AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY

1. SUBJECT CLASSIFICATION

A. PRIMARY: Agriculture — AF25-0000-0000

B. SECONDARY: Soil fertility,fertilizers,and plant nutrition

2. TITLE AND SUBTITLE

Soluble and slow-release nitrogen fertilizer effects on grass forage,as influenced by rate and placement

3. AUTHOR(S)

Allen,S.E.; Terman,G.L.; Hunt,C.M.

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1971	8p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS

TVA

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

(In J.of agr.science,v.77,p.397-404)

9. ABSTRACT

10. CONTROL NUMBER

PN-RAA- 209

11. PRICE OF DOCUMENT

12. DESCRIPTORS

Controlled release
Dissolving
Field tests
Forage grasses
Nitrogen

13. PROJECT NUMBER

14. CONTRACT NUMBER

PASA RA (QA) 5-69 Res.

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

10

J. agric. Sci., Camb. (1971), 77, 397–404
With 4 text-figures
Printed in Great Britain

X 97

Soluble and slow-release nitrogen fertilizer effects on grass forage, as influenced by rate and placement

BY S. E. ALLEN, G. L. TERMAN AND C. M. HUNT
National Fertilizer Development Centre, Tennessee Valley Authority, Muscle Shoals, Alabama, U.S.A.

(*Revised MS. received* 28 *June* 1971)

SUMMARY

Soluble ammonium nitrate (AN) and urea were compared with slow-release oxamide and sulphur-coated urea (SCU) as N sources for clipped annual ryegrass (*Lolium multiflorum*) or common bermuda grass (*Cynodon dactylon*) in four greenhouse experiments. Mixed and surface applications of a wide range of N rates were evaluated for 9 to 14 cuttings of grass forage. Both granular oxamide and SCU exhibited slow-release N properties, especially when surface-applied. Uptake distribution of N with high application rates of AN and urea tended to resemble that with the slow-release sources. Slow-release properties of oxamide and SCU were accentuated at high application rates. Lower N recovery from surface-applied urea than from AN indicated volatilization loss of urea N. Volatilization loss also occurred with oxamide, but low N recovery from oxamide and SCU resulted largely from incomplete dissolution of the granules during the 18- to 34-week experimental periods. Very low N recovery was obtained from urea formaldehyde having an activity index of 42.

INTRODUCTION

DeMent, Hunt, & Stanford (1961) and Engelstad, Hunt & Terman (1964) showed that granular oxamide released N rather slowly for maize (*Zea mays*) and that fine oxamide was equal to soluble ammonium nitrate (AN) as an N source. However, high cost of production has prohibited the commercial use of oxamide as a fertilizer. Urea-formaldehyde, although higher in cost than AN and other soluble fertilizers, has been used rather widely to reduce the need for repeated N applications on turf and ornamentals.

Sulphur-coated urea (SCU) produced by the Tennessee Valley Authority has been found by TVA agronomists (Allen, Mays & Terman (1968), Mays & Terman (1969*a*, *b*), Mays (1970), Allen, Hunt & Terman (1971)) to be a satisfactory N source for grass forage. A single spring application of SCU was similar to split applications of AN and urea in terms of seasonal distribution of grass growth and total N (crude protein) content. Rate of dissolution of urea N is influenced greatly by amount of coating, addition of microbicide, temperature, and placement for grass forage (Allen, Hunt & Terman, 1971).

During conduct of some of the previously reported research, it was observed that rather high rates of soluble N sources also tended to result in considerable late-season growth and N uptake and thus simulate results with slow-release N sources. Greenhouse pot experiments were conducted to compare a rather wide range of rates of both soluble and slow-release oxamide and SCU products. The purpose of the present paper is to report these results.

MATERIALS AND METHODS

Contents of N, amounts of coatings, and dissolution characteristics of the N sources compared in Exps. 1–4 are shown in Table 1.

