TURFGRASS SOILS AND FERTILITY RESEARCH REPORT 2000

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It seems hard to believe that my first year at Michigan State University is almost complete. It's certainly been a very busy year as I've focused on establishing a research program and traveling the state to meet those working in the turfgrass industry. Thom Nikolai served as my research technician for my first 9 months but has now taken a teaching position in the two-year turfgrass management program. It will be difficult to replace Thom and I am grateful for his assistance as I strived to establish my program. I have taken on two graduate students working towards a Masters degree. Brian Leach started in June and is concentrating his research on the Sloping Green Research Project. Kevin O'Reilly has recently started graduate school and will be working on the Long Term Nitrogen Fate Research Project.

I look forward to continuing several research projects this year and investigating new areas. I am also eager to continue my explorations of Michigan and establish relationships with those working in the turfgrass industry.

The research results presented in this report are preliminary in nature and additional years of data are necessary to make definitive conclusions.

EFFECTS OF ROOTZONE MATERIAL AND DEPTH ON MOISTURE RETENTION PROBLEMS IN UNDULATING USGA PUTTING GREENS (THE SLOPING GREEN)

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Introduction

The United States Golf Association (USGA) introduced guidelines for constructing putting greens over thirty years ago and since then the USGA green has become the standard for golf course putting greens. The concept behind the USGA recommendations for putting green construction is to build a green that provides a measure of resistance to compaction in the rooting zone and drains quickly to an optimum soil moisture level. If greens lacked slopes there is little doubt that most, if not all, USGA greens would perform well. However with the slopes present on putting greens today, the USGA greens do not always perform ideally. Two problems that have commonly been encountered on greens are "Localized Dry Spot" (LDS) and "Black Layer". These problems are primarily associated with extremes in soil moisture in the rootzone of the green (Wilkinson and Miller, 1978; Tucker et al., 1990; Cullimore et al., 1990; Berndt and Vargas, 1992).

Specifications for a USGA putting green require that the sandy rootzone mixture be placed at a uniform depth of 30 cm (12"), across the entire surface of the green. However, the uniform rootzone mix depth does not account for the lateral flow of water in a sloping rootzone. Lateral flow occurs in sloping soil profiles when gravitational and surface tension forces acting on the water become larger than the attraction of water to the soil. This lateral flow causes lower water contents in high areas of the putting green resulting in dry soil conditions and susceptibility to LDS. Water flows laterally to the lower parts of the green causing higher water contents closer to the surface in the same green. This is the location where Black Layer most frequently occurs.

Research was initiated in 1998 at the Hancock Turfgrass Research Center to investigate whether or not altering the rootzone depth, decreasing it in high areas and increasing it in low areas, will increase the water content near the soil surface in high areas and decrease the water content of the rootzone mix in low areas.

Materials and Methods

In 1998, a 950 m^2 (10,000 ft^2) research putting green was constructed at the Hancock Turfgrass Research Center at Michigan State University. The entire putting green is subdivided into 12 sloping plots. The profile of the green (from North to South) consists of a 2.3 m (8') long flat portion (toeslope North), followed by a seven percent 5.3 m (17.3') long slope (backslope North) to the summit, followed by a more gradual three percent 12.2 m (40') long downward slope (backslope South), followed by a final 4.5 m (14.7') long flat portion (toeslope South) (Figure 1). Barriers in the form of particle board dividing walls and PVC liners were placed along the length of each plot to prevent lateral movement of water between plots. Each plot received one of three rootzone mixes; sand/peat, sand/soil, or straight sand. Three plots (one of each rootzone type) have a rootzone mix with a uniform 30 cm (12") depth (standard USGA type) and three have a rootzone mix depth varying from 20 cm (8") at higher elevations to 40 cm (16") at lower elevations (modified USGA type). Drainage tiles were placed in trenches at strategic locations across the plots: at the extreme ends of each plot as well as at the end of each slope, and in the middle of the backslope of the 3% slope (Figure 1). The trenches were filled with gravel to cover the tiles and each tile was connected to a solid pipe that discharges at the lower end of each slope to a rain tipping bucket. A series of 120 Time Domain Reflectometry (TDR) probes and cables were buried in the soil to measure soil moisture in 10 cm (4") increments at several locations in every plot. The plots are arranged in a two factor complete randomized split-block design and are replicated twice. A Rainbird irrigation system was installed to provide uniform irrigation coverage for the entire green. The green was seeded with creeping bentgrass (*Agrostis palustris*) cultivar 'L-93' in June of 1998.

In 2000, data were collected on soil moisture, leaf surface temperature, turfgrass quality and color, root weights, and quantity of drainage water from various regions of the green.

Turfgrass quality, color, and leaf surface temperatures were taken from five locations per green (toeslope North, backslope North, summit, backslope South, and toeslope South). Soil moisture readings were collected for four different 'dry down cycles' during the summer using a TRIME portable TDR unit for the 0 to 10 cm depth. A TDR100 and a series of multiplexers were used to measure soil moisture with the permanently installed probes at depths of 10-20 cm, 20-30 cm and 30-40 cm. Soil moisture measurements were taken in the Northfacing toeslope (TDR location 1), summit (TDR location 2), and at two locations in the Southfacing toeslope (TDR locations 3 and 4) (Figure 1). Root samples are in the process of being washed and weighed and results will be presented in future reports. Thirty-six rain tipping buckets were installed at the south end of the green to quantify the amount of water draining from three locations on the south slope of the green (Figure 1). Data from the rain tipping buckets were collected continuously throughout 2000.

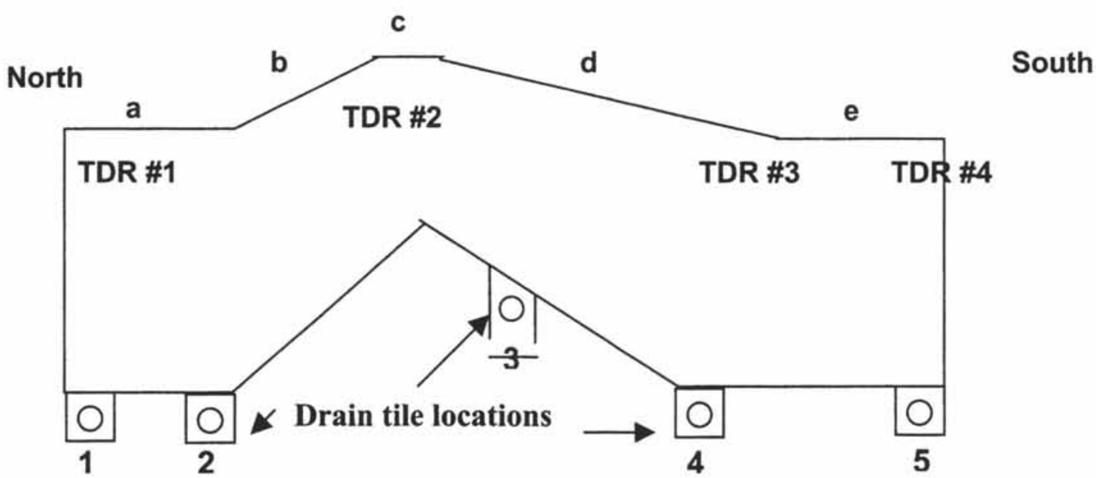

Figure 1. Cross section through plots with variable rootzone depth and different locations for measurements: (a) toeslope North, (b) backslope north, (c) summit, (d) backslope South, (e) toeslope south.

Results and Discussion

Turfgrass quality, color, and leaf surface temperatures

There were no consistently significant differences observed in quality, color, or leaf surface temperatures among the treatments in 2000. At several sampling times, there were location x construction type x rootzone mix interactions for turfgrass quality but analysis of the three way interaction revealed no important differences among the treatments. The abundant rainfall received throughout the spring and summer of 2000 in East Lansing resulted in few differences in turfgrass quality and color on the green.

