TURFGRASS CULTURAL PRACTICES REPORT

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The research reported herein was conducted at the Hancock Turfgrass Research Center. Financial support was provided by the Michigan Turfgrass Foundation and it is gratefully acknowledged.

Leaf Mulch Studies

Since 1990 three studies have been conducted at the Hancock Turfgrass Research Center (HTRC) that examine the feasibility of mulching leaf litter into existing turfgrass canopies. The first study examined different leaf rates (50 and 100 lbs. dry leaves / 1000 sq. ft.) and the timing of nitrogen fertility. The objectives were to determine if there were any negative effects of mulching tree leaves into the existing turfgrass canopy with a lawn mower and if the nitrogen fertility would enhance leaf litter decomposition. The study ended in 1996 concluding that there were no negative effects of mulching the leaves into the turf at the rates applied and that the nitrogen treatments did not aid in the degradation of the leaf litter. The second study was initiated in October, 1991 to examine the effects of mulching different leaf types (oak and maple) at a rate of 100 lbs. dry leaves per 1000 sq. ft. into a Midnight Kentucky bluegrass turf using a rotary push-mower. This study was concluded in the fall of 1998. Objectives included were to determine if the different leaf types would have an effect on soil pH and or turfgrass quality. Turfgrass quality increased on plots that had maple leaf treatments due to the fact that fewer broadleaf weed growth was observed in these plots. No differences were observed regarding soil pH for the duration of the field experiment. Soil cores taken in the fall of 1998 concluded that there was an increase in the amount of organic matter in plots that had oak and maple leaves mulched into them compared to the check plot (Table 1). Tissue analysis of clippings collected in October of 1998 also found that the grass plants that came from plots having leaves mulched into them also had a greater percentage of carbon and nitrogen. However, the carbon nitrogen ratio was not affected.

Table 1. % of Organic Matter in the Thatch Layer and the % of Carbon and Nitrogen in the Turfgrass Clippings of Poa pratensis cv. Midnight from October of 1998

	% Organic Matter	% C in turf tissue	% N in turf tissue	C/N Ratio
Control	7.5 b	1.7 b	0.13 b	13
Oak leaves	8.9 a	2.1 b	0.16 a	13
Maple Leaves	8.4 a	2.1 b	0.16 a	13
LSD at (0.05)	0.7 *	0.1 *	0.01 *	N.S.

* Significant at 0.01 probability level.
Means in columns followed by the same letter are not statistically different at the 5% level using the LSD mean separation test.

The previous studies led us to conclude that there were more benefits than negatives for turf managers and homeowners that mulch tree leaves into their existing sites. The question became "Could there be an expanded roll for turfgrass in the leaf litter collection process"? With decreasing landfill space many states have looked to farm fields as a means of alleviating their leaf litter disposal. Truckloads of leaves were taken to farms and the leaves were tilled into the soil. However, it was found that this activity had the potential to increase the C/N ratio to 50 to 1. When the C/N ration goes above 30 to 1 nitrogen inputs are required to put the system in balance to make nitrogen available to the plant for uptake. It was also determined that some loading of heavy metals was taking place due to the collection process of the leaf litter and automobile parts were being reported by farmers who partook in the exercise. With that in mind our third leaf mulching study was initiated in October of 1995. The objective was to determine if low maintenance turfgrass sites could take heavy loads of deciduous leaves and maintain their usefulness. The study consisted of mulching a mix of deciduous leafs into an existing sunny seed mix turf (Kentucky bluegrass, perennial rye, and fine fescue). Excessive dry leaf rates of 150, 300 and 450 lbs. per 1000 sq. ft. were mulched in with the aid of a mulching mower. Two mower deck heights (1.5 and 3 inches) were included in the study to determine if deck height had a significant impact on the degradation of the leaf litter. The area was mowed at 2.5 inches for the remainder of the year. Furthermore, since the plots represented low input turfgrass areas they never received fertilization for the three years in which the experiment ran. Check plots were included in the study and there were three replications of each treatment.

When mulching in leaves at such excessive rates visible leaf litter was observed in the early spring. In Table 2 the percentage of each plot displaying visible leaf litter in the early spring is reported. As expected, as the rate of leaves mulched into the plots increased, the percentage of visible leaf litter increased. However, at the higher deck leaf-mulching height of 3" there was reduced visibility of leaf litter the following spring. This is most apparent at the dry leaf rate of 300 lbs. / 1000 sq. ft. It is noteworthy that all visible leaf litter soon dissipated as the grass growth increased in the spring.

Table 2. Percentage of Visible Leaf Litter March 31, 1998

Leaf Mulching Rate	1.5" Mower Deck Mulching Height	3" Mower Deck Mulching Height
Control	0.0 d	0.0 d
150 lbs. / 1000 sq. ft.	5.0 cd	3.0 cd
300 lbs. / 1000 sq. ft	21.0 b	6.0 c
450 lbs. / 1000 sq. ft.	51.0 a	47.7 a
LSD at (0.05)		4.0 *

* Significant at 0.01 probability level.
Means followed by the same letter are not statistically different at the 5% level using the LSD mean separation test.

Since the plots represent turfgrass areas of low input it follows that areas receiving leaf litter for mulching would be municipal parks and low-maintenance ball fields. This means that the areas would be utilized for numerous outdoor activities that would result in persons coming into contact with the turf. With that in mind the surface hardness of the plots were taken twice in 1999 with the aid of the Clegg Impact Hammer. Data is reported in Table 3. The greater the number, the harder the surface. On July 29 all numbers are greater than on June 11. This suggests that the plots were drier due to less rainfall and increased temperatures in the summer. On July 29 the control plot was harder than plots receiving leaf mulch treatments. This indicates that leaf mulching provides a cushion that would be more forgiving to come in contact with for persons engaging in physical activity in the area.