The oxamide (Ox.) was pan granulated as for a previous study (Engelstad, Hunt & Terman, 1964) with 1 % of animal glue and 2 % kaolin clay. The −6+10 mesh (U.S. standard) granules were screened out. The ammonium nitrate (AN), urea ammonium phosphate (UAP), and sulphur-coated urea (SCU) were TVA products. Urea formaldehyde (UF, Borden Chemical Co., having an A.O.A.C. activity index of 42) and urea were commercial products. Sulphur-coated urea was made by TVA by spraying preheated granular urea with molten S in a pan granulator, and sealing with wax (Rindt, Blouin, & Getsinger, 1968).

The Hartsells fsl (pH 5·1), an infertile soil residual

Table 1. *Partial composition of the −6+10 mesh* granular N sources compared in the experiments*

N source	Symbol	Total N (%)	Total coating (%)†	Dissolution in H_2O at 38 °C, % in 24 hrs	Dissolution in H_2O at 38 °C, % in 5 days	Experiment in which compared
Ammonium nitrate	AN	33·5	—	100	—	1–4
Urea	U	46·0	—	100	—	3, 4
Urea ammonium phosphate	UAP	30·0	—	100	—	1
Oxamide	Ox.	30·5	—	< 10	—	1, 2
Urea formaldehyde (−35 mesh)	UF	38·4	—	—	—	1
Sulphur-coated urea (A)	SCU	36·5	21·3	0·9	1·0	3
SCU (A)+microbicide	SCU+M	36·7	20·8	0·6	1·0	3
SCU (B)	SCU	37·8	19·0	0·3	3·4	4
SCU (B)+microbicide	SCU+M	36·9	19·4	0·8	1·7	4

* Mesh sizes are U.S. standard.
† The coatings consisted of elemented S, 3% wax, 1% conditioner, and 0·5% coal tar oil (M).

Table 2. *Soil type, amounts of soil, and nutrient application rates*

Exp. no.	Soil type	Dry soil/culture (kg)	Nutrients applied, ppm: 2:1 $CaCO_3$+$MgCO_3$	N	P	K	Zn
1	Hartsells fsl	17·0	1176	70 and 140	176*	35*	5
2	Hartsells fsl	17·0	2000	140 to 490	176*	35*	5
3	Hartsells fsl	6·5	1540	77 and 154	230*	30*	5
4	Mountview sil	6·25	1500	160, 320, and 640	96	48	5

* 28 ppm of P and 35 ppm of K also surface-applied as KH_2PO_4 after cutting 5.

from sandstone was obtained from Colbert County, Alabama. It was limed (Table 2) to pH 6·4 for Exp. 1, to pH 7·1 for Exp. 2, and to pH 6·2 for Exp. 3. All fertilizer and lime additions were made by individual cultures. Mountview sil, an infertile soil (pH 5·0), obtained in Lawrence County, Tennessee, was similarly limed to pH 6·5 for Exp. 4.

Each treatment, including no N, was replicated twice in Exps. 1 and 2 and three times in Exps. 3 and 4. Applications of P as triple superphosphate (20·7% P), K as K_2SO_4, and Zn as $ZnSO_4.5H_2O$ for good growth were also mixed with each soil prior to cropping. Water requirements were determined by weighing; demineralized water was added to bring the cultures to 18% for Hartsells fsl and 24% for Mountview sil. All experiments were conducted in unshaded greenhouses equipped with evaporative air cooling. Daytime temperatures usually ranged from 25 to 35 °C, with occasional summer maxima of 38–40 °C.

Grass clippings from individual pots (except for some very-low-yielding cuttings) of each clipping and experiment were dried at 80 °C for 72 h or to constant weight, weighed, and analysed for total N by a micro Kjeldahl method which included reduction of nitrates (Bremner, 1965, p. 1164). Apparent recovery of applied N was calculated as the difference between mean uptake of N in forage from N-treated pots and no-N checks, expressed as a percentage of the amount of N applied.

EXPERIMENTS CONDUCTED AND RESULTS

Experiment 1

Annual ryegrass (*Lolium multiflorum*) was seeded in December 1964 in coarse sphagnum moss on greenhouse benches (Terman, Allen & Clements, 1966). After a dense turf was formed in 1–2 weeks, 30 × 30 cm square pieces of turf were cut, pressed on the soil in each 36 × 35 × 15 cm wooden box, and watered. The grass was clipped at 2-week intervals for 9 cuttings. The N sources were both mixed with the soil as single applications before planting and topdressed just after turf establishment. Split topdressings of soluble N sources

(AN-S and U-S) were also applied in 4 equal increments at turf establishment and after the first 3 cuttings.

