Quality and disease suppression on a bentgrass green by frequent fertilizer applications

D. Settle, SK Lee, Chris Painter, and R. Kane – Chicago District Golf Association

Manufacture Sponsor
Pearl Valley Organix – Healthy Gro Fertilizer (*processed chicken manure*)

Objective
Evaluate different nitrogen sources for their influence on disease development on golf greens. Fertility effects on turf quality and suppression of common foliar fungal diseases of dollar spot (*Sclerotinia homoeocarpa*) and brown patch (*Rhizoctonia solani*) would be evaluated. We were keenly interested in collecting data on how fertilizers might impact fairy ring (multiple basidiomycetes) on greens.

Introduction
Dollar spot and brown patch. Diseases of fine turfgrass are very important because their suppression each season requires multiple fungicide applications and will utilize many different chemical families. Of all pesticides necessary on golf courses, more money is spent on fungicides. None requires more input than dollar spot because it is a chronic fungal pathogen that is active across a wide temperature range. During most years in Chicago, dollar spot will likely affect greens from May until November. Brown patch is a warm temperature fungus, and can blight greens from July thru September whenever frequent rainfall and humid conditions exist. Brown patch requires a minimum temperature of about 70 degrees and leaf wetness duration of at least 10 hours. A majority of cool-season turfgrasses are highly susceptible to both dollar spot and brown patch diseases.

Fairy Ring. Fairy ring is of increasing concern on Chicago golf course greens. There is speculation that use of an organic nitrogen source may promote disease development in turfgrass systems. However the interaction between fertilizer source and fairy ring has not been scientifically studied in the golf environment to our knowledge. That an organic fertilizer might increase fairy ring likely arises from the knowledge that the fungi use organic matter for its food source. With time, all sand-based greens accumulate organic matter levels in the upper rootzone. On sand-based greens, thatch is caused by the stoloniferous growth habit of creeping bentgrass, *Agrostis stolonifera.* Because stolons are lignin-rich, microbes cannot degrade at rates equivalent to its production. It is the best explanation of why fairy ring exists on greens, and this is independent of nitrogen source, but may be influenced by nitrogen amount.

Fairy ring occurrence is difficult to predict both spatially (which greens will be affected) and temporally (time of outbreak). Also, symptoms can be difficult to identify and can easily be confused with brown patch at times. Rings or arcs can be of three types. Type I are necrotic/dead bands; type II are green/stimulated bands; and type III are delineated by aboveground mushrooms or puffballs. The types can occur singularly or in combination.

Recent molecular research in North Carolina suggests fewer than 10 fungi are responsible for fairy ring on golf greens (Miller et. al., 2007). On Chicago greens the disease occurs midsummer and rings are frequently associated with puffballs (e.g. *Lycoperdon* spp.). Preventive fungicide applications are used to suppress fairy ring at summer. Nevertheless we continue to see mixed success even with the best chemistries (e.g. Bayleton or ProStar). Fairy ring is a very difficult disease to study.

Value
If cultural practices influence disease development (e.g. fertility) the information would be useful for golf course superintendents to utilize in their integrated pest management program for golf greens. A reduction in fungicide use on greens would benefit both budgetary and environmental standpoints.

Materials and Methods

All fertilizers were applied frequently at 0.25 lb N per 1000 ft^2 every 14 days with a total of 3 lbs N per year. Application rate and frequency was determined by a written survey conducted at a Chicagoland Golf Course Superintendents Association meeting during April, 2007 at Winnetka Golf Club.

The fertilizer trial was initiated on June 19, 2007 at Sunshine Golf Course in Lemont, IL using an L-93/G-2 creeping bentgrass green (**Image 1**). The green was originally seeded September, 2002 and continues to remain 100% creeping bentgrass. The green was mowed at 5/32 inch 5 to 6 times weekly.

Image 1. A fertilizer trial begins and granular treatments are watered in by Nate Settle after application on an L-93/G-2 creeping bentgrass green at Sunshine Golf Course in Lemont, IL. *D. Settle 6-19-07*

Treatments (**see below**) were applied on plots that measured 4 × 6 ft. Each plot was replicated 4 times using a randomized complete block design. A CO_2-powered backpack sprayer was used to apply foliar treatments and a hand-shaker container was used to apply granular treatments. All granular applications were watered-in (1/4 inch) immediately after application. Turfgrass quality was visually rated on a scale of 0 to 9; with 0=dead, 6=acceptable, and 9=excellent. Disease was estimated visually whenever present, by number of infection centers (dollar spot) or by percent plot area damage (brown patch and fairy ring). Spectrum Technologies Field Scout TCM 500 NDVI Turf Color Meter was used weekly to estimate Normalized Difference Vegetation Index from areas without disease symptoms within each plot (**Image 2**). Each plot was measured from six locations by placing the 4 inch diameter glass lens directly on the dry turfgrass canopy to measure reflectance at red and far-red wavelengths. A higher NDVI value indicates better color and density. Plots without fungicide were over-sprayed with Emerald at 0.18 oz per 1000 ft^2 on September 26, 2007 to preserve turfgrass integrity on the green.

Fertility study treatments: Fertilizer and/or fungicide rates and application frequency in a study on Sunshine Golf Course's number 3 green in Lemont, IL from June to September, 2007.

Treatment	Percentage (N-P-K)	Lbs N/M/ application	Application frequency
1. Untreated	No fertilizer	0	
2. Fungicide (Emerald + ProStar)[x]	No fertilizer	0	28 days
3. Fungicide + Urea foliar 46-0-0	46-0-0	0.25	varies[y]
4. Urea foliar 46-0-0	46-0-0	0.25	14 days
5. Poly/Sulfur Coated Urea 21-4-11	21-4-11	0.25	14 days
6. Synthetic fertilizer 13-0-26	13-0-26	0.25	14 days
7. Synthetic fertilizer 18-9-18	18-9-18	0.25	14 days
8. Healthy Gro 2-5-4	2-5-4	0.25	14 days
9. Healthy Gro 2-5-4 + HumiCal[z]	2-5-4	0.25	14 days
10. Healthy Gro 8-3-8	8-3-8	0.25	14 days
11. Healthy Gro 8-3-8 + HumiCal	8-3-8	0.25	14 days
12. Milorganite 6-2-0	6-2-0	0.25	14 days

[x] Emerald (0.18 oz/M) + ProStar (4.5 oz/M) was selected to provide broad spectrum control of dollar spot, brown patch and fairy ring.

[y] Fungicide application is every 28 days, and Urea is applied every 14 days.

[z] HumiCal is applied at the label rate of 500 lbs/acre.

Image 2. Spectrum Technologies Field Scout TCM 500 NDVI Turf Color Meter was used weekly to estimate Normalized Difference Vegetation Index from areas without disease symptoms within each plot on an L-93/G-2 creeping bentgrass green at Sunshine Golf Course in Lemont, IL. *D. Settle 6-28-07*

Results

The number 3 green at Sunshine course has a history of fairy ring outbreaks during midsummer. For example, in 2006 an aggressive outbreak of fairy ring was observed. Unfortunately, in 2007 only minor fairy ring outbreaks were observed on Sunshine's 3 green. The same was true at a majority of courses in the Chicago District. Record rainfall during July and August probably suppressed fairy ring symptoms. Wet conditions mask the negative effect of mycelium growth which otherwise cause hydrophobic soil conditions that interfere with normal water infiltration and plant hydration in the upper rootzone.

Nevertheless, substantial data was obtained for both dollar spot and brown patch (**Figure 1 and 2**) and both are known to be influenced by fertility. Significant dollar spot damage began following the third week of July. Brown patch disease pressure midsummer was purportedly greater than had been seen in a decade or more by experienced superintendents. Differences in visual quality and color/density (by NDVI) were also observed throughout the study period. Visual and NDVI effects across treatments peaked during fall (**Image 3**).

