Release Characteristics of Nitrogen Fertilizers in Peat and Sand

Munoo Prasad* and Michael J. Woods

Release rates of six slow release N-fertilizers (ureaformaldehyde, hoof and horn, isobutylidenediurea, magnesium ammonium phosphate, osmocote, and casein) and calcium ammonium nitrate were studied in sphagnum moss peat and sand using leaching columns. Total nitrogen released was higher in sand than in peat and this difference was more marked in the case of ureaformaldehyde, hoof and horn, and isobutylidenediurea. The percentages released in peat over a 14-week period for ureaformaldehyde, hoof and horn, isobutylidenediurea (coarse), isobutylidenediurea (fine), casein, magnesium ammonium phosphate, osmocote and calcium ammonium nitrate were 32, 42, 69, 71, 76, 83, 85, and 95, respectively. The rate of nitrogen release from magnesium ammonium phosphate, isobutylidenediurea, and casein accelerated in the latter half of the experiment. There was a time lag of a few weeks in the production of nitrate-nitrogen in the peat compared with the sand. The feasibility of some of these fertilizers in peat for short season crops is discussed.

The release rates of ureaformaldehyde (UF), hoof and horn, isobutylidenediurea (IBDU), osmocote, and magnesium ammonium phosphate (Mag Amp) have already been studied (Basaraba, 1964; Bredakis and Steckel, 1963; Bridger *et al.*, 1962; Hamamoto, 1966; Hays, 1963; Lunt and Oertli, 1962; Lunt *et al.*, 1964; McCants, 1969; Oertli and Lunt, 1962). Soil was the medium used in most of these studies, but sand and water were used in some instances. A review of the literature revealed that the release rates of these fertilizers from peat substrates have not been reported. It was, therefore, considered that a study of the release pattern and forms of nitrogen released in peat over a 3-month period would be valuable because of the characteristic microbial activity (Herlihy, 1967; Penningsfeld and Kurzmann, 1966) and buffering capacity (Penningsfeld and Kurzmann, 1966) of peat. The high rate at which leaching may occur in peat (Haveraaen and Steenberg, 1967; Penningsfeld and Kurzmann, 1966; Prasad and Woods, 1969) suggests that slow release fertilizers may be particularly useful in peat substrates. In addition, the study of the release of nitrogen in peat was considered valuable because of the homogeneity of the medium and the greater reproducibility of results.

The present experiment was designed to study the release pattern and forms of nitrogen released from commercially available and experimental fertilizers. The release rates of these fertilizers were also studied using river sand for comparative purposes. The formation of leachable nitrogen was considered to represent the amount of released nitrogen which would be available to the plant.

MATERIALS AND METHODS

The characteristics of seven fertilizers differing in nitrogen content and particle size (Table I) were compared using two replicates in virgin sphagnum moss peat and sand. The characteristics of casein were studied in peat only. The experiment was carried out in a heated greenhouse at 18° C day/night minimum temperature. About 1400 cc of moist peat (weighing about 960 g after drainage ceases from a 30 cm column) was mixed with 12 g of dolomitic limestone to bring the pH to about 6.5. This amount of peat and the same volume of river sand (2 kg) having a pH of 6.8 were then mixed separately with 600 mg of nitrogen from each nitrogen fertilizer and placed in a 20 cm deep PVC (Polyvinyl chloride) pipe having a diameter of 10 cm. A plastic mesh held by a rubber band was attached to the bottom of the PVC cylinder. The pipes were placed in Buchner funnels of 11 cm diameter. A round disc of glasswool was placed on the sand and the peat to assist in uniformly distributing the water. The top of the pipe was covered by perforated polythene to reduce evaporation and maintain the peat and the sand at approximately the moisture content of a drained 20 cm column. One liter of nitrogen-free tap water was added initially and then once a week over a 14-week period. This amount of water was designed to displace the bulk of the liquid phase from the peat and sand. The periodic removal of the accumulated nitrogen would reduce immobilization and recycling of nitrogen released during incubation. The leachates were analyzed at weekly intervals for the first 8 weeks and subsequently at 2-week intervals. "Total" nitrogen was determined by the standard Kjeldahl method without modification to exclude NO_3-N, NH_4-N with Nessler's reagent and NO_3-N by the Xylenol method (Byrne, 1968). The nitrogen fraction derived by the subtraction of NH_4-N from Kjeldahl nitrogen was termed "organic." The NO_2-N fraction was not determined. Losses of fertilizer N due to volatilization, if any, were ignored.

