# UCRTRAC Accumulative Research Summary
## Section B: Impact of Turfgrass Chemicals and Fertilizers on the Environment
## Project 5

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**Title:** Development of BMPs for Fertilizing Lawns to Optimize Plant Performance and N-trogen Uptake while Reducing the Potential for Nitrate Leaching.

**Objectives:** 1) Evaluate annual N rate and source on tall fescue to determine which factor(s) optimize plant performance and N uptake while reducing the potential for nitrate ($NO_3^B$) leaching; 2) quantify the effect of N fertilizer rate and source on visual turfgrass quality and color, clipping yield, tissue N concentration, N uptake, concentration of $NO_3^B$-N and $NH_4^+$-N in leachate at a depth below the rootzone, and concentration of $NO_3^B$-N and $NH_4^+$-N in soil; and 3) develop BMPs for lawns under representative irrigation practices to optimize plant performance and N uptake while reducing the potential for $NO_3^B$ leaching.

- Treatments: No nitrogen check; ammonium nitrate, Polyon, Milorganite, and Nutralene each applied at an **annual** N rate of either 4.0, 6.0, or 8.0 lb/1000 $ft^2$. Annual N rate was divided into four equal applications on 1 Mar., 15 May, 15 Aug., and 15 Oct. Individual plot size = 5.0 x 7.0 ft (Table 1 and Fig. 1).

- Measurements are highlighted in objective 2. However, for a more detailed description of measurements, please see Table 2.

- The plot was maintained to produce a good quality tall fescue. Please see Table 3 for information concerning plot management.

**Location:** Marathon III tall fescue plot that was seeded during April 1996. The plot is located at the UCR Turfgrass Field Research Facility. Please note that the same study is being conducted at the University of California, Davis.

**Duration:** 3.7 years (field phase of research at UCR was from October 2002 to October 2004)

**Funding Source:** California Department of Food and Agriculture, Fertilizer Research and Education Program (CDFA-FREP)

*Continued . . .*

**Findings at UC Riverside:**

**Visual turfgrass quality ratings.** This report covers data and analyses of visual turfgrass quality for 48 rating dates, taken from 6 Nov. 2002 to 8 Oct. 2004 (Fig. 2). In terms of overall analysis of 13 treatments, all fertilizer treatments were within range of an acceptable tall fescue lawn (Table 4). This assumes that most people are satisfied with a tall fescue lawn when visual turfgrass quality is within the range of 5.5 to 6.5 (scale: 1 = worst, 5 = minimally acceptable, and 9 = best). Overall visual turfgrass quality ranged from 5.5 for Milorganite at an annual N rate of 4.0 lb/1000 $ft^2$ to 6.2 for ammonium nitrate and Polyon at an annual N rate of 8.0 lb/1000 $ft^2$; the check treatment was 4.8. In terms of overall analysis of 12 fertilizer treatments, arranged in a $4 \times 3$ factorial design, ammonium nitrate and Polyon produced overall visual turfgrass quality of 6.0 while Milorganite and Nutralene produced a 5.8 and 5.9, respectively (means significantly different). Also, annual N rates of 8.0, 6.0, and 4.0 lb/1000 $ft^2$ produced overall visual turfgrass quality of 6.1, 5.9, and 5.7, respectively (means significantly different). In terms of 48 rating dates, all fertilizer treatments resulted in a visual turfgrass quality rating $\geq$ 5.5 on 50% or more rating dates (Table 5). Fertilizer treatments that did not result in a visual turfgrass quality rating $\geq$ 6.0 on 50% or more rating dates included Nutralene at an annual N rate of 6.0 lb/1000 $ft^2$ and Milorganite, Nutralene, and Polyon at an annual N rate of 4.0 lb/1000 $ft^2$.