Image 3. Among fertility treatments, peak visual quality and color (NDVI data, 13 Nov) were observed at season end on a L-93/G-2 bentgrass green in Lemont, IL. In each of 4 blocks, the two plots lacking color were without nitrogen, and darkest green were provided by HealthyGro and Urea. Intermediate color occurred with Milorganite, poly/sulfur-coated urea, and synthetic N mixtures. *D. Settle 11-15-07*

VISUAL QUALITY

Standards. Four treatments were designed for comparison to other fertility treatments and included Urea + Fungicide, Urea, Untreated, and Fungicide only (**Figure 3**).

Urea + Fungicide (best quality). *Acceptable quality on 20 of 20 dates.* Foliar-applied quick-release liquid urea with a preventive fungicide program provided best visual quality throughout the season. As expected, the plots benefited from fungicide protection and limited disease development (**Figures 1 and 2**). Without disease and with good color/density, urea + fungicide plots always had acceptable visual quality required of greens.

Urea (intermediate quality). *Acceptable quality on 8 of 20 dates.* Foliar applied quick-release liquid urea without fungicide provided acceptable visual quality on about half dates rated (**Tables 1 to 5**). This treatment represents the common 'spoon-feeding' program that superintendents may utilize for greens. Without fungicide, urea alone reduced dollar spot disease by about half compared to untreated using a season-long AUDPC comparison (**Figure 1; Table 14**). The foliar-applied urea was without fungicide and provided the best standard for comparison to all other granular fertilizer treatments in this study.

Untreated & Fungicide-only (worst quality). *Acceptable quality on 1 of 20 and 0 of 20 dates rated.* Plots that were untreated or given fungicide-only were incapable of providing acceptable quality on any date rated, except untreated on 10 July (**Tables 1 to 5**). The color/density readings by NDVI agreed with visual quality assessments and low values were associated with untreated or fungicide-only plots (**Tables 6 to 10**). Quality ranged from a high of 6.0 to a low of 1.0. Quality progressively declined over the summer period due to nutrient deficiency.

Poor quality was primarily due to dollar spot development in untreated plots (**Image 4**). Even with fungicide protection, nutrient deficiency caused yellowing and thinning which was just as destructive to quality as disease with time (**Image 5**). By fall both the untreated and fungicide-only plots were thin and yellow/chlorotic (**Figure 3**). Fungicide-only plots contained chlorotic bentgrass that appeared worst affected in patches beginning midsummer. This confirmed that symptoms of nutrient deficiency can be confused, at times, with summer disease activity on greens (e.g. brown patch).

Image 4. Disease (both dollar spot and brown patch visible) and poor color and occurred in untreated plots on an L-93/G-2 bentgrass green in Lemont, IL. *D. Settle 8-23-07*


Image 5. Poor color (aerification holes are pronounced) occurred in fungicide-alone plots on an L-93/G-2 bentgrass green in Lemont, IL. *D. Settle 8-23-07*

Synthetic fertilizer products.

Poly/Sulfur Coated Urea 21-4-11 (poor quality). *Acceptable quality on 2 of 20 dates rated.* Poly/sulfur coated urea did not provide acceptable quality on most dates (**Figure 4**). Only twice was quality ever greater than 6.0 visually on 10 July and 17 July (**Tables 1 to 5**). Fertility by poly/sulfur coated urea suffered significant damage from both dollar spot and brown patch diseases. Poly/sulfur coated urea was no different than untreated plots when dollar spot was evaluated the entire season using AUDPC (**Table 15**). This was surprising since N fertility should have reduced dollar spot damage. Additionally, damage by brown patch at midsummer tended to be greater than other treatments. Poly/sulfur coated urea was no different than untreated plots where peak brown patch blighting occurred in August (**Image 5; Table 15**).

Image 5. Slow release poly/sulfur coated urea fertilizer (21-4-11) tended to have high levels of brown patch during August on an L-93/G-2 bentgrass green in Lemont, IL. *D. Settle 8-23-07*

Ammoniacal N, Urea, and Methylene Ureas Combination Product 13-0-26 and 18-9-18 (poor quality). *Acceptable quality on 2 of 20 and 5 of 20 dates rated.* Fertilizers may contain a mixture of synthetic N sources which are both slow and quick release. In this study two formulations designed for golf courses were tested. Both performed almost identically across each individual date rated (**Figure 5**). On one date, 6 November, the 18-9-18 had better visual quality than the 13-0-26 formulation (**Table 5**). The difference appeared to be due to a trend of better color/density using the 18-9-18 formulation according to NDVI analysis– though never statistically different (**Tables 6 to 10**). Overall, both combination products in this test were similar in color/density to slow-release sulfur-coated urea according to NDVI measures of non-diseased turf (**Tables 6 to 10**). Unacceptable quality associated with the combination products was primarily due to levels of dollar spot which peaked in October (**Figure 1; Table 14**).

Organic fertilizer products.

HealthyGro. Comparisons of HealthyGro with and without HumiCal were made. In a 2006 investigation by researchers Dr. John Stier and Eric Koeritz in WI, the combination of HealthyGro + HumiCal resulted in good color versus a conventional/synthetic fertilizer on a USGA green (unknown variety). They did not use HealthyGro alone and so the impact of HealthyGro itself to improve turfgrass color and reduce disease was unknown. In this study HealthyGro was applied with and without HumiCal. We found HumiCal did not improve HealthyGro performance visually (**Figures 6 and 7**). HealthyGro treatments with HumiCal will not be discussed further, though detailed data was analyzed (**Tables 1 to 15)**.

HealthyGro 2-5-4 (good quality). *Acceptable quality on 16 of 20 dates rated.* Among organic N treatments, Healthy Gro 2-5-4 provided acceptable quality on 80% of dates rated (**Figure 6**). This was both due to good color/density as assessed by NDVI (**Tables 6 to 10**), as well as excellent dollar spot suppression (**Image 6**).

Dollar spot reduction by HealthyGro 2-5-4 was pronounced during September and October and was similar to plots treated with fungicide (**Figure 1; Table 14**). Across the entire season HealthyGro 2-5-4 suppressed dollar spot infection center number and overall was not different to the fungicide Emerald according to AUDPC analysis. This much suppression of dollar spot was not expected. For brown patch development, differences were less pronounced among all fertility treatments in this study. All fertility treatments were less blighted by brown patch than untreated plots, and HealthyGro 2-5-4 was similar to HealthyGro 8-3-8 (**Figure 2; Table 15**).

Image 6. Good color and dollar spot disease suppression by HealthyGro 2-5-4 on an L-93/G-2 bentgrass green in Lemont, IL. Photo taken when plots had 5 infection centers for HealthyGro 2-5-4 versus 52 infection centers for untreated. *D. Settle 8-22-07*

Healthy Gro 8-3-8 (intermediate quality). *Acceptable quality on 9 of 20 dates rated.* The 8-3-8 formulation and provided acceptable quality on 45% of dates rated (**Figure 7**). Compared to HealthyGro 2-5-4 similar color existed in 8-3-8 plots by NDVI analysis, but more dollar spot development occurred (**Figure 1**). Overall, dollar spot negatively impacted HealthyGro 8-3-8 visual quality and its dollar spot suppression was similar to a majority of fertility treatments across the entire season.

Milorganite 6-2-0 (poor quality). *Acceptable quality on 2 of 20 dates rated.* Milorganite plots were acceptable visually on only 10% of dates rated (**Figure 8**). Milorganite was intermediate in its color/density and did not suppress dollar spot well (**Figure 1; Image 7**). Generally, Milorganite had more brown patch development compared to many other fertility treatments on multiple dates (**Figure 2; Table 15**).

