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Nitrogen Release from Sulfur-Coated Urea, as Affected by Coating Weight, Placement and Temperature[1]

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ABSTRACT

Greenhouse and laboratory studies were conducted to measure the factors controlling release of N from sulfur-coated urea (SCU). Results of two greenhouse pot experiments with common bermudagrass (*Cynodon dactylon*) and a third with uncropped soil in controlled environment regimes showed that the rate of dissolution of SCU increased greatly with higher temperatures of cropping or incubation. Dissolution rates of SCU granules were decreased by heavier coating with S, by inclusion of 0.5% coal tar oil microbicide in the coating, and by surface application, as compared to mixing with the soil. Satisfactorily coated urea (SCU) or split applications of uncoated ammonium nitrate (AN) or urea both resulted in more uniform distribution of forage production and N uptake than did a single application of urea or AN at time of seeding. Greater yields of forage were obtained from single applications of some SCU products than from urea or AN. Apparent volatilization losses of surface-applied urea were severe, particularly at higher growth or incubation temepratures. Losses of N were reduced, but not entirely eliminated by S-coating.

Additional index words: Slow-release N fertilizer, Bermudagrass, Incubation.

SEVERAL years of research and development by TVA chemical engineers (4) have resulted in a potential for producing sulfur-coated urea (SCU) products varying widely in coating weight and rate of dissolution in water. Several of these products have proven to be satisfactory sources of N for forage crops under field conditions in northern Alabama (1, 2, 3). Lower toxicity of SCU than of soluble N sources for turf and grain crops has also been shown.

At the same time field experiments were being carried out with larger batches of SCU, smaller laboratory-scale lots produced with a wider range of experimental variables were evaluated in the greenhouse and laboratory. The purpose of this paper is to present results on the effects of coating weight, placement, and temperature on the rate of release of N from SCU.

MATERIALS AND METHODS

Contents of N, as well as coating and dissolution characteristics of fertilizers are shown in Table 1. Dissolution in water at 38 C (a laboratory procedure used to characterize SCU products) increased with decrease in coating weight (4).

Mountview silt loam, an acid (pH 5.0) infertile soil collected near Lawrenceburg, Tennessee, was used in all experiments. To deplete the soil to a very low level of available N, bulk lots were limed to pH 6.3 with a 2/1 mixture of $CaCO_3$ and $MgCO_3$ and fertilized with adequate amounts of P and K as concentrated superphosphate and K_2SO_4 prior to cropping for 4 weeks with corn (*Zea mays* L.) in the greenhouse. The crop was then removed and the soil processed in a soil-shredding machine prior to use in experiments 1, 2, 3 as follows:

Experiment 1

Additional P, K, and micronutrients were applied at nonlimiting levels and the soil was placed in plastic pots (6.25 kg of dry soil/pot). Sources of N to supply 0, 500 or 1000 mg of N/pot (80 or 160 ppm) were mixed with the soil prior to planting or surface applied after emergence of the crop. Common bermudagrass (*Cynodon dactylon*) was seeded on June 23, 1967, and single surface applications of N were made on July 3. Split applications of uncoated urea (U) or ammonium nitrate (AN) were applied in five equal increments (on July 3 and after clippings 1, 2, 3, and 4). Beginning on July 19, forage was clipped at 5 cm above the soil at 2-week intervals until eight clippings were harvested. The experiment was conducted in an unshaded greenhouse equipped with evaporative air conditioning. Daytime temperatures usually ranged from 25 to 35 C with occasional maxima of 38 to 40 C. Forage from each clipping was dried, weighed, and analyzed for total N by individual replicates. All 59 treatments, including unreported mixtures of urea and SCU, were replicated three times.

