following treatment. These two treatments also gave an average 42% increase in grass yield for the year following treatment but were inferior to leaf mold, an organic soil amendment, which had a 61% increase in grass yield for the year. Leaf mold stimulated grass growth but, as can be expected, resulted in an 81% increase in nematodes due to increased root production. Unfortunately, the increase in nematode population can prove detrimental to grass growth during the next growing season. The possibility becomes implicit, and worthy of further test, that annual nematicide treatment and an annual treatment with an organic soil amendment applied six months apart could yield the best results.

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EFFECTIVENESS OF SLOW-RELEASE N FERTILIZERS IN MAINTAINING TURFGRASS QUALITY AND GROWTH[1]

J. B. SARTAIN
University of Florida, IFAS,
Soil Science Department,
Gainesville, Florida 32611

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Abstract. **A number of synthetic slow-release N sources were compared with $(NH_4)_2SO_4$ at two N rates (7.5 and 15.0 g N/m^2/90 days) relative to their influence on the growth and quality of 'Derby' ryegrass and 'Tifway' bermudagrass over a three year period. In general, CIL SCU IBDU and $(NH_4)_2SO_4$ produced the highest yields and visual rating on the ryegrass. A mottled appearance was observed in the turfgrass for the first 4 to 6 weeks after application where TVA SCU was used. In contrast, the TVA SCU, Ag Ind. SCU ,CIL SCU and Oxamide produced the highest yield and visual rating on the bermudagrass. Acceptable turfgrass growth and quality can be maintained throughout a 12-week period by the use of 7.5 g N/m^2 from most of the slow-release materials which were tested.**

Turfgrasses require large quantities of N fertilizers to remain a desirable dark green color. In Florida where the soils are sandy and of low exchange capacity and rainfall is high, the movement of soluble N is rapid. Frequent applications of N are common. Nitrogen materials which solublize less rapidly or release their N to the grass according to the uptake pattern of the grass would tend to limit the quantity of N lost through leaching and increase the efficiency of the applied N. Synthetic slow-release N materials have been produced in the recent past which have the capacity to resist immediate dissolution and release their N over a longer period of time.

Urea formaldehyde (UF) has been a more controversial product with about one-third of its N in a form having negligible controlled-release characteristics, and another third in a form with very slow availability (2). Reports on IBDU show that it has characteristics markedly different from UF. Availability rate of N depends on granular size and the presence of water (1). The primary characteristics reported for IBDU are a slow initial release of N and an abrupt response curve once the material begins releasing N. Sulfur-coated urea (SCU) has been shown to have a relatively low dissolution and to be a good product on warm season turfgrasses (3).

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Research was initiated at the Horticultural Unit near Gainesville with the following objectives: (1) To determine the effectiveness of synthetic slow-release N materials in supplying N to 'Tifway' bermudagrass and 'Derby' ryegrass, (2) To evaluate the effect of climatic conditions on the release properties of the N materials, and (3) To evaluate the effect of application rate on the effectiveness of the N sources.

Materials and Methods

Several different synthetic slow-release N materials were evaluated relative to their influence on the visual appearance, yield and N uptake of bermudagrass (*Cynodon dactylon* (L.) PERS X *Cynodon transvaalinsis* BURTT DAVY) and perennial ryegrass (*Lolium perenne* L.). During the fall 'Derby' ryegrass was seeded over 'Tifway' bermudagrass growing on a loamy fine sand (Typic Quartzipsamment). Nitrogen treatments were applied in a split-plot arrangement on plots 1.83 x 2.73 m and replicated three times. Whole plot treatments were composed of two N rates (7.5 and 15.0 g N/m^2). Sub-plot treatments were different sources of slow-release N with $(NH_4)_2SO_4$ as a standard water soluble N material. All N sources were applied at 90-day intervals.

This investigation extended over a three year period and the N sources under study changed as information on the materials was acquired and as new synthetic slow-release N sources became available. Clippings were collected for yield and total N analysis at 45-day intervals. Visual ratings were made on a weekly basis in 1978 and on a biweekly basis in 1979 and 1980. The range of the rating scale was 1 to 9 with 5.5 representing the minimum acceptable turfgrass. Mowing heights were maintained at 1.9 and 2.5 cm for bermudagrass and ryegrass, respectively.