Image 7. Intermediate color and disease suppression by Milorganite on an L-93/G-2 bentgrass green in Lemont, IL. Photo taken when plots had 15 infection centers for Milorganite versus 52 infection centers for untreated. *D. Settle 8-22-07*

Discussion

This study was unable to investigate the relationship between fertility source (organic versus synthetic) and fairy ring disease because its development was limited in Chicago during an overly wet summer of 2007. However, we found certain fertility treatments were capable of good suppression of both dollar spot and brown patch diseases. In 2007, both were present at high levels beginning midsummer throughout Chicago.

We found that a granular organic source of nitrogen can be useful to reduce disease development of dollar spot over synthetic/conventional sources of nitrogen. Why an organic fertilizer is able to suppress dollar spot better could be due to multiple reasons beyond nitrogen level. It may be due to the ratio of N-P-K, its derived N source, or because of direct or indirect (microbial) antagonism. Of organic products in this study, HealthyGro 2-5-4 alone provided acceptable visual quality on a majority of dates rated because it suppressed dollar spot better than other granular fertilizers tested in this study. Interestingly, HealthyGro 2-5-4 was better than HealthyGro 8-3-8, and this may be related to its different formulation. Using HealthyGro 2-5-4, more P and K was necessarily applied versus 8-3-8 so a similar level of nitrogen could exist at each application.

Overall, the light frequent applications adopted in this study worked well for the HealthyGro organic nitrogen derived from chicken waste. HealthyGro was as good, or better spoon-feeding with liquid urea. Interestingly, another organic nitrogen source, Milorganite, did not perform as well in this test. Frequent light applications are necessary when utilizing an organic fertilizer source which has low levels of nitrogen, otherwise too much product is visible on the turfgrass canopy and/or it risks being collected by mower baskets with clippings. Light, frequent applications of materials are common on golf courses and could be easily done when using organic fertilizer products. In contrast, the same light frequent applications of granular conventional/synthetic fertilizers may not be optimal based on this study's results. Those products are specifically formulated to provide controlled-release over an extended period and so they perform optimally when high rates are used less frequently (e.g. poly/sulfur coated urea).

Anytime disease suppression exists using cultural practices it can provide greater flexibility for a superintendent selecting fungicide strategies to control disease. For example, in 2001, Fry, Settle, and Tisserat showed that the dollar spot resistant bentgrass cultivar L-93 provided a greater ability to choose among various fungicide strategies on a Kansas golf green when compared to other bentgrass cultivars such as Crenshaw ("Bentgrass cultivar selection influences disease management strategy", *Golf Course Management, December, 2001*). In this study frequent applications of HealthyGro 2-5-4 could potentially allow reduced fungicide use on a golf course green when compared to other granular fertilizers. Additionally, HealthyGro fertilizer is an organic nitrogen source and this may be desirable attribute for some golf courses.

FIGURES

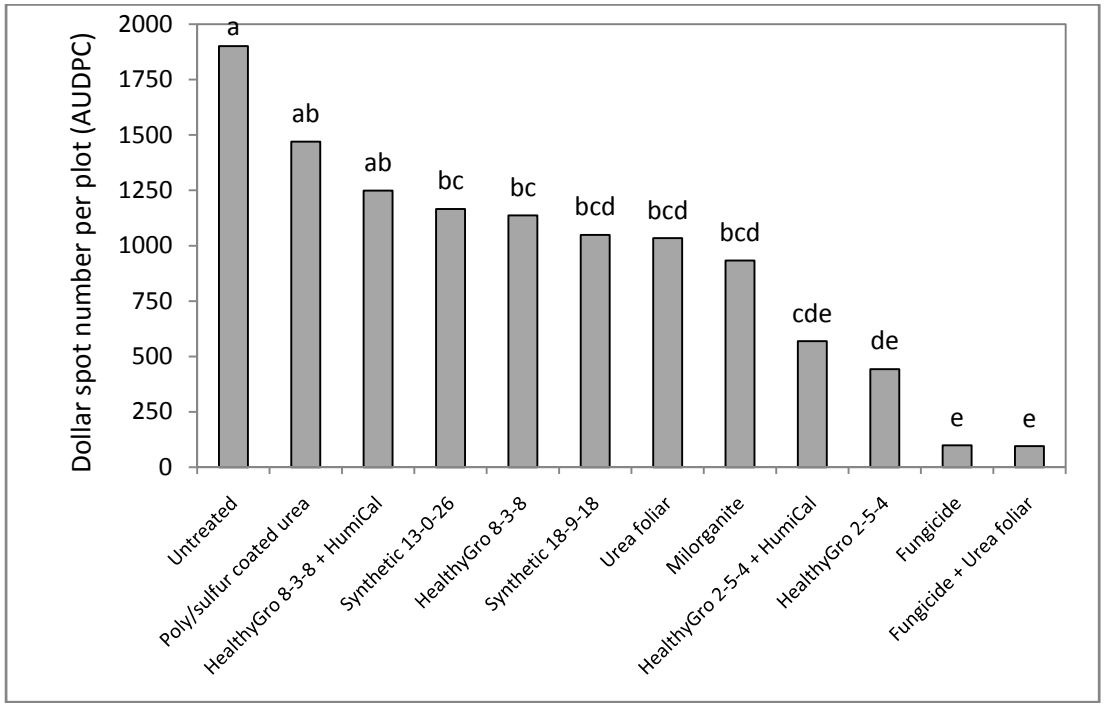

Figure 1. Dollar spot disease summarized across an entire season using AUDPC on an L-93/G-2 green in Lemont, IL when N was applied at 0.25 lb N/1000 ft^2 every 14 days for a total of 3 lbs N/1000 ft^2 for 2007. Means with the same letter are not significantly different by Fisher's LSD test ($P < 0.05$).

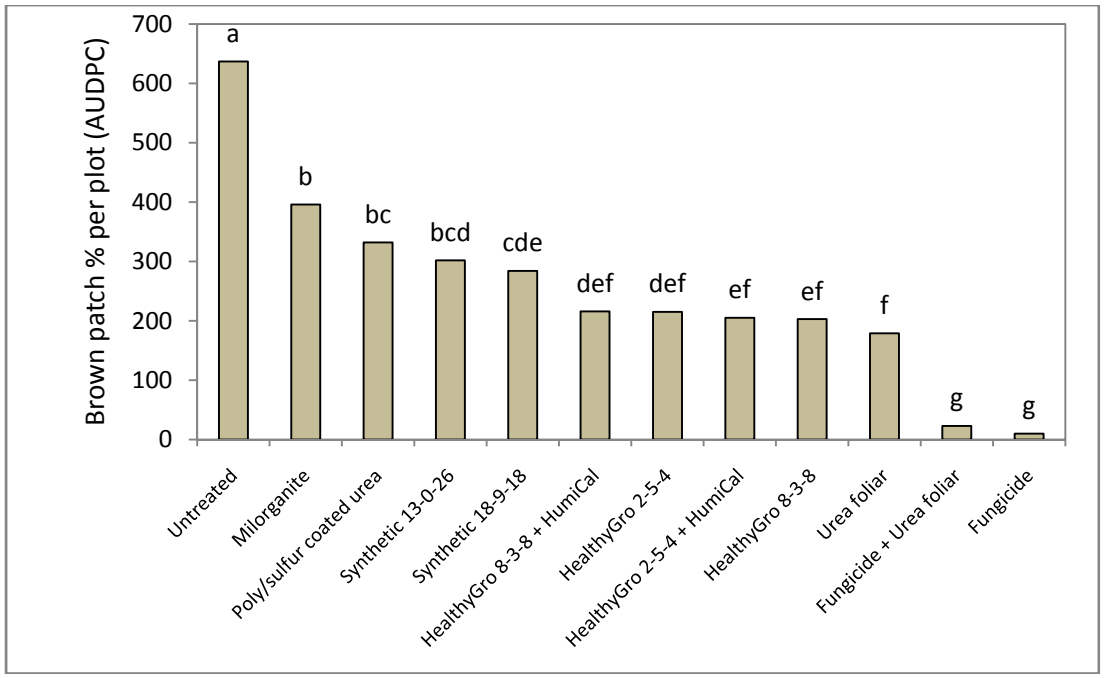

Figure 2. Brown patch disease summarized across an entire season using AUDPC on an L-93/G-2 green in Lemont, IL when N was applied at 0.25 lb N/1000 ft^2 every 14 days for a total of 3 lbs/1000 ft^2 N for 2007. Means with the same letter are not significantly different by Fisher's LSD test ($P < 0.05$).

