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Response of non-flooded rice to nitrogen rate

(Gerak balas tanaman padi tanpa air bertakung terhadap kadar nitrogen)

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Key words: non-flooded rice, nitrogen rate, water management, growth, yield

Abstract

Nitrogen and water supply are important factors that influence rice growth and yield. The grain yield response to N application rate was significantly quadratic in nature irrespective of water management practices. A higher yield response to N application rate was observed under flooded as compared to non-flooded (NF)-saturated and non-flooded (NF)-field capacity conditions. The estimated N rates for maximum yield were 99, 105 and 126 kg/ha for flooded, NF-saturated and NF-field capacity conditions, respectively. The higher amount of N needed for maximum rice yield under NF-field capacity conditions was probably due to greater N losses as a result of alternate wetting and drying of soil as well as the reduced root system. However, the optimum N rate for maximum yield did not differ very much between flooded and NF-saturated conditions indicating the close similarity in N requirement under both water management practices. The dry shoot biomass response to N rate was quadratic but it was not significant under flooded and NF-saturated conditions. However, a significant quadratic response was observed for dry root biomass under flooded and NF-saturated conditions. The dry shoot and root biomass response to N rate was significantly linear under NF-field capacity conditions.

Introduction

Nitrogen is a crucial factor for high rice yield and high yielding varieties which usually require high rates of N for maximum yield. However, excessive application of N may reduce yield due to increased lodging, heavy mutual shading of leaves as well as increased damage from insect pests and diseases (Hall et al. 1968). Ramasamy et al. (1997) observed a significant positive yield response to N application up to 150 kg/ha, but a negative effect on yield with the application of 200 kg N/ha. A negligible yield advantage with the application of 150 kg N/ha over 100 kg N/ha was observed. They also noted a greater shoot and root biomass with higher N rates.

Problems with over-application of N arise when N fertilizer is relatively cheap and in wishing to ensure good yields, farmers are unconcerned about applying excessive amounts of N, much of which is wasted or lost through denitrification and ammonia volatilization (Peoples et al. 1995). However, in countries where the cost of fertilizer is high, N fertilizer applications are often well below the recommended levels.

Besides N, water supply is another important factor, which influences rice growth and yield, and these two factors

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often interact with each other. Nitrogen uptake is reduced under water stress as a result of reduced transpiration rate (Yambao and O'Toole 1984). When water stress is the most limiting factor for growth, yield does not respond to increased N application under rainfed upland conditions (Yoshida 1975). The low yield of upland rice is mainly due to water stress and insufficient N supply (Crosson 1995). Otoo et al. (1989) found an interaction of N supply and soil water deficit on photosynthesis and transpiration in rice. Hence, changes in water management practices may alter N availability to rice which will subsequently affect growth and yield.

Growing rice requires large amount of water. The present global water crisis threatens the sustainability of irrigated rice production as the demand for available water from urban and industrial sectors is likely to receive priority over irrigation for agriculture. This scenario may necessitate the adoption of rice production practices that reduce water input without impairing yield and at the same time saving water.

This experiment was therefore conducted to determine the effects of N rate applied under different water management practices on growth and yield of rice.

Materials and methods

A greenhouse experiment was carried out at MARDI Station Seberang Perai using sandy clay loam of the Sogomana soil series. The experimental design was a split plot design with water management as the main plot and N rate as the subplot with four replications. Polyvinyl chloride (PVC) cylinders, each 50 cm high and has a diameter of 20 cm were used as the growing pots. Sample of 15 kg air-dried soil was packed into each pot, to form approximately a 40 cm soil column. Rice variety, MR 84 was grown at the seeding rate of 40 kg dry seeds per hectare (5 seedlings per pot).

Three water management practices were evaluated:

- Flooded: application of 0.05 m water from 7 days after seeding (DAS) and followed by removal of water at about 10 days before maturity.
- Non-flooded (NF) -saturated: application of water just to wet the soil with no standing water throughout the growing period of the crop. Excess water in the pot was removed through a hole made at the same level as the soil surface in the pot.
- Non-flooded (NF) -field capacity: periodic irrigation to maintain the soil at about field capacity from seeding to maturity. Irrigation was done when the water potential fell to –0.03 to –0.05 MPa, as measured with a tensiometer installed at 15 cm soil depth.

The N rates tested were 0 (control), 50, 100, 150 and 200 kg N/ha in the form of urea solution. The latter was applied in three splits at the ratio of 0.4:0.3:0.3 irrespective of rates tested. The first split was applied at 21 days after seeding (DAS), followed by the second split at 45 DAS and the final split at the panicle initiation (PI) stage. Triple super phosphate and muriate of potash as the source of P_2O_5 and K_20, respectively, were applied at the rate of 50 kg/ha during the first N application at 21 DAS. The amount of fertilizer applied was calculated on the basis of soil surface area of each pot.