**Concentration of $NO_3^-$-N in leachate.** This report covers data and analyses of $NO_3^-$-N concentrations in leachate on 48 sample dates from 9 Oct. 2002 to 29 Sept. 2004 (Fig. 3). These data were affected by a change in irrigation protocol on 2 July 2003. From 16 Oct. 2002 to 1 July 2003, the protocol was (100% $ET_{crop}$/DU) minus rainfall, based on the previous 7 d cumulative $ET_o$. Though visual ratings were not affected, this protocol caused some dry soil conditions. To alleviate this situation we decided to fall back on our historical knowledge of maintaining tall fescue during the summer in Riverside; that is 110% $ET_o$, based on the previous 7 day cumulative $ET_o$. Thus, we initiated this new irrigation protocol on 2 July 2003 which continued to the end of the field study. During minimalist irrigation from 16 Oct. 2002 to 1 July 2003, $NO_3^-$-N concentrations in leachate were low (< 1 ppm) and differences among fertilizer treatments were basically not significant. Please note that the EPA Maximum Contaminant Level (MCL) for nitrates in drinking water is 10 ppm. It should be noted that the average $NO_3^-$-N concentration of irrigation water was 4.2 ppm. During well-watered irrigation from 2 July 2003 to 29 Sept. 2004, $NO_3^-$-N concentration in leachate was higher than the previous period. However, concentrations are probably not problematic except for one fertilizer treatment: ammonium nitrate at an annual N rate of 8.0 lb/1000 $ft^2$ (four applications at a N rate of 2.0 lb/1000 $ft^2$). On several sample dates, $NO_3^-$-N concentration in leachate exceeded 10 ppm. This occurred following the 15 Aug. and 17 Oct. 2003 and 13 Aug. 2004 fertilizer treatment application dates.

**Summary:** These data concerning nitrate leaching, from a well-established tall fescue, will help support BMPs for fertilizing tall fescue lawns to optimize plant performance and nitrogen uptake while reducing the potential for nitrate leaching. Several preliminary observations follow.

1. Minimalist irrigation reduces the potential for nitrate leaching. However, sufficient irrigation is needed to promote healthy turfgrass.

2. An annual N rate of 4.0 to 6.0 lb/1000 $ft^2$ produces an acceptable to good quality tall fescue lawn. Higher rates are not necessary and increase the risk of nitrate leaching.

3. Slow-release N sources (Nutralene, Milorganite, and Polyon) cause less nitrate leaching than a fast-release N source (ammonium nitrate) (data not shown).

4. The amount of nitrate leaching from a fast-release N source can be drastically reduced if N rates of individual applications do not exceed 1.0-1.5 lb/1000 $ft^2$.

**Status:** The field phase of this study was recently completed in October 2004. We are now in the phase of completing data analyses, development, and summary. A Final Report is due September 2005. Information associated with this study has been presented at several meetings. Information associated with this study has been published in abstracts, conference proceedings, and *News from the UCR Turfgrass Program*.

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Table 1. Protocol for 13 N fertilization treatments for the CDFA-FREP study (four N sources x three rates plus a no-nitrogen check).

| Date of application | N source[z] ($N-P_2O_5-K_2O$) | Rate (lb N/1000 ft$^2$) | | |
|---|---|---|---|---|
| | | a | b | c |
| 1 Mar. | No nitrogen check | 0.0 | 0.0 | 0.0 |
| | A. Ammonium nitrate 34-0-0 | 1.0 | 1.5 | 2.0 |
| | B. Polyon 43-0-0 | 1.0 | 1.5 | 2.0 |
| | C. Milorganite 6-2-0 | 1.0 | 1.5 | 2.0 |
| | D. Nutralene 40-0-0 | 1.0 | 1.5 | 2.0 |
| 15 May | No nitrogen check | 0.0 | 0.0 | 0.0 |
| | A. Ammonium nitrate 34-0-0 | 1.0 | 1.5 | 2.0 |
| | B. Polyon 42-0-0 | 1.0 | 1.5 | 2.0 |
| | C. Milorganite 6-2-0 | 1.0 | 1.5 | 2.0 |
| | D. Nutralene 40-0-0 | 1.0 | 1.5 | 2.0 |
| 15 Aug. | No nitrogen check | 0.0 | 0.0 | 0.0 |
| | A. Ammonium nitrate 34-0-0 | 1.0 | 1.5 | 2.0 |
| | B. Polyon 42-0-0 | 1.0 | 1.5 | 2.0 |
| | C. Milorganite 6-2-0 | 1.0 | 1.5 | 2.0 |
| | D. Nutralene 40-0-0 | 1.0 | 1.5 | 2.0 |
| 15 Oct. | No nitrogen check | 0.0 | 0.0 | 0.0 |
| | A. Ammonium nitrate 34-0-0 | 1.0 | 1.5 | 2.0 |
| | B. Polyon 43-0-0 | 1.0 | 1.5 | 2.0 |
| | C. Milorganite 6-2-0 | 1.0 | 1.5 | 2.0 |
| | D. Nutralene 40-0-0 | 1.0 | 1.5 | 2.0 |
| Total | No nitrogen check | 0.0 | 0.0 | 0.0 |
| | A. Ammonium nitrate 34-0-0 | 4.0 | 6.0 | 8.0 |
| | B. Polyon 43-0-0 and 42-0-0 | 4.0 | 6.0 | 8.0 |
| | C. Milorganite 6-2-0 | 4.0 | 6.0 | 8.0 |
| | D. Nutralene 40-0-0 | 4.0 | 6.0 | 8.0 |

