | ***c*** | ***b*** | ***ab*** | ***bc*** | ***bc*** |
| | ***Rank‡*** | ***18*** | ***23*** | ***13*** | ***9*** | ***11*** | ***11*** |
| **DryJoy** | Unacceptable | 0.4 | 0.3 | 0.2 | 1.5 | 4.0 | 1.4 |
| *spikeless* | Significant | 3.0 | 2.4 | 1.6 | 10.7 | 24.0 | 10.4 |
| | Moderate | 22.7 | 19.2 | 13.7 | 46.4 | 51.9 | 45.9 |
| | Minimial | 52.3 | 52.3 | 49.8 | 35.1 | 17.7 | 35.7 |
| | None | 21.6 | 25.7 | 34.8 | 6.5 | 2.4 | 6.7 |
| | ***Significance**** | ***a*** | ***a*** | ***a*** | ***bc*** | ***c*** | ***b*** |
| | ***Rank‡*** | ***14*** | ***6*** | ***4*** | ***11*** | ***18*** | ***8*** |

*Table 4. (continued)*

| Spike/Sole | Rating Category | OHCC | MSU | IC | PV | RRGC | CCD |
|---|---|---|---|---|---|---|---|
| | | —— % of ratings at each golf course —— | | | | | |
| **DryJoy** *studded sole* | Unacceptable | 0.8 | 1.8 | 2.6 | 1.2 | 3.0 | 4.6 |
| *softspike xp* | Significant | 6.3 | 12.9 | 17.3 | 9.1 | 19.4 | 26.4 |
| | Moderate | 36.7 | 49.1 | 51.8 | 43.7 | 52.3 | 51.1 |
| | Minimial | 45.1 | 31.0 | 24.6 | 38.3 | 22.2 | 15.8 |
| | None | 11.1 | 5.2 | 3.7 | 7.6 | 3.2 | 2.1 |
| | ***Significance**** | ***a*** | ***b*** | ***bc*** | ***ab*** | ***bc*** | ***c*** |
| | ***Rank‡*** | ***22*** | ***17*** | ***21*** | ***8*** | ***16*** | ***15*** |
| **DryJoy** | Unacceptable | 0.9 | 4.0 | 11.1 | 11.3 | 6.1 | 21.2 |
| *softspike xp* | Significant | 7.2 | 24.0 | 42.8 | 43.0 | 31.6 | 50.3 |
| | Moderate | 39.4 | 51.9 | 38.4 | 38.1 | 48.4 | 24.7 |
| | Minimial | 42.7 | 17.7 | 6.9 | 6.8 | 12.4 | 3.4 |
| | None | 9.7 | 2.4 | 0.8 | 0.8 | 1.6 | 0.4 |
| | ***Significance**** | ***a*** | ***b*** | ***cd*** | ***cd*** | ***bc*** | ***d*** |
| | ***Rank‡*** | ***23*** | ***24*** | ***25*** | ***24*** | ***21*** | ***24*** |
| **Difference** | Unacceptable | 0.2 | 0.9 | 1.2 | 1.5 | 1.4 | 1.3 |
| *turfgrips* | Significant | 1.4 | 7.1 | 8.9 | 10.7 | 10.0 | 9.8 |
| | Moderate | 12.6 | 39.1 | 43.2 | 46.4 | 45.4 | 45.0 |
| | Minimial | 48.7 | 43.0 | 38.9 | 35.0 | 36.4 | 36.8 |
| | None | 37.1 | 9.8 | 7.9 | 6.4 | 6.9 | 7.1 |
| | ***Significance**** | ***a*** | ***b*** | ***b*** | ***b*** | ***b*** | ***b*** |
| | ***Rank‡*** | ***6*** | ***8*** | ***12*** | ***12*** | ***9*** | ***7*** |
| **Difference Tour** | Unacceptable | 0.3 | 0.9 | 0.8 | 1.5 | 1.4 | 3.5 |
| *turfgrips* | Significant | 2.4 | 7.2 | 6.1 | 10.7 | 10.6 | 21.6 |
| | Moderate | 19.6 | 39.5 | 36.2 | 46.5 | 46.3 | 52.3 |
| | Minimial | 52.4 | 42.7 | 45.5 | 34.9 | 35.1 | 19.9 |
| | None | 25.3 | 9.7 | 11.4 | 6.4 | 6.5 | 2.8 |
| | ***Significance**** | ***a*** | ***b*** | ***b*** | ***b*** | ***b*** | ***c*** |
| | ***Rank‡*** | ***9*** | ***9*** | ***8*** | ***13*** | ***10*** | ***13*** |
| **FootJoy Classic** | Unacceptable | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| *spikeless* | Significant | 1.0 | 1.0 | 1.0 | 0.9 | 0.6 | 0.9 |
| | Moderate | 9.0 | 9.1 | 9.3 | 8.4 | 5.7 | 8.6 |
| | Minimial | 43.4 | 43.6 | 44.0 | 42.1 | 34.6 | 42.7 |
| | None | 46.5 | 46.3 | 45.5 | 48.5 | 59.0 | 47.6 |
| | ***Significance**** | ***a*** | ***a*** | ***a*** | ***a*** | ***a*** | ***a*** |
| | ***Rank‡*** | ***5*** | ***2*** | ***2*** | ***1*** | ***2*** | ***2*** |
| **Foot Joy Classic** | Unacceptable | 0.4 | 2.6 | 1.9 | 7.8 | 3.8 | 18.1 |
| *softspike xp* | Significant | 3.3 | 17.5 | 13.5 | 36.3 | 23.1 | 49.2 |
| | Moderate | 24.5 | 51.9 | 49.7 | 44.9 | 52.1 | 28.2 |
| | Minimial | 51.9 | 24.3 | 29.9 | 9.9 | 18.5 | 4.1 |
| | None | 19.8 | 3.6 | 5.0 | 1.2 | 2.5 | 0.5 |
| | ***Significance**** | ***a*** | ***b*** | ***b*** | ***cd*** | ***bc*** | ***d*** |
| | ***Rank‡*** | ***16*** | ***21*** | ***17*** | ***22*** | ***17*** | ***23*** |