Table 3. Surface Hardness Measured with the Clegg Impact Hammer (G)

Leaf Mulching Rate	June 11, 1999	July 29, 1999
Control	49 a	61 a
150 lbs. / 1000 sq. ft.	46 a	51 b
300 lbs. / 1000 sq. ft	40 b	47 bc
450 lbs. / 1000 sq. ft.	41 b	44 c
LSD at (0.05)	3.2 *	6.8 *

* Significant at 0.01 probability level.
Means in columns followed by the same letter are not statistically different at the 5% level using the LSD mean separation test.

As previously mentioned the C/N ratio was a potential problem when applying leaf litter to agricultural fields. For that reason samples were obtained to analyze the C/N ration of the soil on the turfgrass plots in September of 1999. No differences were anticipated regarding the C/N ration because no apparent color differences were recorded on the plots that would indicate that the plots required nitrogen fertilization in comparison with the check plots. Samples were obtained to analyze the C/N ratio in the thatch, the soil below the first three inches under the thatch, and thatch and soil layer measuring a total of three inches. In Table 4 the latter of these three samples is reported. The other two are currently being analyzed in the laboratory. As the amount of leaf litter applied increased, the percentage of carbon and nitrogen increased in the soil thatch layer. However, the increases were such that the C/N ratio did not significantly increase and was maintained well below the 30/1 ratio.

Table 4. Carbon/Nitrogen Ration in Thatch Soil Layer Measuring 3" Below Verdure. September 1999

Leaf Mulching Rate	% C	% N	C/N ratio
Control	1.6 c	0.13 c	12.7
150 lbs. / 1000 sq. ft.	2.0 bc	0.14 bc	14.8
300 lbs. / 1000 sq. ft	2.5 ab	0.18 ab	14.2
450 lbs. / 1000 sq. ft.	2.8 a	0.19 a	14.5
LSD at (0.05)	0.5 *	0.04 *	N.S.

* Significant at 0.01 probability level.
Means in columns followed by the same letter are not statistically different at the 5% level using the LSD mean separation test.

Soil samples collected in September of 1999 are reported in Table 5. Samples were obtained from the standard 0-3" depth. No significant differences were observed regarding the soil pH or the amounts of phosphorous, potassium, or calcium regarding leaf loading.

Table 5. Soil Test Results 0-3" Depth September 1999

Leaf Mulching Rate	PH	Lbs. P/A	Lbs. K/A	Lbs. Ca/A
Control	6.5			
150 lbs. / 1000 sq. ft.	6.5			
300 lbs. / 1000 sq. ft	6.7			
450 lbs. / 1000 sq. ft.	6.4			
LSD at (0.05)	N.S.	N.S.	N.S.	N.S.

* Significant at 0.01 probability level.
Means in columns followed by the same letter are not statistically different at the 5% level using the LSD mean separation test.

Putting Green Rootzone Study

This is a cooperative putting green study with J.N. Rogers III and J.M. Vargas Jr. The research was conducted at the Hancock Turfgrass Research Center on the campus of Michigan State University, East Lansing, Michigan on a 14,400 ft^2 (120 x 120 ft) experimental putting green constructed in summer 1992 and seeded in spring 1993 with Penncross creeping bentgrass. The three rootzone mixes were; an 80:20 (sand: peat) mixture built to USGA recommendations; an 80:10:10 (sand:soil:peat) mixture built with subsurface drainage; and an unamended sandy clay loam textured (58% sand, 20.5% silt, and 21.5% clay) "push-up" style green. The putting greens are 1600 ft^2 (40 x 40 ft), replicated three times, and have individual irrigation control. Each green was split for lightweight green rolling in 1995 producing greens that measured 17 x 35 ft. A collar separates these greens. In 1996 a nitrogen-potassium interaction study was initiated. On each green there are two nitrogen treatments and 3 potassium treatments. This area is funded in part by the United States Golf Association (USGA).

