rin metabolite, but the design of this study in which multiple low doses were administered daily over a period could have masked the presence of trace metabolites. Analysis of the extracts by tlc using a mobile phase of chloroform-methanol (2:1) did reveal the presence of several artifacts which appeared to be saccharin metabolites. Mass spectral analysis showed these artifacts to be the result of saccharin binding to unknown compounds. These complexes were disassociated by the addition of 1 ml of ammonium hydroxide to 200 ml of the mobile phase.

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Evaluation of Isobutylidenediurea and Sulfur-Coated Urea for Grass and Lettuce

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Isobutylidenediurea (IBDU), sulfur-coated urea (SCU), and calcium ammonium nitrate (CAN) were compared at three rates for their effect on two contrasting crops, lettuce and grass, and in two contrasting soil types, organic and mineral, in a greenhouse experiment. Five cuts of grass and three harvests of lettuce were taken over a period of 5 months. In peat with grass and in soil with lettuce, the cumulative yields from the N fertilizers were of the order IBDU > SCU > CAN, in peat with lettuce it was IBDU = SCU ≫ CAN, and in soil with grass there were only slight differences. In contrast to CAN, both IBDU and SCU gave sustained response, although early response to SCU was slow. For the first month the only substantial losses of N through leaching were from CAN; some leaching losses also occurred from IBDU with lettuce.

Isobutylidenediurea (IBDU) and sulfur-coated urea (SCU) are being marketed commercially now in Western Europe and there is great interest in their performance for horticultural crops, lawns, and also as an N source for peat-based composts. Ureaformaldehyde, which is being used as a nitrogen source for peat-based composts, has been found to release N too slowly (Prasad and Woods, 1971a) and it is likely that one of these could be used as a replacement for ureaformaldehyde.

The performance of slow-release fertilizers including IBDU and SCU has been reviewed recently by Lunt (1971) but very little information is available on their performance on peat soils and for crops like lettuce. In view of the fact that peat soils are more susceptible to leaching than mineral soils (Prasad and Woods, 1971b), it was felt that these slow-release fertilizers would show a higher relative efficiency *vis-a-vis* a soluble N source, especially in peat soils. In addition, for a crop like lettuce, a seed bed application in soluble form of more than the small proportion of N which may be subsequently required is hazardous (Scaife *et al.*, 1972). Leaching losses may also be greater due to the low foraging capacity of lettuce and slow-release fertilizers may be particularly attractive in the above circumstances. In view of the above considerations, pot experiments were conducted to examine the efficiency of IBDU, SCU, and calcium ammonium nitrate (CAN) as a nitrogen source by using two types of crop, lettuce and grass, in both mineral and peat soils. Some measurements of leaching losses of nitrogen were also attempted.

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MATERIALS AND METHODS

The soil types were a sphagnum moss peat (decomposition H_2-H_3 on Van Post scale) and a Kinsealy loam (mineral soil). Some of the chemical and physical properties of these two soils are given in Table I.

The SCU used had a coating of sulfur, wax, and microbiocide representing 22.2% by weight of the material, N content of 35.9%, and a dissolution rate of 1.3% daily. IBDU had an N content of 32.5% and had a granule size between 25 and 14 ASTM mesh. These materials were supplied by the Tennessee Valley Authority and Mitsubishi Chemical Industries Ltd., Japan, respectively. The CAN had an N content of 26%, half of which is the ammoniacal form and half is the nitrate form. The fertilizers were added to give 0 (control), 220 (I), and 440 mg (II) of N in 12.5-cm pots in both soil and peat. Both substrates received 1 g of potassium sulfate and superphosphate and the peat soil received a range of trace elements. The pots were sown with perennial ryegrass seed (*cv.* Oriel) (0.8 g per pot) or with a single lettuce transplant (*cv.* Witte Dunsel) (dry weight 0.2 to 0.3 g) on Apr 20, 1971. The design of the experiment was 3 fertilizers × 3 rates of fertilizer × 2 crops with 3 replications for each treatment. For grass, 5 cuts at about 4-week intervals were taken from May 29th onward. Lettuce was harvested thrice (June 6, 1971, Aug 4, 1971, and Sept 15, 1971). After each cut of grass or after each harvest of lettuce, 1 g of potassium dihydrogen phosphate was added. After each harvest of lettuce, the roots of the previous crop were re-

Table I. Soil Data: Chemical and Physical Properties of Soils

Soil type	pH	NO_3-N, ppm	Total N, %	Particle size distribution				Bulk density	Available water capacity, vol
				Clay, %	Silt, %	Sand, %	Gravel, %		
Kinsealy loam	6.9	125	0.42	27	31	35	7	1.40	0.18
Sphagnum moss peat	5.9[a]	65	1.10					0.24	0.63

[a] Limed.

