Priming Effect of ^{15}N-Labeled Fertilizers on Soil Nitrogen in Field Experiments[1]

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ABSTRACT

Evidence of the "priming effect" on the uptake of soil N by additions of rather conservative amounts of fertilizer N was examined in data from two recently reported field experiments. In these experiments, urea and oxamide each labeled with ^{15}N were compared on adjacent locations in successive years with 'Sudax SX11' Sorghum-sudan hybrid (*Sorghum sudanense*) as the test crop. The priming effect in the first experiment was calculated from data from four cuttings during the first year and from a residual cutting during the second year. For the second experiment, data were used from the three cuttings harvested during the year the fertilizers were applied.

Additions of N fertilizer increased the uptake of soil N by 17 to 45% in the first experiment in 1966 and by 8 to 27% in the second experiment in 1967. In the residual cutting of the first experiment, increases in uptake of soil N ranged from less than 0 to 29%. The increase in uptake of soil N by the crops was speculated to be due to stimulation of microbial activity by N fertilizers which increased mineralization of soil N, thus making more soil N available for use by plants.

Additional Index Words: **stable isotopes, isotopic tracers, urea, oxamide, nitrogen fertilizer, mineralization.**

APPLICATIONS OF FERTILIZER N in greenhouse and laboratory experiments have been reported to stimulate, depress, or have no effect on the mineralization of soil N. Stimulation of mineralization of soil N by the addition of fertilizer N has been referred to as the "priming effect" and has been reported in different experiments by Stotzky and Mortensen (1958), Broadbent (1965), Chu and Knowles (1966), Nömmik (1968), and Sapozhnikov et al. (1968). Contrary to this positive priming effect, a negative effect or a depression in the mineralization of soil N has also been reported by other workers (Gerretsen, 1942; Harmsen and Lindenbergh, 1949; Megusar, 1968; and Jansson, 1958). In other situations Harmsen and Kolenbrander (1965) and Fack (1965) found little change in N mineralization as a result of fertilizer additions (H. J. Fack, 1965. Tracer studies on nitrogen transformations in two Ontario soils. Agronomy Abstracts, 83. Amer. Soc. Agron., Madison, Wis.)

With these varying reports from the greenhouse and laboratory, examination of field experiments for additional information about the priming effect is desirable. In such experiments, ^{15}N-labeled fertilizer is necessary (Westerman and Kurtz, 1973) to differentiate between the uptake of soil N and the uptake of fertilizer N. Ideally, such experiments should also involve different types of fertilizer compounds and weather conditions in a field situation. Priming effect has rarely been measured in the field.

We recently reported experiments designed to compare efficiencies and residual effects of two widely different N carriers. Since those experiments did utilize ^{15}N-labeling and extend over 2 years with quite different growing seasons, an opportunity to observe the extent of the priming effect under field conditions was presented.

The objectives of this study were to determine the effects over a 2-year period in the field with both slowly and readily-soluble N fertilizer sources on the uptake of soil N by sudan grass (*Sorghum sudanense*).

EXPERIMENTAL PROCEDURES

Data for this study were provided by experiments described in detail in previous publications (Westerman, 1969; Westerman, Kurtz, and Hauck, 1972; Westerman and Kurtz, 1972). Fertilizers labeled with ^{15}N were applied in field experiments (Experiment I in 1966, Experiment II in 1967). The fertilizers were urea, a readily soluble N source, and oxamide, a slowly soluble N source, and rates of N were 0, 56, 112, and 168 kg/ha. Four harvests of 'Sudax-SX11' were removed in 1966 in Experiment I and three harvests in Experiment II in 1967. Residual effects of N applied in 1966 were measured in 1967. Uptake of fertilizer N in each harvest was determined by isotopic techniques and subtracted from total uptake of N to obtain the uptake of soil N. Standard statistical procedures were utilized to aid in the interpretation of the data and differences mentioned in this discussion were significant at the 0.05 level.

RESULTS AND DISCUSSION

Effects of fertilizer N on the uptake of soil N are shown in Table 1 for the different harvests in the two experiments. By comparing the uptake of soil N in the absence of fertilizer (under column heading "Check") with other values on the same line of the table, the influence of the different amounts of the two carriers on the uptake of soil N can be seen.