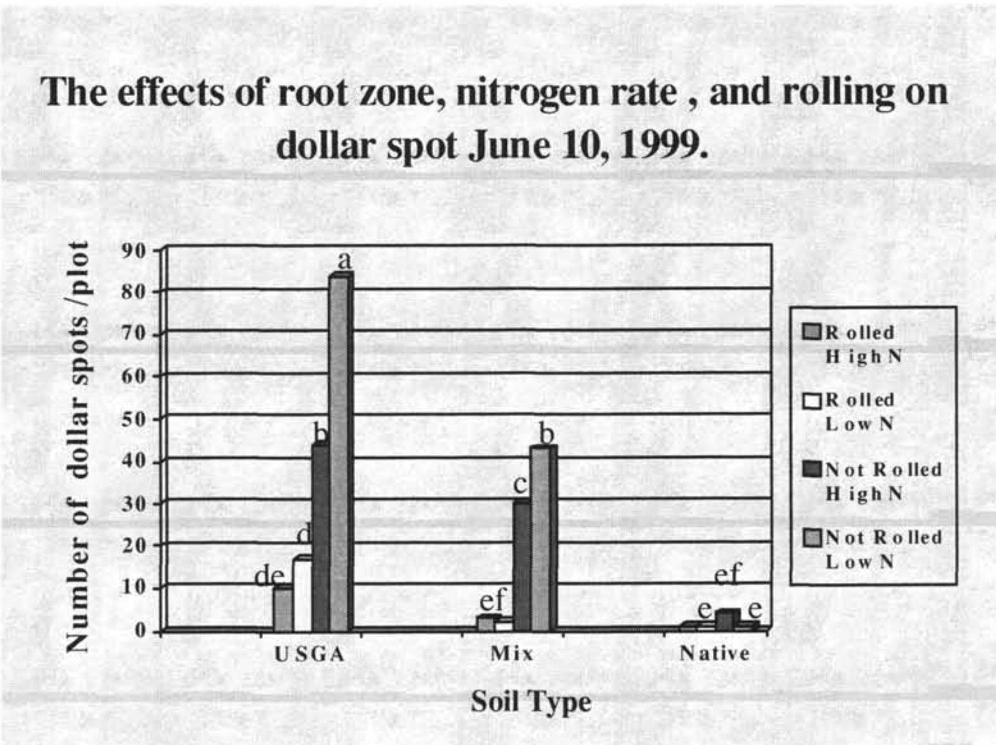
The greens were mowed six times per week at a cutting height of .157 inch and the collars were mowed three times per week at the cutting height of .375 inches. Lightweight green rolling was performed with an Olathe roller three times per week after mowing. The Olathe roller is commonly referred to as a "sidewinder" because the transport tires raise and the practice of rolling takes place perpendicular to the position of the operator. The Olathe has three smooth cylindrical rollers situated under the driver. Sand topdressing has been applied to the greens every two to three weeks throughout the growing season. The sand topdressing has exceeded 1.75 inches.

Beginning in June of 1996 differences in dollar spot activity have been recorded due to construction method and lightweight green rolling. Since that time two observations have persisted 1) the greater the fines in the original construction mix the lesser the degree of dollar spot infection and 2) plots receiving lightweight green rolling three times per week have produced less dollar spot activity than non-rolled plots.

On most dates plots receiving the higher rates of nitrogen displayed less dollar spot severity (Figure 1). Regarding soil type, it was originally hypothesized that as the sand topdressing layer increased, a depth would be obtained that would result in no statistically significant differences regarding the original root zone mix. The assumption was that the finer textured soil created an environment that was favorable to microorganisms that were antagonistic to the casual agents of dollar spot. However, when samples were obtained in the summer of 1998 revealing 54% of the root mass growing in the sand topdress media our thinking began to shift. It is now hypothesized that soil moisture is the driving force in our construction mixes displaying dollar spot activity. The saturated hydraulic conductivity of the different rootzone mixes lends support to this hypothesis.

Prior to the initiation of this study there were reports that golf course superintendents were concerned that lightweight green rolling would increase the severity of diseases like dollar spot. This logical thinking was supported by the fact that the dissemination of the fungus is restricted to the movements of infected leaf debris equipment, people, animals, water, or wind. However, plots that have received the lightweight green rolling have continually displayed less dollar spot symptoms than the non-rolled plots. There are several possibilities for this observation.

Figure 1.



When environmental factors favor dollar spot activity it is generally associated with high humidity that results in a layer of dew on the greens. It is important to note that the plots are mowed with buckets at sunrise. This timing removes the dew on the greens. It is conceivable that enough turgor pressure exists in the roots at this time of day that would allow gutation water to escape from the freshly cut turfgrass blades. Gutation water is rich in carbohydrates and amino acids, which is believed to provide an excellent growing media for dollar spot. Hypothetically, the practice of green rolling immediately after mowing may remove the gutation water along with clipping debris that did not end up in the bucket, this may also be a catalyst for the disease. This is evidenced by the fact that the rollers have a build-up of grass clippings after rolling that necessitate the washing of the machine. It is worthy of consideration that rolling may augment an increase of Ca^{2+} at the cut leaf tips. Calcium has been shown to build up in other plants when wounding occurs. The mineral nutrient reduces the amount of excudate and decreases the possibility of infection at injured sights.

Twice annually since 1996 soil cores have been removed from the plots to measure physical properties of the soil. All calculations utilized to determine the physical properties were obtained using 1993 USGA specifications. As to be expected, the 80:20 mix has displayed a greater hydraulic conductivity than the 80:10:10 which has retained a greater infiltration rate than the native soil greens. This trend was also displayed in regards to total porosity and one of its components air filled porosity. Regarding the second component of total porosity, i.e. capillary porosity, the greater the amount of fines in the mix, the greater the water holing capacity. With use of the SAS program there have not been statistically significant changes in any of the physical properties over time. There have also been no statistically significant differences regarding lightweight green rolling pertaining to soil physical properties.

Green Speed Perception Survey

Eddie Stimpson introduced the Stimp meter in 1937. Its intended use was to provide uniformity in speed from green to green on individual golf courses. Mr. Stimpson states in his article, Introducing the Stimp, "To the greenskeeper who is harassed by two groups of members, half of whom want the greens faster and half of whom want them slower, it would be of some comfort to know that he was maintaining the standard conditions as measured by the Stimp Meter and was determined by the USGA." Fast forward to the 70's when improved technology allowed for thinner manufacturing of bedknives and the USGA gave a Stimp Meter to each of its member clubs. Golfers increased their demands for faster green speeds and began expect uniformity of green speed from golf course to golf course. This unrealistic demand expedited the tighter mowing heights and increased the stress on the golf course superintendent and his/her putting turf.