*Table 4. (continued)*

| Spike/Sole | Rating Category | OHCC | MSU | IC | PV | RRGC | CCD |
|---|---|---|---|---|---|---|---|
| | | —— % of ratings at each golf course —— | | | | | |
| **GreenJoy** | Unacceptable | 0.5 | 1.2 | 0.5 | 0.7 | 1.8 | 1.7 |
| *softspike xp* | Significant | 4.2 | 9.0 | 4.3 | 5.6 | 12.5 | 12.2 |
| | Moderate | 29.1 | 43.6 | 29.2 | 34.4 | 48.7 | 48.3 |
| | Minimial | 50.2 | 38.5 | 50.1 | 46.9 | 31.6 | 32.3 |
| | None | 16.0 | 7.7 | 15.9 | 12.4 | 5.4 | 5.6 |
| | ***Significance**** | ***a*** | ***bc*** | ***ab*** | ***abc*** | ***c*** | ***c*** |
| | ***Rank‡*** | ***19*** | ***13*** | ***7*** | ***5*** | ***13*** | ***9*** |
| **Nike Air Access II** | Unacceptable | 0.5 | 1.2 | 3.6 | 1.1 | 7.2 | 1.0 |
| *spikeless* | Significant | 4.3 | 8.7 | 22.1 | 8.2 | 34.8 | 7.8 |
| | Moderate | 29.4 | 43.0 | 52.2 | 41.8 | 46.1 | 40.9 |
| | Minimial | 50.0 | 39.1 | 19.4 | 40.4 | 10.6 | 41.3 |
| | None | 15.7 | 8.0 | 2.7 | 8.5 | 1.3 | 8.9 |
| | ***Significance**** | ***a*** | ***b*** | ***c*** | ***ab*** | ***c*** | ***ab*** |
| | ***Rank‡*** | ***20*** | ***12*** | ***22*** | ***6*** | ***22*** | ***6*** |
| **Nike Air Zoom** | Unacceptable | 1.1 | 1.0 | 5.7 | 9.6 | 56.9 | 16.1 |
| *turfgrips* | Significant | 8.1 | 7.3 | 30.4 | 40.1 | 35.6 | 48.0 |
| | Moderate | 41.6 | 39.7 | 49.1 | 41.3 | 6.7 | 30.7 |
| | Minimial | 40.6 | 42.5 | 13.1 | 8.1 | 0.7 | 4.7 |
| | None | 8.6 | 9.6 | 1.7 | 1.0 | 0.1 | 0.5 |
| | ***Significance**** | ***a*** | ***a*** | ***b*** | ***bc*** | ***d*** | ***c*** |
| | ***Rank‡*** | ***25*** | ***10*** | ***23*** | ***23*** | ***25*** | ***22*** |
| **Nike Air Zoom** | Unacceptable | 1.0 | 1.0 | 10.5 | 13.1 | 43.5 | 7.8 |
| *wafflespike* | Significant | 7.7 | 8.0 | 41.8 | 45.3 | 44.3 | 36.4 |
| | Moderate | 40.5 | 41.3 | 39.5 | 35.0 | 10.9 | 44.8 |
| | Minimial | 41.7 | 41.0 | 7.4 | 5.8 | 1.2 | 9.8 |
| | None | 9.1 | 8.8 | 0.9 | 0.7 | 0.1 | 1.2 |
| | ***Significance**** | ***a*** | ***a*** | ***b*** | ***b*** | ***c*** | ***b*** |
| | ***Rank‡*** | ***24*** | ***11*** | ***24*** | ***25*** | ***24*** | ***19*** |
| **SoftJoy Terrain** | Unacceptable | 0.4 | 2.8 | 0.8 | 1.7 | 2.3 | 5.0 |
| *softspike xp* | Significant | 3.6 | 18.2 | 6.5 | 12.0 | 15.8 | 28.0 |
| | Moderate | 26.0 | 52.1 | 37.4 | 48.1 | 51.2 | 50.4 |
| | Minimial | 51.5 | 23.5 | 44.5 | 32.6 | 26.5 | 14.7 |