Total yields of dry forage from 9 cuttings of annual ryegrass increased from 15 g/box without applied N to 50 g/box with split applications of 2·4 g of N as AN. Yields with a single application of AN or UAP declined to the no-N check level for cutting 6. With surface-applied oxamide, yields were rather uniform through cutting 7, but declined thereafter. Conclusions based on forage yields were similar to those given below based on N uptake and recovery in the forage.

Total uptake of N, its distribution among cuttings, and the apparent recovery of applied N are shown in Fig. 1. Uptake of N was essentially linear with the 0, 1·2, and 2·4 g rates of applied N. Uptake and recovery of applied N were in the order: surface-applied AN-S > mixed AN, UAP, or oxamide = surface-applied AN > surface-applied UAP > surface-applied oxamide ≫ mixed or surface-applied UF > no N. The poorer results with surface-applied UAP indicate volatilization loss of N, presumably as NH_3. The poorer results with surface-applied oxamide may also indicate volatilization loss, but more probably indicate slower dissolution than occurred with mixed application. The latter is indicated by the 59 and 62 % of the total N uptake in cuttings 5–9, as compared to only 7 to 10 % from AN. Some granule residues recovered after cutting 9 were identified petrographically as unaltered oxamide.

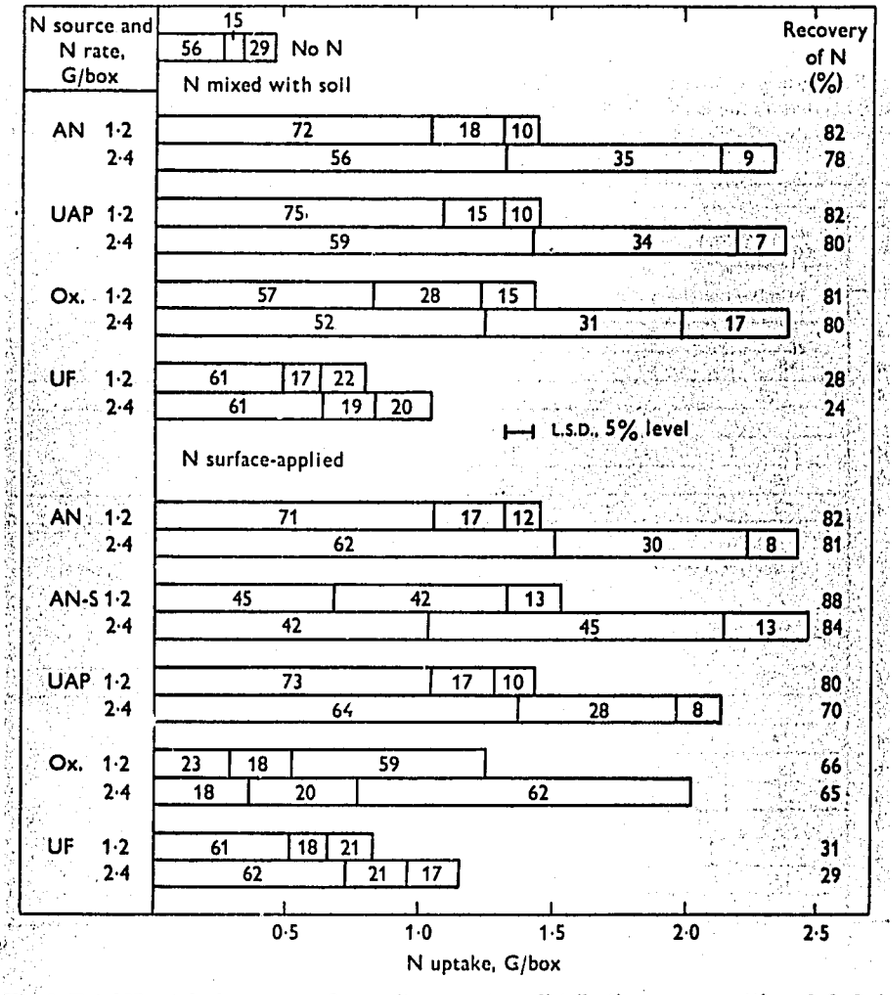

Fig. 1. Total N uptake by ryegrass forage, its percentage distribution among cuttings 1–2, 3–4, and 5–9, and apparent recovery of applied N (Exp. 1).