Relentless pressure remains on the superintendent to maintain fast green speeds, but what change in green speed can a golfer detect given today's low cutting heights? Surely a golfer can determine the difference in green speed between a green that Stimps 6' and one that Stimps at 7'. However, does that detectable difference in green speed exist when comparing a green that Stimps at 9' and one that Stimps at 10'? In an effort to answer these questions six pair of greens where maintained at three different mowing heights (3/16", 5/32", and 1/8") in preparation for an MTF Field Day Survey. One pair at each mowing height was managed to create a one-foot difference in green speed while the other pair was maintained to produce a half a foot difference in green speed.

Results indicate that regardless of mowing height a distance of one foot was detectable while differences in green speed of 8" or less were not detectable to our survey group. How could the turf manager utilize this data? Years of data verify that lightweight green rolling increases green speed by a foot on the day the green is rolled. However, the day after rolling there is generally a 6" difference that remains between the rolled and non-rolled greens (Table 6). Given this knowledge one superintendent might decide to roll his greens everyday in order to keep his green-speed at a maximum. However, another superintendent might decide to roll her greens every other day because the majority of the membership can not tell that the greens are 6" slower on days they are not rolled.

In closing the author's would like to quote the editor of *Golfdom: the Business Journal of Golf,* which published the 1937 article Introducing the Stimp. He wrote of the Stimp Meter, "As for its use in actual play, we have the definite idea that it's out – not only because of the mechanical phase but because the player actually couldn't make enough use of what he has learned about green speed to warrant use of the device. However, there may be something to the device as an instrument for greenkeepers who might want to answer arguments about the speed and uniformity of their greens." The editor then closed with the following insightful comment, "We toss Stimpson's interesting contribution into the lists for the arguments it will provide." Thanks!

Irrigation Timing, Turfgrass Species, Fertility Study

In this cooperative study with David Gilstrap, Kentucky bluegrass, tall fescue, and perennial ryegrass were subjected to three different irrigation regimes: none, 1/10 inch daily in early afternoon, and 1 inch per week at 5:00 a.m. A nitrogen-timing component was also included in the study. Nitrogen was applied as urea in all treatments except one in which it was applied as corn gluten meal. Data collection includes color and quality ratings, broad leaf weed counts, wilt ratings, and surface temperatures, which were taken with an infrared thermometer. During moisture stress periods in 1999 there were obvious differences in turf quality. Plots irrigated daily resulted in more uniform turf quality than plots irrigated once per week during maximum moisture stress.

In Table 6 surface temperature data is reported from June 22, 1999. On the morning of June 22 the weekly irrigation treatments were applied. In the early afternoon the daily treatment was applied and approximately an hour afterwards, the surface temperatures were collected. On June 22 an interaction existed between irrigation treatment and turfgrass species. Statistically the tall fescue maintained the lowest temperature regardless of irrigation treatment. Tall fescue is regarded as having better drought tolerance than most cool season species and the data surface temperatures collected on the non-irrigated plots lend credence to the claim. Overall, the differences in surface temperatures between the irrigated and none irrigated plots exceeded 20 degrees. There are many dates that surface temperatures were recorded in the summer of 1999 that have yet to be analyzed statistically.

Table 6. Surface Temperatures from irrigation Timing Turfgrass Species Study. Data collected June 22, 1999

	Daily Irrigation	Weekly Irrigation	No Irrigation
Kentucky Bluegrass	82.2 de	86.6 c	106.1 a
Perennial Ryegrass	81.6 e	83.9 d	106.5 a
Tall Fescue	81.9 de	83.3 de	102.4 b
LSD at (0.05)		2.1*	

* Significant at 0.01 probability level.
Means followed by the same letter are not statistically different at the 5% level using the LSD mean separation test.

On September 30, 1999 broadleaf weed counts were taken. Data was entered and statistically analyzed. Data in Table 7 shows an interaction that was recorded between irrigation and fertility. Early in this long-term study there is one interesting trend worth drawing attention too. The corn glutton meal treatment consistently produced the lowest amount of broadleaf weeds regardless of the irrigation treatment. The corn gluten meal was included in the study upon the suggestion of an MTF member because it was rumored to have pre-emergent herbicidal activity on broadleaf weeds. So far so good! Dave Gilstrap and Kevin Franks will continue this study given the current retirement of Paul Rieke.

Table 7. Broadleaf weed counts from Irrigation Timing Turfgrass Species Study. Data collected September 30, 1999.

N carrier	Annual N/M^2	Daily Irrigation	Weekly Irrigation	No Irrigation
Urea	2	1.1 de	0.4 de	0.1 e
Urea	2	3.2 abc	1.6 cde	0.4 de
Urea	3.5	1.3 cde	3.6 ab	0.2 e
Urea	3.5	4.4 a	1.4 cde	0.0 e
Urea	4	0.3 bcd	0.9 de	0.1 e
Urea	5	2.3 bcd	1.8 bcd	0.3 e
Urea	5	4.8 a	4.7 a	0.1 e
Corn Glutton	2	0.2 e	1.6 cde	0.0 e
None	0	3.7 ab	0.9 de	0.7 de
LSD at (0.05)		1.0*		

* Significant at 0.01 probability level.
Means followed by the same letter are not statistically different at the 5% level using the LSD mean separation test.

Traveling Golf Spike Study II

Alternative golf spikes have become common in the United States. Thanks in part to research financed by the MTF and the Golf Association of Michigan; MSU has become recognized as the world leader regarding alternative spike issues. This is evidenced by our communications with the Australian Golf Course Superintendents Association, the New Zealand Sports Turf Institute, The Greenkeeper Verband Deutschland, publications in Golf Course Management Magazine, and an invite to Thom Nikolai to speak at this year's GCSAA National Convention in New Orleans. With such international credibility MSU researchers were invited to Germany and Austria in the spring of 1999 to traffic putting greens with different alternative spikes at six different golf courses. Afterwards the members of the clubs were invited to rate the wear produced by the spikes on their putting surface. As in similar studies performed in Michigan and Ohio by MSU the 8mm and 6mm metal spikes received the worst rating regarding wear on the putting surfaces. None of the alternative spikes received a rating that would suggest banning the spikes from the golf course.