Plant height measurement and tiller count were recorded at early tillering (ET), active tillering (AT), panicle initiation (PI) and maturity stages. At maturity, the grain was separated from the straw. The roots and straw were washed, oven dried at 70 °C for 72 h and weighed. Grain yield per pot was obtained from the weight of filled grains calculated at 14% moisture content.

The Duncan Multiple Range Test (DMRT) was used to compare significant differences between treatment means after analysis of variance was conducted. The optimum nitrogen rate for maximum yield under each water management practice was calculated by using the quadratic equation $Y = a + bN + cN^2$, where Y = yield and N = nitrogen rate (Gomez and Gomez 1984) as follows:

$Ny = (-b/2c)$
where Ny = N rate (kg/ha) for maximum yield.

Results and discussion

Crop growth

There was no significant interaction effect between N rate and water management on tiller production and plant height. The different N rates applied had a significant effect ($p = 0.05$) on crop growth as reflected by the significant difference in tiller production during the advanced growth stages (AT and PI) but not at early tillering stage as shown in *Table 1*. A larger amount of N was needed during AT stage for the rapid and active tiller production. During PI stage, more N is required for tiller maintenance as well as for panicle development. Reducing N supply during AT and PI stages would limit tiller production. However, N rates did not significantly affect plant height as measured at various crop growth stages (data not shown).

Crop growth was also influenced by water management. Plants were significantly shorter with less number of tillers *(Table 1)* when rice was subjected to NF-field capacity conditions as compared to rice grown under normal flooded and NF-saturated conditions. These phenomena were probably due to reduced N uptake as a result of smaller root system and various N loss mechanisms from alternate wetting and drying under NF-field capacity conditions (Wells and Shockley 1978).

Shoot biomass

There was an interaction effect between N rate applied and water management on dry shoot biomass at maturity. Regression analysis indicated that the quadratic response of dry shoot biomass to N rate was not significant for flooded and NF-saturated conditions *(Figure 1)*. On the other hand, the response was significant and positively linear under NF-field capacity conditions.

The dry shoot biomass was significantly higher under flooded conditions receiving N between 50 and 150 kg/ha. Beyond this rate (150 kg/ha) the dry shoot biomass decreased to the level similar to that of the control (without N). The dry shoot biomass of the control under NF-saturated conditions was significantly reduced when compared to that of the application of N between 50 and 100 kg/ha, but was not significantly different from N applied at or beyond the rate of 150 kg/ha. There was however, no significant difference in dry shoot biomass with the application of N between 50 and 200 kg/ha under NF-

Table 1. Tiller production at various growth stages as affected by N rate and water management

N rate (kg/ha)	ET				AT				PI			
	Flooded	NFs	NFfc	Mean	Flooded	NFs	NFfc	Mean	Flooded	NFs	NFfc	Mean
0	12	12	6	10.0a	32	33	15	26.7b	31	29	14	24.7c
50	12	13	9	11.3a	33	35	17	28.3b	33	32	15	26.7bc
100	12	13	6	10.3a	33	37	19	29.7ab	31	34	16	27.0bc
150	13	12	6	10.3a	35	39	22	32.0a	35	37	17	29.7a
200	12	12	7	10.3a	35	36	27	32.7a	32	34	20	28.7ab
Mean	12.2A	12.4A	6.8B	10.4	33.6A	36.0A	20.0B	29.9	32.4A	33.2A	16.4B	27.3
CV (%)				18.5				13				10.9

Means in a column followed by a common small letter and in a row at each growth stage followed by a common capital letter are not significantly different at 5%
ET = early tillering AT = active tillering PI = panicle initiation
NFs = Non flooded-saturated NFfc = Non flooded-field capacity

saturated conditions. The dry shoot biomass was very much reduced when rice was grown under NF-field capacity as compared to flooded and NF-saturated conditions *(Figure 1)*.

Root biomass

There was no significant interaction effect between N rate and water management on the dry root biomass at maturity. A significant quadratic response to N rate was observed under flooded and NF-saturated conditions as shown in *Figure 2*. This is in agreement with the finding as reported by Ramasamy et al. (1997). However, the response of dry root biomass to N rate was significant ($p=0.05$) and positively linear under NF-field capacity conditions *(Figure 2)*. Root growth was very much limited when N was not applied irrespective of water management practices.