| | None | 18.5 | 3.5 | 10.7 | 5.7 | 4.1 | 1.9 |
| | ***Significance**** | ***a*** | ***cd*** | ***ab*** | ***bc*** | ***cd*** | ***d*** |
| | ***Rank‡*** | ***17*** | ***22*** | ***9*** | ***16*** | ***15*** | ***18*** |
| **Stabilite Softspikes** | Unacceptable | 0.1 | 0.3 | 0.5 | 0.7 | 0.2 | 0.5 |
| *spikeless* | Significant | 0.8 | 2.1 | 3.9 | 5.5 | 1.9 | 4.2 |
| | Moderate | 7.4 | 17.2 | 27.3 | 34.0 | 16.1 | 29.1 |
| | Minimial | 39.9 | 51.8 | 51.0 | 47.2 | 51.4 | 50.2 |
| | None | 51.8 | 28.6 | 17.4 | 12.7 | 30.3 | 16.0 |
| | ***Significance**** | ***a*** | ***bc*** | ***cd*** | ***d*** | ***b*** | ***cd*** |
| | ***Rank‡*** | ***2*** | ***5*** | ***6*** | ***4*** | ***4*** | ***3*** |

*Table 4. (continued)*

| Spike/Sole | Rating Category | OHCC | MSU | IC | PV | RRGC | CCD |
|---|---|---|---|---|---|---|---|
| | | — % of ratings at each golf course — | | | | | |
| **Stabilite Turfgrips** | Unacceptable | 0.3 | 1.5 | 1.5 | 1.7 | 4.2 | 2.0 |
| *turfgrips* | Significant | 2.5 | 10.8 | 11.3 | 11.9 | 24.7 | 13.9 |
| | Moderate | 19.8 | 46.5 | 47.2 | 48.0 | 51.7 | 49.9 |
| | Minimial | 52.4 | 34.9 | 33.9 | 32.7 | 17.1 | 29.4 |
| | None | 25.0 | 6.4 | 6.1 | 5.7 | 2.3 | 4.8 |
| | ***Significance**** | ***a*** | ***b*** | ***b*** | ***bc*** | ***c*** | ***bc*** |
| | ***Rank‡*** | ***10*** | ***16*** | ***15*** | ***15*** | ***19*** | ***10*** |
| **Turfmaster** | Unacceptable | 0.3 | 2.2 | 1.7 | 1.2 | 2.0 | 3.4 |
| *softspike xp* | Significant | 2.7 | 15.0 | 12.4 | 9.1 | 13.7 | 21.2 |
| | Moderate | 21.1 | 50.8 | 48.5 | 43.7 | 49.8 | 52.3 |
| | Minimial | 52.4 | 27.7 | 31.9 | 38.4 | 29.6 | 20.3 |
| | None | 23.5 | 4.4 | 5.5 | 7.7 | 4.9 | 2.8 |
| | ***Significance**** | ***a*** | ***b*** | ***b*** | ***b*** | ***b*** | ***b*** |
| | ***Rank‡*** | ***13*** | ***20*** | ***16*** | ***7*** | ***14*** | ***12*** |
| **Ultimate 2000** | Unacceptable | 0.6 | 0.6 | 0.9 | 1.6 | 7.8 | 3.7 |
| *turfgrips* | Significant | 4.9 | 5.0 | 6.8 | 11.5 | 36.3 | 22.9 |
| | Moderate | 31.8 | 32.4 | 38.3 | 47.5 | 44.8 | 52.1 |
| | Minimial | 48.6 | 48.2 | 43.8 | 33.4 | 9.8 | 18.7 |
| | None | 14.1 | 13.7 | 10.3 | 5.9 | 1.2 | 2.6 |
| | ***Significance**** | ***a*** | ***a*** | ***a*** | ***ab*** | ***c*** | ***b*** |
| | ***Rank‡*** | ***21*** | ***7*** | ***10*** | ***14*** | ***23*** | ***14*** |

