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Evaluation of Liquid-Applied Nitrogen Fertilizers on Kentucky Bluegrass Turf

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ABSTRACT

Solution and suspension N sources have been developed as substitutes for urea in spray solutions used by lawn-care professionals. A field study was conducted to evaluate the response of Kentucky bluegrass (*Poa pratensis* L.) growing on a Catlin silt loam (Typic Argiudoll), to applications of the new solution and suspension N sources, alone or combined with urea, by comparison to turf response from application of the traditional fertilizer materials ammonium nitrate (AN), Nitroform (ureaform), sulfur-coated urea (SCU), ammonium sulfate (AS), granular urea, spray-applied urea (US), and urea-ammonium nitrate (UAN) solution. Also, urea and AS treated with dicyandiamide (DCD) were compared to the untreated sources. Fertilization rate was 195 kg N ha $^{-1}$ yr $^{-1}$ split into four applications except SCU which was applied twice. Turfgrass color and clipping production were monitored along with thatch accumulation and soil pH. In a second field experiment, foliar burn potentials of the new N sources were evaluated by comparison to burn potentials from US, UAN, and a liquid 12-1.8-3.3 fertilizer. Turf response to Formolene (solution N source) paralleled that due to US. Turf treated with US received higher color ratings than did that treated with Nitroform or FLUF (suspension N source) during the early growing season but this trend was reversed by late summer. Turf fertilized with FLUF resembled turf fertilized with Nitroform but was inferior to turf fertilized with SCU. There was no benefit from the inclusion of DCD with either AS or urea. Soil pH after 2 yr ranged from 5.3 to 6.4 and was lowest with AS treatment; thatch depth ranged from 7.0 to 19.3 mm and was greatest with AS treatment. Formolene and FLUF caused less foliar injury than did US, UAN, or the 12-1.8-3.3 fertilizer. Results from the two experiments indicated that the major advantage of using Formolene or FLUF was the reduced potential for foliar fertilizer burn.

Additional index words: **Turfgrass, *Poa pratensis* L., Liquid fertilizers, Nitrogen sources, Fertilizer burn, Dicyandiamide.**

TURF fertilizers can be classified as either quick-release (water soluble N sources) or slow-release (sources with a dissolution rate much less than that obtained for a completely water soluble source). Quick-release fertilizers provide a rapid initial turf response but may overstimulate the grass or cause foliar injury and have a short residual (2).

Lawn-care professionals make three to five applications of fertilizer to a home lawn during the year. Because customer satisfaction depends on a noticeable turfgrass response to the applied treatment, the lawn-care companies generally use quick-release N sources. Because of its low cost, high water solubility, and relatively low salt index compared to other soluble N sources, urea is the predominant N source used by this industry. Urea is applied either as a spray with water or in a granular form. During certain times of the year, turf response to urea can dissipate before the next application of fertilizer can be made. Also, there is the potential for foliar fertilizer burn because of the wide range of environmental conditions encountered in scheduling multiple applications to a large customer base.

Alternative N sources have been developed for use by lawn-care companies that apply fertilizer as a spray solution in attempts to overcome the drawbacks of urea. These include a suspension N source (FLUF; W.A. Cleary Chemical Corp., Somerset, NJ) and a solution N source (Formolene; Hawkeye Chemical Co., Clinton, IA) with lower salt indexes than urea. Both materials are manufactured by reacting urea and formaldehyde [FLUF, (10); Formolene, (7)], but reaction conditions are such that only a small amount (3.6%) of water insoluble nitrogen (WIN) is contained in FLUF and no WIN is in Formolene. Nitroform (38-0-0; NOR-AM Chemical Co., Wilmington, DE), the first ureaform fertilizer developed for turfgrass, contains 27% WIN. The response characteristics of Nitroform have been reported previously (1,4,6,11,13,14,15,17,18), but little information has been published regarding turf response to Formolene and FLUF.