Water management had a significant effect on the dry root biomass. Significantly lower dry root biomass was noted when rice was grown under NF-field capacity conditions. The dry root biomass was however, not significant between flooded and NF-saturated conditions.

Grain yield

There was a significant interaction effect between N rate and water management on grain yield. Regression analysis indicated that grain yield response to N rate was significantly quadratic for all water management practices tested *(Figure 3)*. The rate of response as indicated by the response coefficient (b value) was, however, higher in flooded conditions (b = 0.4153) as compared to NF-saturated (b = 0.1674) and NF-field capacity (b = 0.0756). The estimated N rate for maximum yield under flooded, NF-saturated and NF-field capacity conditions at a seeding rate of 40 kg dry seed per hectare was 99, 105 and 126 kg/ha, respectively. A higher optimum N rate for maximum yield could be expected with a higher seeding rate of 150 kg/ha as practised

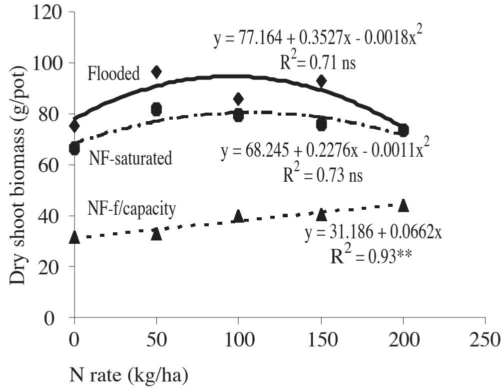

Figure 1. Dry shoot biomass under different water management in response to N rate at maturity

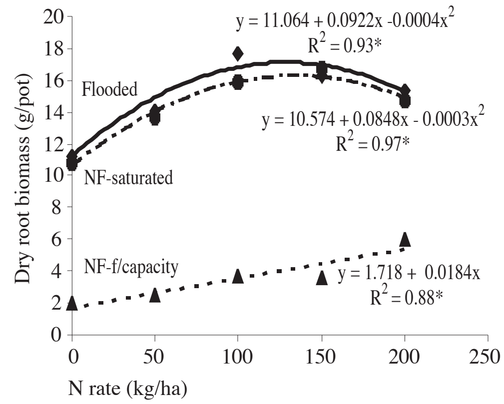

Figure 2. Dry root biomass in response to N rate at maturity

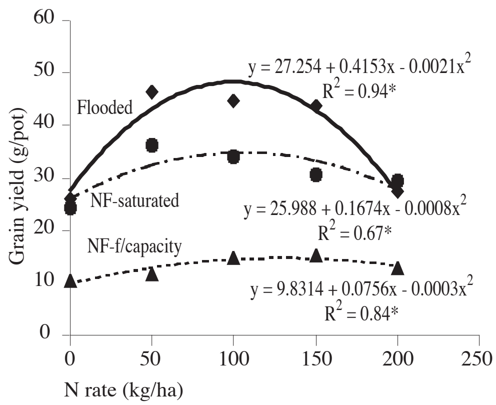

Figure 3. Estimated grain yield response of MR 84 to N rate under different water management

by most farmers, which results in a very dense plant population.

Grain yield responded significantly to N application especially under flooded and NF-saturated conditions. However, no significant yield difference was observed under flooded conditions when N was applied from 50 to 150 kg/ha when yield ranged between 43.72 and 46.36 g/pot. Grain yield was significantly reduced with N application below and beyond the above range of N rates. A higher application of N at 200 kg/ha resulted in detrimental effects on grain yield irrespective of water management practice, but the effect was greater under flooded than NF-saturated and NF-field capacity conditions.

The increase in grain yield due to N fertilization under flooded conditions is in agreement with the findings of Sharma (1995) and Choudhury (1999). A similar yield trend to flooded conditions was observed for NF-saturated conditions. On the other hand, grain yield was not significantly different with the application of N between 50 and 200 kg N/ha but was significantly higher when 150 kg N/ha was applied as compared to the control (without N) under NF-field capacity conditions.

The mean grain yield under NF-saturated and NF-field capacity conditions was 18.0% and 65.4%, respectively, lower than flooded condition. The difference in grain yield among water management practices might be attributed to the difference in root growth measured as dry root biomass *(Figure 2)*. The latter, which might have affected N fertilizer uptake.

Besides having a smaller root system, alternate wetting and drying of soil under NF-field capacity conditions could also cause a decrease in grain yield due to lower soil N availability and uptake as reported by Beyrouty et al. (1994). Reduced N uptake by rice grown under alternate wetting and drying of soil is due to smaller root system and N losses through nitrification-denitrification (Wells and Shockley 1978). When water is the most limiting factor for growth, yield does not respond to increased N application (Yashida 1975).

