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**MOVEMENT, pH EFFECT AND NITRIFICATION OF
BAND-APPLIED ANHYDROUS AMMONIA, UREA AND
SULPHATE OF AMMONIA IN AN ALKALINE BLACK
EARTH**

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SUMMARY

Movement of the ammonium ion was mainly lateral and vertically upward. Anhydrous ammonia had the highest mobility.

Anhydrous ammonia and urea produced a short-lived increase in pH, followed by a rapid drop.

Urea and anhydrous ammonia were almost totally nitrified after 30 days; nitrification of ammonium sulphate was only 80% complete by 90 days.

I. INTRODUCTION

The use of band-applied nitrogen fertilizer as urea, sulphate of ammonia or anhydrous ammonia is common practice in field crop production. It is known that localized high concentrations produced by bands of these fertilizers affect both the soil pH and the nitrification rate of the applied nitrogen (Morrill and Dawson 1967; Eno and Blue 1957). However, most studies of these effects have been either perfusion or incubation studies designed to simulate the fertilizer-soil reaction at a theoretical, and usually unspecified, distance from the line of application. No detailed studies have yet been reported comparing the spatial distribution in time of band-applied ammoniacal fertilizers. This paper seeks to fill this gap with respect to the application of banded ammoniacal fertilizers on an alkaline black earth.

II. METHODS AND MATERIALS

Sixteen plastic-lined iron containers were constructed to take a slab of soil 15 cm wide, 12.5 cm high and 2.5 cm thick. The bottom 7.5 cm was packed with Waco black earth (see Table 1) at 45% moisture to a bulk density of 1.3, the

TABLE 1
SOME PROPERTIES OF WACO BLACK EARTH

Percentage Moisture at pF2	Mechanical Analysis			pH	Total N (%)	Exchangeable Cations (m-equiv./100 g)			
	Clay (%)	Silt (%)	Sand (%)			Ca	Mg	K	Na
56	77	10	13	8.3	0.081	40.2	27.2	2.6	3.7

measured field bulk density below the plough layer. The following treatments were imposed on groups of four slabs: control; urea; ammonium sulphate; anhydrous ammonia.

Solid urea and ammonium sulphate were applied to the centre surface of this layer and covered with 5 cm air-dry soil representing a plough layer. Anhydrous ammonia was applied at the same point after the addition of the "plough layer" using the dispensing apparatus of Papendick and Parr (1966). An application rate of 0.148 g N was used throughout, this being equivalent to a 2.5 cm run in the application of 165 kg N/ha using a tine or applicator spacing of 35 cm.

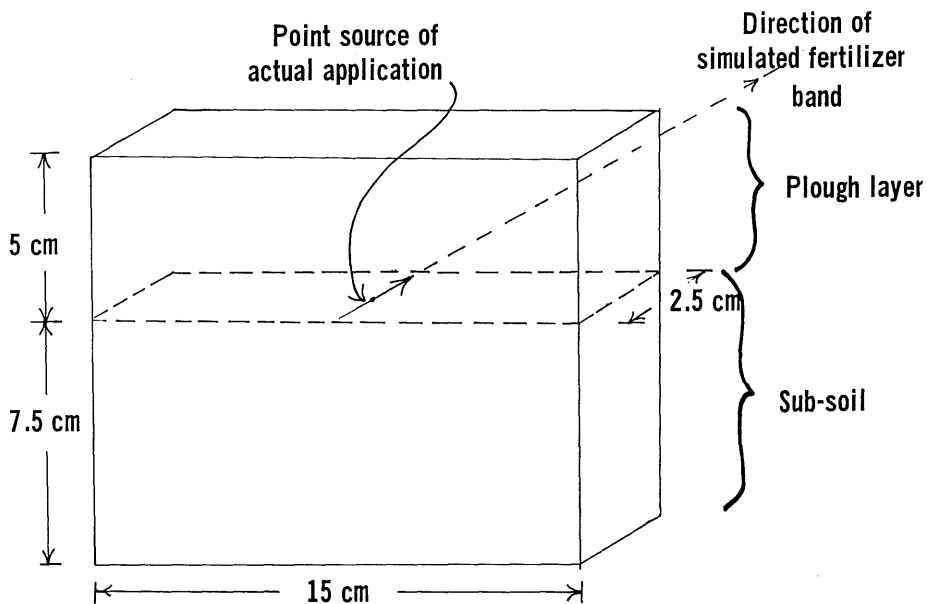


Fig. 1.—Soil slab representing a 2.5 cm thick, 15 cm wide cross-section of a banded fertilizer.