A strategy to extend the response period of a quick-release fertilizer is to combine the N source with a nitrification inhibitor. There have been reports on the efficacy of the nitrification inhibitors nitrapyrin [2-chloro-6-(tricholromethyl)pyridine] and terrazole (5-ethoxy-3-trichloromethyl-1,2,4-thiadiazole) in crop situations (5), but less is known regarding the response of turfgrass to nitrogen sources treated with nitrification inhibitors. Waddington et al. (16) found no significant advantage from the inclusion of nitrapyrin with liquid applications of a 20-13-16.6 soluble N source.

Dicyandiamide (DCD) is a nitrification inhibitor that is 66% N and breaks down in the soil to form ammonia and carbon dioxide (12). Landschoot (4) reported little benefit from including DCD with ammonium sulfate

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applications on Kentucky bluegrass (*Poa pratensis* L.) in Pennsylvania. He evaluated color of turfgrass fertilized with 98 kg N ha^{-1} in the form of seven ammonium sulfate/DCD combinations in which form 0 to 100% of the N was from DCD.

The primary objectives of this research were: (i) to evaluate the response of Kentucky bluegrass to applications of solution and suspension N sources, alone or in combination with urea, by comparisons to responses from applications of standard fertilizers, and (ii) to compare the burn potential of these new fertilizers to that of spray-applied urea (US), urea-ammonium nitrate (UAN), and a liquid 12-1.8-3.3 fertilizer. A secondary objective of this research was to compare turf response to applications of ammonium sulfate (AS) and urea, with or without a portion of the N coming from DCD.

MATERIALS AND METHODS

This research was initiated 1 May 1981 on an established turf consisting of a blend of 'Columbia' and 'Touchdown' Kentucky bluegrasses growing on a Catlin silt loam (Typic Argiudoll) located at the Ornamental Horticulture Research Center in Urbana, IL. All treatments were applied at the rate of 195 kg N ha^{-1} yr^{-1}, split into four applications, except for sulfur-coated urea (SCU) which was applied twice during the growing season. Rates and timings were similar to standard practices in professional lawn care. A randomized complete block design with three replications and a plot size of 0.9 by 3.0 m was used. Liquid treatments were applied using a CO_2-pressurized sprayer with water as a carrier in a volume of 1629 L ha^{-1}. Granular materials were hand applied.

The following fertilizers were applied in this study: FLUF, a suspension fertilizer consisting of low molecular weight, water-soluble and water-insoluble ureaformaldehyde reaction products in which up to 16% of the N is free urea (18-0-0, 3.6% WIN, activity index 78; W.A. Cleary Chemical Corp.); Formolene, a N solution which is a low molecular-weight, water-soluble, ureaformaldehyde-reaction product containing approximately 50% of the N as free urea with the remainder as methylol urea and soluble methylene urea (30-0-1.6; Hawkeye Chemical Co.); Formolene acidified with phosporic acid according to a procedure supplied by the Hawkeye Chemical Company, to determine if a change in solution pH would affect fertilizer properties; Nitroform (powdered ureaform, 38-0-0; NOR-AM Chemical Co.) applied as a suspension in water; urea (46-0-0) applied as either a granule or spray (US); urea-ammonium nitrate solution (UAN, 28-0-0); ammonium nitrate (AN, 33-0-0); ammonium sulfate (AS, 21-0-0); AS with 3.2% of the N from DCD (Allied Corp., Hopewell, VA); sulfur-coated urea (SCU, 37-0-0, LESCO, Rocky River, OH); and granular urea (46-0-0) with 4.6% of the N from DCD. Additional treatments consisted of urea combined with some of the other N sources.

The application timings and rates for each treatment are listed in Table 1. As indicated, certain treatments were not applied in 1983. Turfgrass responses evaluated included turf color and fresh clipping weights. Soil pH and thatch accumulation were also determined.