Results and Discussion

1978. The average yield, N uptake and visual rating for 'Derby' ryegrass and 'Tifway' bermudagrass grown in 1978 as influenced by selected slow-release N sources are given in Table 1. Small differences in yield and N uptake by the ryegrass were noted in response to the N source, except in the case of TVA SCU (5% dissolution). This material is heavily coated and the N is released very slowly during the cool season. A number of statistical classes were noted among the means for visual rating across N sources; however, all sources, except the TVA SCU (5% diss.) produced an average visual rating higher than the minimum acceptable level of 5.5. Both sources of Canadian Industries

Table 1. Effect of N source on the average yield, N uptake and visual rating of 'Derby' ryegrass and 'Tifway' bermudagrass (1978).

Source	Ryegrass Average yield	Ryegrass Total N uptake	Ryegrass Average rating[z]	Bermudagrass Average yield	Bermudagrass Total N uptake	Bermudagrass Average rating
	........kg/ha/day........			........kg/ha/day........		
IBDU (1.0 to 2.5 mm)	6.94a[y]	0.88ab	6.25c	23.74a	2.80a	7.11a
IBDU (0.7 to 2.0 mm)	7.91a	1.00ab	6.80b	23.30ab	2.60ab	7.17a
CIL SCU (Reg)	8.21a	1.02ab	7.54a	20.37bc	2.40bc	7.40a
CIL SCU (fine)	8.35a	1.09a	6.98b	22.54ab	2.72ab	7.50a
TVA SCU (5% diss)	3.07b	0.34c	5.06d	18.76c	2.16c	5.70b
$(NH_4)_2SO_4$	6.15a	0.70b	7.57a	14.86d	1.56d	7.13a

[z]Visual rating scale 1 to 9 with 5.5 representing minimum acceptable turfgrass appearance.
[y]Any two means within a column followed by the same letter do not differ significantly at the 5% level of probability as judged by Duncan's New Multiple Range Test (DNMRT).

Limited Sulfur-coated Urea (CIL SCU) were smaller and more uniform in prill configuration than the TVA SCU and produced a more acceptable turfgrass appearance. A highly mottled, unacceptable appearance was produced by the large granules of the slowly soluble TVA SCU. Soluble $(NH_4)_2SO_4$ declined in visual rating with time, but on the average produced a high quality turfgrass. Isobutylidene diurea (IBDU) did not rank among the top group of N sources in average visual rating. This lower rating is the resultant of a delay in response after application. Approximately six weeks were required after application before an improvement in turfgrass appearance was noted.

Yield and N uptake responses by bermudagrass to the selected slow-release N materials were similar to the observed responses on ryegrass with the heavily coated TVA SCU giving the poorest response. The mottled appearance observed during the cool season growth was not as apparent during the warm season growth. Soluble $(NH_4)_2SO_4$ was generally inferior to the slow-release materials during the warm season. A rapid response in appearance was observed followed by a gradual decline after about four weeks, whereas, many of the slow-release N materials required about four weeks before a response was observed. A mixture of $(NH_4)_2SO_4$ and a slow-release N source should produce a more acceptable turfgrass over the entire rating period than either of the materials used alone.

1979. The responses of the two turfgrasses to the slow-release N sources applied in 1979 are given in Table 2. Average yield and N uptake by ryegrass did not differ significantly across the slow-release N sources. Ryegrass was not growing as rapidly in response to the application of $(NH_4)_2SO_4$ at the end of 45 and 90 days on the average as it was for the other N sources. The average visual rating for $(NH_4)_2SO_4$ was among the top group statistically, however, individual biweekly rating indicate a sharp decline in rating with time and the apparent need for more N after about 6 weeks.

By reducing the thickness of the sulfur-coating on the urea the cool season response to the TVA SCU (30% dissolution) improved. This material is comparable to the SCU produced by the TVA patent which is commercially available. A mottled appearance was produced by this material during the cool season, but it tended to diminish with time such that 30 to 40 days after application the mottling was not apparent. A slight mottled appearance was noted on the CIL SCU (Regular) immediately after application but subsided after 15 to 20 days. The slightly larger particle size of the new formulation of IBDU did not significantly influence the performance of the material.