Soil Moisture

During the summer of 2000 there were five different 'dry down' cycles during which volumetric soil moisture measurements were taken using TDR probes. Data were analyzed separately by depth for the 0-10 and 10-20 cm depths. Since the 20-30 and 30-40 cm depths are not present for both construction methods at all locations on the green, statistical comparisons of these depths was not conducted. The location x construction type and location x rootzone mix interaction were significant throughout the dry down cycles.

Location x Construction Type Interaction 0-10 cm depth

At the 0-10 cm depth there was a significant location x construction type interaction at almost all measurement times. At the beginning of a dry down cycle on August 31, when the rootzone is near field capacity, the location x construction type interaction revealed that at TDR locations 1 and 3 the modified USGA construction type had lower volumetric soil moisture content than the standard USGA construction type (Table 1). There were no differences in volumetric soil moisture content between the construction types at TDR locations 2 and 4. Furthermore, it was evident that there were no differences in volumetric soil moisture content among TDR locations for the modified USGA construction type. However, for the standard USGA construction type the peak of the slope, TDR location 2, had significantly lower soil moisture content values than TDR locations 1 and 3.

Table 1. Volumetric soil moisture for the location x construction type interaction at the 0-10 cm depth on August 31, 2000.

TDR Location	Construction Type: Modified USGA	Construction Type: Standard USGA
1	17.5 B†a‡	24.2 Aa
2	20.8 Aa	17.5 Ab
3	16.2 Ba	23.4 Aa
4	17.6 Aa	22.5 Aab

† Means in a row followed by the same capital letter are not significantly different according to Fischer's protected LSD (p=0.05)

‡ Means in a column followed by the same small case letter are not significantly different according to Fischer's protected LSD (p=0.05)

On September 3, 4 days after an irrigation event, the location x construction type interaction was still significant for volumetric soil moisture content. The modified USGA construction type had lower volumetric soil moisture content values at TDR locations 1, 3, and 4 (Table 2). As on August 31, there were no differences in soil moisture content among the locations for the modified USGA construction type, indicating that the modified USGA construction type had uniform soil moisture across the entire slope of the green. Across the slope of the standard USGA construction type green, volumetric soil moisture content values were lower at the peak of the slope, TDR location 2.

Table 2. Volumetric soil moisture for the location x construction type interaction at the 0-10 cm depth on Septmeber 3, 2000.

TDR Location	Construction Type: Modified USGA	Construction Type: Standard USGA
1	14.1 B†a‡	21.2 Aa
2	14.5 Aa	11.3 Ab
3	14.8 Ba	20.8 Aa
4	13.6 Ba	19.1 Aa

† Means in a row followed by the same capital letter are not significantly different according to Fischer's protected LSD (p=0.05)

‡ Means in a column followed by the same small case letter are not significantly different according to Fischer's protected LSD (p=0.05)

Analysis of the location x construction type interaction at the 0-10 cm depth indicated that the modified USGA construction type had lower volumetric soil moisture content than the standard USGA construction type at TDR locations 1, 3, and 4. Although the differences were not statistically significant at this time, volumetric soil moisture content was greater at the peak of the slope, TDR location 2, for the modified USGA construction type. The results confirm our initial hypothesis that altering the rootzone depth will decrease moisture content in lower regions and increase moisture content on elevated areas of greens.

Location x Construction Type Interaction 10-20 cm depth

Statistical analysis of volumetric soil moisture content for the 10-20 cm depth revealed a significant location x construction type interaction. The location x construction type interaction results were similar to those observed for the 0-10 cm depth. On August 31, day 1 of the dry down, the modified USGA construction type had lower volumetric soil moisture content values than the standard USGA construction type at TDR locations 1, 3, and 4 and higher volumetric soil moisture content values at TDR location 2 (Table 3). In contrast to the moisture contents at the 0-10 cm depth, for the 10-20 cm depth there were no differences in moisture content among locations for the standard USGA construction type. Among locations for the modified USGA construction type, soil moisture content was higher at TDR location 2 than at the other locations. On September 2, three days after an irrigation event, the modified USGA construction type had lower soil moisture content at TDR locations 1 and 4 and was not different from the standard USGA construction type at TDR locations 2 and 3 (Table 4).

Table 3. Volumetric soil moisture for the location x construction type interaction at the 10-20 cm depth on August 31, 2000.

	Construction Type	
TDR Location	Modified USGA	Standard USGA
1	17.0 B[†]b[‡]	22.7 Aa
2	23.2 Aa	17.8 Ba
3	17.3 Bb	21.7 Aa
4	16.4 Bb	22.3 Aa

[†] Means in a row followed by the same capital letter are not significantly different according to Fischer's protected LSD (p=0.05)

[‡] Means in a column followed by the same small case letter are not significantly different according to Fischer's protected LSD (p=0.05)

Table 4. Volumetric soil moisture for the location x construction type interaction at the 10-20 cm depth on September 2, 2000.

	Construction Type	
TDR Location	Modified USGA	Standard USGA
1	15.9 B[†]a[‡]	21.1 Aa
2	20.3 Aa	16.5 Aa
3	16.6 Aa	20.4 Aa
4	15.7 Ba	21.0 Aa

[†] Means in a row followed by the same capital letter are not significantly different according to Fischer's protected LSD (p=0.05)

[‡] Means in a column followed by the same small case letter are not significantly different according to Fischer's protected LSD (p=0.05)

Location x Rootzone Mix Interaction

The location x rootzone mix interaction was also significant throughout most of the dry down cycles. Volumetric soil moisture content values are reported for the location x rootzone mix interaction observed on August 14 and 16, day 2 and 4 of a dry down cycle, respectively (Tables 5 and 6). The results indicate that the sand rootzone mix was drier than the sand/peat and sand/soil rootzone mixes at TDR locations 1, 2, and 3 on August 14 and at TDR locations 1 and 2 on August 16. There were no differences in volumetric soil moisture content among locations for the sand/peat and sand/soil rootzone mixes on both dates. On both August 14 and 16 within the sand rootzone mix plots, the lowest volumetric soil moisture content was at TDR location 2. The results indicate that when volumetric soil moisture content is averaged across the construction types, the sand/peat and sand/soil rootzone mixes do not have differences in soil moisture content across the slope of the green while the sand rootzone mix is consistently drier at the peak of the slope.

Table 5. Volumetric soil moisture for the location x rootzone mix interaction at the 0-10 cm depth on August 14, 2000.

	TDR Location			
Rootzone Mix	1	2	3	4
Sand	11.1 BC†b‡	7.05 Cc	16.6 Ab	15.2 Ab
Sand/Peat	23.2 Aa	23.8 Aa	23.9 Aa	19.9 Aa
Sand/Soil	21.4 Aa	17.8 Ab	20.2 Aa	18.4 Aab

† Means in a row followed by the same capital letter are not significantly different according to Fischer's protected LSD (p=0.05)

‡ Means in a column followed by the same small case letter are not significantly different according to Fischer's protected LSD (p=0.05)

Table 6. Volumetric soil moisture for the location x rootzone mix interaction at the 0-10 cm depth on August 16, 2000.