The high percentages of uptake in cuttings 1 and 2 from AN and UAP (56 to 75%, respectively) and the low amounts in cuttings 5–9 indicate luxury consumption from these soluble sources in early cuttings. The lower percentages of the total uptake in early cuttings from the higher rate of application of AN, UAP, and oxamide indicate a larger amount of available N than the crop could immediately assimilate. The remainder tended to increase the percentage uptake in later cuttings. Thus, the uptake distribution from the high rate of soluble N tended to resemble that from a slow-release N source. However, the only satisfactory slow-release source in this experiment was surface-applied oxamide. Results with UF indicate a soluble N fraction which was recovered in cuttings 1 and 2, and a remaining very-slow-release N fraction, which was largely unavailable to ryegrass over an 18-week period.

Experiment 2

Common bermuda grass turf (*Cynodon dactylon*) was similarly seeded as for Exp. 1 in July 1965, the sod transplanted, and fertilized. Single applications of oxamide were made at turf establishment. Split applications of 1·2 g of N as AN were made at turf establishment and after clippings 1, 1–3, or 1–6 for the 2·4, 4·8, and 8·4 g rates of N. The grass was clipped at 5 cm at 2-week intervals for 5 cuttings and then at 3-week intervals for 8 additional cuttings.

Total yields of dry bermuda grass from 14 cuttings increased from 38 g/box without applied N to 151 g/box with 8·4 g of N as oxamide mixed with the soil. Yield trends were similar for both mixed and surface-applied AN and oxamide and decreased to low levels after cutting 5. Uptake and recovery of N in the forage (Fig. 2) were in the order: mixed AN and oxamide = surface-applied AN-S > surface-applied oxamide ≫ no N.

The lower recovery from topdressed oxamide than from topdressed AN or mixed AN and oxamide may have again resulted in part from volatilization loss of N as NH_3 from the surface-applied oxamide. The odour of NH_3 could be detected for 2 weeks after surface application of oxamide and no granule residues could be identified after cutting 14. However, the higher yields of cutting 14 with oxamide than with no applied N indicated in-