[z] Ammonium nitrate is a fast-release, water soluble N source; Polyon is a slow-release, polymer-coated N source; Milorganite is a slow-release, natural organic N source; and Nutralene is a slow-release, water insoluble, methylene ureas N source.

Note: Potassium sulfate (0-0-50) and treble superphosphate (0-45-0) will be applied to all plots at an annual rate of 4.0 lb $K_2O$/1000 ft$^2$ and 3.0 lb $P_2O_5$/1000 ft$^2$.

Rev. 5 Mar. 2004

Figure 1. Plot plan for development of BMPs for fertilizing lawns to optimize plant performance and nitrogen uptake while reducing the potential for nitrate leaching (UC Riverside).

I II N→

70 ft; 7 ft; 5 ft; 30 ft

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 5 | 2 13 | 3 12 | 4 | 5 10 | 6 5 | 7 4 | 8 7 | 9 | 10 12 |
| 11 4 | 12 9 | 13 2 | 14 3 | 15 8 | 16 10 | 17 TDR | 18 8 | 19 1 | 20 3 |
| 21 1 | 22 | 23 11 | 24 6 | 25 7 | 26 2 | 27 11 | 28 9 | 29 6 | 30 13 |
| 31 2 | 32 1 | 33 8 | 34 TDR | 35 12 | 36 4 | 37 8 | 38 TDR | 39 10 | 40 7 |
| 41 5 | 42 4 | 43 TDR | 44 7 | 45 9 | 46 12 | 47 5 | 48 9 | 49 11 | 50 3 |
| 51 10 | 52 6 | 53 13 | 54 11 | 55 3 | 56 2 | 57 1 | 58 13 | 59 ⌖ | 60 6 |

⌖ Soil temperature datalogger

III IV

**Treatments:**

1 – Ammonium nitrate at annual rate of 4 lb N/1000 $ft^2$
2 – Ammonium nitrate at annual rate of 6 lb N/1000 $ft^2$
3 – Ammonium nitrate at annual rate of 8 lb N/1000 $ft^2$
4 – Polyon at annual rate of 4 lb N/1000 $ft^2$
5 – Polyon at annual rate of 6 lb N/1000 $ft^2$
6 – Polyon at annual rate of 8 lb N/1000 $ft^2$
7 – Milorganite at annual rate of 4 lb N/1000 $ft^2$
8 – Milorganite at annual rate of 6 lb N/1000 $ft^2$
9 – Milorganite at annual rate of 8 lb N/1000 $ft^2$
10 – Nutralene at annual rate of 4 lb N/1000 $ft^2$
11 – Nutralene at annual rate of 6 lb N/1000 $ft^2$
12 – Nutralene at annual rate of 8 lb N/1000 $ft^2$
13 – Control (no-nitrogen check)

I, II, III, IV = replications of a randomized complete block design.
Shaded plots are null plots.
Numbers in upper left corner are plot numbers.
TDR = Time domain reflectometry sensors installed in upper 48-inch depth zone.

