YIELD AND AGRONOMIC CHARACTERISTICS OF TROPICAL RICE AS INFLUENCED BY HIGH NITROGEN RATES

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ABSTRACT

An experiment with treatments comprising of five nitrogen rates (0, 120, 160, 200 and 240 kg N/ha) applied as urea was carried out to evaluate the effects of high nitrogen application on the yield and agronomic performance of two rice varieties; MR 211 and MR 219. Raising nitrogen application was found to increase ($P<0.05$) the number of spikelets per panicle but reduce the percentage of filled spikelets ($P<0.05$). Although the increment in number of spikelets per panicle resulted in the reduction of the filled spikelets percentage, the grain yield was not affected due to sufficient production of spikelets per square meter which maintained the grain productivity. The plant agronomic characteristics such as stem height and duration to grain maturity also increased ($P<0.05$) with nitrogen application. Both varieties differ in the yield components and agronomic characteristics. Between the two varieties, MR 219 is superior to MR 211 in view of the higher grain yield and grain: straw ratio. The result from correlation between yield and yield components implies that the total number of spikelets per square meter was believed to be the major determinant of grain yield.

ABSTRAK

Eksperimen menggunakan lima kadar nitrogen (0, 120, 160, 200 dan 240 kg N/ha) daripada baja urea telah dijalankan untuk mengkaji kesan input nitrogen yang tinggi pada hasil dan prestasi agronomi dua varieti padi; MR 211 dan MR 219. Peningkatan kadar nitrogen didapati telah meningkatkan ($P<0.05$) bilangan biji setangkai tetapi mengurangkan peratusan biji bernas ($P<0.05$). Walaupun peningkatan dalam bilangan biji setangkai memberikan kesan kepada pengurangan dalam peratusan biji bernas, namun keadaan ini tidak mempengaruhi hasil padi. Ini kerana terdapat jumlah biji semeter persegi yang mencukupi untuk mengekalkan produktiviti padi tersebut. Ciri agronomi padi seperti ketinggian batang dan tempoh matang juga didapati meningkat ($P<0.05$) dengan penggunaan baja nitrogen. Kedua-dua varieti didapati berbeza dari segi komponen hasil dan ciri agronomi. Dalam perbandingan di antara kedua-dua varieti, MR 219 adalah lebih baik berbanding MR 211 kerana mempunyai hasil padi dan nisbah padi: jerami yang lebih tinggi. Keputusan daripada ujian korelasi di antara hasil padi dan komponen-komponen hasil menerangkan bahawa jumlah biji semeter persegi merupakan faktor utama yang menentukan prestasi hasil padi.

Key words: Nitrogen, rice, variety, yield components

INTRODUCTION

Rice is the staple food for all Malaysians. With the human population of 26 million and annual growth rate of 2.5%, there is a need to increase the rice grain production to ensure food security through the promotion of rice self-sufficiency. Malaysia is about 65% self-sufficient in rice and still reliant on rice imports, which account for 30% of its consumption. In line with the strategy of the National Agricultural Policy (NAP3) which is to reduce food imports, the Ministry of

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Agriculture and Agro-based Industry Malaysia has targeted to increase the rice grain yield from current average yield of 4.5 t/ha to 10 t/ha (MOA, 2004). Among the steps that have been taken to achieve this target are the application of high levels of nitrogen fertilizer and the use of high yielding varieties in rice establishment.

Nitrogen is the most essential element in determining the yield potential of rice (Cassman et al., 1996; Mae, 1997). The application of nitrogen fertilizer represents a major input to the rice crop and high grain yield can be obtained if an adequate amount of nitrogen is accumulated in the rice plant throughout the growing season. Nitrogen fertilization is essential to maximize the number of panicles per unit area and total number of spikelets, which reflects on grain productivity (Mauad et al., 2003). In the current situation, Malaysian rice farmers are applying nitrogen fertilizer at rates above the recommendation by the Malaysian Agriculture Research and Development Institute (MARDI), as they believe that higher nitrogen levels are essential in maximizing grain yield (Alias and Manaf, 1993).

The rice yield potential is also dependent on the types of variety grown. It is necessary for the rice growers to select a suitable variety in rice establishment. Varieties are responsive to the environmental conditions such as soil fertility, climate and fertilization management practice. Some varieties are very sensitive to environmental changes where as some are more stable varieties (MARDI, 2002).