The slab, as shown in Figure 1, thus represents a 2.5 cm cross-section of a field nitrogen application.

All slabs were brought to and maintained at field capacity (56% moisture) by surface watering, and stored at 20°C. Single slabs for control and each nitrogen source were placed in a deep freeze at -20°C at 1, 7, 30 and 90 days to await analysis. Slabs were sectioned for analysis into 2.5 cm x 2.5 cm x 1.25 cm pieces as shown in Figure 2, with laterally identical sections being combined.

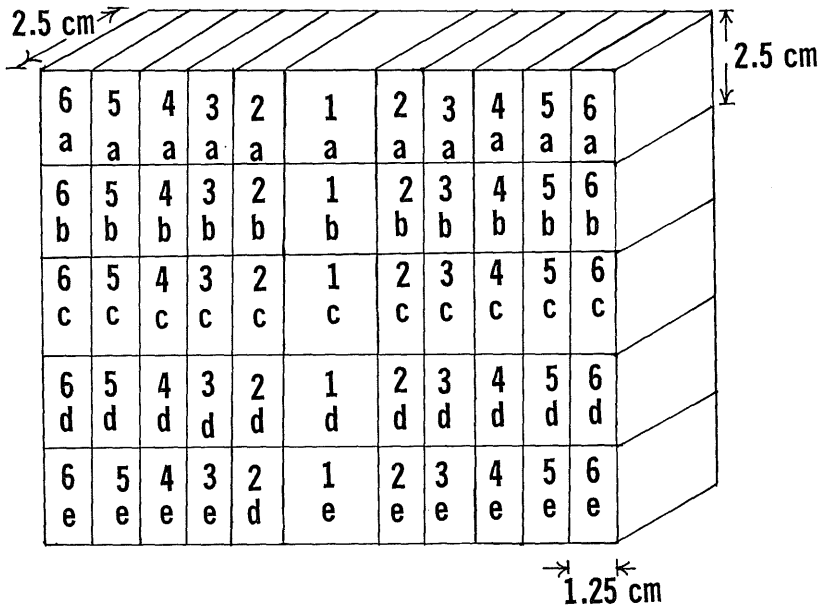


Fig. 2.—Method of sectioning slab for analysis. Laterally identical sections were combined.

After removing a subsample for moisture determination, water was added to the remainder of the sample to give a 1:2.5 soil:water suspension for pH readings. An equivalent volume of 4N KCl was then added and the soil shaken for 1 hr prior to the analysis of the extract for NH₄ nitrogen and (NO₃ + NO₂) nitrogen using the steam distillation procedure of Bremner and Keeney (1966). Urea nitrogen was measured in the urea slabs for the 1-day and 7-day treatments using the urease method of Keeney and Bremner (1967).

III. RESULTS

Complete results of the $\text{NH}_4\text{-N}$ and $(\text{NO}_3 + \text{NO}_2)\text{-N}$ analyses on the soil slabs are shown in histogram Form in Figures 3, 4 and 5.

