

TRANSFORMATION OF NITROGEN TO AVAILABLE FORMS IN THE RHIZOSPHERE OF RICE, MAIZE, SOYBEAN AND JUTE¹

M. A. AHAMMED, and N. C. DEBNATH

*Department of Agricultural Chemistry and Soil Science,
Bidhan Chandra Krishi Viswavidalaya, Kalyani, West Bengal, India*

ABSTRACT

Transformation of nitrogen as influenced by the rhizosphere soil of rice (upland and lowland), maize, soybean and jute were studied at their different stages of growth under field conditions. The rhizosphere soil of all the crop species maintained higher level of $\text{NH}_4^+ - \text{N}$, $\text{NO}_3^- - \text{N}$ and total mineralized N ($\text{NH}_4^+ + \text{NO}_3^-$) than the non-rhizosphere soil. The interaction between growth stages and species indicated that the sequence of species differences with respect to forms of N did not follow the same trend throughout the entire growth period. The content of mineralized N differed from species to species, but the efficiency order of the crop species, varied with the form of N.

KEY WORDS : Jute, Maize, Nitrogen transformation, Rhizosphere, Rice, Soybean

INTRODUCTION

The rhizosphere may be defined as the volume of interaction between a plant's rooting system and its immediate soil environment (Sarkar, 1977). When a plant root grows through the soil, it introduces change to its surroundings. The affected zone differs biologically, chemically and physically from non-rhizosphere soil (Carson, 1974; Rovira and Davy, 1974; Tinker, 1969) and from it, essential growth requirements are obtained by plant roots.

The chemical environment at the soil-root interface may be modified by plant root activities in multifarious ways (Barber, 1962). One of such changes in the rhizosphere, influences the transformation of ammonium

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²Present Address : Agronomy Division, Bangladesh Jute Research Institute, Sher-e-Bangla Nagar, Dhaka—1207, Bangladesh.

nitrogen ($\text{NH}_4^+ - \text{N}$) to nitrate nitrogen ($\text{NO}_3^- - \text{N}$) which is likely to vary from species to species. When ammonium is added to the soil or released from organic matter by mineralization, it is usually nitrified rapidly to nitrate. Ammonium absorption increases as pH increases, whereas NO_3^- uptake tends to decrease with increasing pH (Van den Honert and Hooymans, 1955; Fried *et al.*, 1965; Jungk, 1970). When both NH_4^+ and NO_3^- are present in the same nutrient media, NH_4^+ has been reported to inhibit NO_3^- uptake by some plant species (Fried *et al.*, 1965; Minotti *et al.*, 1969). There were also large differences in the composition of rhizosphere flora which is associated with different species of plants (Rovira and Davey, 1974). Information about the transformation of nutrients in the rhizosphere of different crop species may throw some light to explain the differential adaptability of crop species under similar set of soil environment. With that end in view the present investigation was carried out to study the effect of some crop species, namely, rice, maize, soybean and jute, on the transformation of nitrogen to available forms in the rhizosphere.

MATERIALS AND METHODS

The experiment was conducted in the District Seed Farm of Bidhan Chandra Krishi Viswavidalaya, West Bengal, India. The soil of the experimental field is alluvial in origin. The physico-chemical properties of soil are, pH—8.6, organic C—0.49%, total N—0.05%, 0.5M NaHCO_3 extractable P—11.2 ppm, CEC—8.8 me/100g soil, $\text{NH}_4^+ - \text{N}$ —8.73 ppm, $\text{NO}_3^- - \text{N}$ —6.6 ppm, exch. Ca—6.6 me/100g soil and exch. K—0.80 me/100g soil. The crops which were taken for the study were capsularis jute (*C. capsularis* L.) cv. JRC—7447, olitorius jute (*C. olitorius* L.) cv. JRO—632, soybean (*Glycine max* L.) cv. Improved Pelikan, maize (*Zea mays* L.) cv. Population '61 and rice (*Oryza sativa* L.) cv. IR—36. The rhizosphere effect of rice was studied both under upland and lowland conditions. The plot size of the experiment was 2m × 2m. The experiment was laid out in a randomized block design with three replicates. In each replicate there was a plot which was kept fallow. In all, there were seven treatments. The crops were grown without any fertilizer. In growing the crops, recommended cultural operations were followed. The fallow plots were kept free of weeds throughout the growing season of the crops.

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At intervals of 45, 75 and 105 days after sowing rhizosphere and non-rhizosphere soil samples were collected following the procedure described by Sarkar *et al.* (1979). At each sampling date, the rhizosphere sample was taken by the excision of a soil core, about 15 mm in diameter, centred on the main shoot/root axis of each plant. This was carefully separated from the rooting system to yield about 10g soil material per plant and the product from five plants was bulked. Non-rhizosphere samples were collected from randomly selected spots of each fallow plot from a depth of 0-15 cm. The soils were then air-dried under shade, ground and analysed. Ammoniacal-N and NO_3^- -N were determined following the procedure described by Black (1965).

