UNIVERSITI PUTRA MALAYSIA

OPTIMIZING GRAIN FILLING AND NITROGENUSE EFFICIENCY OF IRRIGATED RICE (*Oryza sativa* L.) THROUGH TIMELY NITROGEN APPLICATION DURING REPRODUCTIVE GROWTH STAGE

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By

ALAGIE BAH

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

May 2009

DEDICATION

To My mother

and

in loving memory of my father

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Master of Science

OPTIMIZING GRAIN FILLING AND NITROGEN-USE EFFICIENCY OF IRRIGATED RICE (O*ryza sativa* L.) THROUGH TIMELY NITROGEN APPLICATION DURING REPRODUCTIVE GROWTH STAGE

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ALAGIE BAH

May 2009

Chairman : Syed Omar Syed Rastan, PhD

Faculty : Agriculture

In the tropics, Nitrogen is considered an indispensible source of nutritional element for the productivity of most crops, especially paddy rice (O*ryza sativa* L.). In flooded rice, applied N fertilizer may be susceptible to losses when the time of application does not match with period of crop demand. Knowledge about accurate timing of N during the reproductive growth stage of flooded rice may be useful in optimizing nitrogen recovery efficiency. A glasshouse experiment was conducted to determine the critical time of nitrogen fertilizer application during panicle initiation (PI) stage to optimize nitrogen recovery efficiency, grain filling and yield of two Malaysian rice cultivars (MR219 and MR232). The treatments comprised a control without N applied (N1) and different timings of urea N-fertilizer applied at the rate of 60 kg N ha^{-1} during panicle initiation stage at 45 (N2), 50 (N3), 55 (N4), 60 (N5) and 65 (N6) days after seeding (DAS) with five replications. The results indicated that plant physiological parameters showed statistical difference among some treatments.

Chlorophyll meter reading (Minolta SPAD-502 leaf chlorophyll meter) for cultivar MR219 in treatment receiving 60 kg N ha^{-1} at 55 days after seeding, gave the highest reading and was significantly higher ($P \leq 0.05$) compared with treatments receiving 60 kg N ha^{-1} at 60, 65 days after seeding and control, where as for MR232, chlorophyll content for treatment receiving 60 kg N ha^{-1} at 55 days after seeding was significantly higher in contrast to treatment receiving 60 kg N ha^{-1} at 45, 60, 65 days after seeding and the control. In cultivar MR219, treatment receiving 60 kg N ha^{-1} at 55 days after seeding produced the highest plant height (92.2 cm) compared to control (77.4 cm) and treatments receiving 60 kg N ha^{-1} at 45 (85.6 cm) and 65 (84.2 cm) days after seeding, while for cultivar MR232, treatments receiving 60 kg N ha^{-1} at 50 days after seeding recorded the highest height (96.0 cm). Higher leaf area index (LAI) was observed in treatments receiving 60 kg N ha^{-1} at 50 and 55 days after seeding for both cultivars. Application of N also resulted in an increased in plant biomass, and was found to be higher in treatment receiving 60 kg N ha^{-1} at 55 days after seeding (400.2 g pot^{-1}) for cultivar MR219, while for MR232, significant increased was observed in treatment receiving 60 kg N ha^{-1} at 50 (367.2 g pot^{-1}). Plant yield and yield component parameters were significantly influenced by timing of N applied during the reproductive stage. Percentage of productive tillers for both cultivars did not significantly vary among treatments except with control. The spikelet number $panicle^{-1}$ was higher in treatments receiving 60 kg N ha^{-1} at 50 and 55 days after seeding for both cultivars. The highest 1000-grain weight (30.3 g) and filled grain percentage (94 %) were recorded in treatments fertilized with N at 55 DAS (N4) for cultivar MR219, while for MR232, similar trend was also obtained with the same treatment (N4), recording the highest 1000-grain weight (28.6 g) and filled grain percentage (89%). Rice grain yield in cultivar MR219 was significantly higher with treatment receiving 60 kg N ha^{-1} at 55 days after seeding (225.75 g pot^{-1}) and treatments receiving 60 kg N ha^{-1} at 50 and 55 days after seeding for MR232 (210.57 and 214.61g pot^{-1}, respectively). The extent of decrease in grain yield due to late N fertilization during reproductive stage in treatments receiving 60 kg N ha^{-1} at 65 days after seeding for cultivars MR219 and MR232 were 39% and 17%, respectively. Based on grain yield, cultivar MR219 tend to be more sensitive to timing of N fertilizer than MR232 N uptake in rice significantly varies with timing of N fertilizer. In both MR219 and MR232, higher Nitrogen recovery efficiency was obtained in treatments receiving 60 kg N ha^{-1} at 55 days after seeding (77% and 72%, respectively).

