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INFLUENCE OF WATER REGIME ON GROWTH, YIELD, AND NITROGEN UPTAKE OF RICE

KERY WORDS: Continuous flooding, alternate flooding and soil drying, mid-season soil drying, N uptake of grain, flood fallow, unfertilized soils

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ABSTRACT

Greenhouse and field experiments were conducted to study the effects of water regime on growth of rice. The greenhouse experiment investigated the effects of two water regimes-continuous flooding and flooding with soil drying between crops for 2 to 3 weeks on the growth of rice during six cropping (for six week each) on seven soils varying widely in total N contents (0.07 to 0.35%). The results averaged for the 7 soils indicated that the drymatter production or N uptake of rice was not affected by the water regimes during the six croppings.

The field experiment conducted during the dry season for two consecutive years (1976 and 1977) on a near neutral clay soil studied the effects of three water regimes (continuous flooding, alternate flooding and soil drying every 2 weeks, and continuous flooding with 2 weeks mid season soil drying after 6 weeks of transplanting) and three levels of fertilizer N (0, 100 and 200 kg N/ha as urea) on grain yield and N uptake of rice. The results confirmed the absence of any significant reduction in grain yield or N uptake as a result of any of the soil drying treatments during the growing season on the unfertilized plots carrying a rice crop. On the plots fertilized with 100 or 200 kg N/ha, alternate flooding and drying resulted in a significant depression in both grain yield and N uptake. Soil analysis supported heavy losses of N in the fertilized plots that underwent alternate flooding and soil drying apparently by nitrification and denitrification reactions.

The results of this study suggest that alternate flooding and drying of soils in the presence of established rice plants may not cause a significant loss of nitrogen in unfertilized plots although in plots fertilized with high rates of N the losses may be large as indicated by the performance of rice crop.

INTRODUCTION

The recent shortage of fertilizer nitrogen coupled with high prices due to energy crisis has stimulated research on the efficient use of soil and fertilizer nitrogen by rice. The water regime of a soil has a profound effect on nitrogen transformations and fertilizer nitrogen use efficiency[13]. Results from several laboratory studies indicate that alternate flooding and soil drying causes heavy loss of soil and fertilizer nitrogen[8,12-14]. There are a few studies that tested the effects of water regimes in the presence of rice crop either under greenhouse or field conditions which indicate that soil drying once or more during the growing season can cause variable results on the performance of rice[6,7,11]. The objective of the present study was to study the influence of soil water regimes on growth and N uptake of rice under greenhouse and field conditions.

MATERIALS AND METHODS

Greenhouse experiment

A greenhouse experiment was conducted with seven soils varying widely in texture, reaction, organic matter and total nitrogen (Table 1) to study their nitrogen supplying power to rice without application of any fertilizer nitrogen under two water treatments; continuous flooding and flooding with soil drying between two successive crops. The uptake of soil nitrogen was determined by raising six successive crops of IR 32 variety of rice for six weeks each.

For soil analyses reported in Table 1, pH was determined by glass electrode, organic matter by the method of Walkley and Black[15] and total nitrogen as described by Bremner[2].

The soils, airdried and screened through a 5 mm sieve, were placed in 16 litre glazed porcelain pots. The pots containing 10 kg of soil were seeded with pregerminated seeds of IR 32. Six plants per pot were grown for 6 weeks under submerged soil conditions. The plants were cut about 5 cm above the soil, dried and analyzed for total nitrogen by the microkjeldahl method[2]. Nitrogen uptake by the plants was computed. Until the next crop was seeded, one set of pots was kept submerged (flood fallow) while in the other the soil was dried for 2-3 weeks (soil drying) till aerobic. This cycle was followed for six crops.

TABLE 1

Analyses of soils used in the greenhouse experiment

Soil Type	pH (1:1 H_2O)	Organic matter %	Total N %
Buenavista clay loam	6.3	1.1	0.07
Lipa loam	7.0	4.3	0.190
Luisiana clay	4.8	2.6	0.175
Maahas clay	6.5	1.6	0.120
Paete clay loam	5.3	10.4	0.350
Pila clay	7.5	3.9	0.185
Quingua silty loam	6.5	2.2	0.115

The soils were fertilized with 50 ppm each of P_2O_5 and K_2O before seeding the first, third and fifth crops.