Controlled Release Fertility Study

On June 8, 1999 a controlled release fertility study was initiated on a Kentucky bluegrass turf at the Hancock Turfgrass Research Center at Michigan State University. The grass was maintained at a 2.5-inch cutting height and was mowed 2 times per week. The study was designed to evaluate four experimental slow release products as compared to six commercially available slow release fertilizers and urea. All treatments were applied at the rates of 1.5 lbs. N/1000 sq. ft. A check plot was included to determine the quickness and duration of turfgrass response to the nitrogen carriers. A total of 12 different treatments were in the study. The treatments are outlined in Tables 1 and 2. There were four replications of each treatment and each plot was 4 feet by 12 feet.

Color ratings for the season are presented in Tables 8a and 8b. As expected the urea received the highest color ratings for the first two weeks after application. On June 14 only the urea, Poly Plus, and Nutralene received numerical values indicating an acceptable turfgrass color. On June 21, two weeks after application, the EXP 43-0-0 A, EXP 41-0-0 B, Polyon, and IBDU were still not receiving acceptable ratings, although all products, with the exception of the Polyon, did receive statistically greater values than the check plot. On June 29, EXP 41-0-0 A, B, and C, along with the Trikote, received the highest color ratings. The Polyon and IBDU still received values less than acceptable yet statistically greater than the check plot. On July 6, four weeks after application, the Polyon and IBDU received acceptable color ratings for the first time. The EXP 41-0-0 series and the Trikote continued to receive a share of the statistically highest color ratings. By July 12, 5 weeks after treatment, all Pursell EXP's shared the highest color ratings. Also on that date the Nitroform started a three-week period of receiving ratings that were considered unacceptable. On July 20, six weeks after application, Polyon received the highest numerical rating statistically sharing the highest color rating with the EXP 41-0-0 B. For the remainder of the study the Polyon received a share of the highest color rating. Also noteworthy on July 20 the IBDU received a below acceptable color rating.

Overall, Polyon received the most statistically significant share of the highest color ratings (nine times). The EXP 41-0-0 A and C received a share of the highest color rating eight times while the EXP 41-0-0 B, EXP 43-0-0, Trikote, and IBDU received a share of the highest color rating seven times apiece. The other products and the number of dates they received a share of the highest color rating are in decreasing order Poly Plus (6 times) Nutralene (4 times) Nitroform (3 times) and urea (2 times).

Table 8a. Controlled Release Fertility Study 1999 Initiated 8 June, 1999 Color ratings 9=excellent, 6 and above is acceptable, and 1 = dead or chlorotic turf

	14 June	21 June	29 June	6 July	12 July	20 July	26 July
EXP 43-0-0 A	4.5 fgh	5.5 ef	7.2 b	7.9 bc	7.9 ab	7.4 bc	7.1 ab
EXP 41-0-0 A	5.0 ef	6.5 bc	8.4 a	8.2 ab	7.9 ab	7.0 cd	6.9 b
EXP 41-0-0 B	4.7 fg	5.9 de	8.4 a	8.4 a	8.1 a	7.6 ab	7.1 ab
EXP 41-0-0 C	4.5 fgh	6.2 cd	8.4 a	8.2 ab	8.0 a	7.2 bcd	6.9 b
POLYON	4.4 gh	4.6 g	5.7 fg	7.2 e	7.5 bc	7.9 a	7.5 a
POLY PLUS	6.2 bc	6.6 bc	6.6 cd	7.4 de	6.7 d	6.9 d	6.6 bc
NUTRALENE	6.6 b	6.9 b	6.4 de	7.1 e	6.5 d	6.0e	6.1 cd
TRIKOTE	5.4 de	6.9 b	8.4 a	8.0 abc	7.4 c	6.9 d	7.0 ab
NITROFORM	5.9 cd	6.2 cd	6.0 ef	7.1 e	5.7 e	5.6 e	5.7 d
IBDU	5.0 ef	5.4 f	5.5 g	7.0 ef	6.0 e	5.9 e	6.0 d
UREA	8.0 a	8.0 a	6.9 bc	7.7 cd	6.7 d	6.0 e	6.0 d
CHECK	4.0 h	4.4 g	4.5 h	6.6 f	3.5 f	4.7 f	4.5 e
probability @ 0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LSD	0.51	0.43	0.44	0.42	0.46	0.45	0.51

Means in columns followed by the same letter are not statistically different to the 5% level using the LSD mean separation test.