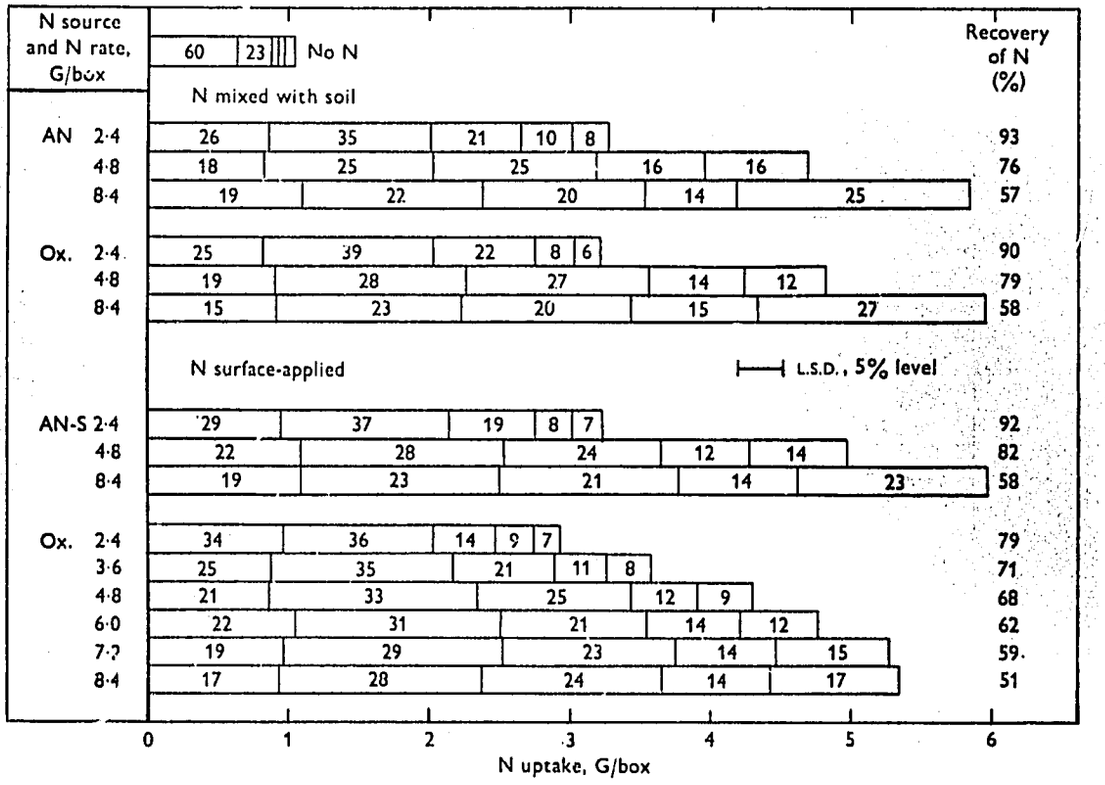

Fig. 2. Total N uptake by bermuda grass, its percentage distribution among cuttings 1–2, 3–4, 5–6, 7–8, and 9–14, and apparent recovery of applied N (Exp. 2).

complete utilization of the applied N. There was again a consistent decrease in the percentages of N taken up by cuttings 1 and 2 with increase in amount of N applied. The reverse was true for cuttings 9–14. Apparent recovery of N from the lowest rate of mixed AN and oxamide and surface-applied AN-S was very high (90–93%), but recovery decreased with rate of application in all situations.

Experiment 3

For Exp. 3, 6·5-kg lots of limed and fertilized soil (Table 2) were placed in 25 cm diameter plastic pots and seeded in December 1966 to annual ryegrass, which was clipped twice to deplete available soil N and the clippings discarded. In January the clipped turf along with a 2·5-cm layer of soil was carefully removed from each pot. The exposed soil was then removed, mixed with the N sources for one series, returned to the pots, and the sod layer returned. To a second series the sod layer was returned and the N sources topdressed. Split applications of AN and U were made in equal increments at date of turf establishment and after clippings 1–4. The grass was then clipped at 2-week intervals for 10 clippings.

Total yields of dry forage from 10 cuttings of ryegrass in Exp. 3 increased from 4·6 g/pot without applied N to 19 g/pot with split application of 1·0 g of N as AN. Uptake distribution and apparent

