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Recovery of Field-Applied Fertilizer Nitrogen by Rice

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ABSTRACK

Suatu kajian di ladang tentang pengambilan baja N oleh padi (Oryza sativa L.) *telah dijalankan untuk menilai keberkesanan pengurusan pembajaan. Kajian telah di jalankan di sawah petani selama dua musim. Sampel tanah pada tiga kedalaman 0 – 15 cm, 15–30 cm dan 30–45 cm, dan sampel air diambil pada tiap-tiap dua minggu sehingga masa penuaian. Pengambilan baja N oleh tumbuhan telah ditentukan dengan mengambil perbezaan di antara pengambilan N oleh tumbuhan yang dibaja dan kawalan. Walaupun kaedah ini memberi nilai yang lebih tinggi disebabkan kesan 'priming', dalam keadaan kajian ini dijalankan kesan ini diandaikan sangat minimum. Pertambahan kandungan amonium N dalam tanah tidak berlaku walaupun selepas sahaja penambahan baja N di buat. Kehilangan baja N, sama ada melalui pengambilan oleh tumbuhan atau proses kehilangan yang lain berlaku dengan cepat. Amonium N yang lebih tinggi hanya didapati dalam sampel air pada awal musim, tetapi tidak pada pertengahan musim selepas pembajaan N yang kedua. Pengambilan baja N oleh tumbuhan ialah 36% pada musim biasa dan 30% pada luar musim. Kebanyakan N terdapat dalam bijian. Lebih kurang 69 kg daripada 95 kg jumlah N yang di serap oleh tumbuhan pada satu hektar berpunca daripada tanah. Lebih daripada 64% baja N yang ditambah hilang atau terikat dalam tanah.*

ABSTRACT

Field estimation of the recovery of fertilizer N applied to rice (Oryza sativa L.) *was carried out as an appraisal of the prevailing fertilizer management practice. The study was carried out on a farmers field for two growing seasons. Soil samples at three depths, 0–15 cm, 15–30 cm and 30–45 cm and water samples were collected every two weeks during the growing season. The plant recovery of fertilizer N was estimated by the difference between the N treated plots and the controls. Although this method could overestimate the fertilizer N recovery due to priming effect, under the conditions in the study the effect was assumed to be minimal. An increase in ammonium N content in the soil was not observed even immediately after N application. The removal of fertilizer N from the soil through either plant uptake or loss processes was very rapid. Higher ammonium N was only detected in the water samples early in the growing season but not at the mid-season after the second N application. The recovery of fertilizer N in the plant were 36% and 30% during the main and off-seasons respectively. Most of the N was in the grain. About 69 kg of the 95 kg of the total-N removed by the crops per hectare was derived from the soil. More than 64% of the fertilizer N applied was either lost or immobilized in the soil.*

INTRODUCTION

Surface application of fertilizer N for rice usually results in low plant recovery (De Datta, 1981). Most of the fertilizer N applied is either lost or immobilized in the soil (Crasswell and Vlek, 1979). The low N recovery is not only an economic waste, but also a hazard to the environment.

Losses of applied N through denitrification and volatilization are the two most important processes although leaching and immobilization could also occur (Crasswell and Vlek, 1979). Although most of the fertilizer N used in rice is in the ammonium form, the presence of the oxidized zone in the soil-water interphase and in the rhizosphere could oxidize the ammonium N to nitrate N which in turn could be denitrified and lost (Reddy and Patrick, 1986). Urea is a common source of N in rice. Application of urea usually results in rapid hydrolysis to ammonium with significant pH increase, a condition which favours ammonia volatilization (Velk and Stumpe, 1978). More than 30% loss through volatilization from either urea or ammonium sulfate applied to rice was reported (Fillery and De Datta, 1986). In an experiment using N^{15} the amount of fertilizer N leached out of the rice root zone was not substantial; however an important amount was immobilized in the soil organic matter (Patrick and Reddy, 1976).

Field estimation of fertilizer N utilization by crop is very useful as an appraisal for the effectiveness of a fertilizer practice. This study aimed to determine plant recovery and seasonal changes of ammonium N in the root zone under farm practices normally carried out in this region.