In the first two harvests of the first experiment, considerably larger amounts of soil N were taken up from the

Table 1—Soil nitrogen (kg/ha) taken up by sudangrass as influenced by rates of fertilizer nitrogen (kg N/ha)

Harvest date		Check, 0	Urea 56	Urea 112	Urea 168	Oxamide 56	Oxamide 112	Oxamide 168
			Experiment I (1966)					
June 30		32.5	41.6	46.0	57.7	52.0	40.4	40.1
July 28		36.9	55.4	68.2	68.5	54.9	62.7	65.5
Aug. 30		18.2	16.4	21.0	19.8	14.2	21.2	23.5
Oct. 20		29.0	22.9	24.2	23.3	23.9	18.1	20.6
	Total	116.6	136.3	159.4	169.3	145.0	142.4	149.7
			Experiment I (1967) Residual					
July 20		86.1	82.1	83.4	82.3	102.6	91.8	111.3
			Experiment II (1967)					
July 20		103.4	102.7	102.0	78.1	116.1	98.5	103.6
Aug. 14		39.0	54.6	75.7	87.9	60.9	66.9	75.4
Sept. 14		20.2	18.6	17.4	22.8	19.0	18.8	26.8
	Total	162.6	175.9	195.1	188.8	196.0	184.2	205.8

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fertilized plots than from the unfertilized. In fact, the uptake of soil N increased as the rates of the readily soluble fertilizer, urea, increased. Similar differences were found in the second harvest of the second experiment. While uptake of soil N was increased by oxamide during the second harvest of both experiments, the increase was about the same for all rates of oxamide in 1966. That is, increasing uptake of soil N with increasing applications of oxamide was observed only in the second harvest in Experiment II.

In comparison with the first experiment, amounts of soil N in the first harvest of the second experiment were large and essentially unaffected by fertilizer. This difference from Experiment I probably resulted from weather differences between the two seasons. In the first experiment, the crop was planted early, the weather was cool, and growth was slow. Mineralization of soil N was probably slow but it was accelerated by fertilizer N. In the second experiment, planting was delayed and weather was warmer and favorable for a large yield and rapid mineralization of soil N. Under these conditions of the second experiment, fertilizer N had little influence on the mineralization and uptake of soil N. As a result, a relatively large amount of soil N was taken up by the crop regardless of the fertilizer treatment.

In the last harvest of the first experiment, the uptake of soil N from the control plots was greater than from fertilized plots. Apparently the readily-mineralized soil N had been reduced to a lower level in the plots receiving N fertilizer. In this situation the small amounts of fertilizer N still present in the soil were not effective in mineralizing further soil N. Perhaps after the prolonged cropping, the residual fertilizer N was largely present in organic combinations in plant roots and soil organic matter.

In the residual effects of the fertilizers during the second year of the first experiment, uptake of soil N from plots fertilized with urea was no greater than from the unfertilized plots. On the other hand, uptake of soil N from plots fertilized with oxamide was greater than from the controls. This delayed effect of oxamide was in agreement with the properties of the carrier and in agreement with yields that have been reported (Westerman and Kurtz, 1972). Since N from oxamide was not as effective as urea early in the first season, and also since more N from oxamide was still in the soil at the end of that season, its larger residual effect might have been expected. However, since the existence of undissolved oxamide in the soil until the second year is difficult to believe, the greater carry-over of N from oxamide may have resulted from delayed absorption into plants during the first season with a resulting greater carry-over and release of oxamide N during the second season.

In individual harvests in both experiments over the 2-year period, fertilizer N caused increases, slight decreases, and no effect on uptake of soil N. But the overall net effect was increased uptake of soil N which ranged from 17 to 45% in the Experiment I and from 8 to 27% in Experiment II. The residual effect in the second year of Experiment I ranged from 0 to 29%.

The priming effect is usually considered to result from a stimulation of microbial activity by the addition of N fertilizer. Increased microbial activity is thought to increase decomposition of organic materials with an accompanying mineralization of soil N. This explanation is compatible with the events that were observed. Unfortunately conditions of these field experiments permitted no opportunity to estimate microbial populations or other parameters that would permit a comparison of the microbial activities under different treatments.

Other explanations for the priming effect have been suggested. Biological exchange of fertilizer N with soil N might be an explanation. However, we have not been able to isolate evidence for such an exchange in our experiments because the release of soil N was much greater than the fertilizer N retained by the soil. Also the "root effect" proposed by Sapozhnikov et al. (1968) on the basis of greenhouse experiments could not be evaluated from our field experiments. Since the density of roots in a pot experiment in the greenhouse would be greater than in the field, the effect of roots in promoting mineralization would probably have been less important in our experiments.