Turf color was visually rated using a scale of 1 to 9, with 1 representing brown turf and 9 representing a dark green color. Color ratings were taken approximately 1 week apart throughout the growing season starting with the second application of fertilizer in 1981 and continuing through July of 1983.

The plots were mowed weekly at a height of 64 mm with a mulching rotary mower so that clippings were returned to the plots. On alternate mowings in 1981 and 1982, the growth rate of the turf was evaluated by collecting clippings from a 1.3-m^2 area on each plot using a rear-bagging rotary mower and determining the fresh weight of the clippings. Clippings were returned to respective plots after weighing.

Thatch depth was measured on 27 May and 6 Oct. 1982 by removing three plugs (50 by 50 by 50 mm deep) from each plot, removing the verdure, placing a 373 g weight on the plug, and measuring the compressed thickness of thatch. In November of 1982, soil pH was determined using samples taken to a depth of 50 mm, on a 50:50 (weight/weight) mixture of soil and distilled water.

A separate analysis of variance, using a split plot in time with fertilizer treatment as the main plot and rating date as the subplot, was conducted for color ratings and clipping weights for the 7 to 9 week period between each fertilizer application. Because there was a significant date × fertilizer treatment interaction, a separate analysis of variance was then conducted for each date when color or clipping production was evaluated. Treatment means were evaluated for each date using planned, single degree-of-freedom contrasts as indicated in Table 2. Additional analyses of variance were conducted for thatch depth and soil pH. With these data, means were evaluated using Fisher's Least Significant Difference Test since it was of interest to rank the treatments according to their influence on thatch development and soil pH (Table 3). Since all treatments were applied at the same N rate, thatch accumulation and soil pH reflected qualitative differences between the treatments.

Table 1. Schedule of treatment rates and dates of application.

Treatment	Application date: 01 May 81 / 21 Apr 82 / 06 May 83	18 Jun 81 / 18 Jun 82 / 16 Jun 83	06 Aug 81 / 19 Aug 82 / 16 Aug 83	09 Oct 81 / 14 Oct 82
	kg N ha^{-1}			
	Granular applied			
Ammonium nitrate	48.8	48.8	48.8	48.8
Ammonium sulfate	48.8	48.8	48.8	48.8
Ammonium sulfate + 3.2% DCD	48.8	48.8	48.8	48.8
Sulfur-coated urea	97.6	--	97.6	--
Urea	48.8	48.8	48.8	48.8
Urea + 4.6% DCD†	48.8	48.8	48.8	48.8
	Liquid applied			
FLUF†	48.8	48.8	48.8	48.8
FLUF/urea, 50:50†	24.4:24.4	24.4:24.4	24.4:24.4	24.4:24.4
FLUF/urea, 75:25	36.6:12.2	36.6:12.2	36.6:12.2	36.6:12.2
Formolene†	48.8	48.8	48.8	48.8
Formolene w/WIN†	48.8	48.8	48.8	48.8
Formolene/urea, 50:50	24.4:24.4	24.4:24.4	24.4:24.4	24.4:24.4
Nitroform†	48.8	48.8	48.8	48.8
Nitroform/urea I	0:24.4	73.2:12.2	0:0	61.0:24.4
Nitroform/urea II†	0:24.4	24.4:24.4	24.4:24.4	48.8:24.4
Urea†	48.8	48.8	48.8	48.8
Urea-ammonium nitrate	48.8	48.8	48.8	48.8
Check (no fertilization)	--	--	--	--

† Applied during each season; others applied in 1981 and 1982 only.

Carrier Rate Study

A separate experiment was conducted to determine the burn potential of Formolene and FLUF in comparison to urea, UAN, and a liquid 12-1.8-3.3 fertilizer (urea-ammonium polyphosphate-potassium chloride). All fertilizers were applied at the rate of 49 kg N ha^{-1} with water as a carrier, using a CO_2-pressurized sprayer with application volumes of 1.2×10^3, 8.2×10^2, and 4.1×10^2 L ha^{-1}. The fertilizers were applied on 8 May, 23 June, 26 July, and 12 Oct. 1982 to an area adjacent to the first experiment using a randomized complete block design with a factorial arrangement of treatments and a plot size of 0.9 by 3.0 m.