RESULTS

From the cumulative leaching from the N-fertilizers (Figure 1) one can see that the total amount of nitrogen released was in all cases higher in the sand than in the peat. The curves were corrected for similar peat and sand columns not receiving any fertilizer. The difference in the release of nitrogen was more marked in the case of fertilizers like UF, hoof and horn, and IBDU than among fertilizers like Mag Amp, osmocote, and CAN. The ratio of released nitrogen from sand/peat varies from 1.32 to 1.21 and 1.11 to 1.06 in the former and latter groups of fertilizers. The difference in release in the sand and peat is primarily the result of differential release in the earlier weeks. Apart from this the release patterns are similar in peat and sand.

The nitrogen released in peat over 14 weeks was 32% from UF, 42% hoof and horn, 69% IBDU (coarse), 71% IBDU (fine), 76% casein, 83% Mag Amp, 85% osmocote, and 95% CAN. The release rate was steady in the case of UF and hoof and horn, while Mag Amp and IBDU (coarse) showed increasing release at about the 7th and 10–12th week stages, respectively. Osmocote, which showed its maximum release at the 2–3 week stage, gave a steady but declining release for about 10 weeks. Casein showed release maxima at the 4–5 week stage and again at the 10th week. The fine IBDU released its nitrogen earlier than the coarser fraction. CAN released more of its nitrogen in the first 4 weeks.

The forms of nitrogen released from N-fertilizer in peat and

Department of Glasshouse Crops, The Agricultural Institute, Kinsealy, Dublin, Ireland.

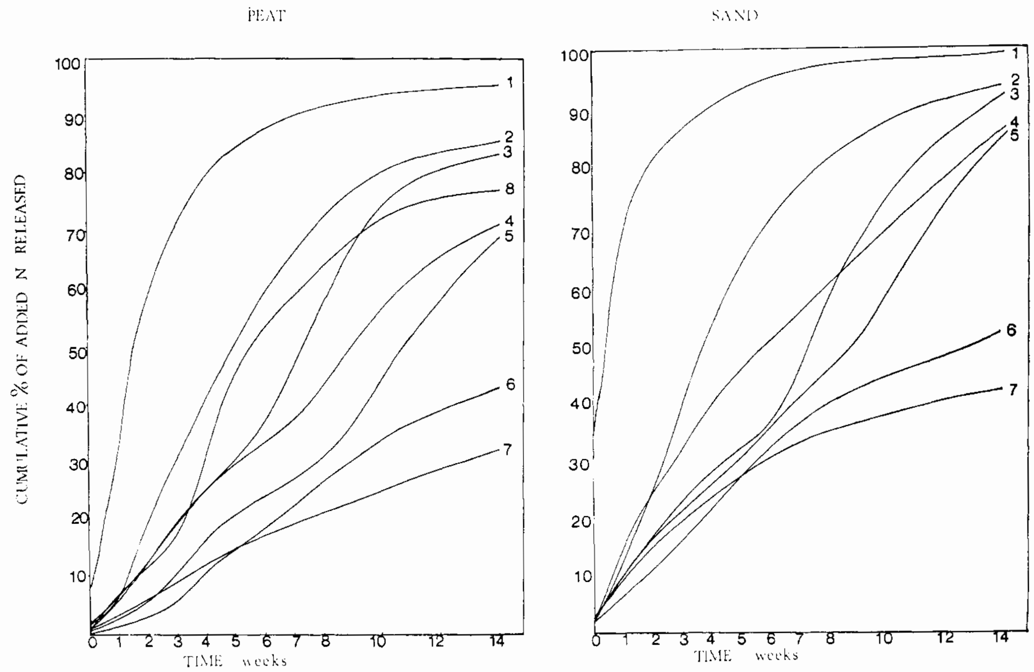

Figure 1. Release of nitrogen from N-fertilizers in peat and sand columns (minus control)