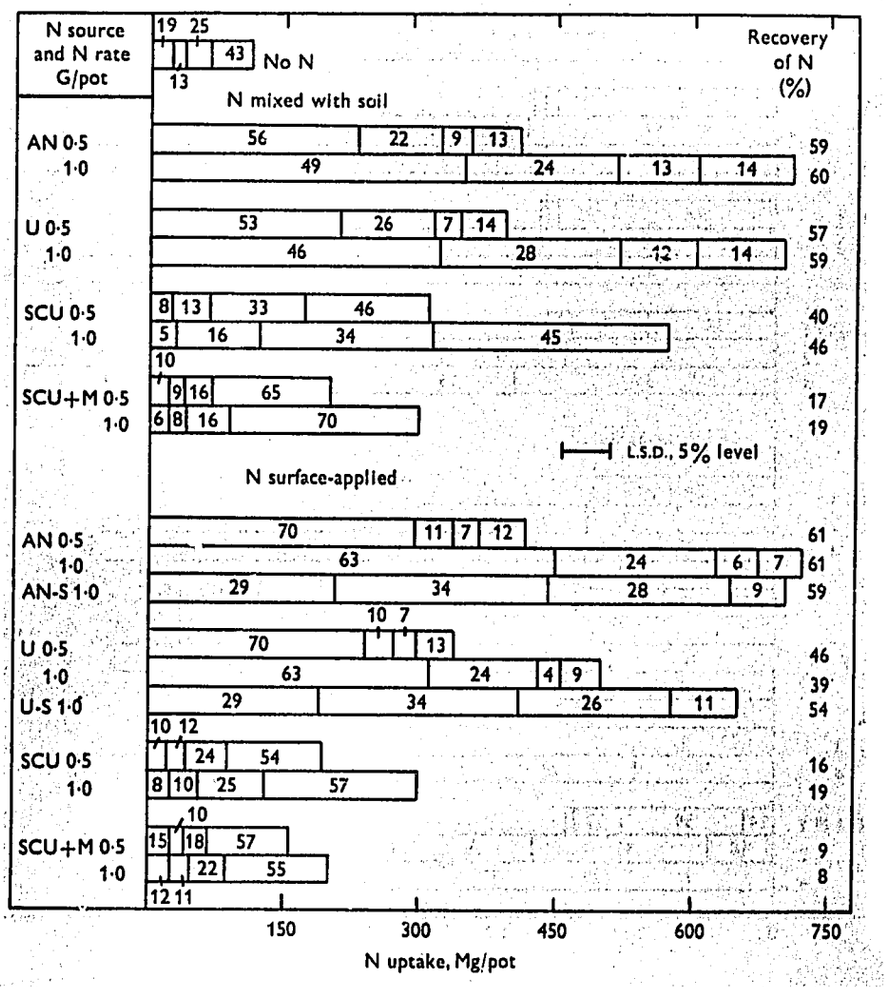

Fig. 3. Total N uptake by ryegrass forage, its percentage distribution among cuttings 1–2, 3–4, 5–6, and 7–10, and apparent recovery of applied N (Exp. 3).

recovery of applied N are shown in Fig. 3. These were in the order: mixed AN and U = surface-applied AN and AN-S > surface-applied U-S > mixed SCU > surface-applied U > mixed SCU+M and surface-applied SCU > surface-applied SCU+M > no N. Thus, much higher N uptake and recovery resulted with AN than with U surface-applied, but recovery from U was much higher with split application. As in Exp. 1, this indicates serious loss of N from the single applications of surface-applied U.

Inclusion of coal-tar oil microbicide in the SCU coating had a pronounced effect on slowing the release of N with mixed application and a lesser effect with surface application. Release of N from these lots of SCU and SCU+M was too slow for satisfactory recovery of N by the 10 clippings of ryegrass over the 20-week period.