Experiment 2

Soil, prepared as for Experiment 1 was placed in plastic pots (3 kg of dry soil/pot). Sources of N to supply 0, 300, or 600 mg of N/pot (100 or 200 ppm) were mixed with the soil prior to planting or surface-applied soon after emergence of the crop. Split applications of AN or urea were made in four increments (after emergence and after clippings 1, 2 and 3). Common bermudagrass was seeded on February 20, 1968, and cultures were placed immediately in a controlled-environment chamber set to provide for 16-hour days at 35 C and 8-hour nights at 24 C, a regime intended to maximize losses of surface applied urea, as well as accelerate the dissolution of SCU. Forage was harvested six times at 2-week intervals, beginning on March 18. All 23 treatments, including other unreported coated products, were replicated 3 times.

Experiment 3

Experiment 3 was conducted to measure release of N from SCU under a wider range of environmental conditions than was possible in plant growth experiments. Cultures were incubated in cartons holding 1 kg of Mountview soil, prepared as for Experiment 1. To facilitate removal of granule residues after incubation, portions of the same soil were screened to pass through a 16-mesh sieve. SCU granules to supply 150 mg of N/carton (150 ppm) were placed in or on the surface of 100-g portions of the screened soil, which was separated from the main soil mass by plastic screens. For layered placement, SCU granules were placed 2.5 cm below the surface in the center of the screened soil layer. Cultures were maintaind at 22% moisture by watering with demineralized water as required. Duplicate cultures of all 120 treatments were placed in plant growth chambers set to provide for: (a) 15 C days and 5 C nights, (b) 25 C days and 15 C nights, or (c) 35 C days and 25 C nights. Cultures were prepared at suitable intervals to permit incubation periods of 2, 5, 8, 12 or 16 weeks. Granule residues were recovered on July 15, 1968, and analyzed for total N. Release of N from the granules was determined by subtracting the amount of N recovered from the 150 mg applied and expressing the result on a percentage basis.

RESULTS AND DISCUSSION

Experiment 1

Total yields of forage obtained with 1000 mg of N and their distribution among clippings 1-2, 3-4, 5-6, and 7-8 are shown in Fig. 1. Very little growth was obtained without applied N, while yields with 500 mg of N (not reported) were about 50% of those with

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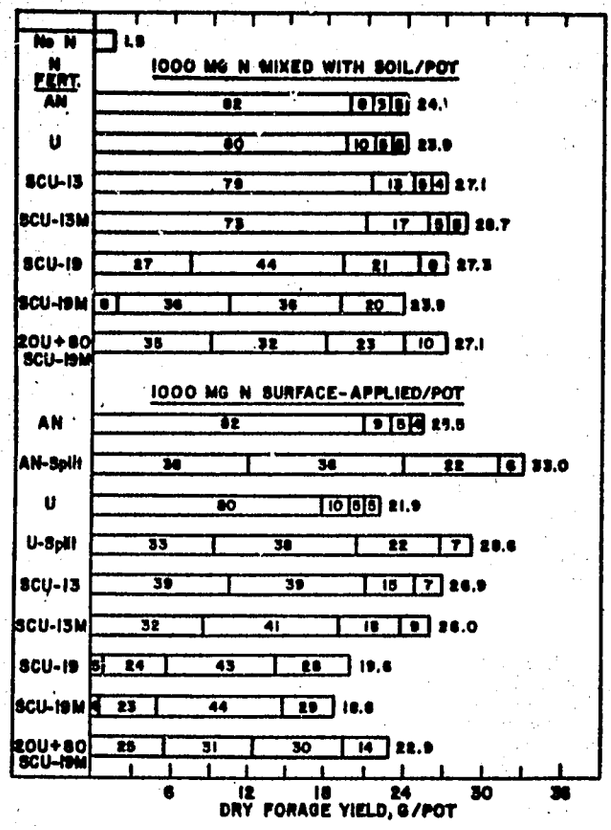

Fig. 1. Total bermudagrass forage yield and its percentage distribution among clippings 1-2, 3-4, 5-6 and 7-8, as affected by N source (Experiment 1). LSD (5%) among total yields = 1.6 g/pot.