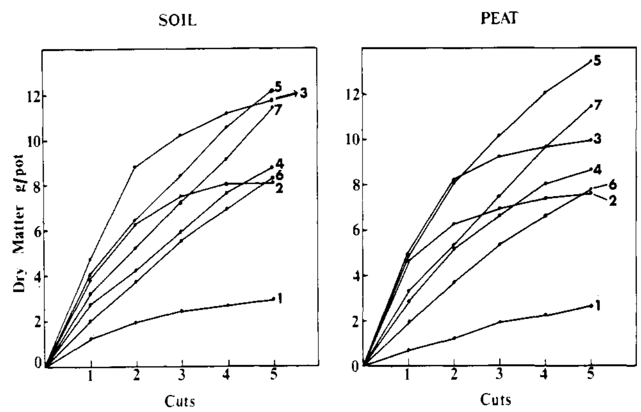

Figure 1. Cumulative yield of forage by perennial ryegrass (cut five times at 4-week intervals) in soil and peat as affected by rate and source of N. 1. Control; 2. CAN I; 3. CAN II; 4. IBDU I; 5. IBDU II; 6. SCU I; 7. SCU II; S.E. (cumulative yield), soil, 0.51; peat, 0.34.

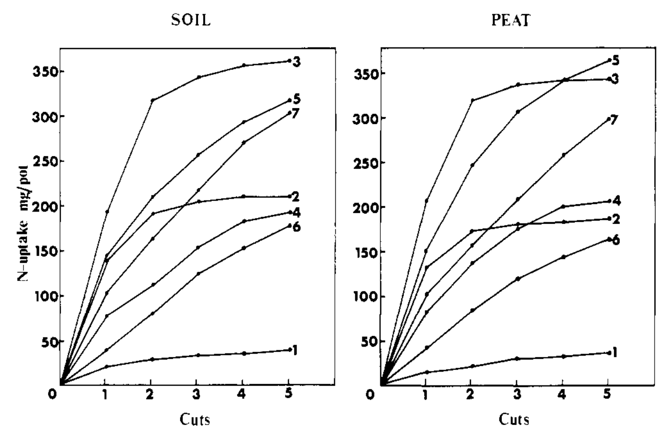

Figure 3. Cumulative uptake of N by perennial ryegrass (cut five times at 4-week intervals), in soil and peat as affected by rate and source of N. 1. Control; 2. CAN I; 3. CAN II; 4. IBDU I; 5. IBDU II; 6. SCU I; 7. SCU II; S.E. (cumulative uptake), soil, 19; peat, 20.

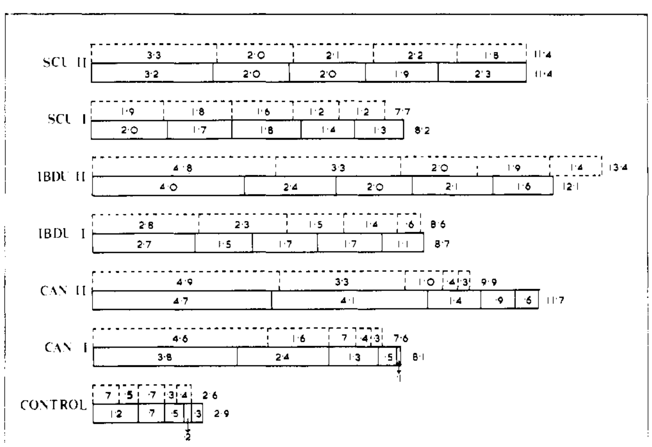

Figure 2. Total perennial ryegrass yields and their distribution among five cuttings as affected by rate and source of N (unbroken line = soil, broken line = peat).

moved before fresh seedlings were transplanted. Fresh and dry weights of the samples were taken and analyzed for nitrogen (Bryne, 1968). N uptake was calculated by multiplying dry weight of plant (minus the roots) with % N content of the dry matter. Since the roots were not sampled, the N recovery data would be a slight underestimate.