Keywords: *Oryza sativa;* urea; Days after seeding (DAS); glasshouse; grain yield; timing; Nitrogen recovery efficiency (NRE); Panicle initiation

Abstrak tesis yang dikemukakan kepada senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master of Science

MENGOPTIMUMKAN PENGISIAN BIJIRIN DAN KECEKAPAN KEGUNAAN NITROGEN BAGI PADI (*Oryza sativa* L.) MELALUI PEMBERIAN NITROGEN PADA MASA YANG SESNAI DI PERINGKAT PEMBIAKAN PERTUMBUHAN

Oleh

ALAGIE BAH

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Facklti : Pertanian

Di kawasan Tropika, Nitrogen (N) dianggap sebagai satu unsur pemakanan yang tidak dapat ditukarganti bagi produktiviti kebanyakan tanaman, terutamanya padi (*Oryza sativa*). Bagi padi sawah, baja N yang diberi berkemungkinan hilang jika masa pemberian baja tersebut tidak serentak dengan tempoh pengambilan oleh pokok. Pengetahuan bagi memastikan tempoh masa tepat untuk pemberian baja N sepanjang peringkat pertumbuhan reproduktif padi sawah adalah berguna bagi mengoptimumkan penggunaan baja N yang lebih effisien. Satu eksperimen rumah kaca telah dijalankan untuk menentukan tempoh masa kritikal dalam pemberian baja N pada masa pembentukan tangkai (PI) bagi mengoptimumkan penggunaan baja N yang lebih efisien dan penghasilan padi untuk dua kultivar padi di Malaysia (MR219 dan MR232). Rawatan yang diberikan termasuk satu Kawalan, tanpa memberi baja N