1 CAN
2 Osmocote
3 Mag Amp
4 IBDU (fine)
5 IBDU (coarse)
6 Hoof and Horn
7 UF
8 Casein

Table I. Characteristics of the Fertilizers Tested

	%N	Granule Size		A.S.T.M. Mesh	
		35	35–10	10–4	4
UF	38.7	33	63	4	0
Hoof and Horn	12.3	17	48	28	7
Casein	11.5	68	329	0	0
Mag Amp	7.3	2	45	53	0
Calcium ammonium nitrate (CAN)	22.8	0	19	81	0
Osmocote[a]	14.7	0	13	87	0
IBDU (coarse)	32.4	between 14–10			
IBDU (fine)	32.5	between 25–14			

[a] Membrane resin coated fertilizer containing 40% as NO_3-N and the rest as NH_4-N. UF Activity Index = 40 min. Product Data No. 292-3, Hercules Powder Co., Wilmington, Del.

sand are shown (Figure 2) for the first 8 weeks because only NO_3-N was present in substantial quantities subsequently. There was a time lag of a few weeks between the release of NO_3-N in sand and in peat in all fertilizers tested. Organic N was an important fraction in the case of casein, IBDU, and UF.

DISCUSSION

The difference between N leached from the sand and the peat in the initial leaching would be explained in part by the greater volume of water which percolated through the sand, since the peat absorbed more of the initial addition of water. Differences in peat and sand in the subsequent weeks which give higher total nitrogen release in sand than in peat are due to low bacterial activity of the peat relative to the sand (Penningsfeld and Kurzmann, 1966) and to the exchange properties of peat. The sterility of peat retards the initial microbial breakdown of UF and of hoof and horn. In addition,