RESULTS

NH_4^+ -N content

The results of the rhizosphere effect of different crop species on NH_4^+ -N content of soil are shown in Table 1. The results of the main effects of species showed that the rhizosphere soil of all the species maintained higher NH_4^+ -N than non-rhizosphere soil. Soybean and upland rice recorded the highest level of NH_4^+ -N followed by two species of jute and the lowest level was maintained by lowland rice. The main effects of days have shown that NH_4^+ -N content of the soil decreased with the age of the crops except the upland rice. The interaction between days and species was significant. The rhizosphere effect varied with the age of the plants and the species differences did not follow a single trend throughout the growth period. At 45 days of growth stage olitorius jute maintained lower NH_4^+ -N than soybean and capsularis jute, though its main effect was at par with capsularis jute. At 75 days of growth stage the effect of maize was at par with two species of jute and lowland rice. At 105 days of growth stage the effect of soybean was at par with capsularis jute and maize and lowest level of NH_4^+ -N was in lowland rice.

NO_3^- -N content

The results of the NO_3^- -N content of rhizosphere and non-rhizosphere soils are shown in Table 2. As it was observed in case of NH_4^+ -N, all the crop species maintained higher level of NO_3^- -N in the rhizosphere than in the non-rhizosphere soil. But the crop species differed among themselves in

the magnitude of the effect. In the rhizosphere soil, the highest level of NO_3^- —N was maintained by capsularis jute followed by maize, olitorius jute, lowland rice, upland rice and soybean. The last two were at par in their effects. The main effects of growth stages showed that the highest level of NO_3^- —N was maintained at 75 days of growth stage and the level of NO_3^- —N was more at 45 days than at 105 days of growth stage. The interaction between growth stages and species was significant. At the initial growth stage, the effect was highest in capsularis jute and this was significantly higher than in the other crops. At 75 days of growth stage olitorius jute and maize were at par with capsularis jute, whereas at 105 days of growth stage maize and upland rice were at par with capsularis jute. At 45, 75 and 105 days of growth stages the lowest values were recorded by soybean, upland rice and olitorius jute respectively.

Total mineralized N

The results of the total mineralized N ($\text{NH}_4^+ + \text{NO}_3^-$) as influenced by the rhizosphere of different crop species are shown in Table 3. The main effect of the crop species have shown that the mineralization of N in the rhizosphere soil of all the crop species was more than in the non-rhizosphere soil. The effect of soybean was at par with that of capsularis jute. Mineralization was lowest in lowland rice and the effect of olitorius jute, maize and upland rice were at par. On an average, the highest amount of mineralized N was maintained at 75 days of growth stage and the amount at 45 days was more than at 105 days. Growth stage and species interaction was significant. At 45 days of growth stage the amount of mineralized N was highest in capsularis jute and lowest in maize; but at 75 days of growth stage the value was highest in soybean and lowest in lowland rice. On the other hand at 105 days of growth stage, upland rice recorded the highest value while the lowest value was recorded by lowland rice.

DISCUSSION

The results indicated that the rhizosphere soil of all the crop species maintained higher level of NH_4^+ —N, NO_3^- —N and total mineralized nitrogen N ($\text{NH}_4^+ + \text{NO}_3^-$) compared to the non-rhizosphere soil. The interaction between the growth stages and the crop species indicated that the sequence of crop species differences did not follow the same trend through-

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out the entire growth period. The overall results revealed that the rhizosphere of all the crop species favourably influenced the mineralization of N, but its magnitude differed with the crop species. The species differences were also influenced by growth stage of the crops. Greater mineralization of N in the rhizosphere than in non-rhizosphere soil and the species differences of crop might be due to variation in the root density as well as the composition of microbial population. Elliot *et al.* (1981) demonstrated the significant role of protozoa at the rhizosphere in accelerating the mineralization of immobilized nitrogen. Exudation of organic materials by roots also influence microbial activity which alternately release fixed nitrogen in the root-soil interface (Barber and Martin, 1976; Sauerbeck and Johnen, 1977).

CONCLUSION

The experiment has shown clearly that rhizosphere soil of several crop species has a higher mineralized N content than the adjoining non-rhizosphere soil. It was also found that its magnitude varies with crop species and their growth stage. The higher mineralized N in the rhizosphere soil was attributed to root-exuded organic compounds and microbial activity.

REFERENCES

- Barber, S. A. 1962. A diffusion and mass-flow concept of soil nutrient availability. *Soil Sci.* 93: 39—49.
- Barber, D. A. and J. K. Martin. 1976. The release of organic substances by cereal roots into soil. *New Phytol.* 76: 69—80.
- Black, C. A. 1965. *Methods of Soil Analysis. Part II. Chemical and Microbiological Properties.* Agronomy Vol. 9, pp. 771—1572. Am. Soc. Agron. Inc., Madison, Wisconsin, U. S. A.
- Carson, E. W. 1974. *The plant root and its environment.* University Press of Virginia, Charlottesville.
- Elliott, E. T., D. C. Coleman and C. V. Cole. 1981. The soil-root interface. pp. 221—229. Academic Press Inc. (London) Ltd.
- Fried, M., F. Zoldos, P. B. Vose and I. L. Shatokhim. 1965. Characterizing the NO_3 and NH_4 uptake process of rice roots by use of N—15 labelled NH_4 NO_3 . *Physiol. Plant* 18: 313—320.