Field Experiment

A field experiment was conducted for 2 years to study the effects of three water regimes on grain yield and uptake of nitrogen by grain during the dry seasons of 1976 and 1977 (February through June). The soil was Maahas clay, the major soil series of the Institute farm. During the 1976 experiment, the soil of the field analyzed as follows: pH, 6.5; organic matter, 2.0%; total N, 0.19%; NH_4^+-N, 16.2 ppm; and NO_3^--N, 2.1 ppm. In the 1977 experiement the soil of field tested: pH, 6.1; organic matter, 2.1%; total N, 0.185%; NH_4^+-N, 38 ppm; and NO_3^--N, 3 ppm. The rice varieties used during the two seasons were IR 1561-228-3 and IR 36, respectively. A basal application of 50 kg/ha P_2O_5 and K_2O was made during each year as triple superphosphate and muriate of potash.

There were nine treatments consisting of all combinations of three levels of N (0, 100 and 200 kg/ha applied as urea) and three water regimes: viz., continuous flooding, alternate flooding and drying for 2 weeks each, and continuous flooding and with mid-season soil drying once at 6 weeks after transplanting. These treatments were tested in a randomized complete block design with water treatments as the main plots and nitrogen treatments as sub-plots replicated three times. Three-week-old seedlings were transplanted at a spacing of 20 x 20 cm. All nitrogen fertilizer was broadcast and incorporated into the soil just before transplanting. Usual practices for control of insect, pests were followed.

A maturity, an area of 5 sq.m. was harvested from each plot for grain yield. Nitrogen uptake by grain was computed by analyzing grain samples for total nitrogen by the microkjeldahl method[2].

Soil analysis for inorganic nitrogen forms

In 1976 the design of the field experiment was such that there were an equal number (27) of uncropped plots, which received the same treatments. Soil samples were taken from both cropped and uncropped plots after the first and second cycles of flooding and drying and analyzed immediately for NH_4^+ and NO_3^--N. Fifty g wet samples were extracted with 250 ml of 2 N KCL and aliquots of the filtered extract were analyzed for NH_4^+ and NO_3^--N following steam distillation with MgO and Devarda's alloy[3].

RESULTS AND DISCUSSION

The data averaged for the 7 soils on dry matter yields and nitrogen uptake by six crops of IR 32 under two water regimes in the greenhouse experiment are shown in Table 2. The results indicate that

TABLE 2

Dry matter yield and N uptake of IR 32 rice averaged for y soils receiving no fertilizer nitrogen, under 2 water regimes.

Crop No.	Drymatter wt. (g/plot) Continuous flooding	Soil drying between crops	Δ	N uptake (mg N/kg of soil) Continuous flooding	Soil drying between crops	Δ
1	6.1	5.6	0.5 ns*	21	19	2 ns*
2	29.4	33.2	-3.8 ns	68	77	- 9 ns
3	15.0	13.0	2.0 ns	33	27	6 ns
4	19.1	15.9	3.2 ns	45	34	11 ns
5	8.7	6.6	2.1 ns	16	12	4 ns
6	8.7	6.1	2.6 ns	17	12	5 ns
Average	14.5	13.4	1.1 ns	33	30	3 ns

*ns = not significant

neither the dry matter weight nor the nitrogen uptake was significantly influenced by the water treatments. Dry matter yields and nitrogen uptake during the six croppings were similar under the two water treatments inspite of wide differences in the contents of organic matter and total N in the soils studied.

The results of the 1976 and 1977 field experiments are presentedin Fig. 1 and 2. They confirm the greenhouse observation that, when no fertilizer nitrogen was applied, alternate flooding and drying did not significantly affect the grain yield or nitrogen uptake of grain. In general the grain yield and nitrogen uptake were lower during the 1976 season as compared to 1977 season because in 1976 the crop was damanged by a typhoon. During the 2 weeks of soil drying the soil generally became aerobic and drying was effective.

