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Critical Time of Nitrogen Application During Panicle Initiation on the Yield of Two Malaysian Rice Cultivars (*Oryza sativa* L.)

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ABSTRACT

Nitrogen is the most limiting nutrient in rice production. N fertilizer is susceptible to losses when the time of application does not match with period of crop demand. A glasshouse experiment was conducted to determine the critical time of nitrogen fertilizer application at panicle initiation on grain yield of two Malaysian rice cultivars (MR219 and MR232). The experiment consisted of five N treatments applied each at 60 kg ha^{-1} at 45 (N1), 50 (N2), 55 (N3), 60 (N4) and 65 (N5) days after seeding (DAS) with five replications. Prior to this stage, a total of 75 kg N ha^{-1} was applied during vegetative growth stage (at 15 and 35 DAS). Plant physiological parameters such as height, SPAD value and LAI showed statistical difference among some treatments. Application of N also resulted in an increase in plant biomass. The results demonstrate that the split appication of fertilizer N at PI stage (55 DAS) significantly increased percentage of filled grains, 1000-grain weight and total grain yield. Incorrect timing of N application (65 DAS) at PI stage, drastically reduced rice yield to approximately 39% for MR219 and 17% for MR232. Farmers should be advised to apply N between 50 DAS and 55 DAS, even though application of N at 55 DAS was far better than 50 DAS in terms of yield parameters.

Keywords: ***Oryza sativa,*** **urea, days after seeding (DAS), glasshouse, grain yield, timing, panicle initiation, critical growth stages**

INTRODUCTION

Rice (*Oryza sativa* L.) is a unique crop of great antiquity and akin to progress in human civilization (Smith *et al.,* 2003). It is estimated that about 40% of the world's population consume rice as their major source of food. The importance of rice for food security and socioeconomic stability is self-evident. Rice production has been described as the world's single most important economic activity. The increase in production is possible if soil, water, nutrients and other production inputs are used efficiently. Sustainable rice production is a key to improving global livelihood of both small scale farmers in developing countries and rice producing countries worldwide. Thus meeting the challenges for sustainable increase in rice production and production efficiency is vital for alleviation of poverty and attainment of food security worldwide.

Nitrogen is the most important and yield-limiting nutrient in rice production worldwide (Lin *et al.,* 2006). Nitrogen promotes rapid growth of rice, increases leaf area, spikelet number per panicle, percentage of filled grains and grain protein content (Dobermann and

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Fairhurst, 2000). Rice production consumes approximately 20% of the total N fertilizer used for agriculture in the world (Mew *et al.,* 2003).

In rice plants, leaf N is remobilized to the grains during the grain filling period along with actively produced photosynthates. That is, there is a compromise between the supply of N and photoasimilates from leaves to the grains during grain filling such that enough N must remain in leaves to allow photosynthesis to continue, yet enough N must be transported to the grains to allow normal grain development and storage of adequate reserves (Shiratsuchi *et al*., 2005).

This N fertilizer is often not effectively used by irrigated rice because of improper timing and rates of application. It is typically required in greater quantities than any other nutrient if rice farmers are to reap high yields and profits. Inappropriate N management has detrimental effects on crop yield and the environment and aggravates disease and pest incidence. Nitrogen fertilization is a key input in increasing rice production. The introduction of high-yielding varieties has greatly increased the prospect of increasing yields but this goal will not be reached without great increases in the use and efficiency of N on rice.

Since fertilizer is an expensive input, an economical and appropriate method of application needs to be determined to enhance productivity and profit of the growers under given situation (Manzoor *et al.,* 2006). Dobermann and Cassman (2002) noted that average farm yield levels of 70 – 80% of the attainable yield potential are necessary to meet expected food demand in the next 30 years; research must seek to develop nutrient management approaches that optimize profit, preserve soil quality, and protect natural resources in systems that consistently produce at these high yield levels. Achieving these goals will require novel strategies for more precise plant nutrient management tailored to the technologies, dynamics and spatial scales relevant to each system.