	TDR Location			
Rootzone Mix	1	2	3	4
Sand	11.0 A†c‡	6.0 Bc	14.5 Ab	13.6 Ab
Sand/Peat	23.4 Aa	20.4 Aa	21.9 Aa	21.0 Aa
Sand/Soil	19.2 Ab	16.4 Ab	17.1 Ab	16.0 Ab

† Means in a row followed by the same capital letter are not significantly different according to Fischer's protected LSD (p=0.05)

‡ Means in a column followed by the same small case letter are not significantly different according to Fischer's protected LSD (p=0.05)

Drainage Water

The quantity of drainage water from three different locations on the south slope of the green was collected continuously throughout 2000. Water was collected from drain tiles located approximately 2.3 m (8') south of the peak of the slope (drain tile #3), at the base of the south backslope (drain tile #4), and at the south end of the south toeslope (drain tile #5) (Figure 1). A total of 1.25 cm (0.5") of water was applied at 10:00 a.m. uniformly across the entire green on September 3. No irrigation had been applied for the previous 4 days. The amount of water collected from the three drain tiles and the time over which it was collected are presented in Figures 2-4. Drain tile number three collected the smallest amount of water and only four of the rootzone mix/construction type greens had any water collected at this drain tile (Figure 2). All three of the modified USGA construction type greens had water draining from drain tile number 3 and only one of the standard USGA construction type greens, the USGA sand/peat rootzone mix, had water draining from drain tile number 3. Drain tiles number 4 and 5 had larger amounts of water draining from them and all greens had water draining from these tiles (Figures 3 and 4). For drain tile number 4, all of the standard USGA construction type greens had water draining from the tile before the modified USGA construction type greens (Figure 3). For drain tile number 5 the results are not as clear (Figure 4). The time order of water draining from drain tile #5 is as follows: standard USGA sand rootzone mix, modified USGA sand rootzone mix, standard USGA sand/soil rootzone mix, standard USGA sand/peat rootzone mix, modified USGA sand/soil rootzone mix, and finally the modified USGA sand/peat rootzone mix.

The percent of the total water collected from the south slope of the green that drained from each individual drain tile is presented in Table 7. Drain tile number 3 had a maximum value of 8.5% of the total water collected from tiles 3, 4, and 5. For the standard USGA construction type, the highest percentage of water drained from tile number 4. For the modified USGA construction type, the highest percentage of water drained from tile number 5.

Although preliminary in nature, these results seem to indicate that by altering the rootzone depth more water is collected off the peak of the slope and less drains to the lower regions of the green. Further replication of irrigation events in 2001 and complete installation of tipping buckets on the north side of the green will enable more definitive conclusions with respect to the amounts of water draining from various regions of a sloped putting green.

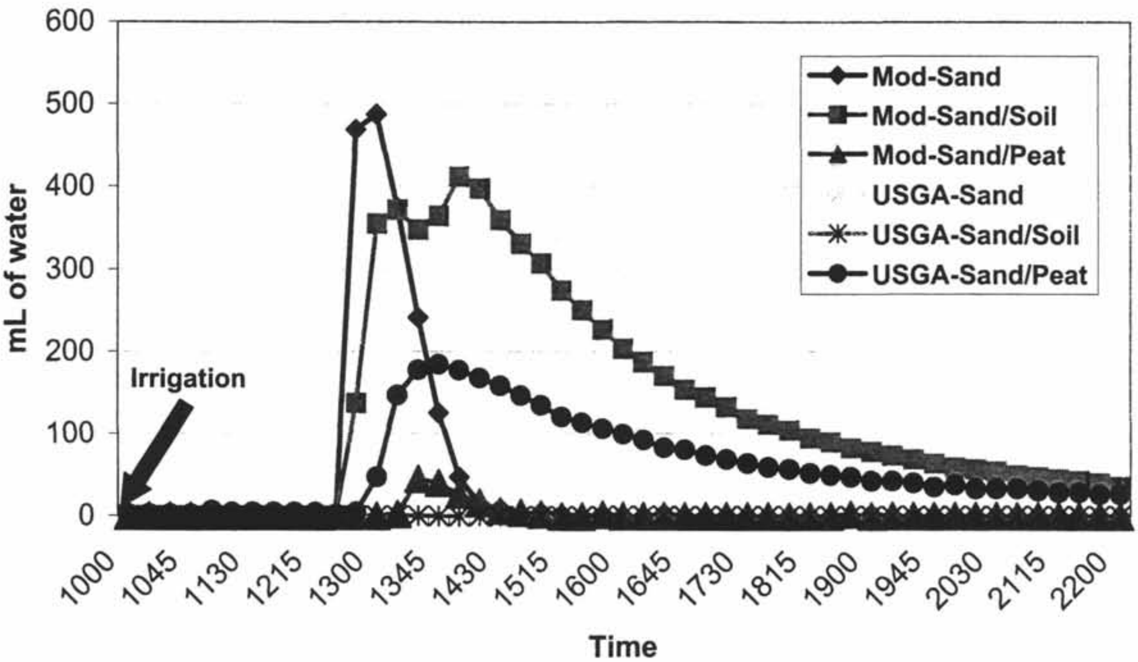

Figure 2. Amount of water collected from drain tile number three after an irrigation event on September 3.

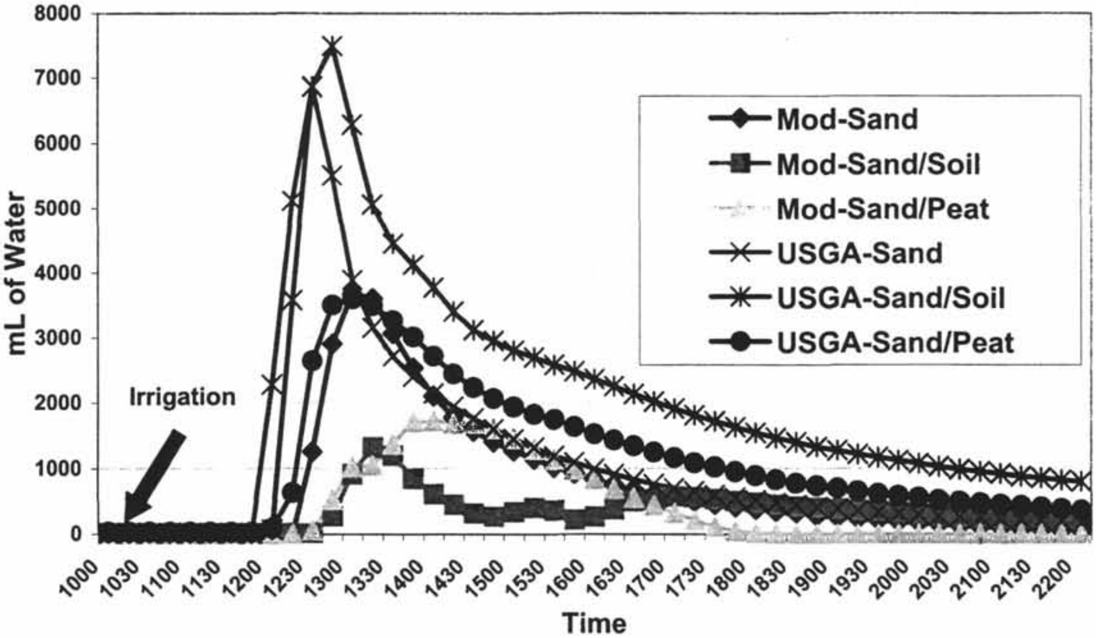

Figure 3. Amount of water collected from drain tile number four after an irrigation event on September 3.