Table 2. Summary of single degree-of-freedom planned comparisons of color ratings and clipping weights of Kentucky bluegrass fertilized with various N sources for 3 yr.

Treatment 1	vs.	Treatment 2	Color ratings†			Clipping weights‡		
			1 > 2*	2 > 1*	1 = 2	1 > 2*	2 > 1*	1 = 2
Ammonium sulfate		Ammonium sulfate + 3.2% DCD	7	1	28	5	0	14
Urea, granular		Urea + 4.6% DCD	2	5	39	0	0	19
Sulfur-coated urea		Urea, granular	10	12	14	4	3	12
Urea, liquid		Urea, granular	0	12	24	0	3	16
FLUF		Urea, liquid	4	4	38	0	1	18
Nitroform		Urea, liquid	9	10	27	0	2	17
Formolene		Urea, liquid	4	0	42	0	0	19
Ammonium nitrate		Urea-ammonium nitrate	21	0	17	1	0	18
FLUF		Sulfur-coated urea	1	21	16	0	5	14
Nitroform		Sulfur-coated urea	1	16	21	1	8	10
FLUF		FLUF/urea 50:50	5	3	38	0	1	18
FLUF		FLUF/urea 75:25	1	1	36	2	1	16
Formolene		Formolene/urea 50:50	0	0	38	1	0	18
Formolene		Acid Formolene	9	2	35	5	3	11
Nitroform		Nitroform/urea I	11	10	34	0	4	15
Nitroform		Nitroform/urea II	3	3	32	0	1	18
FLUF		Nitroform	2	2	42	0	0	19
Urea, liquid		Check	40	0	6	16	0	3

* Significant at the 0.05 probability level.
† 46 rating dates for treatments applied 1981 to 1983; 36 rating dates for treatments applied in 1981 and 1982 only.
‡ Clippings collected in 1981 and 1982.

Fertilizer burn was evaluated as a percentage of the total leaf surface area of the plot that was damaged (Table 4). Data were analyzed for a factorial arrangement of treatments with N source and application volume as the factors. The most severe fertilizer burn occurred due to the 28 July application and data for this date only are presented in the results section.

RESULTS

The N sources and programs evaluated in this research generally provided acceptable results as evidenced by the predominance of color ratings above 7 on a scale of 1 to 9 (Fig. 1 and 2). There were, however, significant differences between treatments for all parameters measured. Summaries of the significant differences in color ratings and clipping weights are given in Table 2. Planned comparisons were designed (i) to determine the efficacy of Formolene and FLUF compared to US; (ii) to compare FLUF, which contains 20% WIN, to SCU and Nitroform, two traditional slow-release N sources; (iii) to determine the effect of combining urea with Formolene, FLUF, and Nitroform; (iv) to determine the efficacy of the bacterial inhibitor DCD as an additive to turfgrass fertilizers; and (v) to compare granular applications of urea and ammonium nitrate to US and UAN, respectively.

Turfgrass responses to Formolene applications paralleled the response to applications of US. Significant differences between the treatments occurred on only four of 46 rating dates for color, while there was no significant differences due to treatment in clipping weights. Similarly, turfgrass response to FLUF was generally not different from response to US. On eight occasions, there were significant differences in color rating; there was a significant difference in clipping weight on only one occasion. Turfgrass color from US

Table 3. Soil pH value and thatch accumulation for Kentucky bluegrass after two seasons of treatment with various N sources.