Rev. 5 Mar. 2004

Table 2. Protocol for measurements collected during the CDFA-FREP study.

| Measurement | Frequency | Method and other comments |
|---|---|---|
| 1. Visual turfgrass quality | Once every 2 weeks | 1 to 9 scale, with 1 = worst quality, 5 = minimally acceptable quality, and 9 = best quality for tall fescue |
| 2. Visual turfgrass color | Same time as turfgrass quality | 1 to 9 scale, with 1 = worst color (brown), 5 = minimally acceptable color, and 9 = best color (dark green) for tall fescue |
| 3. Clipping yield, TKN, and N uptake | Four growth periods, with each period spanning four consecutive weekly clipping yields. All periods start one month following each of the four N-fertility treatment application dates (Table 1). Generally, periods are: 1 Apr. to 30 Apr.; 15 June to 15 July; 15 Sept. to 15 Oct.; and 15 Nov. to 15 Dec. | Weekly clipping yield, representing 7-d growth, is collected from 9.2 $ft^2$ (26% of the total surface area) from each plot with the same mower used for routine mowing, except a specially constructed collection box is attached to the mower. Weekly clipping yields are dried at 60 to 67 ºC in a forced-air oven for 48 h and immediately weighed. Yield reported as $g \cdot m^{-2}$. The four weekly yields within each growth period are pooled by the 52 plots and ground. TKN analysis is conducted at the DANR laboratory located at UC Davis. With appropriate calculations, N uptake during four 4-week growth periods is determined. |
| 4. $NO_3^-$-N and $NH_4^+$-N concentration of soil water below rootzone | Once every 2 weeks | One suction plate lysimeter was installed in each plot so the distal tip of the lysimeter cup is at a depth of 2.5 ft below the soil-thatch layer (approximately 0.6 inch deep). The lysimeters were installed at a 45º angle so the lysimeter cup is below undisturbed soil. They were constructed using high-flow ceramic cups (round bottom neck top cups, 1.9-inch diameter, Soil Moisture Equipment Corp. catalog number 653X01-B01M3) and 2-inch diameter PVC pipe. A vacuum of approximately –40 KPa is applied to the lysimeters 24 h before the leachate sampling day. Samples are acidified to pH 2.4-2.8, frozen, and stored until shipped via next-day air to the DANR Laboratory, then stored at 4 ºC until analyzed for $NO_3^-$-N and $NH_4^+$-N by flow injection analyzer method. Analysis occurs within 28 d of leachate collection. |
| 5. Soil water content | Once every 7 d | Volumetric soil water content is determined from the 0- to 48-inch soil depth zone at the same time each Wednesday using four time domain reflectometry (TDR) sensors (MoisturePoint MP-917 TDR unit with Type 2 probe) installed in four null plots within the research plot. The most recent irrigation event is on Tuesday mornings. |
| 6. $NO_3^-$-N and $NH_4^+$-N concentration in soil | Beginning of study (20 Dec. 2002) and at 12 months (1 Oct. 2003) and 24 months (1 Oct. 2004) after initial fertilizer treatments | Two soil cores are taken from each plot and separated into two soil depth zones for the initial sampling: 0 to 12 inches and 12 to 30 inches. For the second and third sampling, cores are separated into three soil depth zones: 0 to 12 inches, 12 to 24 inches, and 24 to 36 inches. A grid is used to ensure that no part of the plot is sampled more than once for the duration of the study. Cores from each plot are pooled by depth; 6 g soil from each plot and depth zone is immediately placed in 40 ml of 2 M KCl to begin the extraction process. Standard procedures are followed to determine $NO_3^-$-N and $NH_4^+$-N concentration on a dry soil basis. |
| 7. Weather data | Continuous | Data obtained from a CIMIS station located at the UCR Turfgrass Research Project. Soil-temperature data loggers also are installed on the research plot. |
| 8. Statistical procedures (to date) | | Most measured variables are statistically analyzed according to a RCB design with 12 treatments arranged in a 4 × 3 factorial. When the no-nitrogen check treatment is included, a RCB design is used to analyze all 13 treatments. Overall analyses involved a repeated measures design, with measurement date as the repeated measures factor. |