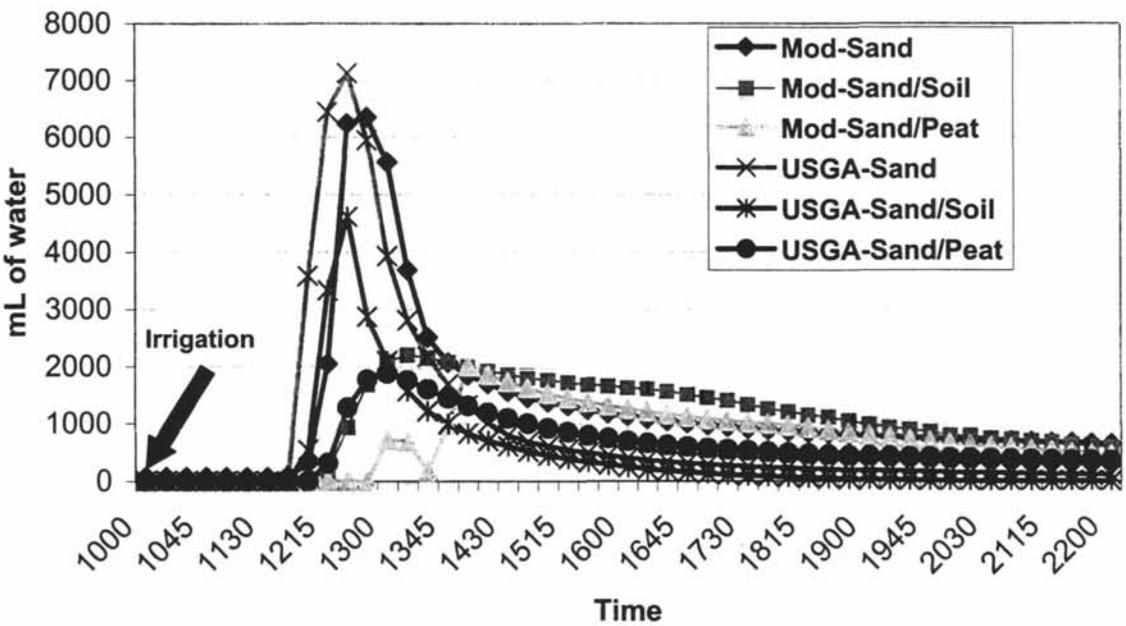

Figure 4. Amount of water collected from drain tile number five after an irrigation event on September 3.

Table 7. The percent of the total drainage water collected from the south slope of the green that drained from each drain tile.

	Drain Tile		
Construction Method/Mix	3	4	5
Modified Sand	1.79†	36.3	61.9
Modified Sand/Peat	8.53	22.6	68.9
Modified Sand/Soil	0.26	36.3	63.4
USGA Sand	0.00	55.4	44.6
USGA Sand/Peat	0.00	80.9	19.2
USGA Sand/Soil	3.34	63.5	33.2

† Percent of water collected

Conclusions

The results from 2000 confirm our initial hypothesis that altering the rootzone depth decreases soil moisture content near the putting green surface in lower regions of the green and increases soil moisture content near the putting green surface in higher areas of greens. The concern that was raised in the 1999 report that lower moisture content in the lower regions of the green could lead to greater susceptibility to drought stress still needs to be considered. Analysis of rooting depth in these areas should provide valuable information to help determine the relevancy of this concern.

Future Directions for 2001

Research will continue to investigate soil moisture content using TDR probes throughout the entire season of 2001. Rain tipping buckets will be installed on the north side of the green so an entire balance of water applied to the green will be able to be accounted for through the drainage water. A soil gas analyzer has been acquired this fall and will be used in 2001 to measure gas concentration at different locations and depths in the green.

Acknowledgements

This research is currently supported by grants from the United States Golf Association, Golf Course Superintendents Association of America, and the O.J. Noer Turfgrass Foundation. We are also grateful for support from the Michigan Turfgrass Foundation, TriTurf Inc., Rainbird, and Bruce Mathews from Design3.

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LONG TERM NITROGEN FATE IN KENTUCKY BLUEGRASS

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Introduction

Extensive research has been conducted in the last 10 years on nitrate-nitrogen leaching in turfgrass systems. The majority of research has indicated that turfgrass poses little risk to the environment from nitrate leaching. Research conducted at MSU by Miltner et al. reported that the majority of ^{15}N labeled urea nitrogen applied to Kentucky bluegrass never even reached the soil. The majority of applied nitrogen was taken up by the plant, immobilized in the thatch layer, or lost to volatilization. Only 0.23% of the ^{15}N labeled urea was collected in the drainage water of lysimeters 1.2 m below the soil surface over a three year period following application.

Research has also shown that turfgrass builds organic matter for a period of about 10 years following establishment and then reaches an equilibrium where no further net N immobilization occurs. The question under investigation is whether or not after an extended period of time, 10 years, will the amount of nitrate-nitrogen leaching from a turfgrass system change. The research is important because it will indicate if the amount of nitrate nitrogen leached from a mature turf occurs at a level where an alteration in fertilizer practices needs to be considered.

Materials and Methods

Four intact large lysimeters at the Hancock Turfgrass Research Center and the surrounding turfgrass area will be used to examine nitrogen fate on a mature turf. The lysimeters were established with Kentucky bluegrass sod in the fall of 1990 prior to a USGA-sponsored N fate study conducted from 1991-1993.

The research was initiated in 1998 and will potentially last for the next 25 years. The experimental design is relatively simple. Two of the large lysimeters and 1/2 of the surrounding area originally established in 1990 will be treated annually with 240 kg N ha^{-1} (5 lb. N/1000 $ft.^2$). The remaining two lysimeters and surrounding area will be treated with 96 kg N ha^{-1} (2 lb. N/1000 $ft.^2$). Lysimeter percolate will be collected periodically, volume measured, and a subsample collected for N analysis. This procedure will continue indefinitely.

In the fall of 2000, ^{15}N labeled urea was applied to the plot area to determine mass nitrogen balance. The leachate from the large lysimeters will be monitored for N and $^{1}5N$. In addition, ^{15}N labeled urea was applied to micro-plot areas for intensive sampling of the turfgrass system. Soil, thatch, verdure, and roots will be sampled for $\%^{15}N$ enrichment to determine mass nitrogen balance for the system. The number of microplots installed was sufficient to enable periodic sampling for the next 25 years.

Results

The 240 kg N ha^{-1} (5 lb. N/1000 $ft.^2$) treatment has yielded nitrate concentrations in the leachate greater than 10 ppm nitrate-nitrogen since September of 1999 (Figure 1). With the exception of one sampling date, the 96 kg N ha^{-1} (2 lb. N/1000 $ft.^2$) treatment has always had nitrate-nitrogen concentrations less than 4 ppm.

The 240 kg N ha^{-1} (5 lb. N/1000 $ft.^2$) treatment has leached a total of 65 kg N ha^{-1} or 12% of the total applied nitrogen since 1998 (Figure 2). The 96 kg N ha^{-1} (2 lb. N/1000 $ft.^2$) treatment has leached a total of 15 kg N ha^{-1} or 7% of the total applied nitrogen.

Future Directions

Leachate will continue to be monitored indefinitely and mass nitrogen balance will be determined for the turfgrass/soil profile in 2001 and 2002.

Acknowledgements

This research is currently supported by grants from the United States Golf Association and the Michigan Turfgrass Foundation.

Figure 1. NO_3-N Concentration (1998-2000)