MATERIALS AND METHODS

The study was carried out on a farmer's field in Tanjung Karang, Selangor, Malaysia for two growing seasons; the main-season from July to October 1984 and the off-season from February to April 1985 The soil was Bakau Series (Typic Hydraquent) with a clay texture, 0.19% N, 2.44% organic carbon, pH (H_2O) 4.40 and CEC 23.60 me 100 g^{-1} soil.

Immediately after transplanting, 3 m x 3 m plots were set up in the field. The seedlings were planted at a planting distance of 25 cm x 25 cm. The rice variety planted was MR10. There were two treatments viz control (without N) and 80 kg ha (similar to the rest of the field). Both treatments received 40 kg K ha^{-1} and 40 kg P ha^{-1} as muriate of potash and triple superphosphate respectively with the first N application. The timing and the rate of fertilizer application were as practised by the farmers. The N as urea was surface-applied twice, the first application with 40 kg N ha^{-1} at 35 days after transplanting for the main-season and 25 days after transplanting for the off-season. The second N application of 40 kg N ha^{-1} was applied at 70 and 52 days after planting for the main and the off-season crop respectively. The control plots were separated from the rest of the field with 25 cm high metal borders pressed to a depth of 10 cm into the soil. The treatments were replicated three times in a completely randomised block design.

The plants were harvested at 119 days and 101 days after transplanting for the main and the off-season crop respectively. The harvested plants were dried at 60 °C and after drying the grains were separated. The grain and the straw were analysed for total-N (Bremner and Mulvaney, 1982).

Plant recovery of fertilizer N was calculated by difference, using the following equation:

$$\text{Apparent \% N recovery} = \frac{NF - NC}{R} \times 100$$

Where NF = N uptake by plants grown on the N fertilized plot;

NC = N uptake by plants grown on the control plot;

R = the rate of fertilizer N applied

Soil samples at three depths 0–15 cm, 15–30 cm and 30–45 cm (for both seasons) and water samples (for off-season crop only) were collected at two week intervals during the growing season. The ammonium N was extracted from the 20 g (oven dry basis) fresh soil samples by shaking for 1 hr with 40 ml 2N KC1. The $NH_4 - N$ in the soil extracts and in the water samples were analysed using steam distillation method (Keeney and Nelson, 1982).

RESULTS AND DISCUSSION

Ammonium-N in Soil

The main form of inorganic N in submerged soil is the ammonium form. The changes in the ammonium-N content of the soil at three depths during the growing seasons are given in *Figures 1* and *2*. In both growing seasons, the ammonium-N content ranged between 5 to 50 ug g^{-1}. There was

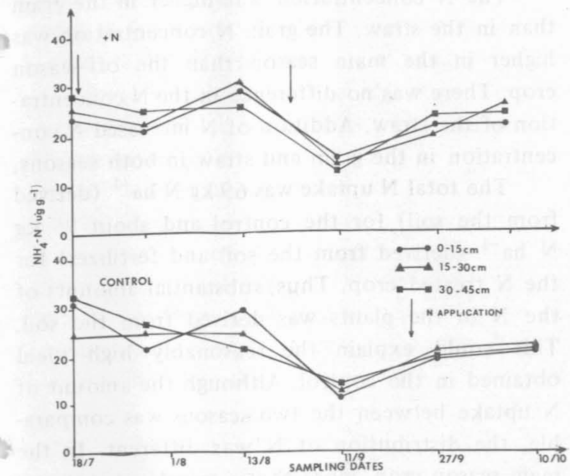

Fig. 1: Ammonium-N content in the soil during the growing season (main-season).