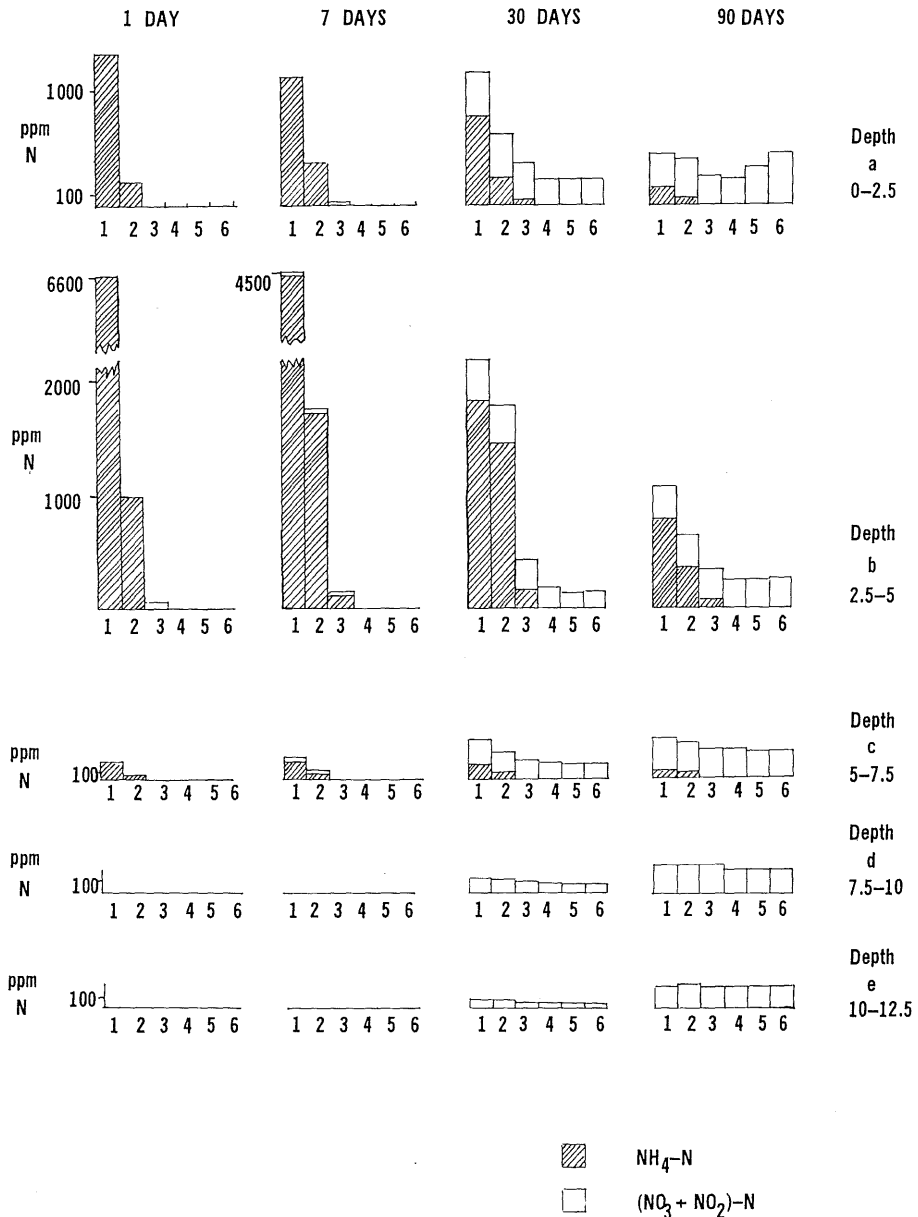


Fig. 3.—Sulphate of ammonia: Distribution of NH_4 nitrogen and $(\text{NO}_3 + \text{NO}_2)$ nitrogen in soil slabs, sampled as shown in Fig. 2, for four times of sampling after fertilizer addition. Lateral distance as for Fig. 4.