1000 mg and were similarly distributed. Total yields with mixed application were in the order: SCU-13M > SCU-19 = SCU-13 = 20% Urea + 80% SCU-19M > AN = Urea = SCU-19M (products identified in Table 1). Thus, 4 of 5 SCU formulations yielded more total forage than did urea or AN. As regards distribution of forage yield among clippings, 80-82% of the total from AN or urea was harvested in clippings 1-2, as compared to 78% from SCU-13 and 27% from SCU-19. Addition of microbicide (M, coal tar oil) further delayed release of N at both coating weights, as shown by the marked tendency for later production from SCU-13-M and SCU-19M. Addition of 20% urea to SCU-19M supplied adequate N for early crop growth. In consequence, the 20% urea + 80% SCU-19M mixture resulted in the most uniform yield distribution of any mixed treatment.

Table 1. Total N contents, coatings and dissolution of the N sources in water.

N source	Symbol	Total N, %	Total coating, %	Elemental S, %	Microbicide (M),* %	Dissolution in H_2O at 38 C, % in: 24 hrs	5 days	Experiment in which compared
Ammonium nitrate	AN	33.5	--	--	-	100	-	1-3
Urea	U	46.0	--	--	-	100	-	1-3
S-coated urea	SCU-13	39.5	12.8	9.1	-	7	17	1,3
S-coated urea	SCU-13M	39.4	13.3	9.0	0.5	4	8	1,3
S-coated urea	SCU-19	38.1	18.5	15.2	-	1	2	1,3
S-coated urea	SCU-19M	37.3	19.0	15.2	0.5	2	3	1,3
S-coated urea	SCU-11	40.6	11.8	7.6	-	27	38	2
S-coated urea	SCU-20	37.0	19.5	15.0	-	1	1	2

* The microbicide was coal tar oil.

When N sources were surface applied, total yields were in the order: AN-split > U-split > SCU-13 > SCU-13M = AN > 20% urea + 80% SCU-19M > U > SCU-19 > SCU-19M. The lower yields from urea as compared to AN, apparently reflect substantial volatilization losses from urea as NH_3. Distribution of yield among clippings was, of course, modified by split applications of AN or urea or by varying the coating weight of SCU. Similarly, comparison with data from mixed treatments clearly shows slower dissolution of surface-applied SCU, as well as relatively little effect of microbicide. The poorer performance of SCU-19 and SCU-19M was undoubtedly related to incomplete dissolution of granules, since numerous intact granules were recovered from the soil surface 16 weeks after application. As with mixed treatments, the most uniform forage production was obtained from a mixture of 20% urea + 80% SCU-19M.

Total uptake of N by the forage (Fig. 2) shows similar source and placement effects as do forage yields. With mixed placement, recovery of applied N was 70 to 75% for all sources, except formulations containing SCU-19M. Of the total N uptake from AN or urea, 90 to 91% was in clippings 1-2, as compared to 82-88% for SCU-13M or SCU-13 and 7-26% for SCU-19M or SCU-19. High uptake values from soluble sources in early clippings resulted in lower yields per unit of N uptake than was true for SCU. With AN, 32 g of forage was produced per g of N