The watering regime was adjusted to provide a total of approximately 200 ml of leachate for the period Apr 30 to May 29, 1971. Leachates were collected and analyzed for Kjeldahl N modified to include nitrate-*N* using steam distillation with MgO and Devarda alloy. In the first 10 days of planting, leaching was prevented by adding small quantities of water frequently. The total amount of water added per week ranged from 300 to 400 ml applied twice a week from April 30th. After May 29th, the same watering regime was maintained but no leachate was collected. After the final harvest, soil samples were taken and the pH was determined on them.

RESULTS

Dry Matter Yield of Grass. The cumulative yields of grass obtained in five successive cuts from the soil and the peat are shown in Figure 1. In soil, the cumulative yield showed that there was a slight difference in yield among the different fertilizers at their respective rates although IBDU gave the highest yield, followed by SCU and CAN. In peat, the cumulative yield data after five harvests showed that there was a much bigger difference in performance among IBDU, SCU, and CAN, especially at higher rates, when compared to these treatments in soil.

In the soil at the first cut, best yields were recorded by CAN II, with CAN I and IBDU II and IBDU I and SCU II giving almost identical yields, respectively (Figure 2). SCU I gave very low yields. At second-cut CAN was still superior to the two slow-release fertilizers at equivalent rates. The two slow-release fertilizers gave almost identical yields. At the third cut both SCU and IBDU gave similar yields, while those from CAN treatments were lower. Similar trends were present at fourth and fifth cuts. In peat at first cut the pattern of yield data was similar to the soil. In the second cut yields were similar except that the large response to CAN II was not present. At the third, fourth, and fifth cuts the yield pattern was similar to that of soil.

The main difference between the yield data from soil and peat during the duration of the experiment was that in peat the reduction in cumulative yield from a soluble fertilizer occurred earlier.

Nitrogen Uptake of Grass. Generally the N uptake followed closely the yield at each cut in both soil and peat (Figure 3). However, the high rate of CAN showed luxury uptake of N at the first cut in both soil types.

The N from the CAN fertilizer in soil and in peat appeared to be exhausted earlier in peat. The % recovery of N was lower from peat than from soil in the case of CAN

Table II. Recovery of Fertilizer Nitrogen (% of Applied)

Treatment	Grass		Lettuce	
	Soil	Peat	Soil	Peat
SCU I	63.4	61.4	64.0	63.6
II	60.4	59.8	55.4	52.7
IBDU I	69.0	79.0	71.4	73.1
II	63.4	73.8	59.8	62.0
CAN I	77.7	67.6	54.5	46.8
II	71.8	69.6	53.5	44.5

Table III. Nitrogen Losses by Leaching in First Month (mg)

Treatment	Grass		Lettuce	
	Soil	Peat	Soil	Peat
Control	1.5	2.2	2.0	1.9
SCU I	2.0	2.0	3.8	4.3
II	2.2	3.0	4.8	6.2
IBDU I	2.6	2.5	6.2	8.4
II	3.2	5.0	7.8	12.0
CAN I	5.0	6.5	7.9	9.8
II	8.0	14.0	15.0	20.4
SE	0.4	0.6	0.9	1.5

fertilizer, while the reverse was the case with IBDU. There was not much difference in the recovery of N from soil or peat in the case of SCU (Table II).

Dry Matter Yield of Lettuce. The yield of lettuce grown in soil and peat is shown in Figure 4. From Figure 4 it is obvious that in soil IBDU gave the highest yield followed by SCU and CAN at their respective levels. This trend was more pronounced with lettuce than with grass.

At the first harvest in soil CAN I gave the highest yield, followed by IBDU II and SCU II (Figure 5). CAN II had a depressing effect on yield. The yield depression in soil at the high CAN level and the lack of it in peat could have two causes. Since water was applied twice a week and the soil had a lower water-holding capacity than peat, salt damages would have occurred earlier in soil due to marginal moisture conditions. In addition, the higher leaching in peat would reduce the salt concentration. In the second harvest there was little difference among the various fertilizers at their respective rates except that CAN I gave a low yield. At the third harvest both IBDU and SCU performed identically, while there was no residual effect from the CAN treatment.

In peat at the first harvest CAN gave the highest yield, followed by IBDU and SCU at the high rate (Figure 5). But by the second harvest the yields from CAN at both rates had fallen considerably, while IBDU and SCU performed well. At the third harvest SCU was performing better than IBDU and there was no response from CAN treatments. The cumulative yields of lettuce obtained from SCU and IBDU were similar (Figure 4). A higher cumulative yield of lettuce was recorded by CAN treatments from soil than in peat.