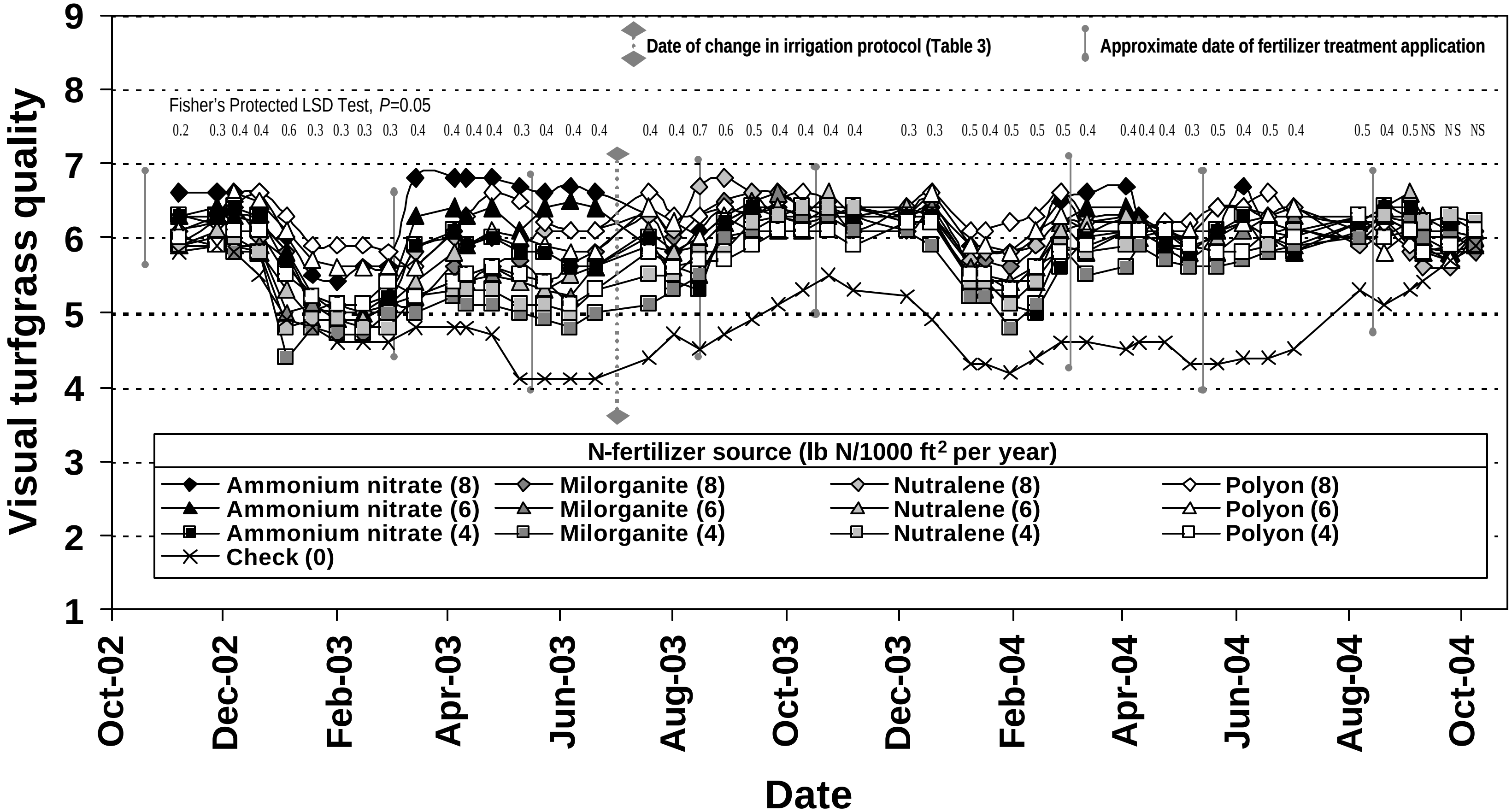
Rev. 27 Aug. 2004

Table 3. Protocol for research plot management and associated information for the CDFA-FREP study.