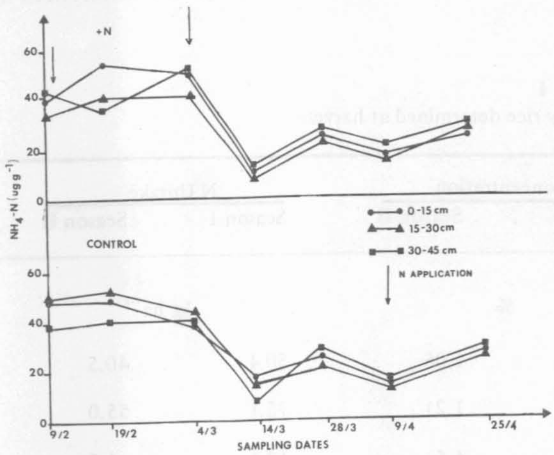

Fig. 2: Ammonium-N content in the soil during the growing season (off-season).

no marked difference in the ammonium-N content among the three soil depths. The ammonium-N contents were high at the beginning of the growing seasons due to lower N requirement by the rice plants (Moore *et al.*, 1981). The lowest ammonium N content occurred during the middle of the growing season which coincided with the peak of the N requirement. The ammonium-N rose slightly from the mid-season until harvesting. This slight rise was probably due to lower N requirement by crop and possible mineralization of organic matter. Another possible reason could be due to drying of the field as the crop matured, so that most of the ammonium-N remained in the soil rather than being distributed in the water. A similar trend has been reported by Moore *et al.* (1981).

Although N was applied (N treated plots) twice, there was no marked increase in ammonium-N immediately after each application. This indicated that removal of ammonium-N from the soil occurred in less than two weeks. Similarly, rapid removal of ammonium-N following N fertilization in rice was also reported by others (Patrick and Reddy, 1976; Moore *et al.*, 1981 De Datta and Crasswell, 1982). Such a trend has also been reported in maize and barley (Khanif *et al.*, 1984).

Ammonium-N in Water

The changes in ammonium-N content in water during the growing season is shown in *Figure 3.* The ammonium-N concentration was higher in the water samples from plots which received N than the control. The difference was high at the beginning of the growing season and decreased as the season advanced. Addition of fertilizer N at the beginning of the growing season resulted in an increase in ammonium-N concentration in the water. However, an increase in ammonium-N due to mid-season N application was not detected. The higher ammonium-N that occurred early in the season after N application than the mid-season suggested a rapid N uptake and high N demand by the growing rice plants at mid-season as compared to the earlier growing stage. Substantial amounts of fertilizer N at the beginning of the growing season could have been in the water since it was not detected in the soil.

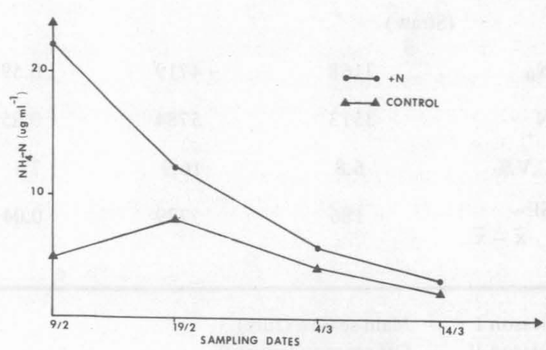

Fig. 3: Ammonium-N content in the water during the growing season (off-season).

Dry Matter Yield and N Uptake

The dry matter yield and N uptake are presented in Table 1. The N treatment significantly increased plant N uptake (both in the straw and the grain) and grain yield. The straw weight, however, was not affected by the N application. The plant N uptake and straw drymatter was significantly higher in the off-season than in the main-season. The grain yield in the N treated plot was higher than the control in both seasons. Also, there were differences in the grain to straw ratios between the two seasons. In the main season, the grain to straw ratios were more than 1.0 while in the off-season crop the ratios were 0.8. The proportion of grain produced, in the main-season was higher than the vegetative parts and it was *vice versa* in the off-season crop. This could be due to the differences in the time of harvesting, the timing of N application and the weather conditions.

The N concentration was higher in the grain than in the straw. The grain N concentration was higher in the main season than the off-season crop. There was no difference in the N concentration of the straw. Addition of N increased N concentration in the grain and straw in both seasons.