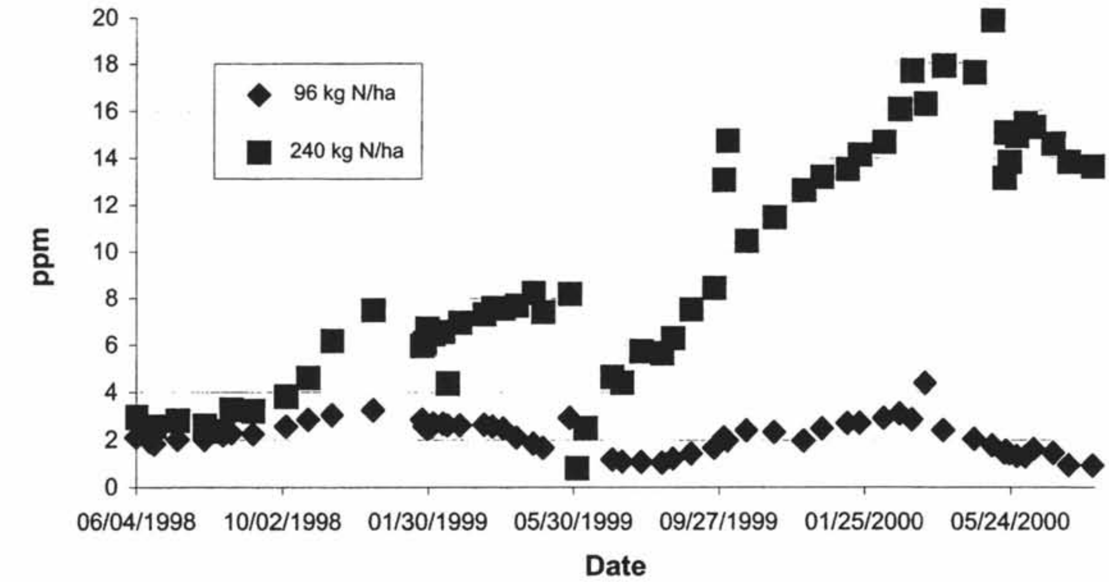
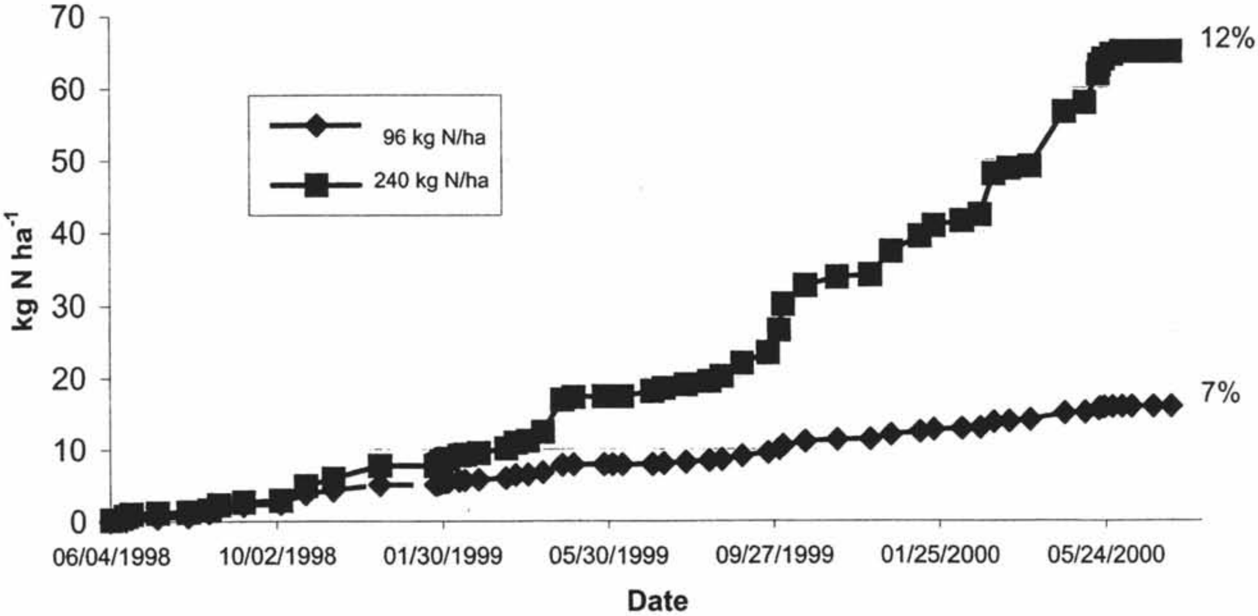


Figure 2. Total N Recovered (1998-2000)



ALTERNATIVE SPIKE RESEARCH 2000: TRACTION AND LONG TERM WEAR

T.A. Nikolai, J.N. Rogers III, and K.W. Frank

Alternative Spike Traction Research

On 17 July 2000 an alternative spike traction study was conducted at the Forest Akers Driving Range at Michigan State University. Thirty six volunteers capable of wearing size 11 golf shoes took part in the testing. While signing in to participate the volunteers were asked to NOT look at the soles of the shoes while lacing them on. Afterwards the participants began an obstacle course by lacing on a pair of golf shoes and proceeding to the driving range tee to hit golf balls. After hitting several golf balls they were asked to rate the traction of the pair of shoes they were wearing on a scale of 1 to 5. The traction scale was 5 = excellent, 4 = very good, 3 = good, 2 = fair, and 1 = poor traction. Next, the participants proceeded to hit several golf balls on a slope and from a sand bunker and assign a traction rating using the same scale. After hitting golf balls from each of the three stations the volunteers repeated the course wearing a different pair of Foot-Joy Dry Joys with a different set of alternative spikes inserted into them. One pair of golf shoes had no alternative spikes inserted and was regarded as a check.

Traction from the Driving Range Tee

Traction data from the driving range tee are presented in Figure 1. The 8 mm metal spike received the highest percentage of excellent ratings. However, through statistical analysis of ordinal data, all treatments followed by the same letter in parenthesis are considered statistically equivalent. Statistical analysis revealed the Spider Bite, Black Traction, and Black Widow provided the same amount of traction as the 8 mm spike. At the other end of the traction scale was the check pair of shoes with 43% of the participants rating the traction as poor and another 39% rating them as fair. Of the alternative spikes, the Tred-Lite treatment received the fewest amount of excellent and the greatest percentage of poor and fair ratings from the driving range tee.

Traction from a Slope

Data regarding traction during the golf swing from a slope are presented in Figure 2. Once again the 8mm metal spike received the highest percentage of excellent ratings with Spider Bite and Black Widow giving the same amount of traction as the 8 mm metal spike. The flat sole check treatment was regarded as least acceptable traction with 68% of the participants giving them a rating of poor. Of the alternative spikes, the Tred-Lite treatment received the greatest amount of poor and fair ratings but statistically provided the same amount of traction as six other alternative spike treatments.

Traction from a Bunker

Data regarding traction while hitting golf balls from a sand bunker are given in Figure 3. In striking a ball from a sand bunker Black Widow received the highest percentage of excellent ratings with Spider Bite, 8 mm metal, Scorpion, and Eclipse statistically equivalent to the Black Widow. Once again the flat sole check treatment was regarded has having the worst traction. The Tred-Lite, Extra Performance, Shadow, and GreenKeepers had the poorest traction from the bunker of any of the alternative spike treatments.

Long Term Wear Study

On 10 June 2000 a long term wear study (six weeks) was initiated on a USGA putting green at the Hancock Turfgrass Research Center. Prior to initiation, traffic pattern observations were made throughout the United States and Norway. The purpose of these observations were to collect data on golf course putting greens that would allow for practical amounts of traffic to be applied on research plots on a daily basis.

The dilemma regarding long term wear studies has been how much traffic to apply on a daily basis. Past traffic studies at other Universities have resulted in putting surfaces being deteriorated to the point of bare soil. Applying traffic to this extent is unrealistic and serves little, if any, practical purpose. The quandary for research is that golf courses move the cup daily to minimize traffic while research plots must be confined to a given area for the purpose of collecting data as well as space and time constraints. MSU's traffic observations are an attempt to make the traffic research plots as realistic as possible by changing the amount of wear each plot receives on a daily basis.

The long term wear study was a randomized complete block design with three replications. The same 12 treatments that were in the traction study plus a non-trafficked check plot were used in the study. Each plot was partitioned into two distinct areas that received different amounts of traffic six days of the week (unless rain events postponed trafficking). Each plot consisted of an inner traffic area measuring 2'3" x 2'3"centered within an outer traffic area that measured 3'7" x 3'7". Traffic was applied to these two areas consistent with the field observations that were averaged from the aforementioned multiple sites in the United States and Norway. Wear tolerance ratings were taken on a scale from 1 to 5 with 1 = poor wear tolerance and 5 = excellent wear tolerance.

Wear ratings obtained on the six days that heavy traffic was applied are presented in Table 1. The heavy traffic treatment represents the amount of footsteps that occur in the vicinity of the cup on a day that 200 rounds of golf are played. The 8 mm metal spike received the lowest rating on all six dates. On 12 July, all plots performed satisfactorily with the 8 mm metal spike receiving the lowest ranking and only Diamond Back, Scorpion, and Black Traction not receiving wear ratings statistically equivalent to the non-trafficked check plot.

On 18 July, Scorpion, Spider Bite, and Eclipse shared the statistically lowest rankings with the 8 mm spike. By 27 July, the third day of heavy traffic, the 8 mm metal spike and Spider Bite displayed the most visible damage to the plots. On 3 August, the 8 mm spike received a rating of 1 meaning all three replications of the study received a ranking equivalent to poor wear tolerance.