Nitrogen Uptake of Lettuce. Generally, the N uptake followed closely the yield in both soil and peat (Figure 6). However, the high rate of CAN showed luxury uptake at the first harvest in soil. The differences in the N uptake between all the slow-release fertilizers and CAN and between SCU and IBDU were greater in peat than in soil.

There were no consistent differences between peat and soil in % recovery of N by lettuce from the slow-release fertilizers (Table II). However, CAN showed a lower recovery in peat.

In soil there was little difference between the two crops in their recovery of N from SCU and IBDU; however, grass recovered considerably more N from CAN. In peat, lettuce recovered less N from SCU II, CAN I and II, and IBDU I and II than grass.

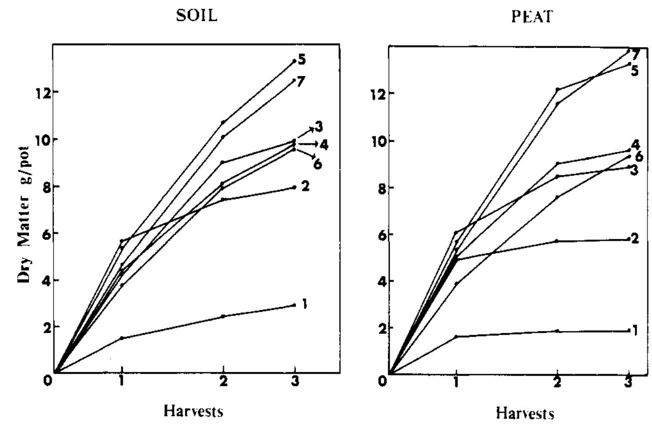

Figure 4. Cumulative yield of lettuce (harvested three times), in soil and peat as affected by rate and source of N. 1. Control; 2. CAN I; 3. CAN II; 4. IBDU I; 5. IBDU II; 6. SCU I; 7. SCU II; S.E. (cumulative yield), soil, 0.46; peat, 0.39.

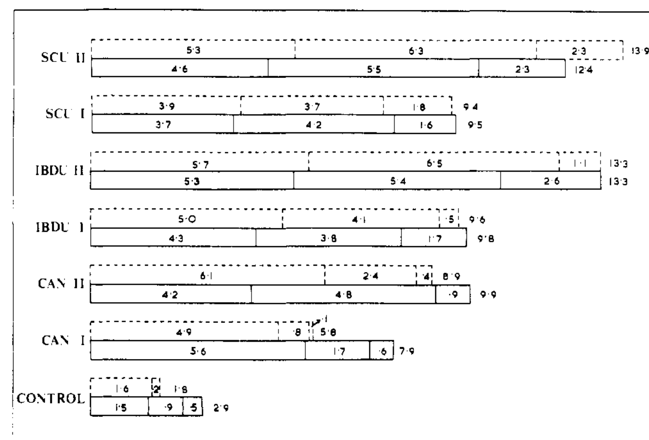

Figure 5. Total lettuce yields and their distribution among three harvests as affected by rate and source of N (unbroken line = soil, broken line = peat).

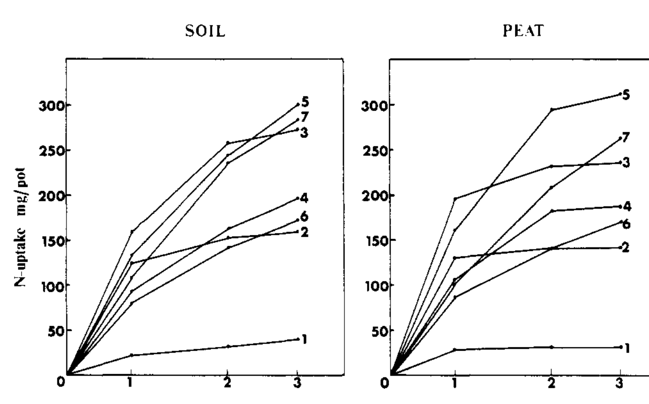

Figure 6. Cumulative uptake of N by lettuce (harvested three times) in soil and peat as affected by rate and source of N. 1. Control; 2. CAN I; 3. CAN II; 4. IBDU I; 5. IBDU II; 6. SCU I; 7. SCU II; S.E. (cumulative uptake), soil, 15; peat, 18.