Efficient use of N applied to rice has been a course of concern in rice production especially in flooded rice. Irrigated rice (*Oryza sativa* L.) yield increases in Asia have slowed down in recent years (Dobermann *et al.,* 2003). Further, yield increases are likely to occur in smaller increments through fine-tuning of crop management. In field experiments, flooded rice generally recovers only 20 – 40% of applied N, whereas upland rice normally recovers about 40-60% (De Datta, 1981). The split application of fertilizer N remains an essential component of recommendation, however the time of application especially at critical stages varies depending on the type of rice cultivar. Application of N during critical stages may optimize leaf N distribution, thereby maintaining high canopy photosynthesis, especially during grain filling stage (Qi Jing *et al.,* 2007). Inappropriate N management also has detrimental effects on crop yield and the environment and aggravates disease and pest incidence. Varying the application of fertilizer N to match the specific needs of rice can increase yield, while also reducing N loss and maximizing recovery of fertilizer N. Therefore, the objective of this study was to investigate the correct time of N application, specifically at the panicle initiation stage for two indica rice cultivars (MR219 and MR232) taken from Malaysian Agricultural Research and Development institute (MARDI).

MATERIALS AND METHODS

A greenhouse experiment was conducted at field 10, Universiti Putra Malaysia (02°N 59.476’ 101°E 42.867’, 51 m altitude) between December 2007 and March 2008. Two indica rice cultivars (MR219 and MR232) from Malaysian Agricultural Research and Development Institute (MARDI) were planted for the experiment. The average yield of MR219 and MR232 is estimated at 8 – 10 t ha^{-1} (MARDI, 2006).

Pots of 40 cm height and 34 cm diameter size filled with 15 kg of uniformly mixed soil were used. The experimental soil was Bakau series obtained from Tanjong Karang, a major rice growing area located in Kuala Selangor, Peninsular Malaysia. Characteristically, the soil is loamy clay with pH 5.1, CEC 16 cmol kg^{-1} soil, 16.3 g organic C kg^{-1}, 1.46 g total N kg^{-1}, 5.3 mg available P kg^{-1} and 72.6 mg K kg^{-1}.

Weather records were taken between the months of December 2007 and February 2008. Average minimum and maximum temperatures were recorded with a minimum and maximum thermometer at ten days interval (*Fig. 1*).

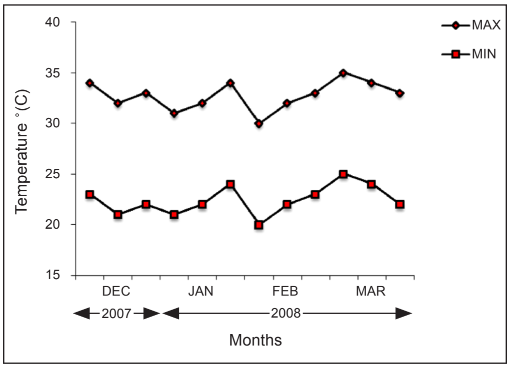

Fig. 1: Minimum and maximum temperature distribution of the glasshouse

The experiment consisted of five N treatments and two varieties (MR219 and MR232) with five replications arranged in a completely randomized design. The varieties were separately arranged within the same glasshouse. The five N treatments comprised of different timings of urea N-fertilizer (60 N kg ha^{-1}) applied at five days interval during the panicle initiation stage (45 (N1), 50 (N2), 55 (N3), 60 (N4) and 65 (N5) days after seeding (Table 1)). During early crop establishment (15 DAS) and midtillering stage (35 DAS), 50% of N fertilizer (75 kg ha^{-1}) was top dressed in all treatments. At 75 DAS, 10% of the N (15 kg ha^{-1}) was also applied to all treatments. A total amount of 150 kg N/ha equivalent was applied in all treatments.

Phosphorus and potassium fertilizers were applied based on the standard recommended rate in all treatments. Phosphorus (90 kg P_2O_5 ha^{-1}) as rock phosphate and potassium (150 kg K_2O ha^{-1}) as muriate of potash were applied basally at early crop establishment stage (14 DAS). Vita-Grow ® (90 mL/18 L) was sprayed as a micronutrient foliar fertilizer at the midtillering stage (30 DAS) in all treatments.

The rice seeds were pre-germinated in ZAPPA® solution for 24 hours and then broadcast into the soil moistened at saturation. There were ten seedlings sown per pot. After seedling establishment (14 DAS), about 10 cm water depths were maintained throughout the growing period until two weeks before harvesting, in order to allow ripening and drying of the grains. Adequate pest and disease control measures were taken throughout the plants' growth.

Sampling was conducted to determine the yield and yield components of rice plants. Ten flag leaves were sampled from each pot at grain filling stage (85 DAS) to measure the chlorophyll content (SPAD value) and leaf area index (LAI). Plant height was measured on 10 plants per pot at 80 DAS. At maturity (110 DAS), 10 panicles were sampled from each pot to determine the yield and yield components of the rice plants. The panicles were separated into filled and unfilled spikelets. The samples were then oven-dried at 70°C for 48 hours to constant weight. Data were subjected to analysis of variance and means comparison (DMRT at 5% P level) of different measured parameters were performed using SAS system.