A somewhat different response was obtained when the same slow-release N sources were used on bermudagrass. During the warm season growth, TVA SCU (30% dissolution) promoted the highest yield, N uptake and visual rating of all the materials. However, the CIL SCU (Regular) produced a more uniform response throughout the rating period. As was observed in 1978, $(NH_2)_4SO_2$ is inferior to the slow-release N sources during the warm season growth period when relatively large quantities of leaching rainfall occurs. A lower average visual rating was observed for IBDU, however, the overall appearance of the turfgrass was well above the minimum acceptable level at all times throughout the growth period.

Table 2. Effect of N source on average yield, total N uptake and visual rating of 'Derby' ryegrass and 'Tifway' bermudagrass (1979).

Source	Average yield	Total N uptake	Average[z] rating
	Ryegrass		
	..........kg/ha/day..........		
IBDU (1.0 to 2.5 mm)	16.84a	2.26a	7.01bc
IBDU (0.7 to 2.0 mm)	17.98a	2.38a	7.00bc
CIL SCU (Reg)	18.99a	2.45a	7.61a
CIL SCU (fine)	18.68a	2.49a	7.00bc
TVA SCU (30% diss)	17.47a	2.31a	6.54d
$(NH_4)_2SO_4$	13.09b	1.50b	7.30ab
	Bermudagrass		
IBDU (1.0 to 2.5 mm)	20.53b	2.50b	6.59e
50% IBDU + 50% CIL SCU	20.27b	2.18b	6.87dc
CIL SCU (Reg)	22.84b	2.33b	7.69ab
CIL SCU (fine)	22.45b	2.32b	7.37nc
TVA SCU (30% diss)	29.55a	3.19a	7.75a
$(NH_4)_2SO_4$	16.45c	1.57c	7.09cd

[z]Any two means within a column followed by the same letter do not differ significantly at the 5% level of probability as judged by DNMRT.

1980. Ryegrass growth and appearance was significantly influenced by the N source during the winter and early spring of 1980 (Table 3). The small prilled CIL SCU (fine) and IBDU produced the highest yield and N uptake compared to the other slow-release N sources on a statistical basis. The only slow-release N source which failed to produce the maximum statistical yield and N uptake was a new and experimental sulfur-coated urea produced by TVA. This product is produced by coating an evaporative melt urea with sulfur and is referred to as TVA Evaporative-Melt SCU.

Average visual ratings for all materials were high and well above the minimum acceptable level. Individual ratings for CIL SCU (both sizes), TVA SCU (30% diss) and Ag. Ind. SCU (a product produced by Agricultural Industries under the TVA patent) were statistically similar and high in quality. As in the two previous years (1978 and 1979), a long lag period elapsed after application of IBDU before maximum response was noted. During this cool season period maximum visual ratings were not observed until eight weeks after application, but at no time did

Table 3. Effect of N source on average yield, N uptake and visual rating of 'Derby' ryegrass and 'Tifway' bermudagrass (1980).

Source	Average yield	Total N uptake	Average[z] rating
	Ryegrass		
	..........kg/ha/day..........		
TVA Evp. Melt SCU	6.1b	0.74cd	6.6c
Ag Ind. SCU	7.5ab	0.93abcd	7.7b
IBDU (1.0 to 2.5 mm)	8.3a	1.16a	7.3d
33% IBDU + 67% CIL SCU	6.6ab	0.86bcd	7.4cd
CIL SCU (Reg)	7.8ab	0.96abc	7.8a
CIL SCU (fine)	8.0a	1.09ab	7.7b
TVA SCU (30% diss)	7.7ab	0.97abc	7.4cd
$(NH_4)_2SO_4$	6.0b	0.68d	7.5c
	Bermudagrass		
TVA Evp Melt SCU	19.1d	1.93a	7.3a
Ag Ind. SCU	13.1bc	1.26bcd	7.0ab
IBDU (1.0 to 2.5 mm)	8.1d	0.85e	6.7b
Oxamide	10.4cd	1.06cde	7.0ab
Ureaform	9.6cd	0.94de	6.8b
CIL SCU (Reg)	15.4ab	1.50b	7.2a
CIL SCU (fine)	14.7b	1.40bc	7.2a
TVA SCU (30% diss)	16.8ab	1.66ab	7.4a
$(NH_4)_2SO_4$	15.5ab	1.38bc	6.9ab

zAny two means within the same column followed by the same letter do not differ significantly at the 5% level of probability as judged by DNMRT.