Fertilizer source†	Soil pH	Thatch accumulation
	November 1982	October 1982
		mm
Ammonium nitrate	6.24bc‡	15.9a–c
Urea-ammonium nitrate	6.29a–c	8.8fg
Ammonium sulfate	5.32d	19.3a
Ammonium sulfate + 3.2% DCD	5.42d	19.2ab
Sulfur-coated urea	6.11c	14.0bc
Urea, granular	6.32ab	11.2c–g
Urea + 4.6% DCD	6.23bc	12.7c–f
Urea, liquid	6.37ab	9.6d–g
FLUF	6.44a	12.6c–f
FLUF/urea 50:50	6.33ab	9.9d–g
FLUF/urea 75:25	6.33ab	9.1d–g
Formolene	6.26a–c	7.9fg
Formolene w/WIN	6.33ab	8.7fg
Formolene/urea 50:50	6.35ab	7.7fg
Nitroform	6.41ab	7.0g
Nitroform/urea I	6.32ab	6.3g
Nitroform/urea II	6.40ab	14.2a–d
Check (no fertilization)	6.35ab	7.9fg
LSD (0.05)	0.20	5.2

† All treatments supplied 195.2 kg N ha^{-1} per season.
‡ Means followed by the same letter are not significantly different as determined by Fisher's LSD Test (P = 0.05).

Table 4. Foliar fertilizer burn injury from liquid N sources at three application volumes.

Treatments applied 26 July 1982; ratings taken 29 July 1982.

N source	Spray volume	% Injury	Mean
	L ha^{-1}		
12-1.8-3.3	4.1×10^2	6.7	
	8.2×10^2	11.7	7.8b†
	1.2×10^3	5.0	
Urea	4.1×10^2	8.0	
	8.2×10^2	7.7	6.7b
	1.2×10^3	4.3	
Urea-ammonium nitrate	4.1×10^2	15.0	
	8.2×10^2	16.7	12.0a
	1.2×10^3	4.3	
Formolene	4.1×10^2	0.3	
	8.2×10^2	0.0	0.1c
	1.2×10^3	0.0	
FLUF	4.1×10^2	0.0	
	8.2×10^2	0.0	0.0c
	1.2×10^3	0.0	

† Means followed by the same letter are not significantly different at P = 0.05 by the Fisher Least Significant Difference Test.

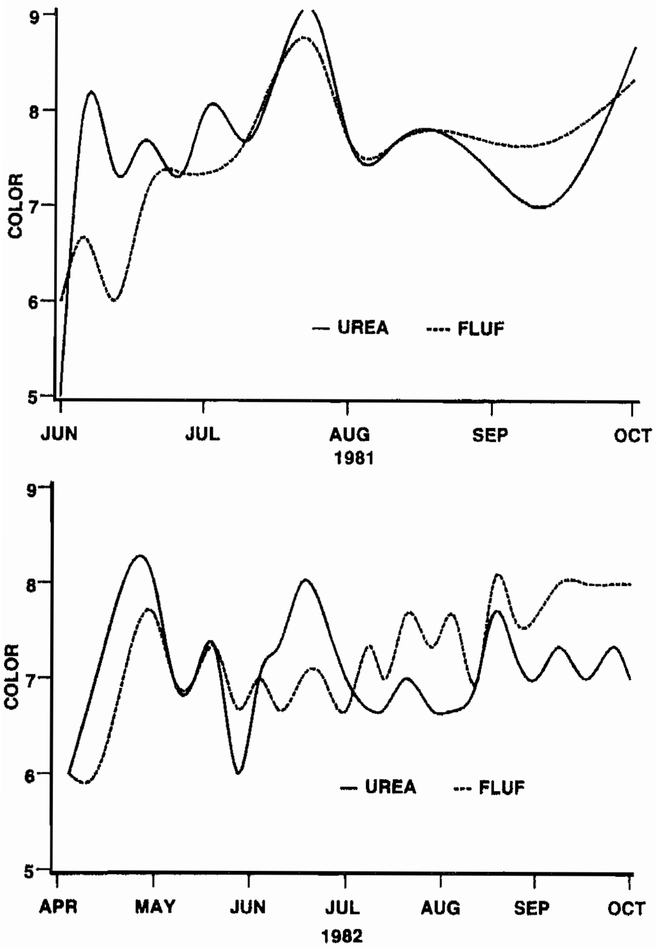

Fig. 1. Color response of Kentucky bluegrass treated with FLUF or urea, in 1981 or 1982. Spline routine used to smooth curves (9) (1 = brown turf, 9 = dark green).