RESULTS AND DISCUSSION

Application of N fertilizer yielded significant differences among some treatments for both cultivars in terms of plant height, leaf chlorophyll content (SPAD reading) and LAI. Treatment N3 produced highest plant height for cultivar MR219 (92.2 cm) and was significantly different from N1 (85.6 cm) and N5 (84.2 cm) (*Fig. 2*). In MR232, statistical difference was noted in the plant height of treatments N2 (96.0 cm) and N5 (85.4 cm). Difference observed in plant height could be attributed to increase in panicle length due to application of N at critical stage of PI.

SPAD value for MR219 was significantly higher in N2 (39) and N3 (38) compared to N4 (33), where as in MR232 cultivar, treatments N3 and N4 recorded statistical difference with N5 in terms of SPAD value (Table 2). Comparatively, cultivar MR219 recorded higher average SPAD reading than MR232. LAI measurement was

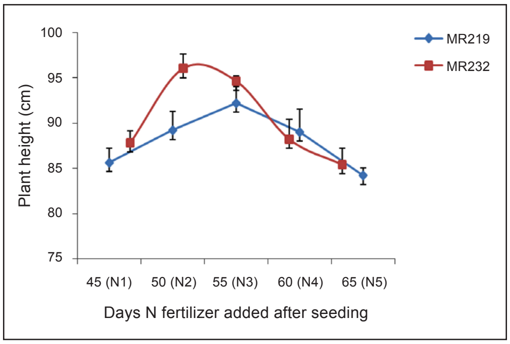

Fig. 2: Plant height patterns of the rice cultivars at 80 DAS. Error bars represent standard error of the means

TABLE 1
Amount of N applied on rice cultivars (MR219 & MR232) at different time during the panicle initiation stage

Treatments	Days After Seeding				
	45	50	55	60	65
	kg N ha^{-1}				
N1	60	-	-	-	-
N2	-	60	-	-	-
N3	-	-	60	-	-
N4	-	-	-	60	-
N5	-	-	-	-	60

significantly higher in treatment N3 for both cultivars MR219 and MR232 (8.4 and 7.9) respectively. The high occurrence of LAI in treatment N4 indicates better plant canopy structure.

Application of N resulted in an increase in plant biomass (*Fig. 3*). The highest plant biomass was observed in N3 (400.2 g pot^{-1}) for MR219, where as in MR232, N2 recorded the highest (367.2 g pot^{-1}). The fact that N2 and N3 yielded the highest plant dry weight might be attributed to application of N at critical growth stages such as 50 and 55 DAS. This experiment confirms the observation made by Dobermann *et al.* (2000) that N uptake at midtillering and panicle initiation stage tends to increase the biomass of plants' leaves, stems and panicles.

Spikelets number per panicle are presented in *Fig. 4*. Treatment N3 for both cultivar MR219 and MR232 accounted for the highest grain number per panicle, (135) and (131) respectively. However, lowest grain number per panicle was recorded in N5 for both cultivars. It was observed that application of N before or after 55 DAS, steeply decreased grain number. Application of N during these periods, may lead to wastage because the N might not be efficiently utilized by the plant. In both MR219 and MR232, grain number per panicle was considerably higher due to application of N at 55 DAS (*Fig. 4*). This indicated that the applied N was efficiently utilized by the plant, thus making it possible for

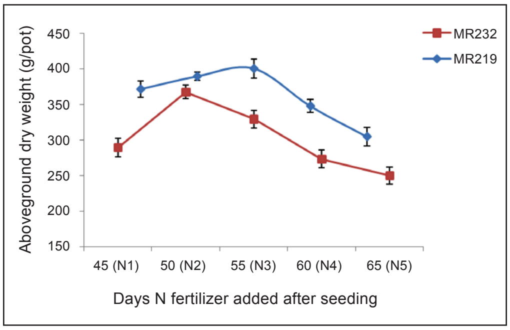

Fig. 3: Effects of partitioning of N on aboveground dry weight of the rice cultivars. Error bars represent standard error of the means

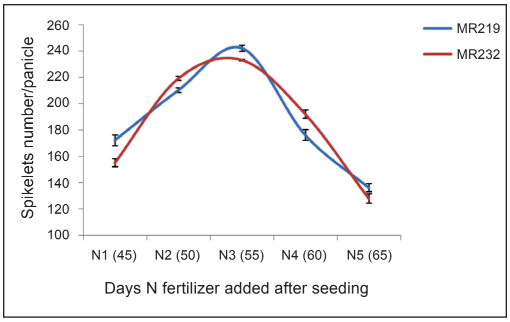

Fig. 4: Spikelet number per panicle as affected by N application at PI stage. Error bars represent standard error of the means

the plant to translocate the carbohydrates into the organs.