This paper aims to evaluate the effects of high nitrogen rates on two different varieties of rice and their interaction with grain productivity and agronomic performance.

MATERIALS AND METHODS

The experiment was conducted from 22nd March, 2004 to 12th July, 2004 in Universiti Putra Malaysia. The soil was classified as Bakau Series (*Typic hidrajelbars*) and its chemical properties indicates: pH_w = 6.24; CEC = 16.2 cmol (+)/kg, SOM = 9.04%; total N = 0.45%; available P = 74 ppm; Na = 0.27 cmol (+)/kg; K = 0.031 cmol (+)/kg; Ca = 8.11 cmol (+)/kg; and Mg = 6.89 cmol (+)/kg.

The treatments comprised of 5x2 factorial combination of five nitrogen rates (0, 120, 160, 200 and 240 kg N/ha) with two rice varieties (MR 211 and MR 219), giving a total of 10 treatment combinations. The 10 treatment combinations were replicated four times in a Completely Randomized Design (CRD). The experimental units were polyethylene (PE) tanks (1.1 diameter, 47.4 cm height) filled with soil up to 37 cm depth.

The rice was established by direct seeding in PE tanks. The rice seeds were soaked in clean water for four days before sowing. The pre-germinated seed were sown by broadcasting seeds at rate of 500 seeds per square meter (MARDI, 2002). At 5-7 days after sowing (DAS), water was supplied gradually and maintained at ± 5cm during early vegetative and reproductive stage. Split urea ($CO(NH_2)_2$) fertilizer were applied at 15, 35, 55 and 75 DAS at ratio of 15%, 35%, 25% and 25% for the respective growth stages (MARDI, 2002). The phosphorus (Triple Super Phosphate) and potassium (Muriate of Potash) fertilizer were applied once at 15 DAS at the rate of 80 kg P_2O_5/ha and 150 kg K_2O/ha. At 90 DAS, the water was drained out via a tap attached to the PE tank. Weed control was done manually, when necessary.

The stem height was recorded before harvesting. The grain yield and yield components were determined at maturity. The data were analyzed using analysis of variance and correlation procedure of SAS Institute Inc., USA. F-Test and Duncan Multiple Range Test (DMRT) were carried out for mean comparisons between the treatments. Correlation analysis was carried out to determine the relationship between the yield and yield components.

RESULTS

The analysis of variance (ANOVA) as shown in Table 1 indicate the effects of nitrogen rates and varieties and their interactions on the yield and agronomic performance of two rice varieties.

No foliar diseases and lodging were observed during the experiment. The stem height was recorded at panicle emergence. There was a linear increase in stem height with increasing nitrogen application (P<0.01) (Figure 1a). The stem height was below 85 cm even under the highest nitrogen application. Variety MR 211 had a significantly shorter (P<0.05) stem height (53.07 cm) compared to MR 219 (57.36 cm) (Figure 2a). There was also a linear increase in days to maturity with increasing nitrogen application (P<0.05) in both varieties (Figure 1b). However, variety MR 211 had a significantly shorter (P<0.001) maturation period (102 DAS) than MR 219 (108 DAS) (Figure 2b). The number of panicles per square meter was not affected by the nitrogen application. However, significant differences (P<0.01) between the varieties were observed where variety MR 219 produced more panicles

(615 panicles) compared to variety MR 211 (456 panicles) (Figure 2c). There was a quadratic increase (*P*<0.05) in the number of spikelets per panicle with increasing nitrogen rates (Figure 1c). The maximum number of spikelets per panicle produced was 170 under highest nitrogen application of 240 kg N/ha and the minimum number of spikelets per panicle produced was 77; without nitrogen application (0 kg N/ha). The number of spikelets per panicle recorded included the filled, half-filled and non-fertilized spikelets. Varietal differences in the number of spikelets per panicle were not significant (*P*>0.05). In nitrogen rates, however, resulted in a quadratic decline (*P*<0.05) in the percentage of filled spikelets (Figure 1d). Varietal differences in the production of spikelets per square meter were significant (*P*<0.01) where MR 219 produced higher number of spikelets per square meter (72 677 spikelets) compared to MR 211 (52 216 spikelets) (Figure 2d). It was found that variety MR 219 had a significantly (P<0.001) greater grain yield (8.0 t/ha) than MR 211 (5.5 t/ha) (Figure 2e). Similarly, variety MR 219 had a significantly higher (*P*<0.01) grain to straw ratio (0.88) compared to MR 211 (0.62) (Figure 2f). The grain to straw ratio was not affected by the nitrogen fertilization level.