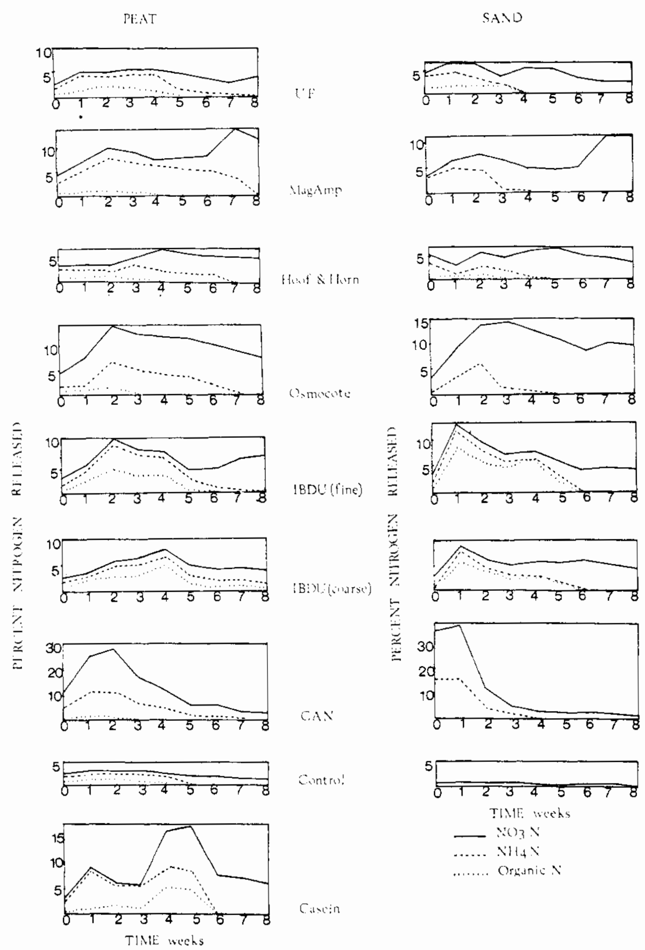

Figure 2. Forms of nitrogen released from N-fertilizers in peat and sand

the paucity of nitrifying bacteria in peat (Herlihy, 1967) retards nitrification of all fertilizers added. The lack of these processes had a greater effect on fertilizers like hoof and horn, UF, and to a lesser extent Mag Amp, than fertilizers like osmocote and CAN which already contain varying amounts of NO_3-N. Hence the nutrient release ratio in sand and peat is wider in the former group of fertilizers. The paucity of nitrifying bacteria would cause NH_4-N to remain longer in the soil solution and thereby have a greater likelihood of absorption by the peat, especially in the earlier weeks. This would contribute further to the widening of this ratio. On the other hand, the removal of NH_4-N from the soil solution in the peat by this process could slightly accelerate the dissolution of these fertilizers. In the case of IBDU, the difference in total nitrogen released in peat and sand would be attributed to a greater extent to the exchange capacity of peat for NH_4^+ and to a lesser extent to the microbial activity since microbial activity has only a minor effect on dissolution of IBDU (Hamamoto, 1966; Lunt and Clark, 1969).

The results show that although UF is releasing its nitrogen at a steady rate, the total amount released in 14 weeks is small. Mineralization studies carried out by other workers show similar (Basaraba, 1964) or slightly higher release rates (Hays, 1963).

The experiment has further sustained the view that hoof and horn has slow release properties and this is in agreement with Penningsfeld and Kurzmann (1966), who also noted that hoof and horn had slow release properties in peat. Owen *et al.* (1950), however, found no slow release properties when hoof and horn was incubated in the soil. This discrepancy could be due to the higher bacterial activity in the soil than that in the sand or peat used in this experiment. The hoof and horn used in the present experiment was also coarser grained than that used by Owen *et al.*, which had been ground to pass through a 1 mm sieve.

The total amount of nitrogen released from coarse and fine IBDU in peat and sand is slightly lower than that found by the workers of the Mitsubishi Chemical Industries (1969). Higher temperatures were used in their experiment and higher temperature is known to accelerate the breakdown of IBDU (Hamamoto, 1966). The low nitrate production from IBDU during the early weeks gives some evidence for an inhibiting effect of isobutyric acid on the nitrifying bacteria. The isobutyric acid is apparently not being decomposed due to lack of microbes. This isobutyric acid could also affect plant growth. Subsequent experiments at Kinsealy showed that IBDU at 1.8 g/l. of peat had a toxic effect on tomatoes grown in this medium.

The osmocote release curve is similar to that found by Oertli and Lunt (1962). Microbial activity has previously been shown to have no direct effect on nitrogen release (Oertli and Lunt, 1962). The narrow sand/peat release ratio noted in this experiment further substantiates this finding.

The favorable slow release properties shown by Mag Amp confirm the earlier findings of Bridger *et al.* (1962) and Lunt *et al.* (1964). These results are not, however, directly comparable due to the difference in granule size used.

No studies on the release rate of nitrogen from casein over a period of time were found in a review of literature. Widdowson and Shaw (1950) found in a 2-year field experiment that in 1 year only the nitrogen in the casein was more efficiently used than that supplied by repeated dressings of ammonium sulfate, and thereby showed slow release properties. They deduced that this may reflect differences in rainfall and transpiration between the two seasons.

The pattern of release of nitrogen from CAN was typical of water soluble fertilizers and similar to that found by Basaraba (1964) and Knop (1965) for other water soluble fertilizers.

In conclusion these results show that the release of nitrogen from UF and hoof and horn would be inadequate for rapidly growing short season crops. Other workers have also reported nitrogen starvation in a number of plants where UF was used as N-source in soil (Escritt, *1961*; Scarsbrook, *1958*; Terman *et al.*, 1964) and in peat (Prasad and Woods, 1969). Nitrogen starvation was also noted when hoof and horn was used as N-source in peat for tomatoes in experiments in Ireland (Prasad and Woods, 1969). Fertilizers like IBDU, casein, and Mag Amp, and to a lesser extent osmocote, showed release curves similar to those for nutrient absorption in short season crops (Chandler, 1960; Raper and McCants, 1966). The increasing release of nitrogen from these fertilizers at a late stage seems especially favorable in this respect. However, the fact that Mag Amp, IBDU, and casein in the peat are releasing most of their nitrogen in nonnitrate form in the early stage would be detrimental to the growth of a number of plant species (Harada and Takaki, 1964; McKee, 1962; Volk, 1958; Woolhouse, 1958) especially at seedling and propagating stage. The imbalance between nitrogen form could, however, be corrected by adding a nitrate fertilizer as a starter or by inoculating with nitrifying bacteria.