| Activity | Comment |
|---|---|
| Mowing | Once each week, using a walk-behind, rotary mower set at a 1.5-inch mowing height. Clippings collected. |
| Irrigation | **From 16 Oct. 2002 to 1 July 2003: (100% $ET_{crop}$/DU) minus rainfall.**<br>• $ET_{crop}$ = $ET_o$ x crop coefficient ($K_c$). Monthly cool-season $K_c$ used in the calculations.<br>• $ET_o$ = previous 7 d cumulative $ET_o$, obtained from an on-site CIMIS station<br>• DU = distribution uniformity.<br>• Three irrigation events per week. Irrigation events are cycled to prevent runoff.<br>• Total irrigation applied (Riverside) = 73% $ET_o$; total rainfall = 279.1 mm.<br>• Though visual ratings were not affected, this minimalist irrigation protocol, which attempted to make up rainfall, created some dry soil conditions, especially in the 0- to 6-inch root zone depth (Riverside).<br>• To alleviate having to micromanage the plot on the "edge" we changed the irrigation protocol as noted below.<br>**From 2 July 2003 to end of study: 110% $ET_o$.**<br>• 110% $ET_o$ is consistent with our historical knowledge of maintaining tall fescue during the summer in Riverside, Calif.<br>• $ET_o$ = previous 7 d cumulative $ET_o$, obtained from an on-site CIMIS station<br>• Three irrigation events per week. Irrigation events are cycled to prevent runoff.<br>• Rain ($\geq$ 0.25 inches or greater) is not subtracted from the irrigation amount but may result in a cancellation of an irrigation event.<br>• From 2 July 2003 to 6 July 2004 (Riverside): total irrigation applied = 116% $ET_o$; total rainfall = 175.4 mm; 12 irrigation events canceled due to rainfall. |
| Irrigation-system check | To ensure accurate and consistent irrigation, the vertical of all heads is checked with a level and adjusted once every 4 weeks and clock operation and irrigation run times are routinely monitored via a log on the controller. Catch-can tests are conducted prior to the initialization of fertilizer treatments and in Jan. 2003 and Mar. 2004. |
| Fertility | Potassium sulfate (0-0-50) and treble superphosphate (0-45-0) are applied to all plots at an annual rate of 4.0 lb $K_2O$/1000 $ft^2$ and 3.0 lb $P_2O_5$/1000 $ft^2$. Application of $K_2O$, at a rate of 1.0 lb/1000 $ft^2$, is made in April, May, October, and November. Application of $P_2O_5$, at a rate of 1.5 lb/1000 $ft^2$, is made in April and November. An annual soil test is taken in Dec. 2001, 2002, and 2003. |
| Pesticide application | In order to ensure representative tall fescue, pesticides will be applied as needed. To date, fungicides have been applied to treat *Rhizoctonia* brown patch. |

Rev. 7 July 2004 – IR

Figure 2. The effect of four N-fertilizer sources and three N-fertilizer rates on visual turfgrass quality of tall fescue, 6 Nov. 2002 to 8 Oct. 2004.




**Visual Turfgrass Quality**
**1 = Brown/dead tall fescue**
**5 = Minimally acceptable tall fescue**
**9 = Best tall fescue**

Table 4. The effect of N-fertility source and rate on overall visual turfgrass quality (1 to 9 scale, with 1 = worst, 5 = minimally acceptable, and 9 = best tall fescue) and on overall visual turfgrass color (1 to 9 scale, with 1 = brown, 5 = minimally acceptable, and 9 = darkest tall fescue) of tall fescue from 6 Nov. 2002 to 8 Oct. 2004.