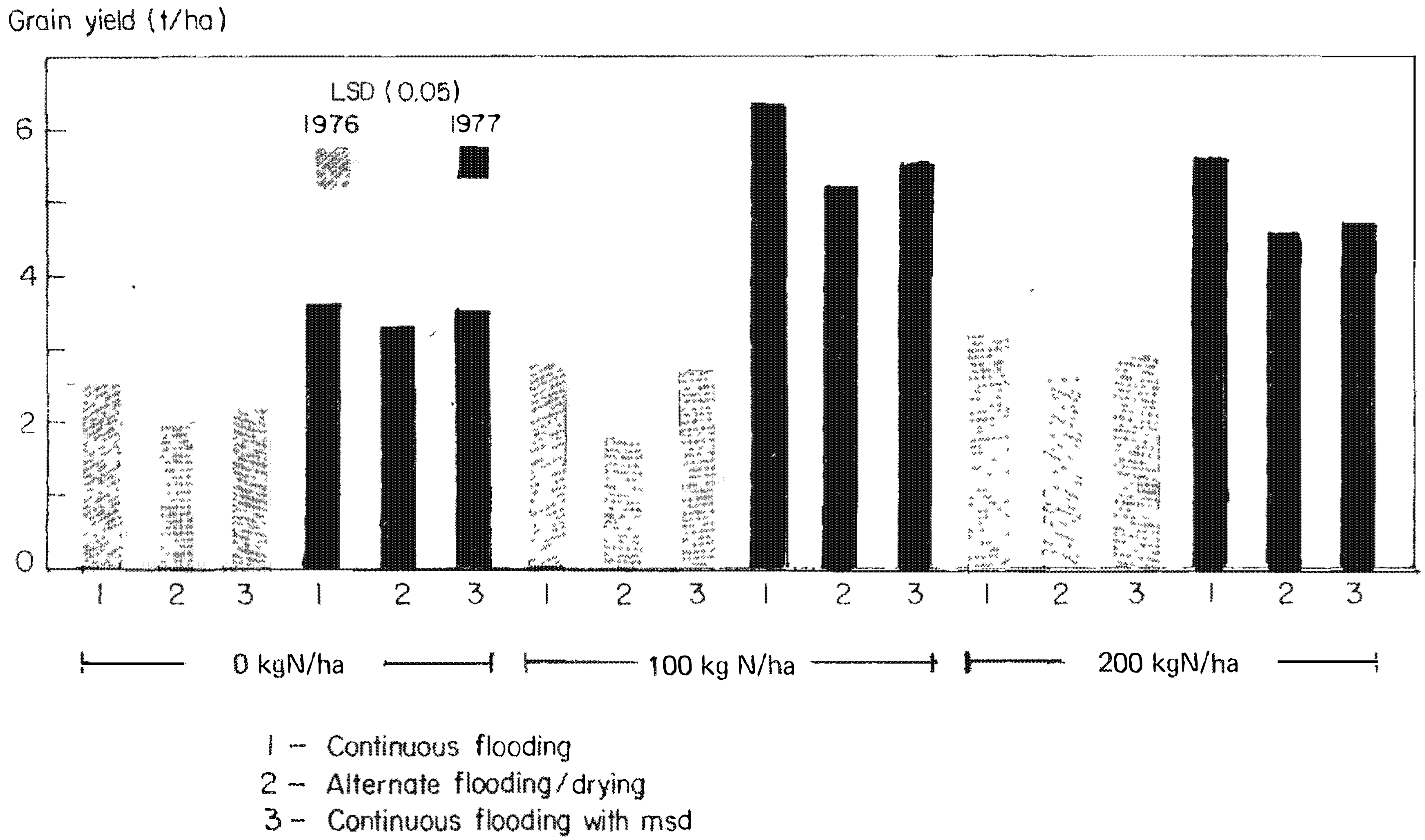

Fig. 1. Effect of different moisture regimes and nitrogen level on grain yield.