Results shown in *Figs. 5, 6* and *7* demonstrated that appication of N fertilizer at 55 DAS during the PI stage (N3) increased the percentage of filled grains, 1000-grain weight and total grain yield. The increase in yield could be due to efficient N uptake by the plants, that led to better photosynthetic rate as shown by the SPAD value (Table 2). Treatment N3 accounted for the maximum paddy yield in both MR219 (225.75 g pot^{-1}) and MR232 (214.61 g pot^{-1}), while N5 produced the lowest yield for both MR219 (137.58 g pot^{-1}) and MR232 (177.63 g pot^{-1}). The results suggest that delaying application of N at PI stage may drastically reduce paddy yield up to approximately 39% for MR219 and 17% for MR232.

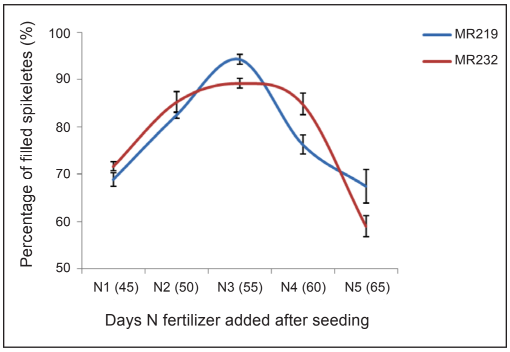

Fig. 5: Effects of N applied on percentage of filled spikelets. Error bars represent standard error of the means

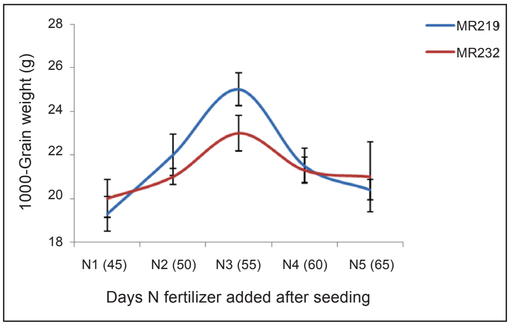

Fig. 6: Effects of N partitioning at PI stages on 1000-grain weight. Error bars represent standard error of the means

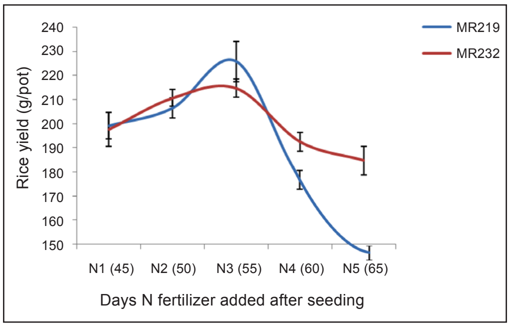

Fig.7: Rice yield as affected by application of N at different days of PI stage. Error bars represent standard error of the means

TABLE 2

Effects of N splitting on chlorophyll content (SPAD value) and LAI

Treatments	SPAD value		Leaf Area Index	
	Cultivar			
	MR219	MR232	MR219	MR232
N1	37ab (1.10)	34b (0.74)	6.6cd (0.16)	6.5c (0.09)
N2	39a (1.34)	35ab (0.59)	6.7d (0.15)	6.6c (0.06)
N3	38a (1.02)	36a (1.33)	8.4a (0.11)	7.9a (1.12)
N4	33b (2.00)	37a (1.16)	7.8b (0.14)	7.0b (0.33)
N5	35ab (1.30)	31c (0.50)	6.0e (0.08)	5.7d (0.06)

In each column, means followed by the same letter(s) are not significantly different at 5% level by DMRT. Numbers in parenthesis are standard error of the mean.

CONCLUSIONS

The results showed that application of N fertilizer at 55 DAS (N3) increased the number of spikelets/panicle, % of filled spikelets, 1000-g grain weight, and rice yield probably due to efficient N uptake. Application of N fertilizer before 50 DAS or after 55 DAS reduced all these parameters. Generally, late application of N after 65 DAS may reduce rice yield to about 39% for MR 219 and 17% for MR 232. The results suggested that practically, farmers should be advised to apply N between 50 DAS and 55 DAS, even though application of N at 55 DAS was far better than 50 DAS in terms of yield parameters. This was to avoid late application of N by the farmers as this may result substantial yield losses.

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