On 14 August, wear tolerance improved for most treatments from the previous weeks rating. This most likely occurred because the plots were sand topdressed and received 0.5 lbs. N per 1000 sq. ft. on 4 August. On 14 August, the 8mm metal spike and the Spider Bite received the lowest wear tolerance ratings. On 21 August, the 8 mm metal spike received the lowest possible rating with all other treatments receiving acceptable ratings.

On 25 August, soil cores were taken from each plot to determine the impact of the traffic on each of the plots. Data are reported in Table 2. Though the treatments were statistically different in their effects on several factors, the practical significance of the results is negligible due to the high variability observed. The Hydraulic conductivity for the Tred-Lite treatment borders on non-acceptable for USGA specifications, however, statistically speaking there was no difference between the Tred-Lite treatment and the check plot. Similar results were seen for bulk density and the total porosity values. The moisture retention at 0.04 bars is considered the soil water that is available to the plant. Once again the Tred-Lite treatment resulted in the lowest numerical value, but only the check plots, spikeless flat sole shoe, and Eclipse resulted in statistically greater moisture retention and the numerical values were of minor importance.

Conclusions

The Black Widow and the Spider Bite were the only alternative spikes that matched the traction of the 8 mm metal spike on all three areas while striking a golf ball. With respect to turfgrass wear ratings, the metal spike received the numerically lowest rating on all dates. However, on three of those six dates there was no statistical difference between the Spider Bite and the 8 mm metal spike. The Black Widow never averaged a wear rating below 3 (a numerical value equivalent to good turf quality).

Acknowledgements

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Table 1. Turfgrass wear tolerance ratings for the heavy traffic treatment.

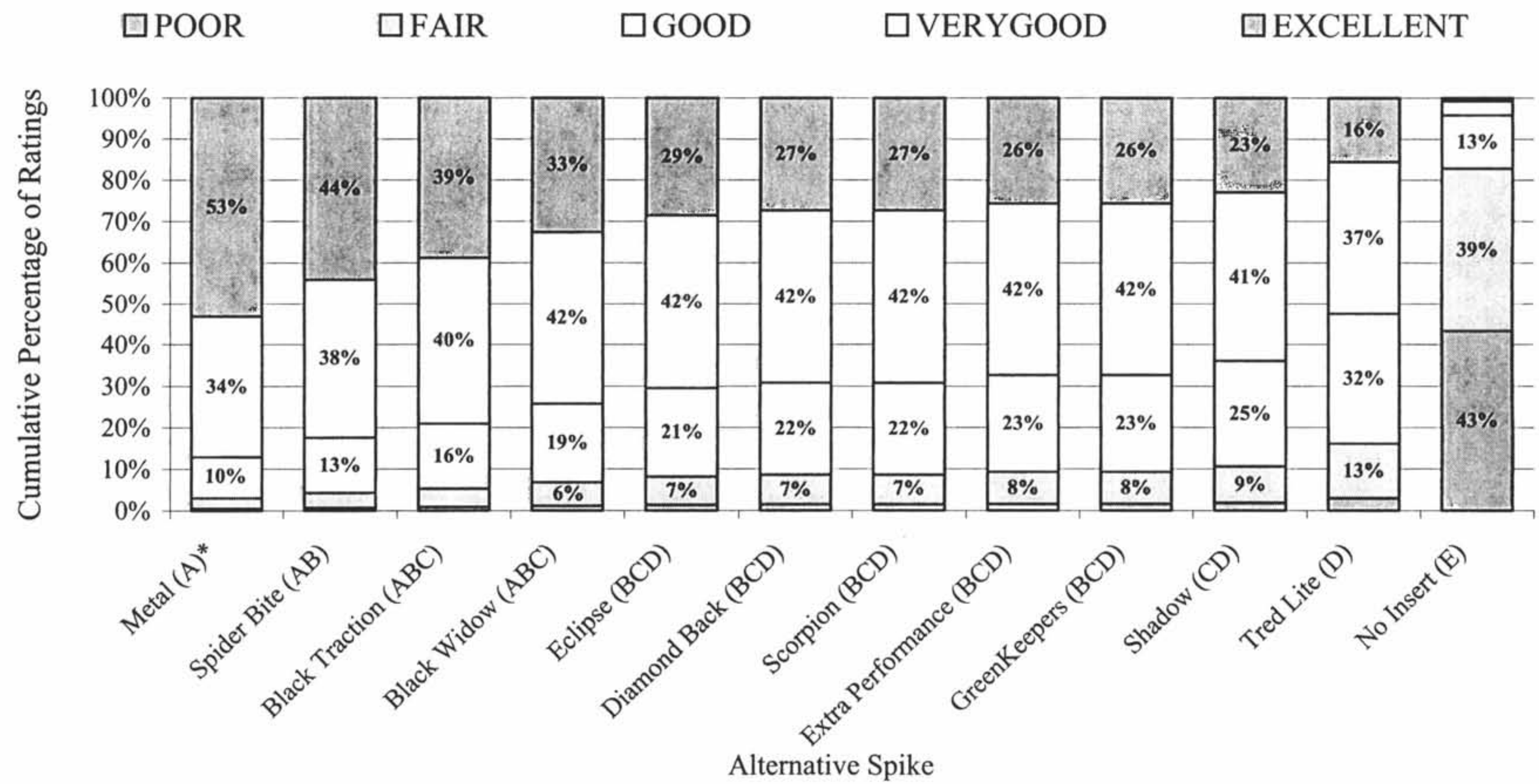
Alternative spike	Date					
	12-Jul	**18-Jul**	**27-Jul**	**03-Aug**	**14-Aug**	**21-Aug**
Black Widow	4.7 ab	4.3 abc	3.0 cde	3.3 bcd	3.3 cd	3.7 bc
Eclipse	4.7 ab	3.3 cde	3.7 bc	3.3 bcd	4.7 ab	4.3 abc
Shadow	5.0 a	4.7 ab	3.7 bc	4.0 ab	4.7 ab	5.0 a
Spider Bite	4.7 ab	3.0 de	2.3 ef	2.3 d	2.3 ef	3.3 cd
Diamond Back	3.7 cd	3.7 bcd	3.7 bc	2.3 d	4.0 bc	4.0 abc
Scorpion	4.0 bc	3.0 de	2.7 de	2.7 cd	3.0 de	4.7 d
Black Traction	4.0 bc	3.7 bcd	3.7 bc	2.7 cd	3.3 cd	4.0 abc
Green Keepers	5.0 a	4.0 abcd	4.0 b	3.7 bc	4.7 ab	5.0 a
8 mm Metal	3.0 d	2.3 e	1.7 f	1.0 e	2.0 f	1.0 e
Spikless flat sole	5.0 a	5.0 a	5.0 a	5.0 a	5.0 a	5.0 a
Extra Performance	4.7 ab	4.7 ab	4.0 b	3.3 bcd	4.7 ab	4.7 ab
Tred-Lite	4.7 ab	4.0 abcd	3.3 bcd	3.0 bcd	4.0 bc	5.0 a
Check	5.0 a	5.0 a	5.0 a	5.0 a	5.0 a	5.0 a
LSD @ 0.05	0.9	1.2	0.96	1.1	0.7	1