Table 8b. Controlled Release Fertility Study 1999
Initiated 8 June, 1999
Color ratings 9=excellent, 6 and above is acceptable, and 1 = dead or chlorotic turf

	2 Aug	10 Aug	16 Aug	30 Aug	7 Sept	13 Sept	20 Sept
EXP 43-0-0 A	6.6 b	6.9 ab	7.2 a	6.7 a	6.5 ab	6.6 ab	6.1 bc
EXP 41-0-0 A	7.0 b	6.4 bc	6.7 abc	6.4 ab	6.5 ab	6.4 ab	6.5 a
EXP 41-0-0 B	6.7 b	6.4 bc	7.0 ab	5.7 bc	6.5 ab	6.1 bc	6.1 bc
EXP 41-0-0 C	6.6 b	6.5 bc	6.7 abc	6.5 ab	6.6 ab	6.7 ab	6.2 ab
POLYON	7.5 a	7.3 a	7.4 a	6.7 a	6.6 ab	7.0 a	6.5 a
POLY PLUS	6.7 b	6.9 ab	7.2 a	6.7 a	6.6 ab	6.6 ab	6.5 a
NUTRALENE	6.1 c	6.5 bc	6.6 abc	6.1 abc	6.2 bc	6.6 ab	6.2 ab
TRIKOTE	6.6 b	6.6 bc	7.0 ab	6.5 ab	6.4 bc	6.5 ab	6.4 ab
NITROFORM	5.6 d	6.1 cd	6.4 bc	6.0 abc	6.2 bc	6.7 ab	6.5 a
IBDU	6.6 b	6.6 bc	7.1 ab	6.5 ab	6.9 a	7.1 a	6.5 a
UREA	6.0 cd	5.6 d	6.0 c	5.4 c	6.0 c	6.0 bc	6.1 bc
CHECK	4.7 e	4.9 e	5.1 d	4.4 d	4.7 d	5.4 c	5.9 c
probability @ 0.05	0.00	0.00	0.00	0.00	0.00	0.01	0.00
LSD	0.49	0.61	0.86	0.77	0.49	0.84	0.29

Means in columns followed by the same letter are not statistically different to the 5% level using the LSD mean separation test.

WETTING AGENT STUDY

In a container study, the effects of Primer wetting agent and Midorich soil conditioner (at two application rates) on water distribution patterns in a sandy rootzone mix and a soil with a higher content of silt and clay (sand/soil) were investigated. Table 10 shows volumetric soil moisture content in soil columns at different depths averaged over all sampling dates after repeated applications of Midorich soil conditioner and Primer wetting agent.

Table 10. Soil moisture content for different soils at different depths averaged over all sampling days.

Treatment/Depth	Soil moisture (Vol.%) 5 cm Sand	Sand/Soil	15 cm Sand	Sand/Soil	25 cm Sand	Sand/Soil
Primer	9.3 a	16.1 a	15.3 a	20.1 a	24.3 a	25.1 a
Midorich (high)	10.1 b	15.9 b	13.4 b	20.7 a	21.3 b	24.9 a
Midorich (low)	9.4 a	16.2 b	13.3 bc	20.8 a	22.5 b	21.2 b
Water	9.7 ab	18.1 b	12.6 c	20.7 a	18.7 c	25.7 a

† values in columns followed by the same letter are not significantly different from each other (a=0.05, Fisher's LSD test for multiple comparison of means).

For depths greater than 5 cm, high sand content rootzones treated with Primer wetting agent show significantly greater water holding capacity than rootzones treated with water or Midorich soil conditioner. At 5 cm depth Midorich treated sand columns showed significantly greater soil moisture content compared to columns treated with water or Primer.

The Sloping Green

This project continues to receive considerable attention. Turf was established in 1998 on three mixes: sand; sand: peat: and sand: soil. The sand plots established most slowly due to low water holding capacity and were the slowest to green up in the spring. As expected, after application of adequate water sand plots dried out faster than sand: peat or sand: soil plots. On some dates the sand: peat plots performed better than sand: soil plots. This was reflected in the soil moisture levels observed in the plots and in the surface temperature measurements. When the topmix in thinner at the high part of the plot there was more moisture in the soil than when the regular 12 inch depth was used. Moisture data support our hypothesis that modification of the depth enhances moisture conditions in the green. Sand plots exhibited more dollarspot than on other mixes. More insights and data are presented on this study elsewhere in the proceedings in a paper authored by Dr. Bernd Leinauer.

Golf spike traction survey

A special thanks to Dr. John Rogers III, John Hardy, and John Sorochan whose help was instrumental in conducting this survey. Alternative spikes have become anything but alternative as the majority of golf courses in America have banned 8mm metal spikes. The banning began, in part, by golfers demanding faster green speeds. As a result golf course superintendents went to tighter mowing heights on the putting surface. The shorter turf required meticulous management practices that resulted in the uplifting of the turfgrass plant from the soil as golfers traversed the green in metal spikes. This uplifting of the plant, commonly called "Christmas trees" by pro golfers, led to a small group a private clubs banning the 8mm metal spike in the early to mid 90's. However, it was probably damage to infrastructure that created the landslide of golf clubs that has banned the metal spike. In January of 1995, 55 golf course in the world had banned metal spikes, by January of 1998 over 3000 courses joined in the ban. Through this time-span (with the aid of numerous research) it has become commonly accepted that the 8mm spike produced the most damage to the putting surface and to infrastructure. It has also been commonly accepted that the alternative spikes are more comfortable on the legs and lower- back after a round of golf. However, it is also regarded as fact that the 8mm metal spike produced the best traction during the swing and on wet slopes. For this reason Michigan State University (MSU) conducted a survey on July 13, 1999 to find-out if there are any alternative spikes on the market that produce traction that is superior or equivalent to the banned 8mm metal spike.

The study was conducted at the Forest Akers East Driving Range in East Lansing on July 13, 1999. Seventy volunteers from across Michigan, Indiana and Ohio took part in the survey. All participants were capable of wearing size 11 golf shoes. While signing in to participate in the survey participants were asked to NOT look at the soles of their shoes while lacing them on. Afterwards, the participants began an obstacle course by lacing on a pair of golf shoes and proceeded to the tee and hit golf balls. After hitting the golf balls they were asked to rate the golf shoe for traction on a scale of 1 to 5. 1 =

excellent traction, 2 = very good, 3 = good, 4 = fair, and 5 was considered poor traction. Next, the participants proceeded to traverse a dry slope, a wet slope, and then concrete. On both dry and wet slopes the participants walked up and down the slope in a method that made a large "W". After traversing each of the stations they were asked to give the golf shoe a traction rating using the identical scale. The volunteers repeated the course wearing nineteen different pair of golf shoes with different soles or spikes inserted into each.