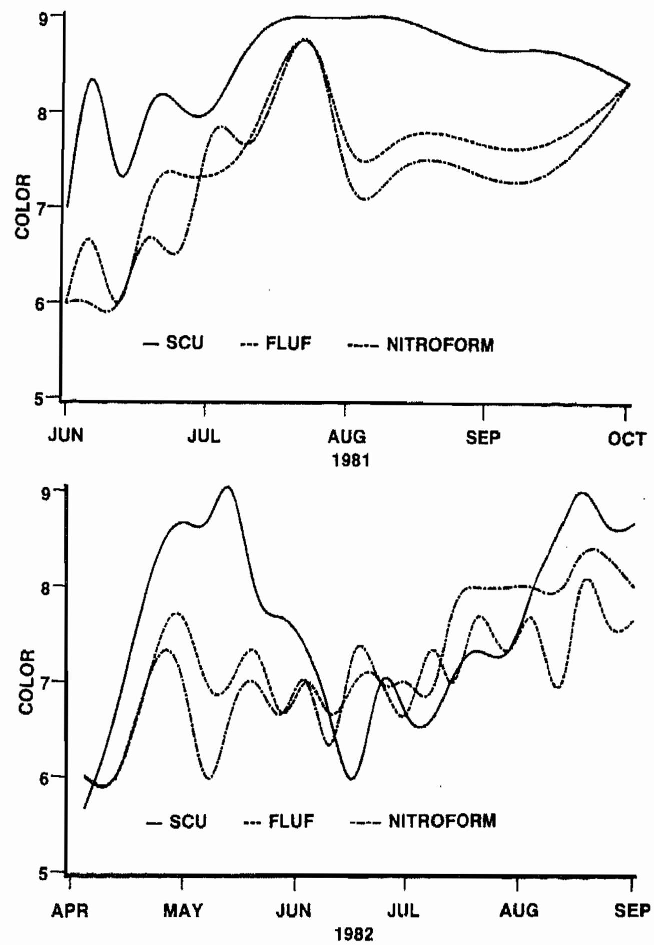

Fig. 2. Color response of Kentucky bluegrass treated with sulfur-coated urea (SCU), FLUF, or Nitroform, in 1981 or 1982. Spline routine used to smooth curves (9) (1 = brown turf, 9 = dark green).

was rated numerically higher than FLUF-treated turf in the spring of the year while this trend reversed itself toward the fall of the year (Fig. 1).

Since FLUF contained 20% of the total N as WIN, it was compared to SCU and Nitroform (Fig. 2). Color ratings for turf treated with FLUF agreed closely with those for turf treated with Nitroform, even though FLUF contains a larger portion of its N in a water-soluble form. FLUF did not compare favorably with SCU.

Because both Formolene and FLUF are reaction products of urea and formaldehyde, their costs are based on an additional manufacturing step and range from 100 to 150% more than that of urea. Costs could be reduced by using mixtures of these products and urea; thus, there was interest in determining the effect of urea additions on turfgrass response. Formolene has approximately 50% of its N as free urea while FLUF contains up to 16% of its N as free urea. Adding urea to Formolene did not change the turfgrass response; adding urea to FLUF had minimal effect on turfgrass response.

No advantage was apparent from adding the nitrification inhibitor DCD to AS. Color ratings for turf fertilized with AS were higher than ratings for turf fertilized with AS + DCD on seven dates, and clipping weights were greater on five dates. Turf fertilized with the urea + DCD combination received higher color ratings than did the urea-fertilized turf in late May, early June, and late October of 1982; however, these differences represented only five of the 46 rating dates.