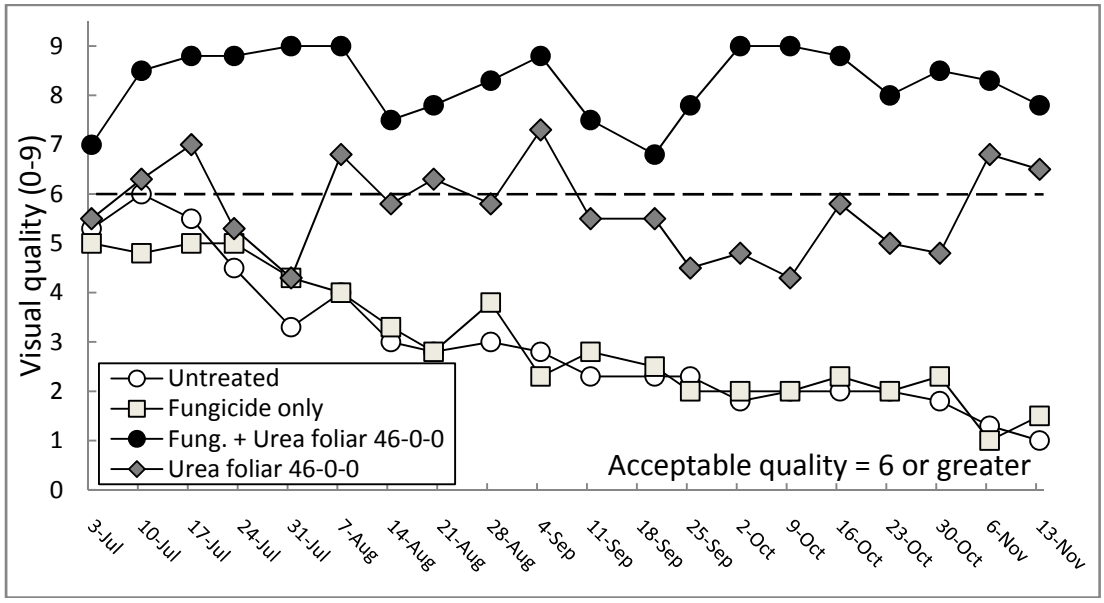

Figure 3. Four treatments were designed for comparison to all other granular fertility treatments and included Urea + Fungicide, Urea, Untreated, and Fungicide-only on an L-93/G-2 green in Lemont, IL. All were applied at a rate of 0.25 lb N/1000 ft^2 every 14 days for a total of 3 lbs N/1000 ft^2 in 2007.

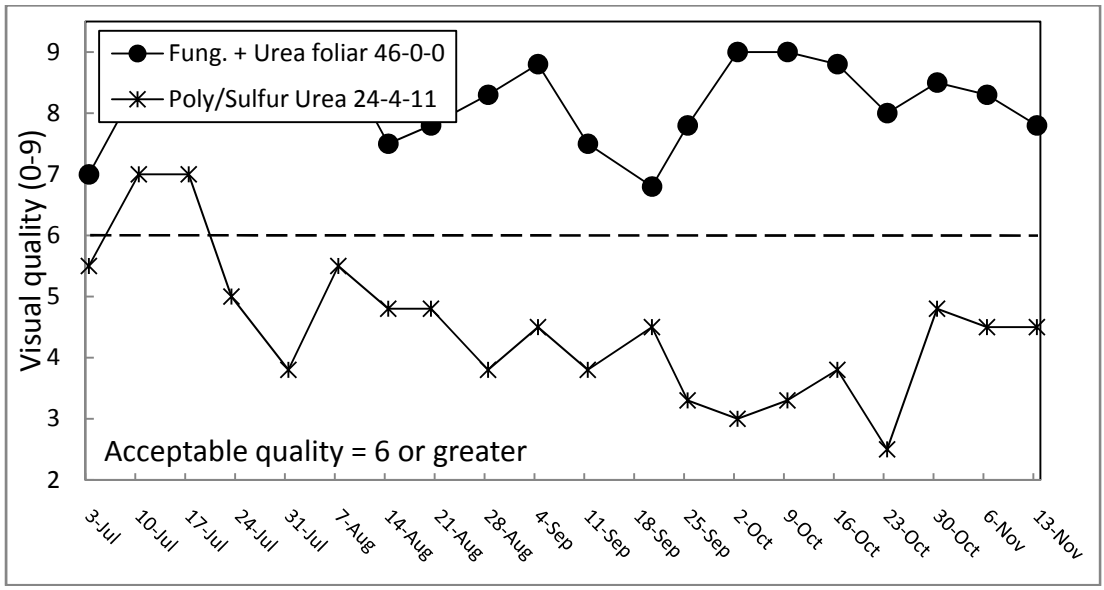

Figure 4. Poly/sulfur coated urea did not provide acceptable visual quality on most dates rated on an L-93/G-2 green in Lemont, IL when applied at 0.25 lb N/1000 ft^2 every 14 days for a total of 3 lbs N/1000 ft^2 in 2007.

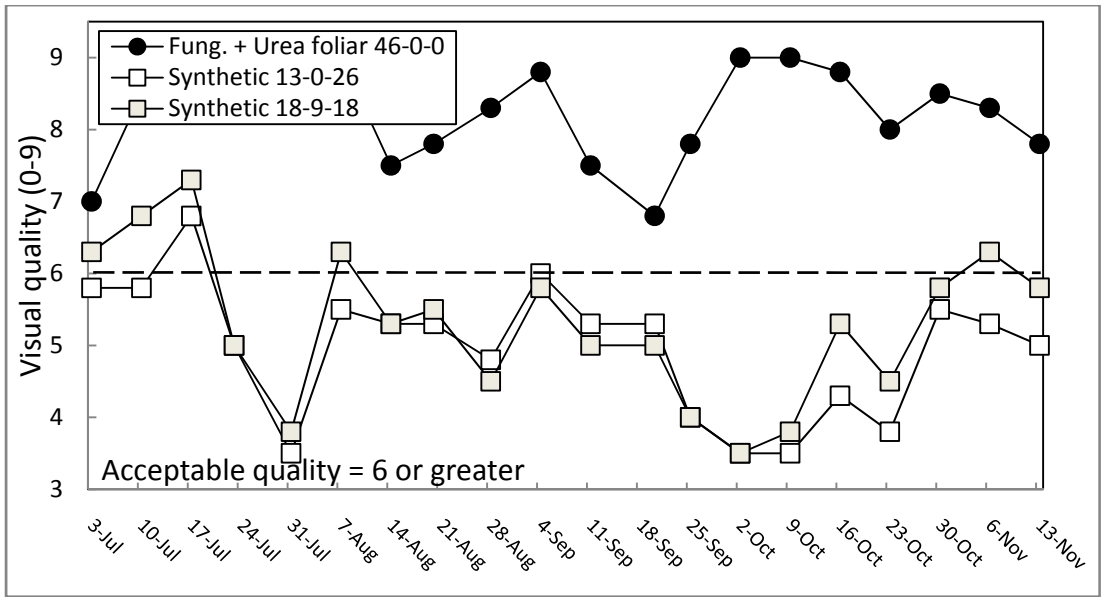

Figure 5. Synthetic mixture of slow and quick release nitrogen (13-0-26 and 18-9-18) did not provide acceptable visual quality on most dates rated on an L-93/G-2 green in Lemont, IL when applied at 0.25 lb N/1000 ft^2 every 14 days for a total of 3 lbs N/1000 ft^2 in 2007.