Table 2. Soil Physical Properties from Alternative Spike Research

	Hydraulic conductivity	**Bulk Density**	**Moisture retention at 0.04 bar**	**Total Porosity**	**Capillary Porosity**	**Air-filled Porosity**
Black Widow	24.3 cde	1.61 abc	12.9 cd	39.3 cde	20.7	18.6
Eclipse	36.8 a	1.56 de	15.2 ab	41.1 ab	23.6	17.5
Shadow	22.4 de	1.62 ab	13.6 bcd	39.0 de	22.0	17.0
Spider Bite	29.6 abcd	1.57 cde	13.5 bcd	40.8 abc	21.2	19.6
Diamond Back	36.1 ab	1.56 cde	13.4 bcd	41.1 ab	20.9	20.2
Scorpion	22.9 de	1.60 abcd	13.9 bcd	39.4 bcde	22.4	17.0
Black Traction	22.8 de	1.62 a	13.8 bcd	38.7 e	22.4	16.3
Green Keepers	23.3 cde	1.62 a	12.8 cd	38.8 e	20.8	18.0
8mm Metal	29.5 abcd	1.58 bcde	13.4 bcd	40.6 abcd	21.0	19.6
Spikeless flat sole	34.6 abc	1.56 e	14.4 abc	41.2 a	22.3	18.9
Extra Performance	31.8 abcd	1.59 abcde	13.3 bcd	39.9 abcde	21.1	18.8
Tred Lite	16.1 e	1.63 a	12.4 d	38.7 e	20.2	18.5
Check	25.4 bcde	1.59 abcde	16.1 a	40.1 abcde	25.6	14.5
LSD	11.3	0.04	1.97	1.71	3.19	4.17
Probability	*	**	*	**	NS	NS

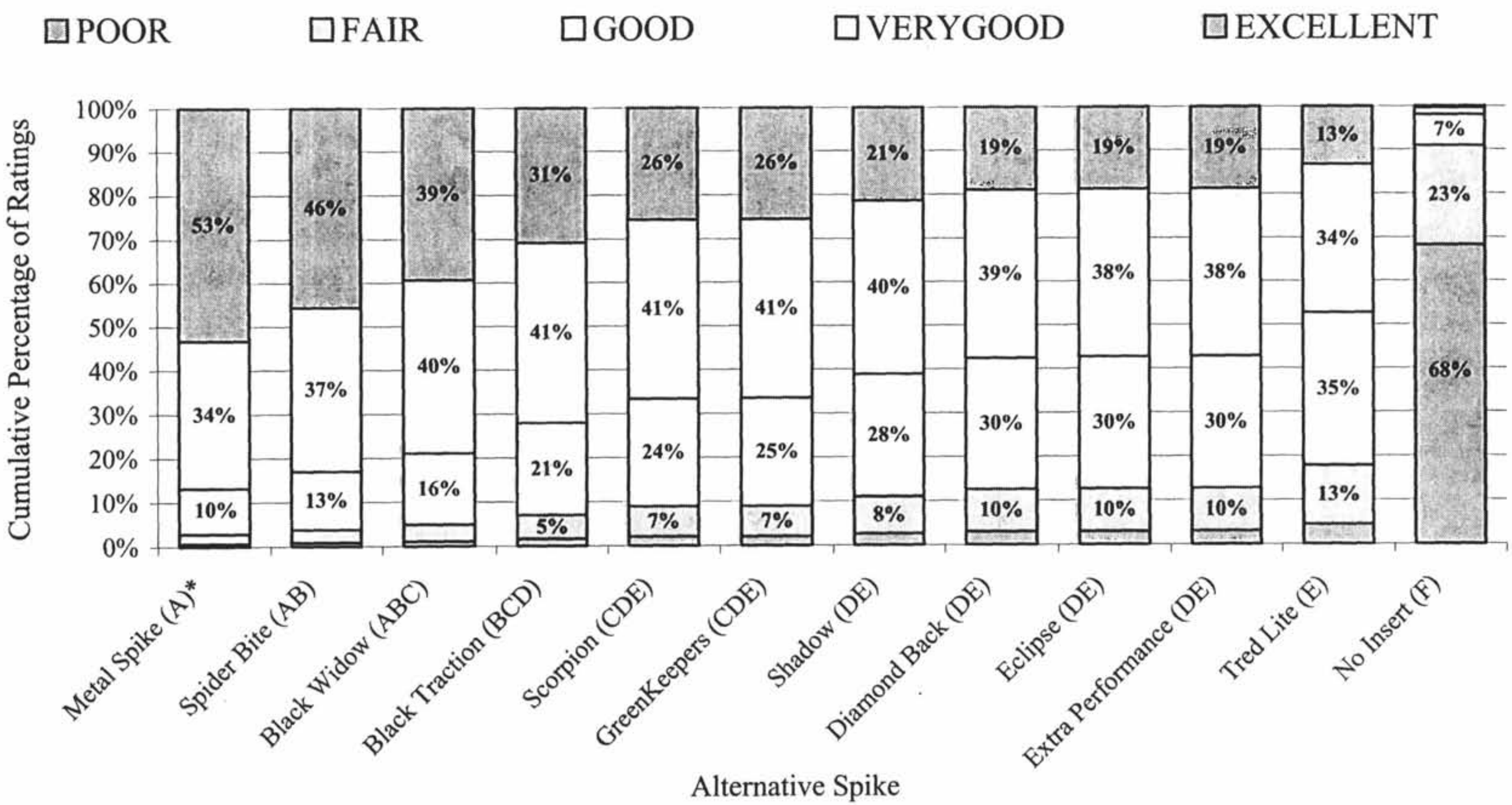
*, **, and NS denote significance at the 0.05, 0.10 probability level, and not significant, respectively.

Figure 1. Alternative Spike Traction from the Driving Range Tee



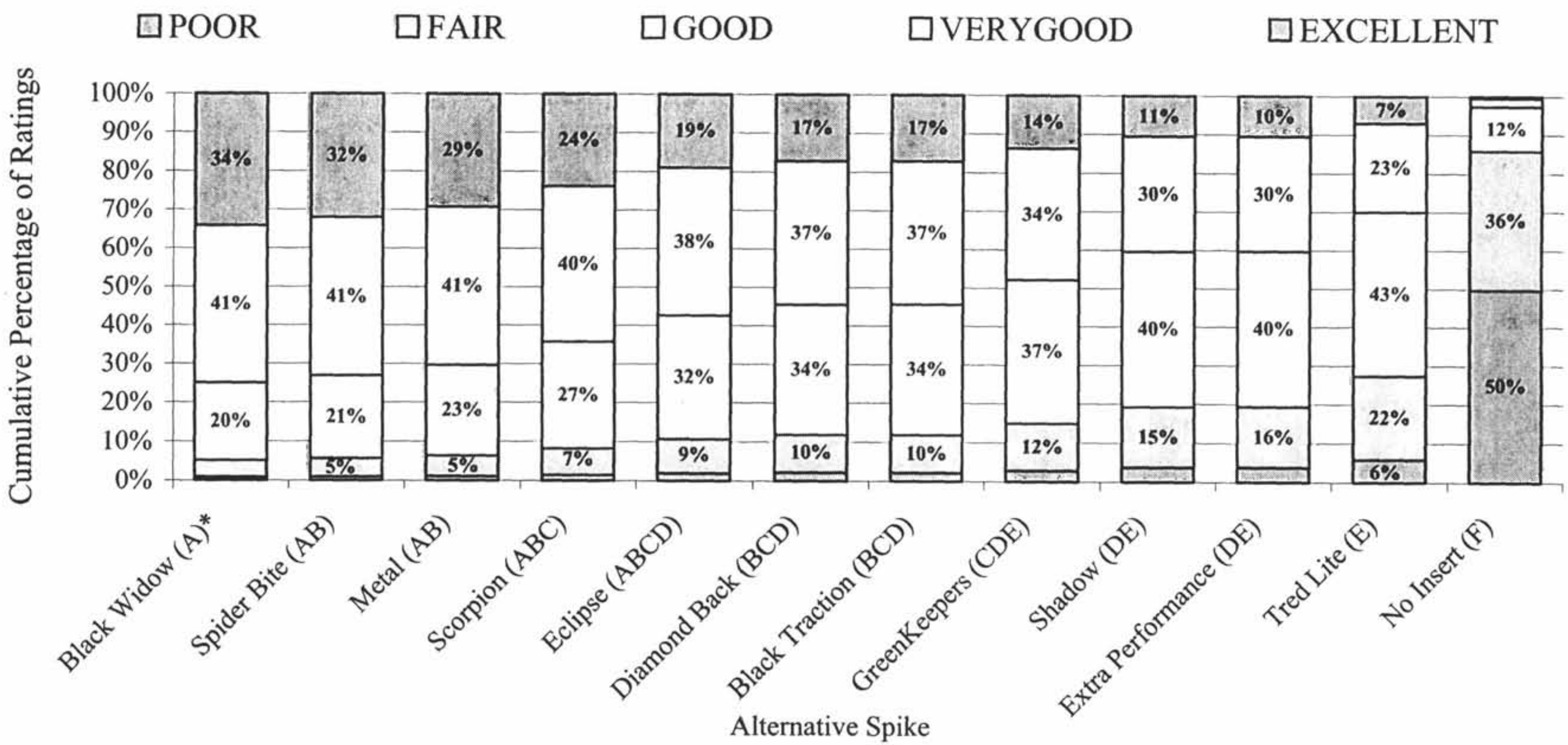
*Bars sharing a letter are not significantly different (P = 0.05).