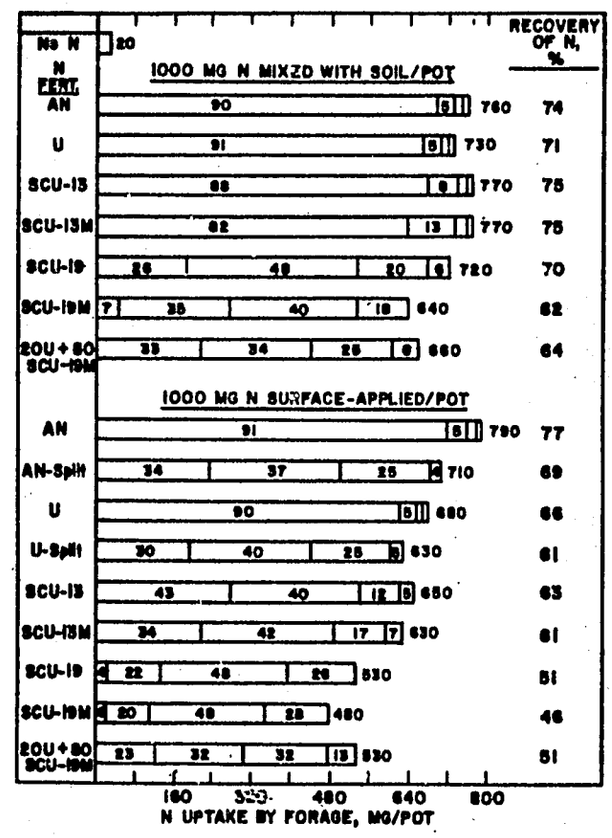

Fig. 2. Total N uptake by bermudagrass forage (mg), its distribution among clippings 1-2, 3-4, 5-6 and 7-8 (%), and apparent recovery of applied N (%), as affected by N source (Experiment 1).

uptake, as compared to 37 g for SCU-13 and 41 g for the 20/80 mixture of urea and SCU-19M, the N source giving the most uniform forage production, and maximum efficiency of N utilization. Results from the 500-mg rate of N (not shown) showed only modification of the yield pattern by SCU. Thus, no extra yield was obtained from SCU at limiting levels of N where little luxury uptake of N from soluble sources occurred.

With surface placement, greater recovery of N from AN than from urea (both single and split applications) reflects apparent volatilization losses as NH_3 from urea. Similarly, lower recovery of N from split applications, as compared to single applications of urea or AN, may reflect more residual N remaining in the soil or crop residues at termination of the experiment. The similarity in distribution of N among clippings with SCU-13, SCU-13M and split applications of urea or AN is striking. In contrast, the entirely different distribution pattern from SCU-19 or SCU-19M is related to slow initial dissolution, as well as incomplete dissolution in 16 weeks.

Experiment 2

Forage yields and uptake of N were essentially linear with the 0, 300, and 600 mg rates of N. With mixed placement of 600 mg of N, yield of forage and distribution among clippings were similar for all sources (Fig. 3) which suggests rapid dissolution of SCU at high temperature. With surface placement, yields were much less from urea, which apparently reflects large volatilization losses as NH_3 from urea. Yield distribution was modified by split applications of AN or urea and by the heavier coated SCU-20. In contrast, SCU-11 apparently released N too rapidly at high temperature for expression of controlled-release effects.

Uptake and apparent recovery of N from the 600 mg applied (Fig. 4) was similar (82-87%) for all mixed sources and surface-applied AN. Recovery was only

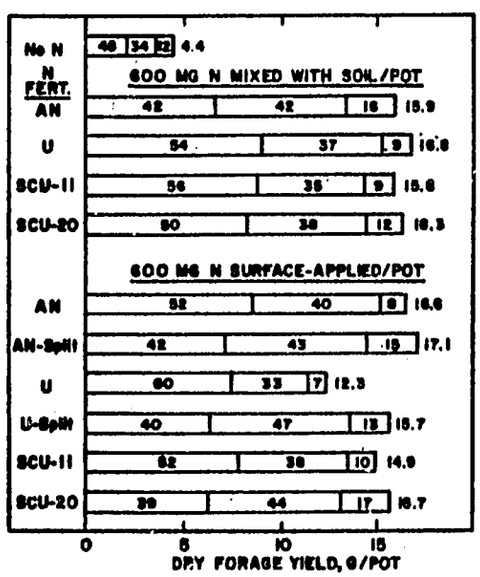

Fig. 3. Total bermudagrass forage yield and its percentage distribution among clippings 1-2, 3-4 and 5-6, as affected by N source (Experiment 2). LSD (5%) among total yields = 0.8 g/pot.