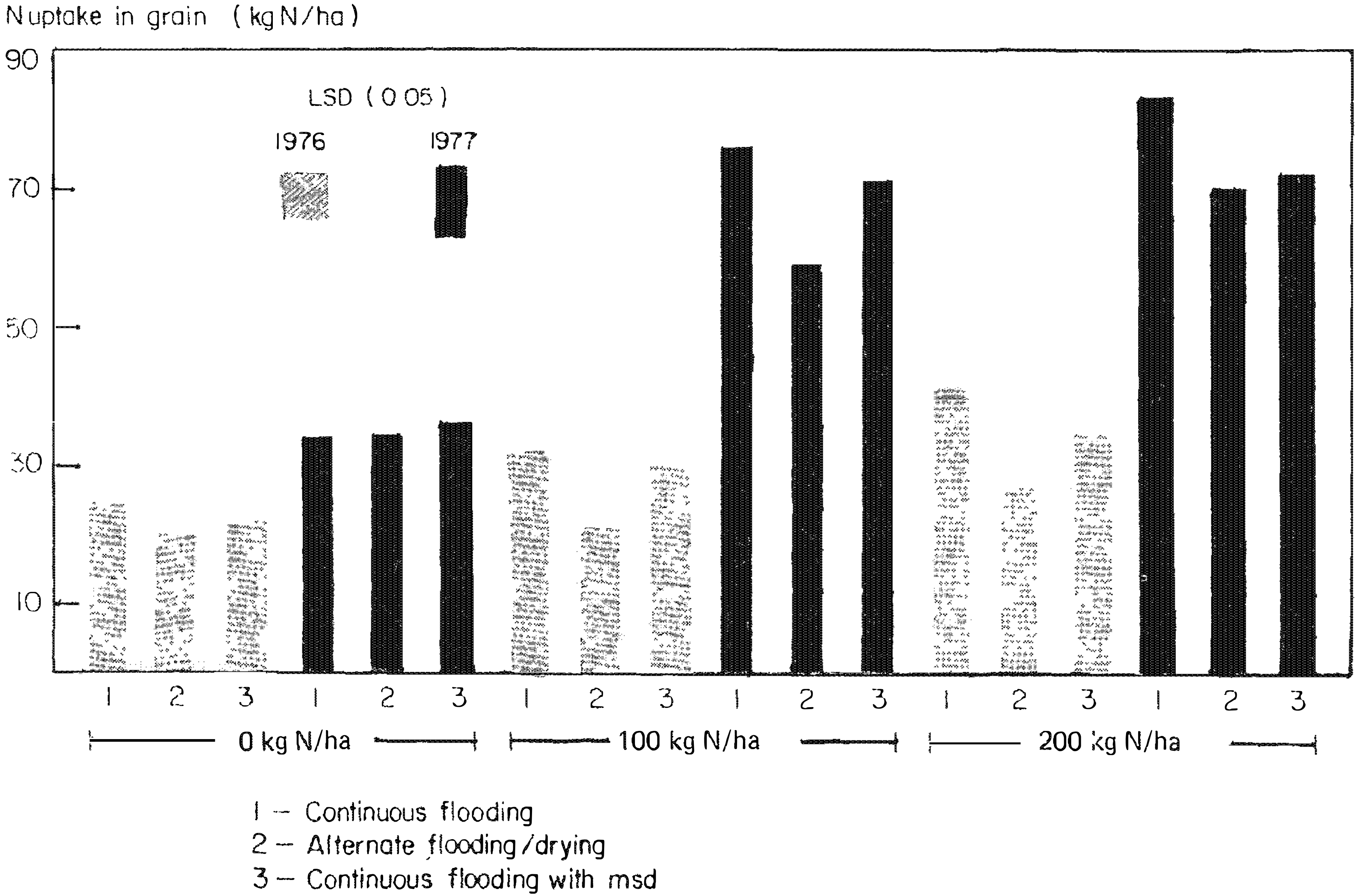

Fig. 2. Effect of different regimes and nitrogen levels on nitrogen uptake of grain.

The data on grain yields of rice from the plots that received no fertilizer nitrogen under continuous flooding, flooding with mid-season drying and laternate flooding and drying water treatments respectively were 2.52, 2.25 and 1.95 t/ha. In 1977, the trend was repeated; the grain yields were not significantly affected by the water regime when no nitrogen was applied. The yields of grain were 3.62 t (continuously flooded), 3.53 t (flooded with midseason soil drying) and 3.27 t/ha (alternate flooding and drying). Similarly the nitrogen uptake of grain on unfertilized plots was not significantly influenced by the water regimes (Fig. 2). But in the presence of applied fertilizer nitrogen at the rate of 100 or 200 kg N/ha, alternate flooding and drying significantly depressed the grain yield as well as the nitrogen uptake (Fig. 1 and 2) in both the years as compared to the continuously flooded water regime. However, there was no significant difference in either grain yield or nitrogen uptake during the 1976 season between continuous flooding or flooding with midseason drying. But in 1977, at 100 kg N/ha, the grain yield was significantly reduced even by midseason soil drying treatment as compared to continuous submergence without affecting the nitrogen uptake of grain.

Also during the 1977 season, there was no positive response to fertilizer nitrogen beyond 100 kg/ha; infact 200 kg N/ha resulted in reduced grain yield due to lodging. The nitrogen uptake of grain was also not significantly increased when fertilizer rate was increased from 100 to 200 kg N/ha under both continuously flooded as well as flooding with midseason soil drying water treatments. However, in the alternate flooding and drying water regimes the nitrogen uptake was significantly increased by 200 kg N/ha rate over the 100 kg N/ha rate. At 100 kg N/ha, the highest grain yield of 6.29 t/ha was obtained in the continuously flooded water treatment while under flooding with midseason drying as well as alternate flooding and drying, the yields were respectively 5.48 and 5.18 t/ha, which were significantly lower compared to that obtained from continuously flooded water regime.