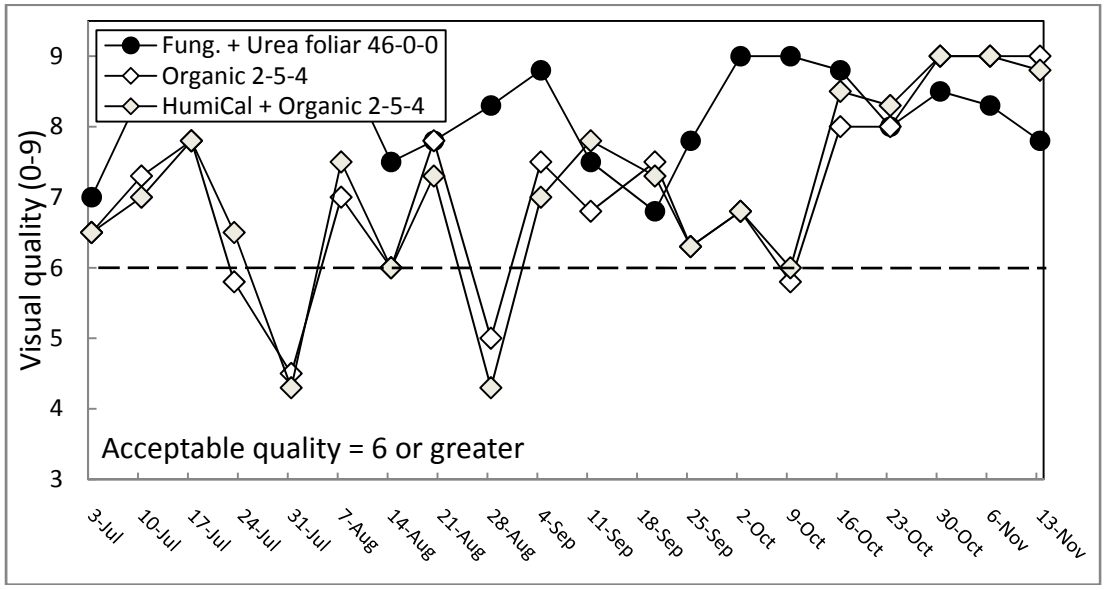

Figure 6. HealthyGro 2-5-4 provided acceptable visual quality on most dates rated on an L-93/G-2 green in Lemont, IL when applied at 0.25 lb N/1000 ft^2 every 14 days for a total of 3 lbs N/1000 ft^2 in 2007.

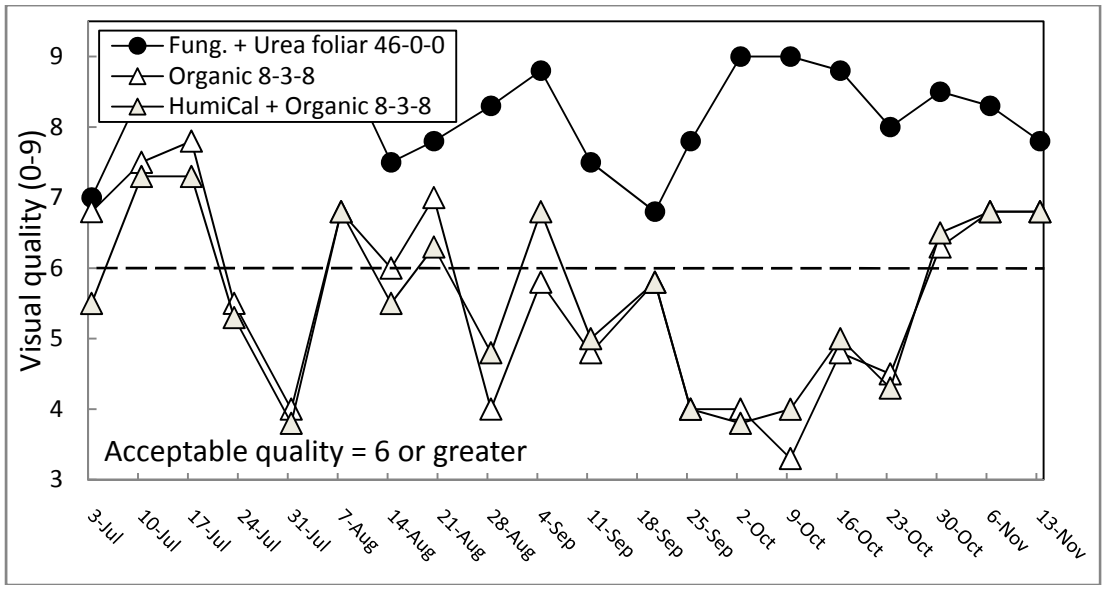

Figure 7. HealthyGro 8-3-8 provided acceptable visual quality on half dates rated on an L-93/G-2 green in Lemont, IL when applied at 0.25 lb N/1000 ft^2 every 14 days for a total of 3 lbs N/1000 ft^2 in 2007.

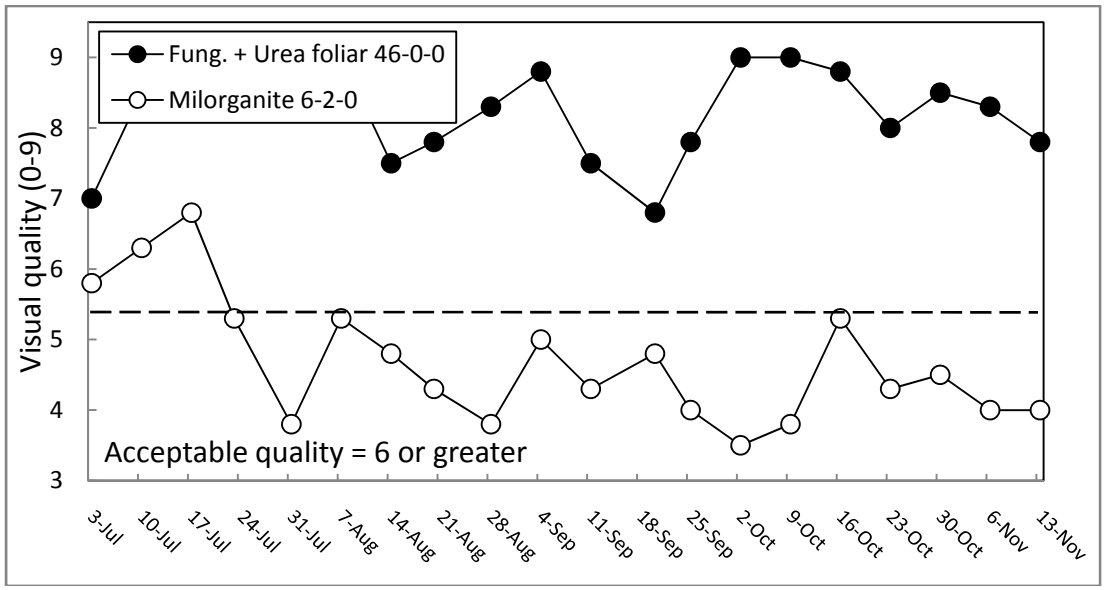

Figure 8. Milorganite 6-2-0 provided acceptable visual quality on half dates rated on an L-93/G-2 green in Lemont, IL when applied at 0.25 lb N/1000 ft^2 every 14 days for a total of 3 lbs N/1000 ft^2 in 2007.

TABLES

Visual Quality Tables

Table 1. Visual quality of an L-93/G-2 creeping bentgrass green treated by different nitrogen sources and/or fungicides in Lemont, IL during July, 2007.