Figure 2. Alternative Spike Traction from a Slope



*Bars sharing a letter are not significantly different (P = 0.05).

Figure 3. Alternative Spike Traction from a Bunker



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

CURRENT TRENDS IN FERTILITY PROGRAMS FOR GOLF COURSE PUTTING GREENS

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Introduction

Spoon feeding programs have become the status quo for fertilization of golf course putting greens. Spoon feeding can be defined as applying small amounts of fertilizer at frequent intervals throughout the season. The objectives of spoon feeding programs are to satisfy the nutritional needs of the plant by applying light, frequent applications of balanced nutrient solutions. Additionally, spoon feeding programs are popular because they maintain control over growth, maintain consistent green speeds, and potentially improve nutrient use efficiency.

The current trend in putting green fertilization is to spray 0.1 lb. N/M every ten days throughout the growing season. This practice leads to 0.3 lb. N/M monthly. Furthermore, if the program is initiated on April 1 and ends November 1, a little over 2 lb. of N/M will be applied annually.

Materials and Methods

On April 28, 2000 a study was initiated that combined historical and current fertility practices at the Hancock Turfgrass Research Center at MSU. The study was conducted on a Penncross creeping bentgrass green that was mowed with a walk behind mower at the bench height of 0.130 inches. Irrigation was provided at 0.1" per day regardless of rain events. Light sand topdressing was applied every two weeks and the plots were verticut in weeks that topdressing was not applied. The eight treatments are outlined in Table 1.

Stimp meter measurements were taken every 5 days starting on June 1. Turfgrass quality ratings were taken throughout the study on a scale of 1 to 9 with 1 = poor, 6 = acceptable, and 9 = excellent quality.

Table 1. Fertilizer treatments

Treatment	Source	Rate/1000 ft.^{2}	Interval	Method
1.	Methex 40-0-0	1.0 lbs. N	30 days	Granular
2.	Urea 46-0-0	1.0 lbs. N	30 days	Granular
3.	14-28-10 28-7-14	1.0 lbs. N 0.1 lbs. N	April 28th 10 days	Granular Foliar
4.	6-2-0 28-7-14	1.0 lbs. N 0.1 lbs. N	April 28th 10 days	Granular Foliar
5.	28-7-14	0.1 lbs. N	10 days	Foliar
6.	Untreated			
7.	28-7-14 Primo Maxx 1EC	0.1 lbs. N 0.04 fl. oz.	10 days 10 days	Foliar Foliar
8.	Methex 40-0-0 Primo Maxx 1EC	1.0 lbs. N 0.125 fl. oz.	30 days 30 days	Granular Foliar

The objectives of the study were to determine the effects of nitrogen rates and application frequency on ball roll distance (green speed), turfgrass quality, and disease symptoms.

Results and Discussion

The monthly 1 lb. N/M treatment consistently had acceptable turf quality ratings (ie. > 6) while the check plot always resulted in unacceptable turf quality. There were no statistically significant differences in turfgrass quality between the monthly 1 lb. N/M Methex treatments with or without Primo.

The plots receiving only 0.1 lb. N/M had unacceptable turfgrass quality on all but two rating dates. However, turf plots treated with 0.1 lb. N/M that were initiated with a pound of nitrogen in the early spring or tank-mixed with Primo had acceptable turfgrass quality on most rating dates.

With respect to green speed, the 0.1 lb. N/M treatment had significantly faster green speeds than the 1 lb. N/M Methex and 1lb. N/M urea treatments throughout most of the study. On average, the 1 lb. N/M Methex and 1lb. N/M urea treatments were approximately 8" slower than the 0.1 lb. N/M treatment.

On the four sampling occasions, significant green speed differences existed between the 0.1 lb. N/M and 1 lb. N/M Methex + Primo treatments. The 0.1 lb. N/M treatment was on average 5" faster than the 1 lb. N/M Methex + Primo treatment.

There were no differences in green speed between the 0.1 lb. N/M with and without Primo. The 0.1 lb. N/M treatments that were initiated in the spring with either a 1 lb. N/M natural organic or 1 lb. N/M starter fertilizer yielded slower green speed measurements on only two and three occasions, respectively, as compared to the 0.1 lb. N/M treatment with no spring fertilizer supplement.

Stimp meter measurements of 6" are commonly accepted as the minimum difference in green speed detectable by the average golfer. For this reason green speed consistency for each treatment was estimated by determining the number of times a 6" difference or less was observed between successive measurements.

In our study there were three days that Stimp meter data were collected resulting in all treatments having greater than a 6" change in green speed. It is hypothesized that rain events were the major contributing factor resulting in the drop in green speed on all three of those dates. These three data sets were disregarded in determining consistency of green speed.

Given the criteria, the check plots had the least variation in green speed with only two observations varying by 6" or more. The 0.1 lb. N/M treatment initiated with a 1 lb. N/M starter fertilizer and the 0.1 lb. N/M treatment tank mixed with Primo resulted in the most consistent green speeds among the fertilized plots, yielding green speed variations greater than 6" on only three occasions. The 0.1 lb. N/M treatment initiated with a 1 lb. N/M natural organic and the 1 lb. N/M Methex + Primo treatment varied by 6" or more four times. The 0.1 lb. N/M every ten days had the most inconsistent green speed of any of the foliar treatments with 6 of the 14 dates resulting in green speed changes of 6" or more. The 1 lb. N/M Methex treatment and the 1 lb. N/M urea treatment varied by 6" or more 6 and 7 times, respectively.

Dollar spot data was collected twice during the study by counting the number of dollar spots per plot. No statistical significance between any of the treatments occurred regarding dollar spot. We believe this was due to the large amount of variation between plots independent of treatment. However, a general trend existed toward less dollar spot on plots receiving less nitrogen.

Conclusions

The 0.1 lb. N/M every ten days treatment without any additional nitrogen application in the spring produced unacceptable turfgrass quality. The 0.1 lb. N/M treatment also produced the most inconsistent green speeds of the four foliar treatments in the study.

Previous studies have suggested that increasing nitrogen decreases the occurrence of dollar spot. However, we noticed that low nitrogen plots had the least dollar spot, but we are not certain if this was a result of fertility regime or the inability to observe dollar spots because of an already thin, weak turf.

Both 0.1 lb. N/M turfs that were initiated with a pound of nitrogen in the spring had acceptable quality for the majority of the season and produced consistently fast green speeds. It is worth noting that the 0.04 fl. oz./M Primo + 0.1 lb. N/M treatment also produced consistent green speed and acceptable quality ratings.

Our research suggests that a spoon-feeding program should be enhanced with additional nitrogen applications in either the spring and /or the fall of each season to achieve acceptable turfgrass quality. The data suggest that the greens will not lose any noticeable speed due to supplementing with a spring feeding and that they may be more consistent for the duration of the season.

The complete results of this study will be published in a future issue of Golf Course Management.

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