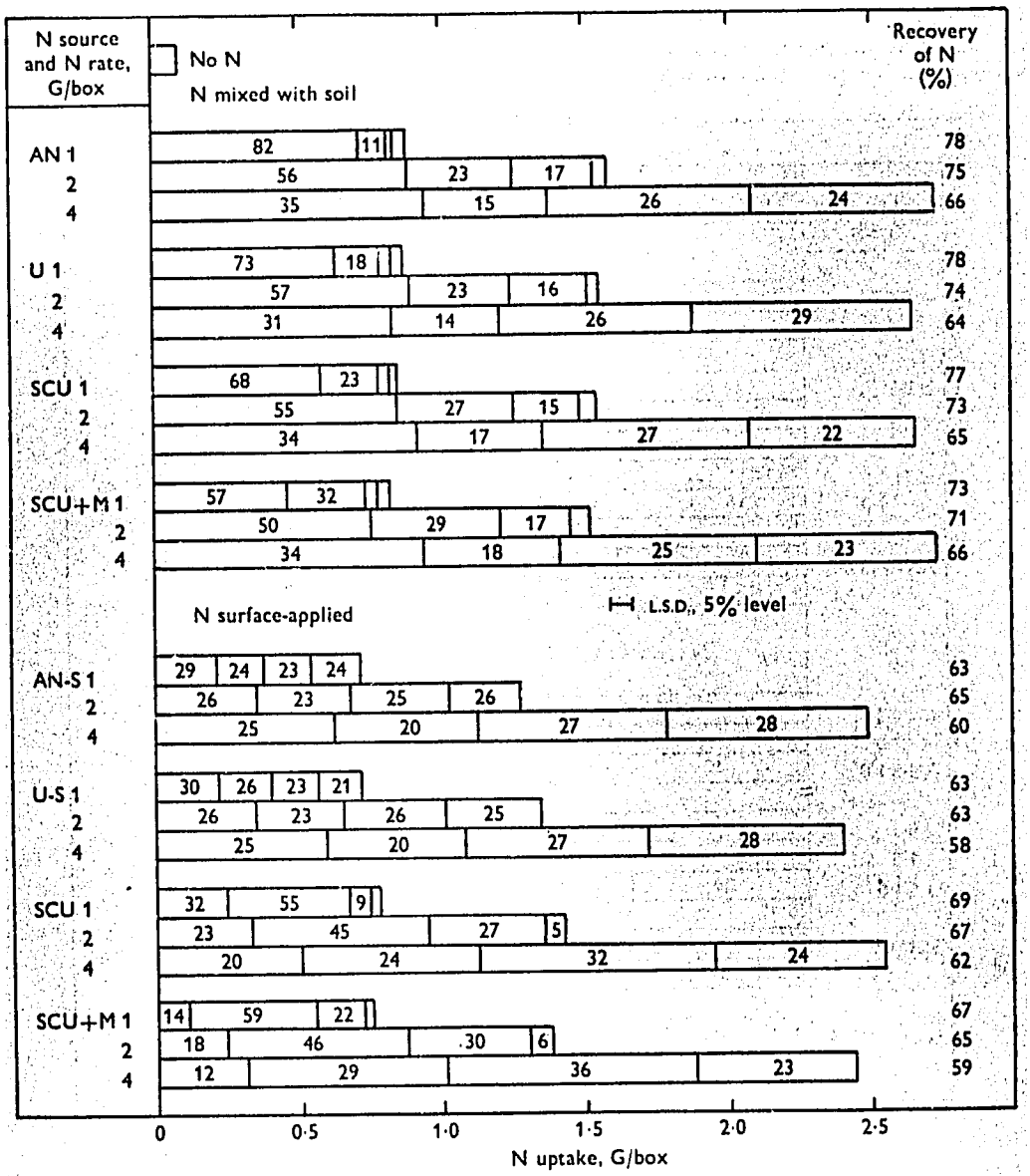

Fig. 4. Total N uptake by annual ryegrass forage, and its percentage distribution among cuttings 1–2, 3–4, 5–6, and 7–10, and apparent recovery of applied N (Exp. 4).

Experiment 4

For Exp. 4, the limed and fertilized soil (Table 2) was placed in pots and cropped to maize for 4 weeks to deplete the soil N. The maize was discarded, the soil processed in a soil shredder, 6·25 kg mixed with the N sources in one series, and returned to each pot. Annual ryegrass was seeded in November 1967 and clipped at 3-week intervals for 10 clippings. Single applications of all sources were mixed with the soil and SCU was topdressed at planting. Split applications of AN and U were topdressed at planting and after clippings 1–7.

Total yields of dry forage from 10 cuttings of ryegrass ranged from 4·6 g/pot without applied N to 54 g/pot with split application of 4·0 g of N as AN. Uptake of N was essentially linear with the 0, 1·0, and 2·0 g applications of N, but became curvilinear with 4·0 g of N/pot. Uptake and apparent recovery of applied N shown in Fig. 4 are similar among AN, U, SCU, and SCU+M at each rate of N mixed with the soil. The same was true for these N sources surface-applied, but N recovery was about 9 % lower. An adequate explanation for the much higher yields with SCU and SCU+M in this experiment in contrast to the poorer yields in Exp. 3 is not obvious, since the SCU products were quite similar. The lower yields and N recovery from all N sources in Exp. 3 probably resulted from discarding two cuttings before N applications and the technique used to establish the turf.

As in Exps. 1–3, percentages of the total N uptake in early cuttings decreased with increase in amount of N applied. The reverse was true for uptake in cuttings 7–10.

DISCUSSION

For lawns and turf in general for recreational use, appearance is more important than yield or N recovery by the grass. Gradual release of N from a single application reduces labour and yet tends to maintain satisfactory growth and colour.