Treatment	Visual Quality[z]				
	3 Jul	10 Jul	17 Jul	23 Jul	31 Jul
Untreated	5.3 a	6.0 a	5.5 cd	4.5 d	3.3 c
Fungicide (Emerald + ProStar)	5.0 a	4.8 a	5.0 d	5.0 cd	4.3 bc
Fungicide + Urea foliar 46-0-0	7.0 a	8.5 a	8.8 a	8.8 a	9.0 a
Urea foliar 46-0-0	5.5 a	6.3 a	7.0 b	5.3 cd	4.3 bc
Poly/Sulfur Coated Urea 21-4-11	5.5 a	7.0 a	7.0 b	5.0 cd	3.8 bc
Synthetic fertilizer 13-0-26	5.8 a	5.8 a	6.8 bc	5.0 cd	3.5 bc
Synthetic fertilizer 18-9-18	6.3 a	6.8 a	7.3 b	5.0 cd	3.8 bc
Healthy Gro 2-5-4	6.5 a	7.3 a	7.8 ab	5.8 bc	4.5 b
Healthy Gro 2-5-4 + HumiCal	6.5 a	7.0 a	7.8 ab	6.5 b	4.3 bc
Healthy Gro 8-3-8	6.8 a	7.5 a	7.8 ab	5.5 bcd	4.0 bc
Healthy Gro 8-3-8 + HumiCal	5.5 a	7.3 a	7.3 b	5.3 cd	3.8 bc
Milorganite 6-2-0	5.8 a	6.3 a	6.8 bc	5.3 cd	3.8 bc

[z] Visual quality rated from 0 to 9 with 6= minimum acceptable, and 9=best. Means with the same letter are not significantly different by Fisher's LSD test ($P < 0.05$).

Table 2. Visual quality of an L-93/G-2 creeping bentgrass green treated by different nitrogen sources and/or fungicides in Lemont, IL during August, 2007.

Treatment	Visual Quality[z]			
	7 Aug	14 Aug	20 Aug	28 Aug
Untreated	4.0 e	3.0 c	2.8 f	3.0 d
Fungicide (Emerald + ProStar)	4.0 e	3.3 c	2.8 f	3.8 cd
Fungicide + Urea foliar 46-0-0	9.0 a	7.5 a	7.8 a	8.3 a
Urea foliar 46-0-0	6.8 bc	5.8 b	6.3 bc	5.8 b
Poly/Sulfur Coated Urea 21-4-11	5.5 cd	4.8 b	4.8 de	3.8 cd
Synthetic fertilizer 13-0-26	5.5 cd	5.3 b	5.3 cde	4.8 bc
Synthetic fertilizer 18-9-18	6.3 bcd	5.3 b	5.5 cd	4.5 bcd
Healthy Gro 2-5-4	7.0 b	6.0 b	7.8 a	5.0 bc
Healthy Gro 2-5-4 + HumiCal	7.5 b	6.0 b	7.3 ab	4.3 bcd
Healthy Gro 8-3-8	6.8 bc	6.0 b	7.0 ab	4.0 cd
Healthy Gro 8-3-8 + HumiCal	6.8 bc	5.5 b	6.3 bc	4.8 bc
Milorganite 6-2-0	5.3 de	4.8 b	4.3 e	3.8 cd

[z] Visual quality rated from 0 to 9 with 6=acceptable, and 9=best. Means with the same letter are not significantly different by Fisher's LSD test ($P < 0.05$).

Table 3. Turf quality of an L-93/G-2 creeping bentgrass green treated by different nitrogen sources and/or fungicides in Lemont, IL during September, 2007.

Treatment	Visual Quality [z]			
	4 Sep	11 Sep	20 Sep	25 Sep
Untreated	2.8 g	2.3 f	2.3 e	2.3 d
Fungicide (Emerald + ProStar)	2.3 g	2.8 ef	2.5 e	2.0 d
Fungicide + Urea foliar 46-0-0	8.8 a	7.5 a	6.8 ab	7.8 a
Urea foliar 46-0-0	7.3 b	5.5 b	5.5 cd	4.5 c
Poly/Sulfur Coated Urea 21-4-11	4.5 f	3.8 de	4.5 d	3.3 cd
Synthetic fertilizer 13-0-26	6.0 cde	5.3 bc	5.3 cd	4.0 c
Synthetic fertilizer 18-9-18	5.8 de	5.0 bc	5.0 cd	4.0 c
Healthy Gro 2-5-4	7.5 b	6.8 a	7.5 a	6.3 b
Healthy Gro 2-5-4 + HumiCal	7.0 bc	7.8 a	7.3 a	6.3 b
Healthy Gro 8-3-8	5.8 de	4.8 bcd	5.8 bc	4.0 c
Healthy Gro 8-3-8 + HumiCal	6.8 bcd	5.0 bc	5.8 bc	4.0 c
Milorganite 6-2-0	5.0 ef	4.3 cd	4.8 cd	4.0 c

[z] Visual quality rated from 0 to 9 with 6=acceptable, and 9=best. Means with the same letter are not significantly different by Fisher's LSD test ($P < 0.05$).

Table 4. Turf quality of an L-93/G-2 creeping bentgrass green treated by different nitrogen sources and/or fungicides in Lemont, IL during October, 2007.

Treatment	Visual Quality [z]				
	2 Oct	9 Oct	16 Oct	23 Oct	30 Oct
Untreated	1.8 f	2.0 a	2.0 e	2.0 d	1.8 f
Fungicide (Emerald + ProStar)	2.0 ef	2.0 a	2.3 e	2.0 d	2.3 f
Fungicide + Urea foliar 46-0-0	9.0 a	9.0 a	8.8 a	8.0 a	8.5 a
Urea foliar 46-0-0	4.8 c	4.3 c	5.8 b	5.0 b	6.8 b
Poly/Sulfur Coated Urea 21-4-11	3.0 de	3.3 d	3.8 d	3.5 c	4.8 de
Synthetic fertilizer 13-0-26	3.5 d	3.5 cd	4.3 cd	3.8 bc	5.5 cde
Synthetic fertilizer 18-9-18	3.5 d	3.8 cd	5.3 bc	4.5 bc	5.8 bcd
Healthy Gro 2-5-4	6.8 b	5.8 b	8.0 a	8.0 a	9.0 a
Healthy Gro 2-5-4 + HumiCal	6.8 b	6.0 b	8.5 a	8.3 a	9.0 a
Healthy Gro 8-3-8	4.0 cd	3.3 d	4.8 bcd	4.5 bc	6.3 bc
Healthy Gro 8-3-8 + HumiCal	3.8 cd	4.0 cd	5.0 bcd	4.3 bc	6.5 bc
Milorganite 6-2-0	3.5 d	3.8 cd	5.3 bc	4.3 bc	4.5 e

[z] Visual quality rated from 0 to 9 with 6=acceptable, and 9=best. Means with the same letter are not significantly different by Fisher's LSD test ($P < 0.05$).

Table 5. Turf quality of an L-93/G-2 creeping bentgrass green treated by different nitrogen sources and/or fungicides in Lemont, IL during November, 2007.

Treatment	Visual Quality[z]	
	6 Nov	13 Nov
Untreated	1.3 e	1.0 g
Fungicide (Emerald + ProStar)	1.0 e	1.5 g
Fungicide + Urea foliar 46-0-0	8.3 a	7.8 bc
Urea foliar 46-0-0	6.8 b	6.5 d
Poly/Sulfur Coated Urea 21-4-11	4.5 cd	4.5 f
Synthetic fertilizer 13-0-26	5.3 c	5.0 ef
Synthetic fertilizer 18-9-18	6.3 b	5.8 de
Healthy Gro 2-5-4	9.0 a	9.0 a
Healthy Gro 2-5-4 + HumiCal	9.0 a	8.8 ab
Healthy Gro 8-3-8	6.8 b	6.8 cd
Healthy Gro 8-3-8 + HumiCal	6.8 b	6.8 cd
Milorganite 6-2-0	4.0 d	4.0 f

[z] Visual quality rated from 0 to 9 with 6=acceptable, and 9=best. Means with the same letter are not significantly different by Fisher's LSD test ($P < 0.05$).