A pair of Foot-Joy Classic golf shoes with no spike inserted into them was included to give validity to the survey. If these leather-soled smooth bottomed golf shoes were not regarded as providing the worst traction than the study would have had little merit. Fortunately, these check pair of shoes were considered to supply far worse traction than any other treatment in the survey (except on dry flat pavement).

Table 11. Key for Traction Survey

Treatment No.	**Spike/Cleat**	**Shoe**	**Abbreviation**
1	8 mm metal	Foot Joy Dry Joys	DJ 8mm
2	Big Foot	Foot Joy Classics	FJC bf
3	DTL	Etonic Difference 2000	ETNC dtl
4	None	Foot Joy Classics	FJC
5	Black Widow	Foot Joy Classics Dry	FJC* bw
6	Softspike XP	Foot Joy Dry Joys	DJ
7	DSS-1	Etonic Difference	Etonic diff
8	EXP.1	Nike Zoom Air	NZA
9	Softspike XP	Foot Joy Soft Joys	SJST
10	Softspike XP	Foot Joy Turf Masters	TM
11	Green Keepers	Foot Joy Dry Joys	DJ gk
12	GreenSpike	Foot Joy Dry Joys	DJ gs
13	Comfort Cleat	Ashworth	AW dnt
14	Tred-Lite MT	Dunlop	DUN tl
15	DWT	Etonic Difference 2000	Etonic dwt
16	Black Widow	Foot Joy Classics	FJC bw
17	Softspike XP	Foot Joy Classics	FJC ssxp
18	Softspike XT	Foot Joy Classics	FJC ssxt
19	DBW	Etonic Difference 2000	ETNC dbw

Data regarding traction during the golf swing is presented in Table 12. In Table 11 a legend for the shoe and inserts is provided for comparison with Tables 12-15. A pair of Dry Joys with the 8mm metal spike inserted into them received the highest percentage of excellent ratings. However, through statistical analysis of ordinal data all treatments followed by the same letter, in parenthesis, is the same. Given this there were four other treatments found to provide the same amount of traction during the swing in our survey. Those four treatments were The Etonic Difference with factory standard DSS-1 cleats, a pair of Foot Joy Classic Drys with the Black Widow spikes, a pair of Foot Joy Classics with the Big Foot cleat, and a pair of Dry Joys with GreenKeepers inserted into their sole. At the other end of the scale were the check pair of shoes with nearly 50% of the participants giving the check shoes a rating of poor and another 33% rating the shoe as fair. No other product performed as poorly as the check pair of shoes. In Figure 1 a pair of Dunlops with theTred-Lite MT spike insert is positioned as the pair of spikes providing the worst traction during the swing. However, nearly 60% of the participants rated the traction as ether "Excellent or "Very Good" with another 26% rating the traction as "Good". It is noteworthy that all treatments with letter "B" following it provides the statistically same amount of traction.

Data regarding traction while traversing a dry slope is given in Table 13. Once again the 8mm metal spike received the highest percentage of "Excellent" ratings with the GreenKeepers inserted into a pair of Dry Joys and the Black Widow inserted in Foot Joy Classic Drys providing traction equivalent to the 8mm spike. The check shoe received unacceptable ratings in excess of 70% of the time.

Data regarding traction while traversing a wet slope is given in Table 14. Under these condition the 8mm metal spike provided traction that none of the alternatives could equal and the check shoes received their worst traction rating with over 80% of the participant's giving them an unacceptable rating.

Traction results while traversing dry flat concrete are presented in Table 15. The Nike Zoom Air with the EXP.1 spike, Etonic Difference with DSS-1 spike, GreenKeepers inserted in the Dry Joys, and Big Foot cleats inserted in the Foot Joy Classics received the highest ratings. At the other end of the scale was the 8mm metal spike receiving an unacceptable rating over 50% of the time. No other treatment performed as poorly as the 8mm metal spike under these conditions.

Overall the alternative spikes performed satisfactorily. In no particular order the GreenKeepers inserted into a pair of Dry Joys, the Black Widow inserted in Foot Joy Classic Drys, Big Foot inserted into Foot Joy Classics, and the Etonic Difference with the DSS-1 spike yielded stability results on turf mimicking that of the 8mm metal spike. It is noteworthy that some of the participants in the survey mentioned that it was difficult to rate the shoes for traction while ignoring the differences in comfort among the different pairs of shoes. However, the results indicate they did a good job of ignoring the comfort dilemma. This is most evident when considering that the check, a pair of Foot Joy Classics with no spikes, consistently performed the worst on turf while the Big Foot cleats that performed equal to the 8mm metal spike was also inserted into Foot Joy Classics. In closing, it was reported by the PGA that in April of 1999 the majority of golfers wore alternative spikes during a tournament for the first time in PGA history.

Table 12. Effects of Different Spikes on Traction During Golf Swing.