the turfgrass visual rating fall below 6.5. Also as in previous years, the overall quality of the ryegrass on $(NH_4)_2SO_4$ treated plots was statistically equivalent to the best of the slow-release materials. Contrary to its observed response on ryegrass, TVA Evp Melt SCU produced an acceptable yield and visual quality response on bermudagrass and was statistically equivalent to all the other sulfur-coated ureas under study. A new experimental product, oxamide, produced a dark blue-green turfgrass color throughout the rating such that at the end of the 12-week rating period the turf quality was superior to all the other materials. Investigations will continue on oxamide. The ureaform product used in this study was a new formulation which was designed for cool season application, however, the growth, N uptake and visual rating at the end of the rating period for this product was inferior to the sulfur-coated products.

Effect of N Rate: Both turfgrasses responded almost linearly to the application of N. A two-fold increase in N resulted in almost a two-fold increase in yield and N uptake by the two turfgrasses (Table 4). A higher overall visual rating was also attained at the higher rate of N (15.0 g N/m^2), but it should also be noted that an acceptable level of turfgrass was obtained with lower rate of N application

Table 4. Effect of N rate on the average yield, N uptake and rating for 'Derby' ryegrass and 'Tifway' bermudagrass (1980).

N rate	Average yield	Total N uptake	Average rating
g/m^2		......kg/ha/day......	
		Ryegrass	
7.5	4.6b[z]	0.51b	6.7b
15.0	9.3a	1.22a	8.1a
		Bermudagrass	
7.5	8.7b	8.78b	6.4b
15.0	18.9a	1.91a	7.8a

zAny two means within a column followed by the same letter do not differ significantly at the 5% level of probability as judged by DNMRT.

(7.5 g N/m^2) of some of the materials. This is an average and not all materials produced an acceptable turfgrass quality.

Effect of Time: The quantity of N accumulated by ryegrass and bermudagrass relative to sampling time as influenced by N source is given in Table 5. A material which is capable of supplying a uniform level of N over an extended period of time is most desireable. The apparent N release characteristics of a slow-release N material can be judged by determining the quantity of N accumulation at different sampling dates throughout the growth period. During the cool season Ag. Ind. SCU and CIL SCU (Reg) had the smallest variation in total N accumulation across sampling dates. On bermudagrass, the sulfur-coated urea products released the largest quantity of N during the first 40 days. No large differences in N accumulation by sources were noted 110 days after application.

Table 5. Effect of N source on the accumulation of N by 'Derby' ryegrass and 'Tifway' bermudagrass over time (1980).

N Source	Days after application 45	90
Ryegrass	gN/ha/day	
TVA Evp Melt SCU	67e[z]	486bc
Ag Ind SCU	232a	540b
IBDU	109cde	884a
33% IBDU + 67% CIL SCU	127cd	627b
CIL SCU (Reg)	191ab	559b
CIL SCU (fine)	132cd	775a
TVA SCU (30% diss)	162bc	602b
$(NH_4)_2SO_4$	115cde	388c
Bermudagrass		
TVA Evp Melt SCU	1309a	58a
Ag Ind SCU	1021abc	30b
IBDU	592d	29b
Oxamide	843bcd	27b
Ureaform	727cd	28b
CIL SCU (Reg)	1189a	27b
CIL SCU (fine)	1114ab	30b
TVA SCU (30% diss)	1283a	42b
$(NH_4)_2SO_4$	1061ab	31b

zAny two means within a column followed by the same letter do not differ significantly at the 5% level or probability as judged by DNMRT.

1. In general, all of the slow release N materials under study required a longer period of time to produce a maximum response than the soluble N source. The greatest lag in response was generally associated with IBDU during the cool season.
2. On 'Derby' ryegrass, IBDU and CIL SCU produced a higher yield and visual rating than did TVA SCU (30% dissolution). It should also be noted that the turfgrass quality and growth on $(NH_4)_2SO_4$ treated plots was equivalent to most of the synthetic slow-release N sources throughout the cool-season growth period.
3. On 'Tifway' bermudagrass, TVA Evp Melt SCU, Ag Ind. SCU, CIL SCU and TVA SCU (30% dissolution) induce equivalent responses. Oxamide produced the highest overall rating at the end of the rating period.

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