The total N uptake was 69 kg N ha^{-1} (derived from the soil) for the control and about 95 kg N ha^{-1} (derived from the soil and fertilizer) for the N treated crop. Thus, substantial amounts of the N in the plants was derived from the soil. This could explain the reasonably high yield obtained in the control. Although the amount of N uptake between the two seasons was comparable, the distribution of N was different. In the main season crop, more N was translocated to the grain than during the off-season crop. This difference, which was also reflected in the tissue N concentration was attributed to the differences in

TABLE 1
Dry matter yield and N uptake by rice determined at harvest

Treatment	Dry Matter Weight		N Concentration		N Uptake	
	Season I	Season II	Season I	Season II	Season I	Season II
(Grain)	Kg ha^{-1}		%		kg ha^{-1}	
N_0	3595	3807	1.42	1.06	50.4	40.5
N_+	4803	4525	1.56	1.21	75.1	55.0
C.V.%	10.3	10.4	13.2	4.5	12.1	4.5
$SE_{\bar{x}-\bar{x}}$	353	353	0.16	0.04	4.7	2.3
(Straw)						
N_0	3168	4719	0.59	0.59	18.6	28.1
N_+	3513	5784	0.65	0.65	22.7	37.6
C.V.%	6.8	16.9	7.4	10.1	10.0	13.0
$SE_{\bar{x}-\bar{x}}$	186	729	0.04	0.05	2.2	2.7

Season I – Main-season (July)
Season II – Off-season (January)
CV – Coefficient of variation
$S_{\bar{x}-\bar{x}}$ – Standard error of the difference between two means

harvesting time, timing of N application and weather conditions.

Fertilizer N-Balance

The amount of fertilizer N removed was estimated by taking the difference in N uptake of the treated plot and the control. There is a fallacy in this estimate due to priming effect (Westerman and Kurtz, 1973). The priming effect is caused by the overestimation of the N derived from fertilizer in the N treated soil because N application stimulates N mineralization. It is also due to a higher accessibility of the roots to a larger soil volume due to better root growth. However, these two conditions were assumed to be minimal in this study. The ammonium-N from the applied fertilizer N was quickly removed from the soil as discussed earlier leaving little chance for it to affect N mineralization rate. The difference in the vegetative yield of the N treated crop and the control was not substantial; thus the root exploitation capacity would not be so great as to create a significant priming effect.

The fertilizer N balance for the two growing seasons is given in Table 2. Only 36% and 30% of the fertilizer N applied were utilized by the plant during the main and the off-seasons respectively. Such values are similar to results reported by others (Crasswell and Vlek, 1979: Reddy and Patrick, 1978; Cao *et al.*, 1984). A major portion of the fertilizer was either lost or remained in the soil. Most of the fertilizer N recovered in the plant was found in the grains. The plant recovery of fertilizer N in the main-season crop was higher than that of the off-season crop, which could be due to the difference in the timing of fertilizer applications. The main-season crop received both N applications later than the off-season crop. It could also be due to the differences in weather conditions and harvesting time, where the main season crop remained in the field for a longer duration.

CONCLUSION

The removal of ammonium-N from the soil after N fertilization was rapid due to rapid plant uptake or loss processes. Addition of fertilizer N increased dry matter yield. The composition of grains and vegetative parts of the dry matter was affected by the time of harvesting and the timing of N application.

The total N uptake in the N treated crops was about 95 kg N ha^{-1} of which a major portion (69 kg N ha^{-1}) was derived from the soil. Most of the N recovered was found in the grains. The recovery of fertilizer N by rice plants were 36% and 30% in the main and the off-seasons respectively. Most (> 64%) of the fertilizer N applied was either lost or immobilized in the soil.

TABLE 2
Fertilizer N balance in rice

	Season I	Season II
Fertilizer N added (kg ha^{-1})	80	80
Fertilizer N in plants (kg ha^{-1})	29	24
Grain	(25)	(15)
Straw	(4)	(9)
Plant recovery of fertilizer N (%)	36	30
Fertilizer N in soil or loss (%)	64	70

Season I – Main season (July)
Season II – Off-season (January)

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