On one-third of the rating dates, turf fertilized with granular urea received higher color ratings than did turf fertilized with US. Ammonium-nitrate-fertilized turf received higher color ratings than did turf treated with UAN on two-thirds of the rating dates.

The depth of thatch and the soil pH associated with each treatment are indicated in Table 3. The largest accumulation of thatch occurred with turf treated with AS or AS + DCD. Thatch accumulation is a function of the growth rate of the turf and the rate of decomposition of the organic matter (2). Factors that affect the rate of decomposition of organic matter include soil moisture, pH, temperature, microorganism population, and soil aeration. Thatch decomposition is favored at near-neutral pH. As expected, soil pH was lowest where turf was fertilized with either of the AS treatments. Where thatch accumulated in association with treatments that had minimal effect on pH, e.g., AN, the increased growth rate, compared to that of the check plot, was probably responsible for the accumulation of thatch.

Carrier Rate Study

Both Formolene and FLUF caused less foliar fertilizer burn than did either US, UAN, or the liquid 12-1.8-3.3. The N source × spray volume interaction was significant, probably as a result of the failure of FLUF and Formolene to burn the turf at any dilution. The burn data were collected after fertilizer application on 26 July 1982, the date when the most severe burn occurred. The high temperature on 26 July was 31°C while for the other application dates it ranged from 14 to 23°C. The results of the experiment indicate that fertilizer burn with US, UAN, and the 12-1.8-3.3 material was more severe at a carrier rate of 8.2×10^2 L ha^{-1} than at the rate of 4.1×10^2 L ha^{-1}. This result may have been due to quicker drying of the fertilizer solution at the lowest application rate and the resultant loss of contact between the leaf surface and the fertilizer material. Undiluted Formolene and FLUF were also applied to turf and there was no burn.

DISCUSSION

Fertilizer manufacturers have developed the technology to react urea with formaldehyde to produce several types of N sources. These N sources differ in the rate at which N is released. The higher the content of WIN, the longer the release period and the slower the initial response of the turf. The differences between US, FLUF, and Nitroform in our research were minimal despite the fact that they represented a range from no WIN to 20 and 66% of the total N as WIN, respectively. Landschoot (4), using these same sources in a field study in Pennsylvania, found considerable differences in turfgrass color due to treatments. Out of 44 rating dates, urea-treated turf rated significantly higher than FLUF-treated turf on 18 dates and significantly higher than Nitroform-treated turf on 36 dates. He spray-applied the fertilizers in the same manner that we did but made two applications per year at 98 kg N ha^{-1} rather than four applications at 49 kg ha^{-1}. Thus, the differences in initial color between the US-treated turf and turf receiving the other treatments would be expected to be greater. Furthermore, we did not start taking data until after the second application of fertilizer in the first year, which meant that some residual Nitroform was probably available to supplement the second fertilizer application. Finally, differences in soil characteristics between the Pennsylvania and Illinois sites may have affected our results.

The SCU treatment was applied two times per year at the rate of 98 kg N ha^{-1} as has been done by other researchers (3,4). The superior color ratings from this fertilizer may have been due to this specific application rate. However, in other research conducted at the University of Illinois (unpublished data), where four 49 kg N ha^{-1} applications of SCU were made, turfgrass color was superior to that generated by other treatments. There have been no indications of a sulfur deficiency on our research area, so these results are attributed to the N-release characteristics of SCU.

Based on our research, the most significant advantage of using either Formolene or FLUF is the reduced potential for foliar fertilizer burn. The lack of response to DCD may have resulted from the excellent nutrient-holding capacity of the Catlin soil. Nelson and Huber (8) have indicated that in crop situations, where nutrient loss is not a problem, there have not been yield responses to nitrapyrin.

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