- Jungk, A. 1970. Interactions between the nitrogen concentration (NH_4 and NO_3) and the pH of the nutrient solution and their effects on the growth and ion balance of tomato plant. *Gartenbauwissenschaft* 35: 13—28.
- Monotti, P. L., D. C. Williams and W. A. Jackson. 1969. Nitrate uptake by wheat as influenced by ammonium and other cations. *Crop Sci.* 9: 9—14.
- Rovira, A. D. and C. B. Davey. 1974. Biology of the rhizosphere. *In* The Plant Root and its Environment. Ed. E. W. Carson. pp. 153—204. University Press of Virginia, Charlottesville.
- Sarkar, A. N. 1977. Biochemistry and Micromorphology of the Rhizosphere. Ph. D. thesis, University of Wales, U. K.
- Sankar, A. N., D. A. Jenkins and R. G. Wyn Jones. 1979. Modification to mechanical and mineralogical composition of soil within the rhizosphere. *In* The Soil-Root Interface. Eds. J. L. Harley and R. S. Russell. pp. 125—136. Academic Press Inc. New York.
- Sauerbeck, D. R. and B. G. Johnen. 1977. Root formation and decomposition during plant growth. *In* Soil Organic Matter Studies. Vol. 1, pp. 141—148. International Atomic Energy Agency, Vienna, Austria.
- Tinker, P. B. 1969. The transport of ions in the soil around plant roots. *In* Ecological Aspects of the Mineral Nutrition of Plants. Ed. I. H. Rotien. pp. 135—147. Blackwell Scientific Publications, Oxford.
- Van den Honert, T. H. and J. J. M. Hooymans. 1955. On the absorption of nitrate by maize in water culture. *Acta Bot. Néerl.* 4: 376—384.

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Table 1. Rhizosphere effect of some crop species on $\text{NH}_4^+ - \text{N}$ content of soil at different growth stages

Crop species	$\text{NH}_4^+ - \text{N}$ (ppm)			
	Days after sowing			
	45	75	105	Mean
Jute (Capsularia)	18.8	9.0	8.8	12.5
Jute (Olitorius)	16.5	10.0	10.2	12.2
Soybean	19.3	18.2	8.2	15.2
Maize	12.2	10.0	8.6	10.6
Upland rice	14.7	17.7	11.9	14.8
Lowland rice	13.1	9.6	6.7	9.8
Non-rhizosphere soil	12.0	8.3	5.4	8.8
Mean	15.2	11.9	8.7	—

	<i>S.Em</i> ±	<i>CD</i> at 0.05 level
a. Main effect of days	0.210	0.601
b. Main effect of species	0.321	0.918
c. Interaction (days × species)	0.556	1.590

Table 2. Rhizosphere effect of some crop species on $\text{NO}_3^- - \text{N}$ content of soil at different growth stages

Crop species	$\text{NO}_3^- - \text{N}$ (ppm)			
	Days after sowing			
	45	75	105	Mean
Jute (Capsularia)	14.9	19.2	7.4	13.8
Jute (Olitorius)	7.5	20.4	5.3	11.1
Soybean	5.7	18.2	5.5	9.8
Maize	9.6	20.2	7.7	12.5
Upland rice	8.9	12.7	8.2	9.9
Lowland rice	10.9	14.2	5.6	10.2
Non-rhizosphere soil	5.1	9.2	4.4	6.2
Mean	8.9	16.3	6.3	—

	<i>S. Em</i> ±	<i>CD</i> at 0.05 level
a. Main effect of days	0.168	0.481
b. Main effect of species	0.257	0.735
c. Interaction (days × species)	0.446	1.274

Table 3. Rhizosphere effect of some crop species on total mineralized N ($\text{NH}_4^+ + \text{NO}_3^-$) of soil at different growth stages

<i>Crop species</i>	<i>Total mineralized Nitrogen ($\text{NH}_4^+ + \text{NO}_3^-$) ppm</i>			
	<i>Days after sowing</i>			<i>Mean</i>
	<i>45</i>	<i>75</i>	<i>105</i>	
Jute (<i>Capsularis</i>)	33.7	28.2	17.2	26.4
Jute (<i>Olitorius</i>)	24.0	30.4	15.5	23.3
Soybean	25.0	36.4	13.7	25.0
Maize	21.8	31.1	16.3	23.1
Upland rice	23.6	30.4	20.1	24.7
Lowland rice	24.0	23.8	12.3	20.0
Non-rhizosphere soil	17.0	17.5	9.8	14.8
Mean	24.1	28.2	15.0	—

S. Em ± CD at 0.05 level

- a. Main effect of days
 b. Main effect of species
 c. Interaction (days × species)

0.378 1.082
 0.578 1.653
 1.002 2.864