Spike Treatment	Poor	Fair	Good	Very good	Excellent
FJC (A)*	46%	33%	14%	5%	1%
DUN tl (B)	4%	12%	26%	43%	16%
ETNC dwt (BC)	3%	10%	24%	44%	18%
DJ gs (BC)	3%	10%	24%	44%	18%
AW dnt (BC)	3%	9%	23%	45%	19%
SJST (BCD)	3%	9%	22%	46%	21%
FJC ssxt (BCD)	3%	8%	21%	46%	22%
FJC bw (BCDE)	3%	8%	21%	46%	22%
NZA (BCDE)	3%	8%	21%	46%	22%
ETNC dtl (BCDE)	3%	8%	21%	46%	22%
DJ (BCDE)	2%	7%	20%	46%	25%
TM (BCDE)	2%	7%	19%	46%	25%
FJC ssxp (CDEF)	2%	7%	18%	46%	27%
ETNC dbw (DEFG)	2%	5%	16%	46%	31%
DJ gk (DEFGH)	2%	5%	15%	46%	33%
FJC bf (EFGH)	2%	5%	15%	45%	34%
FJC* bw (FGH)	1%	4%	12%	44%	39%
ETNC diff (GH)	1%	3%	10%	41%	44%
DJ 8mm (H)	1%	3%	9%	40%	48%

Spike Treatments followed by the same letter are not statistically different to the 5% level using the LSD mean separation test.

Table 13. Effects of Different Spikes on Traction While Traversing a Dry Slope of Turf.

Spike Treatment	Poor	Fair	Good	Very_Good	Excellent
FJC (A)*	29%	42%	21%	7%	1%
ETNC dtl (B)	2%	11%	28%	43%	15%
DUN tl (B)	2%	11%	28%	43%	15%
DJ gs (BC)	2%	10%	27%	44%	17%
FJC ssxt (BC)	2%	10%	27%	44%	17%
TM (BC)	2%	9%	26%	45%	18%
ETNC dwt (BC)	2%	9%	25%	46%	19%
AW dnt (BCD)	2%	8%	24%	46%	20%
FJC ssxp (BCD)	2%	7%	22%	47%	23%
SJST (BCDE)	1%	6%	20%	47%	26%
ETNC dbw (BCDE)	1%	6%	20%	47%	26%
NZA (CDE)	1%	6%	19%	47%	26%
FJC bw (DE)	1%	5%	16%	47%	32%
FJC bf (DE)	1%	4%	16%	47%	32%
ETNC diff (DE)	1%	4%	15%	46%	33%
DJ (E)	1%	4%	14%	45%	37%
FJC* bw (EF)	1%	3%	13%	44%	39%
DJ gk (EF)	1%	3%	12%	44%	40%
DJ 8mm (F)	0%	2%	7%	36%	55%

Spike Treatments followed by the same letter are not statistically different to the 5% level using the LSD mean separation test.

Table 14. Effects of Different Spikes on Traction While Traversing a Wet Slope of Turf.

Spike Treatment	Poor	Fair	Good	Very_Good	Excellent
FJC (A)*	49%	35%	13%	3%	1%
DUN tl (B)	4%	16%	37%	33%	10%
AW dnt (BC)	3%	11%	33%	38%	15%
FJC ssxt (BCD)	2%	10%	31%	40%	17%
TM (BCD)	2%	10%	31%	40%	17%
DJ gs (CDE)	2%	9%	30%	41%	17%
ETNC dtl (CDE)	2%	9%	30%	41%	18%
ETNC dwt (CDEF)	2%	8%	28%	42%	20%
SJST (CDEFG)	2%	7%	25%	43%	23%
FJC ssxp (CDEFG)	2%	7%	24%	43%	24%
ETNC dbw (CDEFG)	2%	7%	24%	43%	24%
NZA (DEFG)	1%	6%	23%	44%	26%
FJC bw (DEFGH)	1%	6%	23%	44%	26%
ETNC diff (EFGH)	1%	6%	22%	44%	28%
DJ (EFGH)	1%	6%	22%	44%	28%
FJC bf (FGH)	1%	5%	20%	44%	30%
DJ gk (GH)	1%	4%	18%	43%	34%
FJC* bw (H)	1%	3%	15%	42%	40%
DJ 8mm (I)	0%	2%	8%	32%	58%

Spike Treatments followed by the same letter are not statistically different to the 5% level using the LSD mean separation test.

Table 15. Effects of Different Spikes on Traction While Traversing Concrete Pavement.

Spike Treatment	Poor	Fair	Good	Very_Good	Excellent
DJ 8mm (A)*	21%	34%	31%	11%	3%
DUN tl (B)	9%	22%	39%	23%	8%
ETNC dtl (BC)	6%	17%	37%	29%	11%
ETNC dwt (BCD)	5%	15%	36%	32%	13%
FJC ssxt (CD)	5%	14%	36%	32%	13%
FJC bw (CDE)	4%	13%	35%	33%	14%
FJC (CDEF)	4%	13%	34%	34%	14%
FJC* bw (CDEFG)	3%	11%	32%	36%	17%
FJC ssxp (CDEFG)	3%	10%	31%	37%	18%
SJST (DEFG)	3%	10%	31%	37%	19%
AW dnt (DEFG)	3%	9%	30%	38%	20%
ETNC dbw (DEFG)	3%	9%	29%	38%	20%
DJ (EFG)	3%	8%	28%	39%	22%
DJ gs (EFG)	3%	8%	27%	39%	23%
TM (FG)	2%	8%	27%	39%	23%
FJC bf (GH)	2%	8%	26%	40%	25%
DJ gk (GH)	2%	7%	24%	40%	27%
ETNC diff (GH)	2%	7%	24%	40%	27%
NZA (H)	1%	4%	18%	39%	37%

Spike Treatments followed by the same letter are not statistically different to the 5% level using the LSD mean separation test.