NDVI/Color using electronic reflectance of red and far-red wavelengths

Table 6. Normalized Difference Vegetation Index of an L-93/G-2 creeping bentgrass green treated by different nitrogen sources and/or fungicides in Lemont, IL during July, 2007.

Treatment	Density/Color[z]				
	3 Jul	10 Jul	17 Jul	23 Jul	31 Jul
Untreated	.764 cde	.773 a	.733 c	.770 d	.739 cd
Fungicide (Emerald + ProStar)	.761 de	.777 a	.755 d	.751 e	.732 d
Fungicide + Urea foliar 46-0-0	.778 abcd	.797 a	.790 ab	.805 ab	.767 a
Urea foliar 46-0-0	.772 bcde	.798 a	.790 b	.808 ab	.769 a
Poly/Sulfur Coated Urea 21-4-11	.764 bcde	.787 a	.797 ab	.796 bc	.766 ab
Synthetic fertilizer 13-0-26	.759 e	.782 a	.788 bc	.795 bc	.762 abc
Synthetic fertilizer 18-9-18	.770 bcde	.798 a	.793 ab	.796 bc	.759 abc
Healthy Gro 2-5-4	.782 ab	.800 a	.797 ab	.814 a	.769 a
Healthy Gro 2-5-4 + HumiCal	.794 a	.795 a	.807 a	.813 a	.767 a
Healthy Gro 8-3-8	.775 bcde	.795 a	.793 ab	.808 ab	.770 a
Healthy Gro 8-3-8 + HumiCal	.780 abc	.795 a	.795 ab	.810 ab	.766 a
Milorganite 6-2-0	.757 e	.781 a	.784 bc	.784 cd	.743 bcd

[z] Larger values = darker green color and greater density. Means with the same letter are not significantly different by Fisher's LSD test ($P < 0.05$).

Table 7. Normalized Difference Vegetation Index of an L-93/G-2 creeping bentgrass green treated by different nitrogen sources and/or fungicides in Lemont, IL during August, 2007.

Treatment	Density/Color[z]			
	7 Aug	14 Aug	20 Aug	28 Aug
Untreated	.784 d	.746 c	.741 c	.735 c
Fungicide (Emerald + ProStar)	.771 e	.748 c	.748 c	.724 c
Fungicide + Urea foliar 46-0-0	.821 ab	.786 ab	.806 a	.796 a
Urea foliar 46-0-0	.817 ab	.785 ab	.799 ab	.786 a
Poly/Sulfur Coated Urea 21-4-11	.816 abc	.786 ab	.799 ab	.779 ab
Synthetic fertilizer 13-0-26	.814 bc	.782 ab	.790 ab	.779 ab
Synthetic fertilizer 18-9-18	.818 ab	.786 ab	.794 ab	.782 a
Healthy Gro 2-5-4	.826 a	.788 a	.785 ab	.794 a
Healthy Gro 2-5-4 + HumiCal	.821 ab	.787 a	.801 ab	.792 a
Healthy Gro 8-3-8	.818 ab	.787 a	.806 a	.785 a
Healthy Gro 8-3-8 + HumiCal	.819 ab	.786 ab	.795 ab	.779 ab
Milorganite 6-2-0	.805 c	.775 b	.778 b	.759 b

[z] Larger values = darker green color and greater density. Means with the same letter are not significantly different by Fisher's LSD test ($P < 0.05$).

Table 8. Normalized Difference Vegetation Index of an L-93/G-2 creeping bentgrass green treated by different nitrogen sources and/or fungicides in Lemont, IL during September, 2007.

Treatment	Density/Color[z]			
	4 Sep	11 Sep	20 Sep	25 Sep
Untreated	.728 e	.716 e	.661 f	.671 h
Fungicide (Emerald + ProStar)	.726 e	.723 e	.672 f	.692 g
Fungicide + Urea foliar 46-0-0	.808 ab	.788 abc	.780 abc	.790 abc
Urea foliar 46-0-0	.804 abc	.779 c	.767 bcd	.776 cde
Poly/Sulfur Coated Urea 21-4-11	.790 cd	.783 bc	.750 ed	.766 e
Synthetic fertilizer 13-0-26	.795 bc	.778 cd	.766 cd	.774 de
Synthetic fertilizer 18-9-18	.792 cd	.777 cd	.761 cd	.770 de
Healthy Gro 2-5-4	.813 a	.795 ab	.802 a	.804 a
Healthy Gro 2-5-4 + HumiCal	.809 ab	.798 a	.789 ab	.794 ab
Healthy Gro 8-3-8	.798 abc	.785 abc	.777 bc	.785 bcd
Healthy Gro 8-3-8 + HumiCal	.797 bc	.779 cd	.768 bcd	.778 bcde
Milorganite 6-2-0	.778 d	.766 d	.732 e	.747 f

[z] Larger values = darker green color and greater density. Means with the same letter are not significantly different by Fisher's LSD test ($P < 0.05$).

Table 9. Normalized Difference Vegetation Index of an L-93/G-2 creeping bentgrass green treated by different nitrogen sources and/or fungicides in Lemont, IL during October, 2007.

Treatment	Density/Color [z]				
	2 Oct	9 Oct	16 Oct	23 Oct	30 Oct
Untreated	.673 g	.649 f	.669 f	.634 g	.647 f
Fungicide (Emerald + ProStar)	.705 f	.688 e	.700 e	.673 f	.691 e
Fungicide + Urea foliar 46-0-0	.799 ab	.785 ab	.792 ab	.779 ab	.806 a
Urea foliar 46-0-0	.794 abc	.771 bc	.789 ab	.769 bc	.797 ab
Poly/Sulfur Coated Urea 21-4-11	.770 de	.765 bc	.768 c	.756 cd	.777 c
Synthetic fertilizer 13-0-26	.775 cd	.764 cd	.769 c	.750 d	.776 c
Synthetic fertilizer 18-9-18	.780 bcd	.767 bc	.778 bc	.755 cd	.779 bc
Healthy Gro 2-5-4	.810 a	.794 a	.804 a	.792 a	.810 a
Healthy Gro 2-5-4 + HumiCal	.807 a	.793 a	.805 a	.796 a	.810 a
Healthy Gro 8-3-8	.795 ab	.779 abc	.788 ab	.773 bc	.799 a
Healthy Gro 8-3-8 + HumiCal	.785 bcd	.773 bc	.786 b	.772 bc	.793 abc
Milorganite 6-2-0	.751 e	.745 d	.748 d	.731 e	.741 d

[z] Larger values = darker green color and greater density. Means with the same letter are not significantly different by Fisher's LSD test (P < 0.05).

Table 10. Normalized Difference Vegetation Index of an L-93/G-2 creeping bentgrass green treated by different nitrogen sources and/or fungicides in Lemont, IL during November, 2007.

Treatment	Density/Color [z]	
	6 Nov	13 Nov
Untreated	.571 h	.579 f
Fungicide (Emerald + ProStar)	.609 g	.612 e
Fungicide + Urea foliar 46-0-0	.771 ab	.788 a
Urea foliar 46-0-0	.758 bc	.775 a
Poly/Sulfur Coated Urea 21-4-11	.732 e	.741 c
Synthetic fertilizer 13-0-26	.733 de	.729 c
Synthetic fertilizer 18-9-18	.739 cde	.745 bc
Healthy Gro 2-5-4	.781 a	.782 a
Healthy Gro 2-5-4 + HumiCal	.783 a	.783 a
Healthy Gro 8-3-8	.768 ab	.770 ab
Healthy Gro 8-3-8 + HumiCal	.754 bcd	.769 ab
Milorganite 6-2-0	.694 f	.686 d

[z] Larger values = darker green color and greater density. Means with the same letter are not significantly different by Fisher's LSD test (P < 0.05).

Dollar spot number

Table 11. Dollar spot number per plot on an L-93/G-2 creeping bentgrass green treated by different nitrogen sources and/or fungicides in Lemont, IL during July, 2007.