| Treatment | | Overall visual turfgrass quality | Overall visual turfgrass color |
|---|---|---|---|
| **ANOVA, repeated measures of a RCB design, 13 treatments** | | | |
| Source[z] | Rate[y] | | |
| Ammonium nitrate | 8 | 6.2 | 6.5 |
| Milorganite | 8 | 6.0 | 6.3 |
| Nutralene | 8 | 6.0 | 6.3 |
| Polyon | 8 | 6.2 | 6.6 |
| Ammonium nitrate | 6 | 6.0 | 6.3 |
| Milorganite | 6 | 5.8 | 6.1 |
| Nutralene | 6 | 5.9 | 6.2 |
| Polyon | 6 | 6.1 | 6.3 |
| Ammonium nitrate | 4 | 5.9 | 6.1 |
| Milorganite | 4 | 5.5 | 5.8 |
| Nutralene | 4 | 5.7 | 6.0 |
| Polyon | 4 | 5.8 | 6.0 |
| Check | 0 | 4.8 | 5.0 |
| LSD, $P = 0.05$[x] | | 0.2 | 0.2 |
| Repeated measures design effects (*P*) | | | |
| Treatment (T) | | < 0.0001 | < 0.0001 |
| Date (D) | | < 0.0001 | < 0.0001 |
| T x D | | < 0.0001 | < 0.0001 |
| **ANOVA, repeated measures of a 4 × 3 factorial design, 12 treatments** | | | |
| Source[z] | | | |
| Ammonium nitrate | | 6.0 | 6.3 |
| Milorganite | | 5.8 | 6.1 |
| Nutralene | | 5.9 | 6.1 |
| Polyon | | 6.0 | 6.3 |
| LSD, $P = 0.05$[x] | | 0.1 | 0.1 |
| Rate[x] | | | |
| 8 | | 6.1 | 6.4 |
| 6 | | 5.9 | 6.2 |
| 4 | | 5.7 | 6.0 |
| LSD, $P = 0.05$[x] | | 0.1 | 0.1 |
| Factorial repeated measures design effects (*P*) | | | |
| Source (S) | | 0.0073 | 0.0064 |
| Rate (R) | | 0.0010 | 0.0003 |
| S x R | | 0.6977 | 0.4437 |
| Date (D) | | < 0.0001 | < 0.0001 |
| D x S | | < 0.0001 | < 0.0001 |
| D x R | | < 0.0001 | < 0.0001 |
| D x S x R | | 0.2442 | 0.3444 |

[z] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y] Annual rates as lb N/1000 $ft^2$ per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P = 0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% $ET_o$ (Table 3).

Table 5. The effect of N-fertility source and rate on the percent of rating dates that tall fescue visual turfgrass quality was ≥ 5.0, ≥ 5.5, ≥ 6.0, and ≥ 6.5 (based on a 1 to 9 scale, with 1 = worst, 5 = minimally acceptable, and 9 = best tall fescue) from 6 Nov. 2002 to 8 Oct. 2004.

| Treatment | | 6 Nov. 2002 to 10 Oct. 2003 | | | | 24 Oct. 2003 to 8 Oct. 2004 | | | | 6 Nov. 2002 to 8 Oct. 2004 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ≥ 5.0 | ≥ 5.5 | ≥ 6.0 | ≥ 6.5 | ≥ 5.0 | ≥ 5.5 | ≥ 6.0 | ≥ 6.5 | ≥ 5.0 | ≥ 5.5 | ≥ 6.0 | ≥ 6.5 |
| | | *------------- % of 24 rating dates -------------* | | | | *------------- % of 24 rating dates -------------* | | | | *------------- % of 48 rating dates -------------* | | | |
| Source[z] | Rate[y] | | | | | | | | | | | | |
| Ammonium nitrate | 8 | 100 | 96 | 79 | 50 | 100 | 100 | 67 | 17 | 100 | 98 | 73 | 33 |
| Milorganite | 8 | 100 | 71 | 46 | 13 | 100 | 100 | 71 | 8 | 100 | 85 | 58 | 10 |
| Nutralene | 8 | 100 | 83 | 67 | 13 | 100 | 100 | 67 | 0 | 100 | 92 | 67 | 6 |
| Polyon | 8 | 100 | 100 | 75 | 25 | 100 | 100 | 88 | 17 | 100 | 100 | 81 | 21 |
| Ammonium nitrate | 6 | 100 | 83 | 67 | 4 | 100 | 92 | 67 | 0 | 100 | 88 | 67 | 2 |
| Milorganite | 6 | 92 | 54 | 29 | 8 | 100 | 92 | 71 | 0 | 96 | 73 | 50 | 4 |
| Nutralene | 6 | 88 | 67 | 21 | 0 | 100 | 88 | 71 | 8 | 94 | 77 | 46 | 4 |
| Polyon | 6 | 100 | 100 | 63 | 8 | 100 | 100 | 75 | 4 | 100 | 100 | 69 | 6 |
| Ammonium nitrate | 4 | 100 | 75 | 46 | 0 | 100 | 83 | 63 | 0 | 100 | 79 | 54 | 0 |
| Milorganite | 4 | 75 | 38 | 17 | 0 | 96 | 83 | 33 | 0 | 85 | 60 | 25 | 0 |
| Nutralene | 4 | 79 | 46 | 17 | 0 | 100 | 83 | 54 | 0 | 90 | 65 | 35 | 0 |
| Polyon | 4 | 100 | 63 | 21 | 0 | 100 | 96 | 50 | 0 | 100 | 79 | 35 | 0 |
| Check | 0 | 25 | 17 | 0 | 0 | 38 | 13 | 0 | 0 | 31 | 15 | 0 | 0 |