Broadbent and Nakashima (1971) concluded from laboratory experiments that osmotic effects may contribute to the mineralization of soil N. However, the rates of N used in our experiments would probably not have influenced osmotic pressure appreciably under field conditions. Admittedly osmotic pressures might be quite high in microsites around dissolving urea particles. Hydrolysis of urea in these microsites might also give rise to concentrated solutions of ammonia and solubilized organic nitrogen materials. Such conditions would not be expected, however, around the slowly-dissolving particles of oxamide. Since the total effect of oxamide was similar—though more prolonged—to that of urea, there is no reason to explain this priming effect by highly concentrated solutions in microsites around fertilizer particles.

In summary, the priming effect which has been studied in laboratory and greenhouse experiments was found to occur in field experiments under realistic agronomic conditions. The effect was most obvious in early or midseason when the influence of fertilizer N on crop growth and presumably also on mineralization was most obvious. By the end of the season, the priming effect was no longer evident; however, a small residual priming effect was identified the next year. Conditions of the experiment suggest that this residual effect resulted from carry-over of oxamide N in readily mineralizable organic forms rather than in undissolved oxamide. Although the priming effect may be explained or influenced by different mechanisms, the simplest explanation is probably that fertilizer nitrogen increased microbiological activity and stimulated the mineralization of soil N. With more soil N being mineralized in the N-fertilized plots, the uptake of soil N by the crop was increased in comparison with the control plots.

This priming effect, while detectable through isotopic techniques, was not large enough to register as a significant decrease in total N in the soil. If a decline in soil N due to the priming effect is to be measured in the field, a long-term experiment would probably be required. The priming effect reported here occurred with low to moderate applications of fertilizer N. Different effects might be found if excessive amounts were applied.

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Uniformity of Limestone Mixing in Acid Subsoil as a Factor in Cotton Root Penetration[1]

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ABSTRACT

Cotton (*Gossypium hirsutum* L.) root growth response to different degrees of mixing limestone in strongly-acid subsoil was determined, using both short-term radicle elongation and full-growth-cycle root extension as criteria. The roots displayed no chemotropic response to limed pathways in the acid subsoil. Roots grew best when the entire subsoil mass was mixed with limestone. However, when applied at an adequate rate, even poorly-mixed limestone increased rooting depth at least twofold. Both radicle elongation rate and final root pattern were closely related to percentage of total subsoil mass limed in the incompletely mixed treatments, even when the neutralized soil zones averaged as much as 7.6 cm apart.

Additional Index Words: **incomplete mixing, rooting depth, rhizotron.**

FAILURE OF PLANTS to develop deep, vigorous root systems is often due to excessive acidity in the subsoil (10)—a common condition in highly-weathered and leached soils. Although liming readily neutralizes acidity of surface soils, no practical method is available for directly incorporating lime into the subsoil with adequate mixing for satisfactory root growth, nor can guidelines be found in the literature for degree of mixing required. One reason is the lack of a quantitative expression for degree of mixing. In the present study, it was assumed that two parameters are involved: (i) percentage of total subsoil mass neutralized, and (ii) mean distance between neutralized soil zones.

Lime moves very slowly in the soil and is beneficial only in the immediate vicinity of application. Metzger (8) and Brown and Munsell (6) reported that 10 to 14 years were required for surface-applied lime to increase the soil pH to a depth of 15.2 cm (6 inches). Direct application of lime to correct subsoil acidity is impractical because of the inaccessibility of the deeper profile zones. The extent of the reaction of lime with acid soil is governed largely by the degree to which they are mixed (13). In surface-soil liming for row crops, repeated tillage insures intimate mixing eventually. With subsoils, no such manipulation occurs after the initial incorporation. Poor plant response to attempted deep placement of lime in field experiments (5) is probably a reflection of incomplete mixing. Although subsoil acidity can be alleviated in time by using high rates of residually basic source of N in conjunction with a deep-rooted, acid-tolerant crop, other approaches to subsoil acidity neutralization need to be evaluated. Thus, the objective of this study was to determine the effect of degree of mixing of lime in strongly-acid subsoil on cotton (*Gossypium hirsutum* L.) root penetration of the subsoil.

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