The recoveries reported here for CAN with grass and lettuce fall in the range reported by other workers for forage and row crops (Allison, 1955; Cooke, 1964). The unaccountable nitrogen would be in the roots, leachates, and volatilization losses. Recovery of N from SCU and IBDU agrees broadly with release characteristics of these fertilizers using leaching columns (Prasad and Gallagher, 1973; Prasad and Woods, 1971a) and with recovery data by other workers (Allen and Mays, 1971; Hamamoto, 1966; Lunt, 1968).

Leaching. In soil with grass, leaching losses for the first month showed maximum leaching with the soluble fertilizer, followed by IBDU (Table III). Leaching of N from SCU was similar to that of the control. Similar trends were present in peat. With lettuce, similar trends were also present in both soil and peat, with the exception that SCU leached more N than control. However, losses of N from all fertilizers were higher in peat than in soil, with lettuce as the crop. Over 4% of the nitrogen from CAN was lost in the first month with lettuce grown in peat.

The effect of rate of application on leaching losses was more pronounced with CAN. The reason for this was that the release of N from slow release fertilizers barely kept in pace with the uptake by the plant, while in the case of CAN excess nitrogen was present, which was leached out.

The difficulty of extrapolating results on leaching losses in pot tests to field conditions is self-evident. However, the above figures are useful to the extent that they establish comparative values for soluble and slow-release fertilizers.

Acidity. There was a drop of 0.1 pH at the higher rates of SCU and IBDU with grass in peat, although this did not occur in soil (data not presented here). A drop of 0.2 and 0.1 pH was recorded by SCU and IBDU treatments, respectively, with lettuce growing in both peat and soil. A slight acidifying action of IBDU and SCU has been shown by Lunt (1968) and by Prasad and Galagher (1973), respectively.

DISCUSSION

These results show that both IBDU and SCU are effective in giving uniform and sustained N nutrition over a period of 5 months both in peat and soil with grass and lettuce crops, whereas CAN, as expected, does not show this property. All these fertilizers behave quite differently in the four different situations. The SCU is least affected by the soil type and crop. IBDU appears to be affected by soil type, showing lower release in soil which is primarily due to a pH effect. Release of N from IBDU has been shown to be affected by pH (Lunt and Clark, 1969). There appears also to be an interaction between soil type and crop, as % utilization of N from IBDU is higher by grass than by lettuce only in peat. It would appear that the higher release of N from IBDU in peat and its consequent leaching is responsible for this. CAN is affected by both soil type and crop. Its efficiency is highest in soil with grass and lowest in peat with lettuce as the crop. This corresponds with leaching susceptibility of the soil and characteristics of the crop. Similarly, a marked advantage as regards yield and N uptake of slow-release fertilizer over soluble fertilizer was found by Lunt (1968) under conditions of high leaching.

SCU with a total coat of 22% releases nitrogen too slowly at the start of the crop, so early yield is depressed. This is in agreement with studies by Allen *et al.* (1968), Allen and Mays (1971), and Allen *et al.* (1971). On the other hand, the nature of the uptake response with time (almost linear) would suggest a high residual effect. By contrast, IBDU shows a fairly good early response. This early response to IBDU was found to be slow for Marion Kentucky Bluegrass by Moberg *et al.* (1970), but they used coarser IBDU than that used in the present experiment.

CONCLUSION

These results show that IBDU would be an ideal N source in peat-based composts for a short-season crop (5 months). It may be necessary, however, to add a small amount of NO_3–N, as nitrifying activity is minimal in the first few weeks, and this may cause NH_4–N damage to sensitive crops (Prasad and Woods, 1971a). SCU could be used as N source for peat composts for nursery stock and ornamental container-grown plants where small amounts of N are required for extended periods. For lettuce production, IBDU (and to a lesser extent SCU) would appear suitable as an N source for two to three harvests without top dressing except, perhaps, in alkaline soils. A supplemental N source may be necessary at an early stage. These results, which show yield depression of lettuce at the higher rate of CAN, confirm the findings of Scaife *et al.* (1972) that it would be hazardous to use CAN for lettuce production in all situations. For peat soils nitrogen top dressing would be necessary after each harvest of lettuce.

For forage production both IBDU and SCU are suitable for giving uniform yield over extended periods. CAN has very little residual effect after two cuts of forage, particularly in peat soils.

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