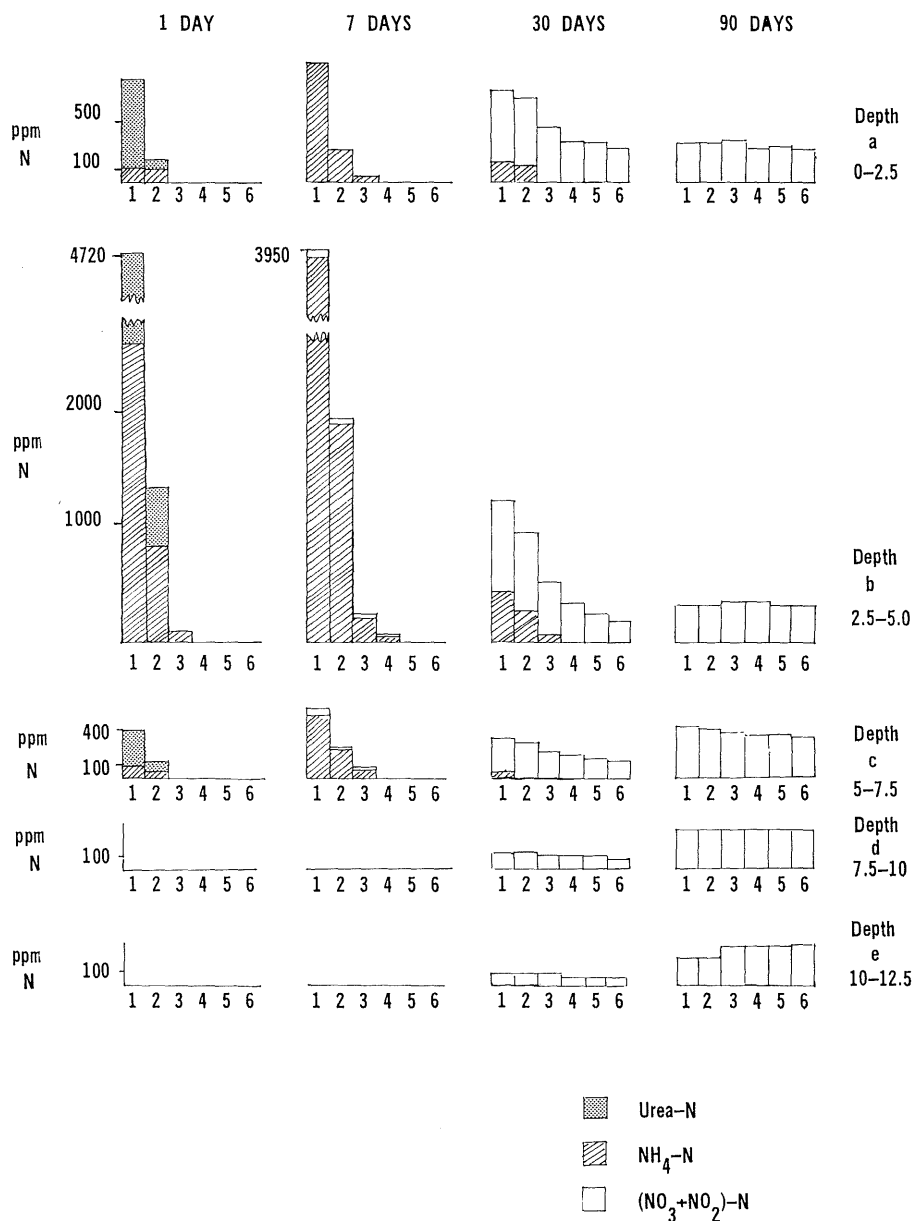


Fig. 4.—Urea: Distribution of NH₄ nitrogen and (NO₃ + NO₂) nitrogen in soil slabs, sampled as shown in Fig. 2, for four times of sampling after fertilizer addition. Lateral distance from vertical line through point of fertilizer application: 1 = 0 - 1.25 cm, 2 = 1.25 - 2.5 cm, 3 = 2.5 - 3.75 cm, 4 = 3.75 - 5 cm, 5 = 5 - 6.25 cm, 6 = 6.25 - 7.5 cm.