Treatment	Dollar spot number [z]				
	3 Jul	10 Jul	17 Jul	23 Jul	31 Jul
Untreated	18 a	25 a	28 a	45 a	130 a
Fungicide (Emerald + ProStar)	2 a	1 a	0 a	0 c	0 b
Fungicide + Urea foliar 46-0-0	4 a	1 a	0 a	0 c	2 b
Urea foliar 46-0-0	16 a	23 a	28 a	32 ab	139 a
Poly/Sulfur Coated Urea 21-4-11	13 a	17 a	20 a	23 b	97 a
Synthetic fertilizer 13-0-26	13 a	21 a	24 a	26 ab	137 a
Synthetic fertilizer 18-9-18	15 a	15 a	22 a	23 b	109 a
Healthy Gro 2-5-4	15 a	18 a	19 a	15 bc	66 ab
Healthy Gro 2-5-4 + HumiCal	18 a	22 a	21 a	20 bc	120 a
Healthy Gro 8-3-8	10 a	14 a	19 a	22 b	108 a
Healthy Gro 8-3-8 + HumiCal	13 a	21 a	29 a	31 ab	139 a
Milorganite 6-2-0	16 a	19 a	23 a	24 ab	100 a

[z] Dollar spot number per 24 ft^2 plot. Means with the same letter are not significantly different by Fisher's LSD test ($P < 0.05$).

Table 12. Dollar spot number per plot on an L-93/G-2 creeping bentgrass green treated by different nitrogen sources and/or fungicides in Lemont, IL during August, 2007.

Treatment	Dollar spot number [z]			
	7 Aug	14 Aug	20 Aug	28 Aug
Untreated	89 a	63 a	52 a	75 a
Fungicide (Emerald + ProStar)	5 d	8 bc	2 c	5 e
Fungicide + Urea foliar 46-0-0	4 d	26 b	2 c	5 e
Urea foliar 46-0-0	29 bcd	10 bc	16 bc	37 cd
Poly/Sulfur Coated Urea 21-4-11	35 bc	21 bc	21 b	66 ab
Synthetic fertilizer 13-0-26	39 b	10 bc	11 bc	36 cd
Synthetic fertilizer 18-9-18	32 bc	7 c	10 bc	46 bcd
Healthy Gro 2-5-4	12 cd	5 c	5 bc	26 cde
Healthy Gro 2-5-4 + HumiCal	19 bcd	4 c	6 bc	21 de
Healthy Gro 8-3-8	24 bcd	9 bc	10 bc	49 bcd
Healthy Gro 8-3-8 + HumiCal	27 bcd	10 bc	14 bc	42 abc
Milorganite 6-2-0	34 bc	8 c	15 bc	35 cd

[z] Dollar spot number per 24 ft^2 plot. Means with the same letter are not significantly different by Fisher's LSD test ($P < 0.05$).

Table 13. Dollar spot number per plot on an L-93/G-2 creeping bentgrass green treated by different nitrogen sources and/or fungicides in Lemont, IL during September, 2007.

Treatment	Dollar spot number[z]			
	4 Sep	11 Sep	20 Sep	25 Sep
Untreated	77 a	113 a	--	217 a
Fungicide (Emerald + ProStar)	3 f	18 d	--	21 c
Fungicide + Urea foliar 46-0-0	3 f	19 d	--	17 c
Urea foliar 46-0-0	24 cde	42 cd	--	153 ab
Poly/Sulfur Coated Urea 21-4-11	55 b	90 ab	--	205 a
Synthetic fertilizer 13-0-26	31 cde	65 bcd	--	170 ab
Synthetic fertilizer 18-9-18	31 cd	71 abc	--	169 ab
Healthy Gro 2-5-4	13 def	21 d	--	86 bc
Healthy Gro 2-5-4 + HumiCal	11 ef	22 d	--	88 bc
Healthy Gro 8-3-8	44 bc	60 bcd	--	162 ab
Healthy Gro 8-3-8 + HumiCal	19 def	72 abc	--	189 a
Milorganite 6-2-0	27 cde	57 bcd	--	139 ab

[z] Dollar number per 24 ft^2 plot. Means with the same letter are not significantly different by Fisher's LSD test ($P < 0.05$).

Table 14. Dollar spot number per plot on an L-93/G-2 creeping bentgrass green treated by different nitrogen sources and/or fungicides in Lemont, IL during October, 2007.

Treatment	Dollar spot number[z]				
	2 Oct	9 Oct	16 Oct	23 Oct	AUDPC
Untreated	361 a	363 a	187 a	89 a	1901 a
Fungicide (Emerald + ProStar)	15 e	13 fg	1 f	0 c	99 e
Fungicide + Urea foliar 46-0-0	1 e	6 g	0 f	0 c	95 e
Urea foliar 46-0-0	179 bcd	183 bcde	85 bcd	50 bc	1034 bcd
Poly/Sulfur Coated Urea 21-4-11	287 ab	307 ab	150 ab	107 ab	1470 ab
Synthetic fertilizer 13-0-26	225 abc	219 bcd	87 bcd	83 ab	1166 bc
Synthetic fertilizer 18-9-18	231 abc	163 cde	72 cdef	41 bc	1049 bcd
Healthy Gro 2-5-4	48 de	61 efg	16 def	10 c	443 de
Healthy Gro 2-5-4 + HumiCal	82 cde	84 defg	12 ef	9 c	569 cde
Healthy Gro 8-3-8	220 abc	267 abc	78 bcde	69 ab	1137 bc
Healthy Gro 8-3-8 + HumiCal	238 ab	259 abc	96 bc	74 ab	1249 ab
Milorganite 6-2-0	194 bcd	155 cdef	50 cdef	46 bc	933 bcd

[z] Dollar spot number per 24 ft^2 plot. Means with the same letter are not significantly different by Fisher's LSD test ($P < 0.05$).

Brown patch percent

Table 15. Brown patch percent per plot on an L-93/G-2 creeping bentgrass green treated by different nitrogen sources and/or fungicides in Lemont, IL during July, 2007.

Treatment	Brown patch percent [z]							
	20 Jul	28 Jul	7 Aug	14 Aug	24 Aug	28 Aug	4 Sep	AUDPC
Untreated	26 a	38 a	53 a	68 a	68 a	65 a	75 a	637 a
Fungicide (Emerald + ProStar)	0 c	0 c	0 d	3 f	0 d	0 d	0 e	10 g
Fungicide + Urea foliar 46-0-0	1 c	0 c	0 d	5 ef	0 d	0 d	0 e	23 g
Urea foliar 46-0-0	3 c	18 b	20 c	23 cde	16 cd	18 cd	18 cde	179 f
Poly/Sulfur Coated Urea 21-4-11	9 bc	20 b	28 c	40 bc	48 ab	53 ab	43 b	332 cb
Synthetic fertilizer 13-0-26	9 bc	28 ab	33 bc	40 bc	28 bc	33 bc	25 bc	302 bcd
Synthetic fertilizer 18-9-18	8 bc	23 ab	28 c	32.5 cd	28 bc	38 bc	24 cd	284 cde
Healthy Gro 2-5-4	1 c	15 bc	16 cd	29 cd	20 cd	31 bc	6 de	215 def
Healthy Gro 2-5-4 + HumiCal	5 bc	20 b	18 cd	26 cd	10 cd	28 c	8 cde	205 ef
Healthy Gro 8-3-8	3 c	18 b	20 c	20 def	20 cd	35 bc	19 cd	203 ef
Healthy Gro 8-3-8 + HumiCal	4 bc	28 ab	20 c	28 cd	13 cd	21 cd	19 cd	216 def
Milorganite 6-2-0	16 ab	30 ab	48 ab	55 ab	29 bc	35 bc	43 b	396 b

[z] Means with the same letter are not significantly different by Fisher's LSD test ($P < 0.05$).