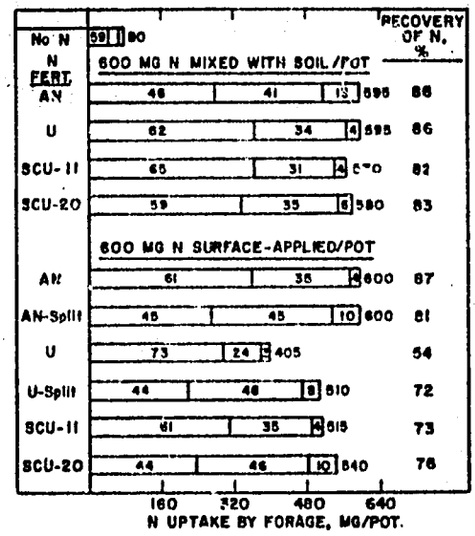

Fig. 4. Total N uptake by bermudagrass forage (mg), its distribution among clippings 1-2, 3-4 and 5-6 (%) and apparent recovery of applied N (%), as affected by N source (Experiment 2).

54% from a single application of urea on the surface, while recovery from SCU or a split application of urea increased to 72-76%. Thus, SCU was effective in reducing losses of NH_3 to the atmosphere. Distribution of N uptake among clippings was similar for SCU-20 and split AN or urea, while the more lightly coated SCU-11 gave an uptake pattern similar to single applications of the uncoated sources.

Experiment 3

As shown in Fig. 5, dissolution of SCU granules layered in the soil was relatively rapid at 20 or 30 C and very slow at 10 C. As in plant growth experiments, increase in coating weight or addition of microbicide decreased the rate of dissolution. Release of 10 to 20% of the total N from all sources in 2 weeks probably reflects dissolution of imperfectly coated granules.

Dissolution of surface-applied SCU (Fig. 6) was much slower at 20 or 30 C, as compared to mixed placement. At 10 C, SCU-19 and SCU-19M were exceptionally stable, while SCU-13 and SCU-13M released N rather rapidly after 8 weeks incubation. As in the plant growth experiments, effects of microbicide were small with surface-placed granules.

CONCLUSIONS

Results from other experiments (1, 2, 3) have shown that SCU may be a superior source of N for forage grasses. Those results, together with those reported here, illustrate the potential for tailoring SCU to fit a wide variety of crop requirements. By varying coating weight, microbicide, placement, etc., it is within the realm of possibility to supply N to a crop from SCU having a dissolution rate closely approximating the crop requirements. This conclusion is supported by Experiment 1 results in which more forage per unit of applied N was produced from a single application of SCU than from urea or AN. Thus, SCU was effective in reducing luxury uptake by early clippings,

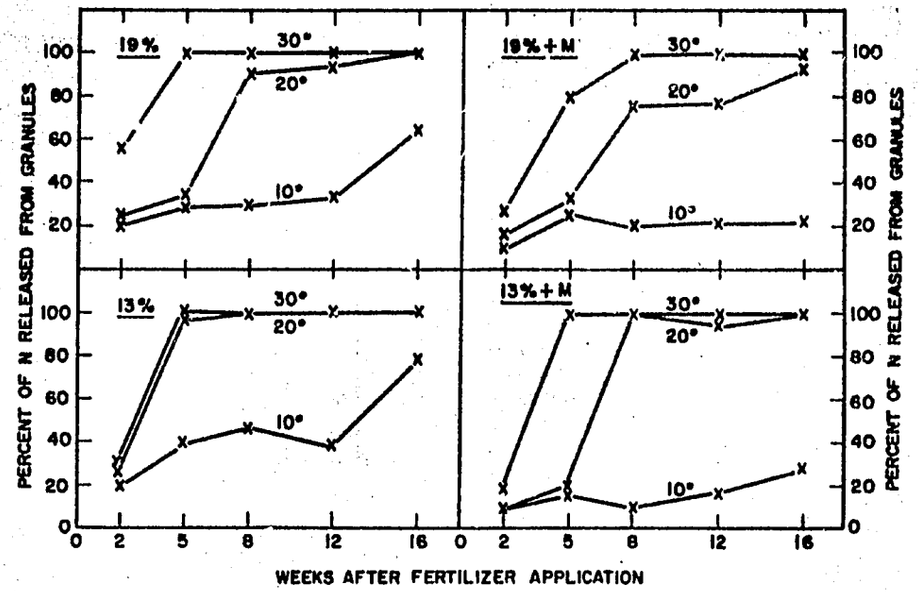

Fig. 5. Release of N from SCU placed in the soil, as affected by coating weight (%), microbicide (M), temperature and time (Experiment 3).