ACKNOWLEDGMENT

We thank Brian McMenamin for technical assistance and the laboratory staff of the Soil Fertility/Chemistry Department, Johnstown Castle, for carrying out the chemical analyses.

LITERATURE CITED

Basaraba, J., *Can. J. Soil Sci.* **44,** 131 (1964).
Bredakis, E. J., Steckel, J. E., *Agron. J.* **55,** 145 (1963).
Bridger, G. L., Salutsky, M., Storostka, R. W., J. AGR. FOOD CHEM. **10,** 181 (1962).
Byrne, E., Methods of Analysis, 91, Soils Division, Wexford, Ireland, 1968.
Chandler, W. V., *N.C. Agr. Exp. Sta. Tech. Bull.* 143 (1960).
Escritt, J. R., *J. Sports Turf Res. Inst.* **10,** 294 (1961).
Hamamoto, M., *Proc. Fert. Soc.* **90,** 1–77 (1966).
Harada, T., Takaki, H. J., *J. Sci. Soil Animal Fertilizers, Jap.* **35,** 181 (1964).
Haveraaen, O., Steenberg, K., *Meld. Norg. Landbrukshoegsk.* **46** (21), 1–2 (1967).
Hays, J. T., *Proc. 11th Annu. Calif. Fert. Conf.* 1, (1963).
Herlihy, M., Research Rep. Soils Division, The Agricultural Institute, Dublin, 80 (1967).
Knop, K., *Albrecht-Thaer-Arch.* **9,** 1011 (1965).
Lunt, O. R., Oertli, J. J., *Soil Sci. Soc. Amer. Proc.* **26,** 584 (1962).
Lunt, O. R., Kofranek, A. M., Clark, S. B., J. AGR. FOOD CHEM. **12,** 497 (1964).
Lunt, O. R., Clark, S. B., J. AGR. FOOD CHEM. **17,** 1269 (1969).
McCants, C. B., *Agron. J.* **61,** 353 (1969).
McKee, H. S., "Nitrogen Metabolism in Plants," p. 1, Clarendon Press, Oxford (1962).
Mitsubishi Chemical Industries, Japan, Note on IBDU, 28 (1969).
Oertli, J. J., Lunt, O. R., *Soil Sci. Soc. Amer. Proc.* **26,** 579 (1962).
Owen, O., Rogers, D. W., Winsor, G. W., *J. Agr. Sci.* **40,** 185 (1950).
Penningsfeld, F., Kurzmann, P., "Hydrokultur und Torfkultur," Verlag Eugen Ulmer, Stuttgart, 83–133 (1966).
Prasad, M., Woods, M. J., Research Rep. Hort. Division, The Agricultural Institute, Dublin 42–44 (1969).
Raper, C. D., Jr., McCants, C. B., *Tobacco Sci.* **10,** 109 (1966).
Scarsbrook, C. E., *Soil Sci. Soc. Amer. Proc.* **22,** 442 (1958).
Terman, G. L., De Ment, J. D., Hunt, C. M., Cope, J. T., Jr., Esminger, L. E., J. AGR. FOOD CHEM. **12,** 151 (1964).
Volk, G. M., *Proc. Fla. State Hort. Soc.* **71,** 69 (1958–1959).
Widdowson, F. V., Shaw, K., *J. Agr. Sci.* **40,** 185 (1950).
Woolhouse, H. W., *Aust. J. Sci.* **21,** 143 (1958).

Received for review July 22, 1970. Accepted October 26, 1970. The postdoctoral fellowship provided by the Department of Education to the first author is gratefully acknowledged.