*Golf courses sharing a letter are not significantly different. ($P < 0.05$).

†The All-Performance shoe was not included at MSU or CCD.

‡Rank among all 27 spikes/soles (26 at MSU and CCD).

Table 4 provides a numerical ranking of each spike for that respective golf course. This can be used to rapidly compare the relative responses of the individual spikes across golf courses. This can be useful in noting large deviance among the rankings to allow for further investigation of the source of the deviation. These rankings should not be used to quantitatively assess the order of each spikes response. Each number ranking could potentially be significantly different from several other spikes. Therefore, the only true method for comparison of this type is to evaluate and utilize figures 1-6.

One distinct difference in this study was the different responses of spikes across the various putting surfaces. While the characteristics of each green have been presented in Table 2, there was no attempt in this study to correlate the importance of various management practices to these spike responses.

There did appear to be differences in spike response based on the age and maturity of the putting surface, as well as the turfgrass species composition. Future studies should be designed to evaluate these factors in a controlled environment.

It should be noted that across all locations the 8mm spike was rated below all alternative spikes. (The 6mm spike was also ranked at the bottom with the 8mm on 4 of the 6 locations). This continues to indicate the golfers distinct displeasure with the metal spike.

One interesting method for comparing the differences among the spikes is to group them in similar categories. We suggest the following for comparison (remember to also use the control in the comparison).

| Grouping Comparison | Spike to be compared (Treatment) |
|---|---|
| Dry Joy Shoe (smooth sole) | 1-9 |
| Soft Spike XP (various sole) | 9, 10, 12, 13, 15, 16, 17 |
| Turf Grips (various perforated soles) | 18, 19, 20, 22, 24 |
| Teaching sole | 11, 14, 21, 23, 26 |

**Conclusions**

Some of the conclusions drawn from this study are bulleted below.

- The 8mm steel spike received the lowest rating at all six locations.
- The ratings varied among golf courses.
- Not all alternative spikes caused the same amount of wear.
- Results from the seven golf soles fitted with the Softspikes XP lead to the conclusion that the smooth golf shoe sole causes more visible wear than the perforated golf sole designs included in the study. The Dry-Joys and the Foot-Joy Classics fitted with the Softspike XP were golf shoes that had smooth soles with a heel.
- Results from the five golf soles fitted with the Turf-Grips lead to the conclusion that some perforated soles cause more wear than others.
- There were five golf soles included in the studies that had perforated soles without an insert for alternative or 8mm spikes. These soles are commonly called teaching golf shoes. The teaching golf soles caused different amounts of wear.

**Future Studies**

From listening to the concerns of all factions involved, through historical review, and through perfunctory steps in building a viable research base, MSU has built a knowledge base regarding the alternative spike/sole debate that is second to none. It is our contention to use this base to establish an alternative golf spike/sole research methodology that is pertinent and accurate that yields results that will be accepted world-wide. We have also come to the realization that through our publications and the speaking circuit many golf course superintendents anticipate annual reports on the newest alternative golf spike/sole designs. For this reason, in the spring and summer of 1999 MSU has chosen one individual that will give 100% of his time to this issue. He will not only study the alternative soles, but will also continue identifying cultural practices utilized by the golf course superintendent that minimize the visual effect of traffic.

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