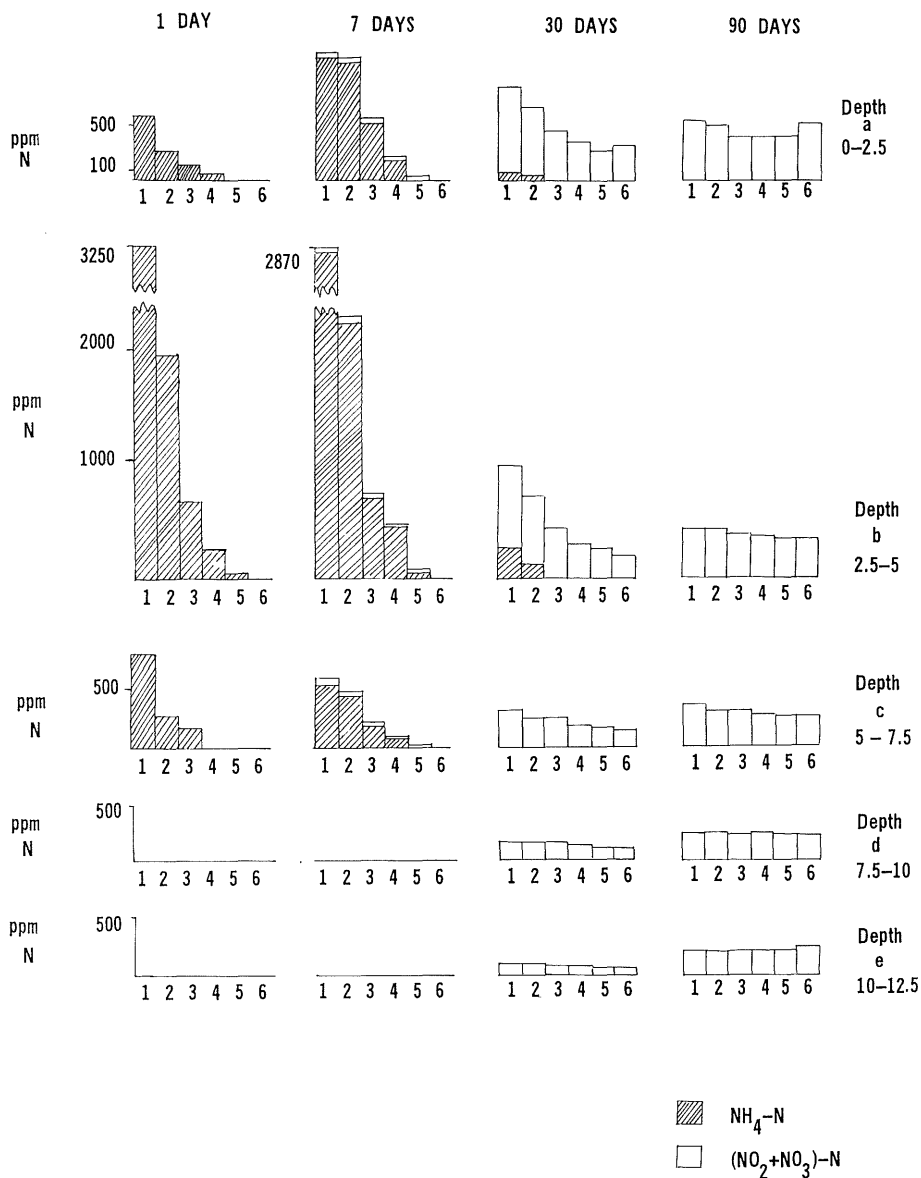


Fig. 5.—Anhydrous ammonia : Distribution of NH_4 nitrogen and $(\text{NO}_3 + \text{NO}_2)$ nitrogen in soil slabs, sampled as shown in Figure 2, for four times of sampling after fertilizer addition. Lateral distance as for Fig. 4.

Changes in pH with time at three lateral distances from the point of fertilizer application in the 2.5-5 cm depth zone are shown in Figure 6. The pH change pattern was similar but less marked in the 0-2.5 cm and 5-7.5 cm depth zones.

Figure 7 shows the percentage of recovered nitrogen remaining as ammonium after various times. Apparent recoveries of added nitrogen (see Table 2) showed no serious loss of nitrogen from the system. This concurs with lysimeter studies reported by Craswell (1972), who found no loss of $\text{NO}_3\text{-}^{15}\text{N}$ when similar soil was maintained at pF2.