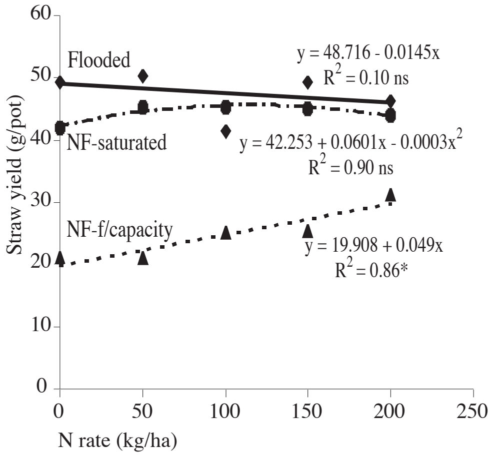

Figure 4. Straw yield response to N rate under different water management

Straw yield

There was no significant interaction effect between N rate and water management on straw yield. Straw yield response to N rate was not significant and negatively linear under flooded conditions *(Figure 4)*. However, a significant positive linear trend was observed under NF-field capacity conditions, while a non-significant quadratic trend in straw yield response to N rate was observed under NF-saturated conditions.

Under flooded conditions, straw yield did not differ significantly among N rates except for 100 kg N/ha which produced the lowest straw yield. There was also no significant difference in straw yield among N rates under NF-saturated conditions. However, a significant straw yield difference was observed under NF-field capacity conditions. Straw yield was higher with the application of 200 kg N/ha, but was not significantly different from 100 and 150 kg N/ha. The increase in straw yield due to N application was mainly attributed to the increase in tiller production *(Table 1)*. The increase in straw yield due to N application is in agreement with the findings of Panda et al. (1995) and Choudhury (1999). Results also showed that straw yield was significantly higher under flooded and NF-saturated than NF-field capacity conditions. This was attributed to taller plants and higher tiller number under flooded and NF-saturated than NF-field capacity conditions.

Conclusion

Rice growth and yield were significantly affected by N application. A higher amount of N was needed during the vegetative growth stage for rapid and active tiller production, while during PI stage, N was needed for tiller maintenance and panicle development. Estimated grain yield response to N application was quadratic in nature irrespective of water management. A higher yield response to N application rate was observed under flooded as compared to NF-saturated and NF-field capacity conditions. The estimated N rates for maximum yield were 99, 105 and 126 kg/ha for flooded, NF-saturated and NF-field capacity conditions, respectively. This implies that a higher amount of N has to be applied to rice grown under NF-field capacity than in flooded and NF-saturated conditions. As expected, N losses under NF-field capacity condition is greater as a result of alternate wetting and drying of soil. The optimum N rate for maximum yield did not differ much between flooded and NF-saturated conditions indicating the close similarity in N requirement under both water management practices. The NF-saturated conditions has an additional advantage in that maintaining a saturated soil throughout the growing season can save water up to 40% without causing a significant reduction in rice yields.

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Abstrak

Nitrogen dan air ialah faktor penting yang mempengaruhi pertumbuhan dan hasil padi. Gerak balas hasil tanaman padi terhadap kadar pembajaan N didapati kuadratik tanpa mengira kaedah pengurusan air. Gerak balas hasil terhadap kadar N didapati lebih tinggi untuk tanaman padi dalam keadaan banjir berbanding dengan keadaan tanpa pembajiran (TB)-tepu atau tanpa pembanjiran (TB)-keupayaan ladang. Anggaran kadar N untuk hasil maksimum ialah 99, 105 dan 126 kg/ha masing-masing untuk kaedah pembanjiran, TB-tepu dan TB-keupayaan ladang. Kadar N yang lebih tinggi diperlukan untuk hasil maksimum pada TB-keupayaan ladang mungkin kerana kadar kehilangan N yang lebih disebabkan oleh keadaan tanah yang sentiasa berubah daripada basah kepada kering dan sebaliknya serta sistem akar yang kurang. Walau bagaimanapun kadar N yang optimum untuk hasil maksimum tidak banyak berbeza antara pembanjiran dengan TB-tepu, dan ini menunjukkan keperluan N lebih kurang sama bagi kedua-dua kaedah pengurusan air.

Gerak balas biojisim pucuk terhadap nitrogen adalah kuadratik tetapi ia tidak ketara dalam keadaan banjir dan TB-tepu. Walau bagaimanapun gerak balas kuadratik yang ketara diperoleh untuk biojisim akar kering dalam keadaan banjir dan TB-tepu. Gerak balas biojisim pucuk dan akar kering adalah linear dan ketara bagi keadaan TB-keupayaan ladang.

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