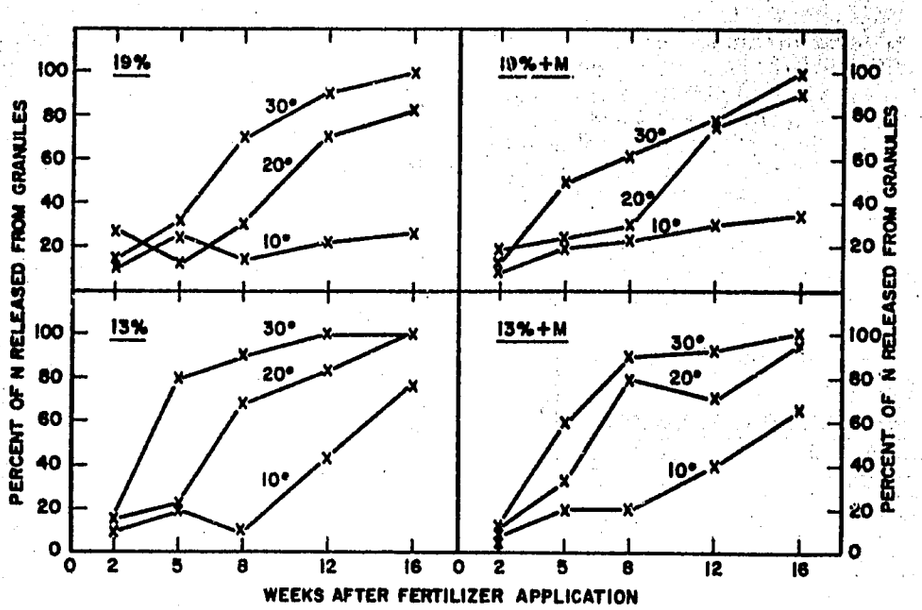

Fig. 6. Release of N from surface-applied SCU, as affected by coating weight (%), microbicide (M), temperature and time (Experiment 3).

as compared to urea or AN. As a result, more residual N remained for later clippings and greater total yield resulted. Similarly, the most uniform forage production was obtained from mixtures of SCU and soluble sources. The latter, of course, supplied N for immediate use by the crop, while SCU became available for later clippings. Whether clipped or grazed grass forage can utilize delayed-release N effectively would, of course, depend on the adequacy of the variety, moisture supply and other growth factors for high yields of the later cuttings.

Results from Experiments 2 and 3 show that the rate of dissolution of SCU is very temperature dependent. Thus, heavier coatings plus microbicide may be required for tropical situations with mixed placement of N. In contrast, lighter coatings without microbicide may be preferred for turf application in cooler climates. The exceptional stability of SCU at 10 C suggests the possibility of fall and winter applications in southern states where this practice is not now recommended. A suitable formulation of SCU should offer protection from leaching and/or denitrification during the winter months, while N would become available for crop use when the soil warms in the spring. Experiment 2 also suggests substantial reduction in loss of NH_3-N from surface placed SCU as

compared to a single application of urea (54 vs. 76% recovery of applied N). At lower temperatures (Experiment 1) it was not possible to make similar comparisons, since incomplete dissolution of surface-placed SCU in 16 weeks was also involved.

Potential uses, other than forage crops and turf, currently under investigation in our own and cooperating laboratories include forestry, forest nurseries, sugar cane, pineapples and rice. The potential for rice culture is promising, since denitrification losses from preplant applications of soluble sources may be substantial. However, lighter coatings may be required, since the rate of dissolution of well coated SCU is very slow in flooded soil.

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