Uniform seasonal distribution of grass growth in an N-deficient situation seems to be the most important criterion for a satisfactory slow-release N fertilizer for grass forage. In most grassland areas the lush early growth is usually excessive and later growth is usually deficient for most efficient grazing. Less early growth and more later growth from a slow-release source has to be demonstrated in comparison with a soluble N source, since water and other growth factors can also modify growth distribution.

If water, temperature, or other growth factors are deficient for early growth and adequate later, then both soluble N sources and those having slow dissolution rates may result in poor early-season growth but good growth later. However, in the reverse situation, neither may result in good late-season growth. Thus, only under growth situations where other growth factors are adequate through the season can a satisfactory evaluation of slow-release N fertilizers be made. The grass species is also important, since some produce best in cool seasons and others in warm seasons. In addition, some species can be maintained in a vegetative state much longer than others. For example, annual ryegrass, will head out and mature in late spring, despite cultural treatments to maintain grass production.

Results from the present experiments show that single topdressed applications of granular oxamide and SCU release N gradually over a long growth period. Nitrogen was released more rapidly (results not shown) from mixtures of fine and coarse oxamide. In no case did oxamide appear to injure the turf. Somewhat similar growth patterns were obtained in the greenhouse cultures with heavy applications of soluble AN or U which retarded initial growth. Much poorer results were obtained with commercial urea formaldehyde, which is widely sold as a slow-release N fertilizer for turf.

The lower recovery of N applied as granular oxamide than as AN may indicate volatilization loss of N as NH_3. However, this result is not conclusive because of less complete utilization in the forage of the N applied as oxamide, as indicated by the higher-than-check yields at the termination of the clipping experiments.

The present high cost of oxamide prohibits field-scale use, but recent research and development are expected to lower cost of production. Results with both oxamide and SCU indicate the feasibility of single applications of suitable slow-release N fertilizer for various types of grasses. Dissolution rates can be varied widely for oxamide by varying the granule size and for SCU by varying properties of the coating.

REFERENCES

ALLEN, S. E., MAYS, D. A. & TERMAN, G. L. (1968). Sulfur-coated urea: an effective slow-release nitrogen fertilizer. *Crops Soils* **21** (3), 13–15.

ALLEN, S. E., HUNT, C. M. & TERMAN, G. L. (1971). Nitrogen release from sulfur-coated urea, as affected by coating weight, placement, and temperature. *Agron. J.* **63**, 529–33.

BREMNER, J. M. (1965). In *Methods of Analysis*, part 2, p. 1164. Madison, Wisconsin: American Society of Agronomy.

DEMENT, J. D., HUNT, C. M. & STANFORD, G. (1961). Hydrolysis, nitrification, and nitrogen availability of oxamide, as influenced by granule size. *J. agric. Fd Chem.* **9**, 453–6.

ENGELSTAD, O. P., HUNT, C. M. & TERMAN, G. L. (1964). Response of corn to nitrogen in oxamide and ammonium nitrate in greenhouse experiments. *Agron. J.* **56**, 579–82.

MAYS, D. A. (1970). Sulphur-coated urea: a slow-release nitrogen source for grass. *Proc. 11th int Grassld Congr., Queensland*, pp. 428–30.

MAYS, D. A. & TERMAN, G. L. (1969*a*). Sulfur-coated urea and uncoated soluble nitrogen fertilizers for fescue forage. *Agron. J.* **61**, 489–92.

MAYS, D. A. & TERMAN, G. L. (1969*b*). Response of Coastal bermuda grass to nitrogen in sulfur-coated urea, urea and ammonium nitrate. *Sulphur Inst. J.* **5** (Autumn), 7–10.

RINDT, D. W., BLOUIN, G. M. & GETSINGER, J. G. (1968). Sulfur-coating on nitrogen fertilizers to reduce dissolution rate. *J. agric. Fd Chem.* **16**, 773–8.

TERMAN, G. L., ALLEN, S. E. & CLEMENTS, L. B. (1966). Greenhouse techniques for soil-plant-fertilizer research. TVA Report No. T66-4SF. 63 pp. Muscle Shoals, Alabama.