The results from correlation analysis between yield and yield components are shown in Table 2. Both grain yield and grain to straw ratio were found to be positively correlated with the number

Table 1. Mean Squares of effects of nitrogen, varieties and their interactions on the yield, yield components and agronomic characteristics in two rice varieties

Source of variation	Degrees of freedom	grain yield (t/ha)	grain: straw	spikelets/m^2	panicles/m^2	spikelets/ panicle	% filled spikelets	maturity (DAS)	stem height (CM)
Nitrogen (N)	4	19.87**	0.08ns	2526883157.94***	27409.40ns	10932.09***	0.026***	27.94***	558.05***
Variety (V)	1	62.00***	0.70***	4186259221.23**	252015.63**	30.63ns	0.0007ns	275.63***	184.04*
N x V	4	6.12ns	0.02ns	455104228.54ns	18503.50ns	122.31ns	0.001ns	7.06ns	11.17ns
Error		3.41	0.05	375394453.61	20520.79	594.09	0.003	3.03	29.68

***P<0.001; **P<0.01; *P<0.05; ns P>0.05.

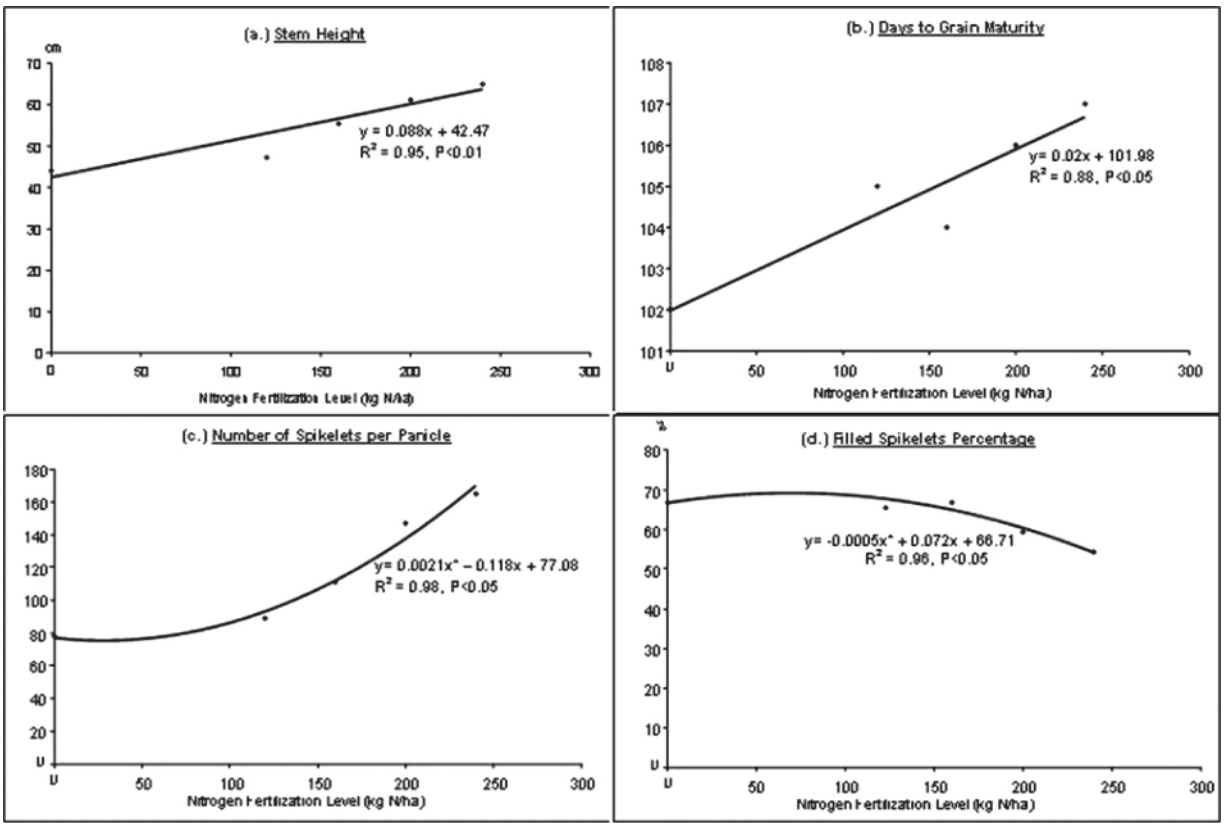

Fig. 1. Effects of nitrogen fertilization on the agronomic characteristics and yield components of rice.