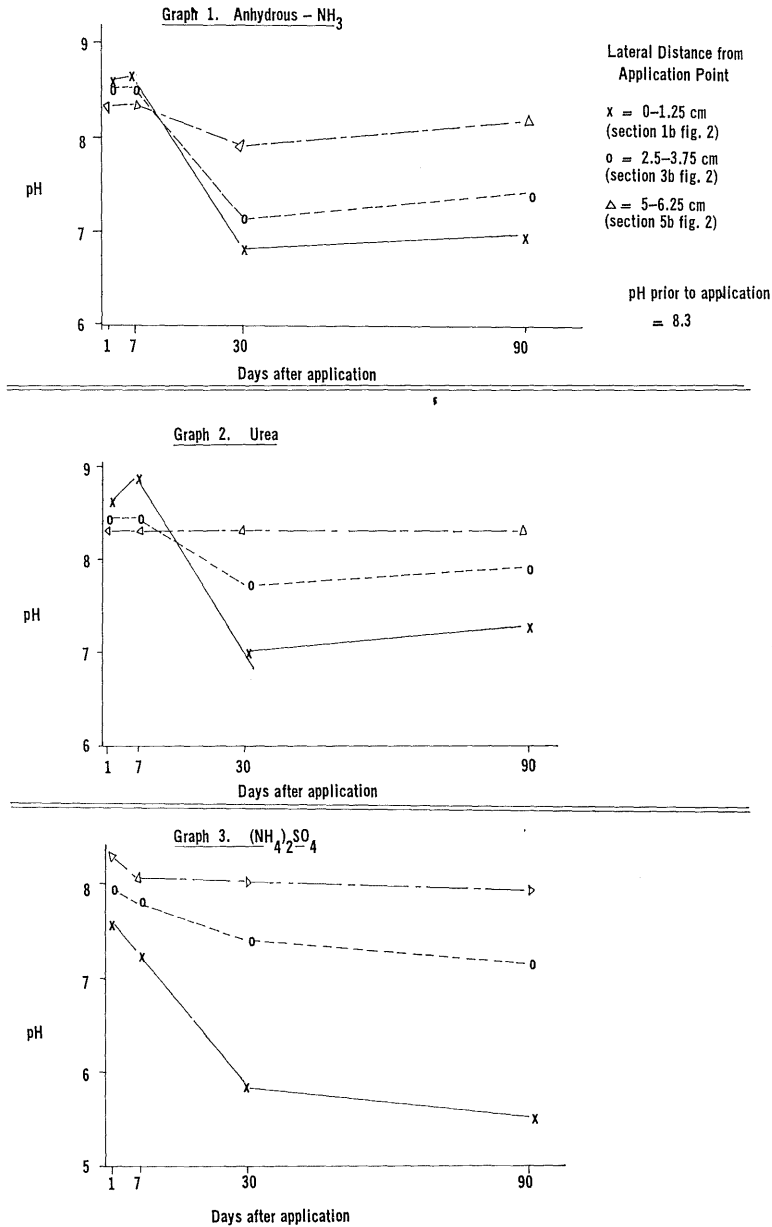


Fig. 6.—Changes in pH with time.