Similar trends were observed with nitrogen uptake of grain in that the nitrogen uptake values were comparable under continuous flooding and flooding with midseason drying treatments. At 200 kg N/ha, the continuously flooded treatment was superior to both flooding with midseason drying and to the alternate flooding and drying for grain yield as well as N uptake during the 1977 season (Fig. 1 and 2).

That alternate flooding and drying of soil results in heavy losses of fertilizer N was further supported by data on soil analysis for NH_4^+ and NO_3^- several times during the 1976 season (Tables 3 and 4).

The NH_4^+ and NO_3^- analysis after 2 cycles of flooding and drying were similar in cropped and uncropped plots. This showed that the uncropped plots roughly lost the amount of N taken up by plants in the corresponding cropped plots. Heavy lossess of N have been reported by several workers under fluctuating moisture regimes under laboratory conditions[4,8,12-14].. However, it will be hazardous to extrapolate these results to the field conditions because in presence of a plant the losses will be significantly changed[4]. This study suggests that in the presence of rice plants in Maahas clay receiving no fertilizer nitrogen, there was little inorganic nitrogen left for loss by nitrification - denitrification after 8 weeks of transplanting (Table 4).

But the more significant finding from this study is that in the absence of fertilizer N and in the presence of a rice crop, soil

TABLE 3

Concentrations of NH_4^+ and NO_3^- in soil after one cycle of flooding and drying.*

Water regime	N rate (kg/ha)	Cropped plots NH_4^+ ppm	Cropped plots NO_3^- ppm	Uncropped plots NH_4^+ ppm	Uncropped plots NO_3^- ppm
Continuous flooding	0	4.1	0.3	18.1	1.2
Alternate flooding and drying	0	4.9	0.5	17.4	0.6
Midseason soil drying	0	4.3	1.1	16.5	0.3
Continuous flooding	100	11.5	1.2	31.8	1.8
Alternate flooding and drying	100	16.0	1.1	20.6	0.8
Midseason soil drying	100	17.9	0.6	31.4	1.1
Continuous flooding	200	14.7	0.6	45.1	1.0
Alternate flooding and drying	200	10.0	0.3	19.2	0.3
Midseason soil drying	200	12.7	0.7	49.9	1.2

*This corresponds to 4 weeks after transplanting and all the values are averages of 3 replications.

drying may not result in substantial reductions in yield or N uptake. However, caution should be taken in identifying the other effects on plant growth associated with soil drying like zinc deficiency, water stress and reduction products produced in the soil[9,10,16]. In the present study none of these factors seemed to be associated with soil drying and the most important effect is probably due to nitrogen. But the situations may arise in highly reduced soils when soil drying may benefit

TABLE 4

Influence of three moisture regimes on the concentrations in the soil of NH_4^+-N and NO_4^--N at three rates of fertilizer N application after 2 cycles of flooding and drying*.

Water regime	N rate (kg/ha)	Cropped plots		Uncropped plots	
		NH_4^+-4 ppm	NO_3^--N ppm	NH_4^+-N ppm	NO_3^--N ppm
Continuous flooding	0	2.2	0.2	14.4	0.6
Alternate flooding and drying	0	2.5	0.5	7.4	1.1
Midseason soil drying	0	2.9	0.0	9.2	1.1
Continuous flooding	100	3.1	0.0	17.1	1.6
Alternate flooding and drying	100	3.9	0.2	5.3	0.4
Midseason soil drying	100	6.4	0.0	[illegible].3	0.5
Continuous flooding	200	4.3	0.2	42.2	0.6
Alternate flooding and drying	200	4.6	0.5	5.5	1.1
Midseason soil dyring	200	4.9	0.0	12.9	1.3

*This corresponds to 8 weeks after transplanting and all the values are averages of 3 replications.

rice growth by alleviating zinc dificiency or by removal of toxic products in addition to its effect on nitrogen nutrition of rice.

CONCLUSIONS

The result reported in this paper suggest that alternate flooding and drying may not always significantly reduce the yield and N uptake from soils not fertilized with nitrogen. However, with high rates of fertilizer N, alternate flooding and soil drying can cause heavy losses of N as revealed by reduction in yield and N uptake of rice.

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