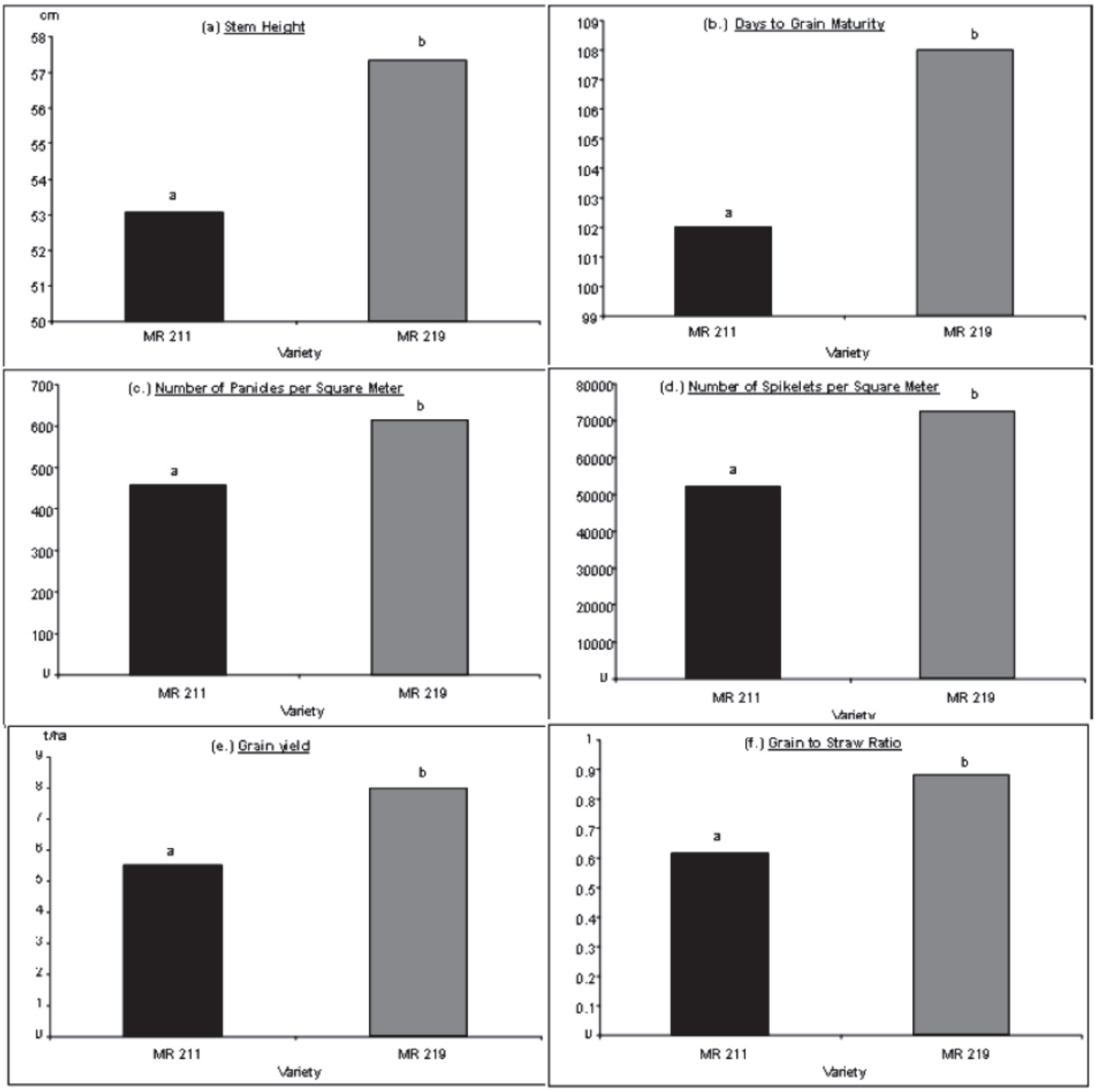

Fig. 2. Varietal differences in agronomic characteristics, yield and yield components of two rice. Means with the same letters are not significantly different (*P*<0.05) according to DMRT.