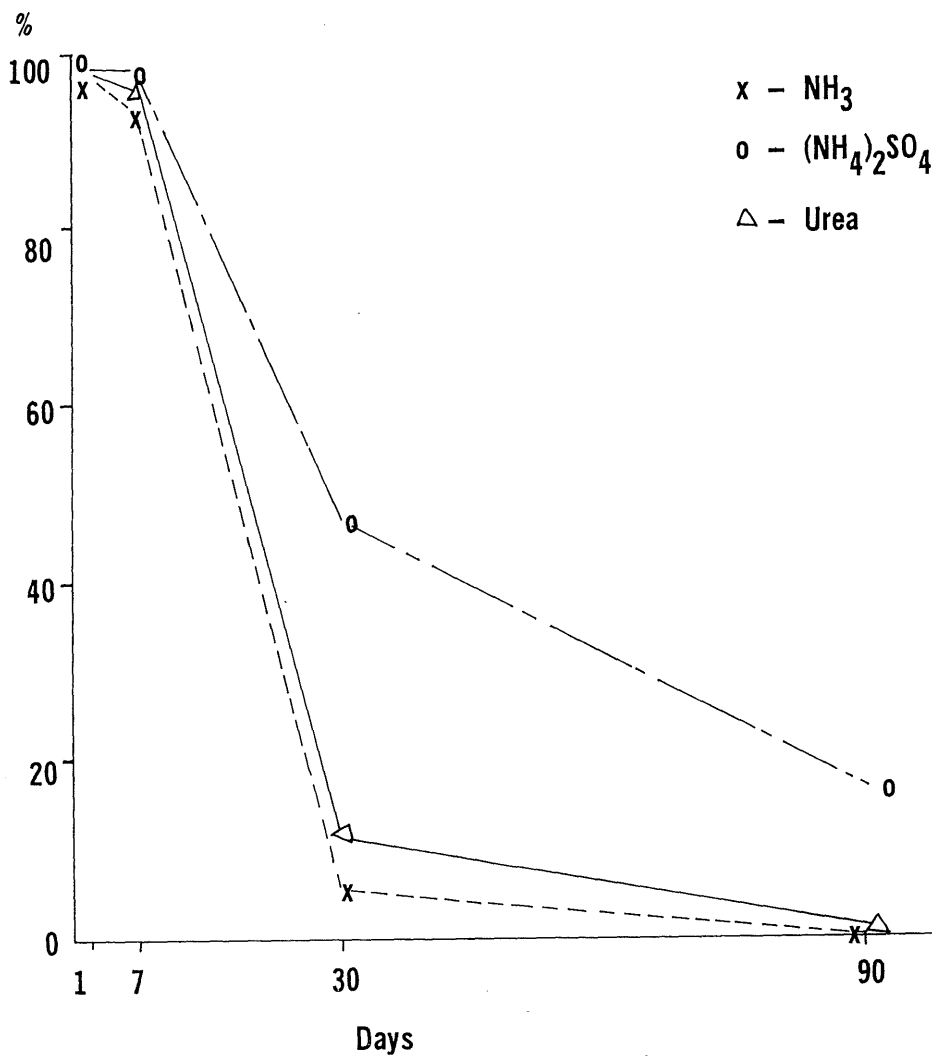


Fig. 7.—Percentage of the mineral nitrogen recovered still present as ammonium (or as ammonium plus urea in the urea treatment).

TABLE 2
PERCENTAGE RECOVERY OF ADDED N*

N Form	1 day	7 days	30 days	90 days
Anhydrous NH ₄	87	88	88	87
Urea	98	91	98	109
Ammonium sulphate ..	98	88	100	90

* Calculated as $\frac{\text{N in treated slab} - \text{N in control}}{\text{N applied}} \times 100$

IV. DISCUSSION

(a) *Movement*.—Movement of the ammonium ion was mainly lateral and vertically upwards. The higher bulk density of the simulated subsoil was an effective barrier to ammonium ion diffusion, but following nitrification there was a ready diffusion of nitrate throughout the slab.

The extent of lateral movement of $\text{NH}_4\text{-N}$ shown by the three forms were:

Anhydrous ammonia	5	-6.5 cm
Urea	3.75	-5.0 cm
Ammonium sulphate	2.5	-3.75cm

The higher mobility of anhydrous ammonia is attributed to gaseous diffusion on application.

(b) *pH changes*.—Anhydrous ammonia and urea produced a pH increase (0.3 to 0.6 pH units) within 2.5 cm of the point of application but this was short-lived and became a marked pH drop (1.3 to 1.6 pH units) due to nitrification between 7 and 30 days.

The initial pH increase was higher with urea due to the more restricted movement and greater point concentration of $\text{NH}_4\text{-N}$ produced by urea.

The pattern of pH drop produced by urea and anhydrous ammonia between 7 and 30 days corresponded with the $\text{NH}_4\text{-N}$ diffusion pattern, showing that nitrification *in situ* occurred even at initial pH levels and $\text{NH}_4\text{-N}$ concentrations considered by others working on lighter soils to be inhibitory to nitrification (Eno and Blue 1957). After 30 days, and the completion of nitrification, pH rose under the buffering effect of the soil.

With ammonium sulphate the pH drop was immediate and not restricted to the small NH_4 diffusion zone, indicating that the acidic effect outside this zone was produced by diffusing sulphate ions. Since nitrification was incomplete, pH was still declining after 90 days.

(c) *Nitrification*.—The marked acidification produced by ammonium sulphate had an inhibiting effect on nitrification.

Nitrification of ammonium sulphate was only 50% complete by 30 days and 80% complete by 90 days, compared to the almost total nitrification of urea and anhydrous ammonia after 30 days (Figure 1).

This rapid nitrification of urea and anhydrous ammonia shows that the inhibitory effect on nitrification of high pH and high ammonium concentration found to occur in closed incubation experiments (Eno and Blue 1957) is of little consequence in an open system. A supplementary incubation experiment carried out with this soil showed that, apart from the expected temporary nitrite build-up during the first 7 days (Morrill and Dawson 1967), nitrite persisted for 30 days only in the presence of an initial 2,500 p.p.m. $\text{NH}_4\text{-N}$ and a pH greater than 7.7. Thus, although not measured in this experiment, the possibility of a persisting nitrite accumulation could be discounted.

(d) *Conclusion*.—In some instances it is advantageous to reduce the rate of nitrification of applied ammoniacal fertilizers. This study shows that ammonium sulphate is the slowest ammoniacal fertilizer to nitrify on an alkaline black earth. This is contrary to the findings of Eno and Blue (1954) working on alkaline sands, and is possibly due to the more restricted diffusion and a greater concentration of acidic effect produced in clay soil.

V. ACKNOWLEDGEMENTS

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