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 $ft^2$ per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% $ET_o$ (Table 3).

Table 6. The effect of N-fertility source and rate on the percent of rating dates that tall fescue visual turfgrass color was ≥ 5.0, ≥ 5.5, ≥ 6.0, and ≥ 6.5 (based on a 1 to 9 scale, with 1 = brown, 5 = minimally acceptable, and 9 = darkest tall fescue) from 6 Nov. 2002 to 30 Jan. 2004.

| Treatment | | 6 Nov. 2002 to 10 Oct. 2003 | | | | 24 Oct. 2003 to 30 Jan. 2004 | | | | 6 Nov. 2002 to 30 Jan. 2004 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ≥ 5.0 | ≥ 5.5 | ≥ 6.0 | ≥ 6.5 | ≥ 5.0 | ≥ 5.5 | ≥ 6.0 | ≥ 6.5 | ≥ 5.0 | ≥ 5.5 | ≥ 6.0 | ≥ 6.5 |
| | | *% of 24 rating dates* | | | | *% of 26 rating dates* | | | | *% of 50 rating dates* | | | |
| Source[z] | Rate[y] | | | | | | | | | | | | |
| Ammonium nitrate | 8 | 100 | 100 | 83 | 71 | 100 | 100 | 100 | 46 | 100 | 100 | 92 | 58 |
| Milorganite | 8 | 100 | 79 | 54 | 29 | 100 | 100 | 92 | 42 | 100 | 90 | 74 | 36 |
| Nutralene | 8 | 100 | 83 | 79 | 25 | 100 | 100 | 92 | 35 | 100 | 92 | 86 | 30 |
| Polyon | 8 | 100 | 100 | 96 | 58 | 100 | 100 | 100 | 77 | 100 | 100 | 98 | 68 |
| Ammonium nitrate | 6 | 100 | 83 | 71 | 58 | 100 | 100 | 85 | 42 | 100 | 92 | 78 | 50 |
| Milorganite | 6 | 100 | 75 | 50 | 17 | 100 | 100 | 85 | 35 | 100 | 88 | 68 | 26 |
| Nutralene | 6 | 100 | 83 | 54 | 17 | 100 | 96 | 85 | 46 | 100 | 90 | 70 | 32 |
| Polyon | 6 | 100 | 100 | 71 | 21 | 100 | 100 | 96 | 38 | 100 | 100 | 84 | 30 |
| Ammonium nitrate | 4 | 100 | 83 | 63 | 21 | 100 | 92 | 77 | 31 | 100 | 88 | 70 | 26 |
| Milorganite | 4 | 79 | 38 | 21 | 8 | 100 | 92 | 62 | 8 | 90 | 66 | 42 | 8 |
| Nutralene | 4 | 100 | 63 | 33 | 8 | 100 | 96 | 85 | 31 | 100 | 80 | 60 | 20 |
| Polyon | 4 | 100 | 75 | 38 | 0 | 100 | 100 | 85 | 8 | 100 | 88 | 62 | 4 |
| Check | 0 | 38 | 25 | 4 | 0 | 46 | 31 | 12 | 0 | 42 | 28 | 8 | 0 |

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 $ft^2$ per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% $ET_o$ (Table 3).

Figure 3. The effect of four N-fertilizer sources and three N-fertilizer rates on $NO_3^-$-N concentration in leachate, 9 Oct. 2002 to 29 Sept. 2004.