Table 2. Correlation between the yield and yield components

	Grain: straw	Spikelets/panicle	Panicles/m^2	Spikelets/m^2	% filled spikelets
Grain yield	r=0.84***	r=0.57***	r=0.67***	r=0.95***	r=-0.37*
Grain: straw		r=0.39*	r=0.68***	r=0.76***	r=-0.19ns
Spikelets/panicle			r=-0.11ns	r=0.71***	r=-0.84***
Panicles/m^2				r=0.59***	r=0.07ns
Spikelets/m^2					r=-0.60***

***P<0.001, **P<0.01, *P<0.05, ns P>0.05.

of spikelets per panicle, total panicles and spikelets per square meter. The number of spikelets per panicle were positively correlated (P<0.001) with total spikelets per square meter but negatively correlated (P<0.001) with filled spikelets percentage. The total panicles per square meter were positively correlated (P<0.001) with total spikelets per square meter. The result indicates that the increment in grain yield and grain: straw ratio was attributed to the increase in the production of spikelets per panicle, total panicles per square meter and total spikelets per square meter.

DISCUSSION

Matsushima (1976) regarded that rice plant with short lower internodes and stem height less than 85 cm as an ideal plant. This is because a short stature plant is associated with higher resistance to lodging. Based on this statement, both variety MR 211 and MR 219 can be regarded as an ideal plant, since both varieties possessed a stem height characteristic that did not exceed 85 cm under nitrogen application. It was believed that the nitrogen fertilization delayed the grain maturity due to excessive vegetative growth. Variety MR 211 matured earlier compared to MR 219. Early-maturing varieties are more advantageous in reducing the rate of pest and disease infestation which in turn, reducing the pesticide use, permitting earlier harvest avoiding rain and reducing the cost of irrigation.

The production of panicles per square meter was not affected by the nitrogen level although most researchers reported that the number of panicles per unit area increased with nitrogen application (Wells and Turner, 1984; Sasahara and Itoh, 1989; Mauad *et al.*, 2003). The reason behind this might be due to the direct seeding cultivation method, whereby the number of panicles per square meter is largely dependent on the seeding rate and percentage of emergence (Yoshida, 1981) and probably due to high proportions of non-productive tillers, which did not produce panicles. Although the number of spikelets per panicle increased with nitrogen fertilization level, this resulted in a decrease of filled spikelets percentage. This is because as the number of spikelets increases, the amount of carbohydrates produced must be shared which may not be adequate in proportion to the number of spikelets. Similar result was also reported by Sasahara and Itoh (1989) on the effects of nitrogen application on the percentage of filled spikelets.

Although the percentage of filled spikelets decreased with increasing number of spikelets per panicle, this did not affect the grain yield. On the contrary, the grain yield increased due to the sufficient production of spikelets per square meter, which was necessary in maintaining high grain yield. Similar result was reported by Dutta *et al.* (2002) who observed that the increased in grain yield was associated with higher number of spikelets per panicle. This is because higher number of spikelets per panicle will bring about an increase in total number of spikelets per square meter which eventually will produce high grain yield. The higher grain yield in variety MR 219 is also believed to be due to the higher production of panicles and spikelets per square meter.

The positive correlation between the grain yield and yield components indicates that the parameters which contributed in producing high grain yield are the number of spikelets per panicle, total number of panicles per square meter and total number of spikelets per square meter. Among these parameters, the total number of spikelets per square meter is believed to be the major determinant of grain yield.

CONCLUSION

The finding of this study indicates that the application of high nitrogen rates resulted in yield improvement. When applying a heavy dressing of nitrogen, proper timing of fertilizer application is important to minimize the stem elongation in order to prevent rice lodging. The grain yield can be further increased if pest infestation is controlled. Both varieties which have been developed through careful selection and screening process, differ in the agronomic characteristics as well as in the yield performance. It appears from this study that the high yielding variety MR 219 is superior to MR 211 in view of its ability to produce higher grain yield and grain: straw ratio. Hence, the varietal differences in this study provide information for rice producers to select a variety with better yield performance. It was believed that the yielding ability of each variety was not only influenced by the fertilization management practices but also dependent on the genetic make-up of its variety.

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