(N1) dan rawatan-rawatan lain termasuk pemberian baja N sebanyak 60 kg N per ha iaitu pada hari ke-45 (N2), hari ke-50 (N3), hari ke-55 (N4), hari ke-60 (N5), hari ke-65 (N6) selepas menabur benih (DAS) dengan 5 replikasi masing-masing. Parameter fisiologi tanaman seperti tinggi pokok menunjukkan perbezaan statistik yang ketara antara rawatan. Bacaan kandungan klorofil (Minolta SPAD-502 leaf chlorophyll meter) bagi kultivar MR219 yang menerima rawatan 60 kg N per ha pada hari ke-55 selepas menabur; menghasilkan bacaan tertinggi dan berbeza katera ($P \leq 0.05$) jika dibandingkan dengan rawatan 60 kg N per ha pada hari ke-60 dan ke-65 serta kawalan. Untuk kultivar MR232, kandungan klorofil bagi pokok yang menerima rawatan 60 kg N per ha pada hari ke-55 adalah berbeza dengan ketara dibanding dengan rawatan yang dibaja pada hari ke-45, ke-60, ke-65 selepas menabur serta kawalan. Untuk kultivar MR219, rawatan 60 kg N per ha pada hari ke-55 selepas menabur menghasilkan ketinggian pokok yang tertinggi (92.2 cm) dibandingkan dengan kawalan (77.4 cm) dan rawatan yang menerima 60 kg N per ha pada hari ke-45 (85.6 cm) dan hari ke-65 (84.2 cm), manakala untuk MR232, rawatan 60 kg N per ha pada hari ke-60 selepas menabur memberi ketinggian pokok yang tertinggi (96.0cm). Indeks Keluasan Daun (LAI) yang lebih tinggi diperolehi daripada rawatan 60 kg N per ha pada hari ke-50 dan ke-55 selepas menabur bagi kedua-dua kultivar. Pemberian N juga menghasilkan peningkatan dalam berat jisim pokok dan didapati rawatan menerima 60 kg N per ha pada hari ke-55 selepas menabur menghasilkan berat jisim pokok yang tertinggi (400.2 g per pasu) bagi kultivar MR219, namun bagi MR 232, peningkatan yang ketara dapat diperhatikan pada rawatan yang menerima 60 kg N per ha pada hari ke-50 selepas menabur (367.2 g per pasu). Hasil pokok dan parameter hasil dipengaruhi secara ketara oleh tempoh masa pemberian baja N pada peringkat pertumbuhan reproduktif. Peratus tangkai produktif bagi kedua-dua kultivar tidak berbeza secara ketara kecuali dibandingkan dengan Kawalan. Nombor spikelets per tangkai bagi pokok yang menerima rawatan 60 kg N per ha pada hari ke-50 dan hari ke-55 selepas menabur adalah tinggi bagi kedua-dua kultivar. Berat 1,000 beras berisi (30.3 g) dan peratus spikelets berisi (94%) telah dicatatkan bagi pokok yang diberi baja N pada hari ke-55 selepas tabur benih (N4) bagi kultivar MR219, manakala bagi kultivar MR232, trend yang serupa juga dapat diperhatikan pada rawatan yang sama (N4), merekodkan berat 1,000 beras berisi yang tertinggi (28.6 g) dan peratus spikelets berisi yang tertinggi (89%). Hasil butiran beras padi bagi kultivar MR219 yang dirawat dengan 60 kg N per ha pada hari ke-55 selepas menabur (225.75 g per pasu) adalah tertinggi dan bagi MR232, rawatan 60 kg N per ha pada hri ke-50 dan hari ke-55 selepas menabur mencatatkan hasil yang tertinggi (210.57 g per pasu dan 214.61 g per pasu). Takat berkurangan dalam hasil butiran beras yang disebabkan oleh pembajaan N yang lewat semasa peringkat pertumbuhan reproduktif (65 DAS) bagi rawatan yang menerima 60 kg N per ha pada nari ke-65 selepas menabur bagi kultivar MR219 dan MR232 adalah 39% dan 17% masing-masing. Berdasarkan hasil butiran beras, kultivar MR219 adalah lebih peka kepada tempoh masa pembajaan N jika dibandingkan dengan MR232. Bagi kedua-dua kultivar MR219 dan MR232, kecekapan pemulihan nitrogen yang lebih tinggi telah diperolehi bagi rawatan 60 kg N per ha pada hari ke-55 selepas menabur (77% dan 72% masing-masing).

Kata kunci: *Oryza sativa*; urea; hari selepas manabur benih (DAS); rumah kaca; hasil butiran beras; tempoh masa; kecekapan pemulihan nitrogen (NRE); pembentukan tangkai (PI)

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I certify that a Thesis Examination Committee has met on 28 May 2009 to conduct the final examination of Alagie Bah on his degree thesis title “Optimizing Grain Filling and Nitrogen-use Efficiency of Irrigated Rice (*Oryza sativa* L.) through Timely Nitrogen Application during Reproductive Growth Stage” in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Uiversiti Putra Malaysia (P.U.(A) 106) 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Examination Committee were as follows:

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This thesis was submitted to the senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Date: 17 July 2009

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or any other institution.

ALAGIE BAH

Date: 4 August 2009

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
AAS	Atomic absorption spectrophotometer
CNAL	The Cornell Nutrient Analysis Laboratory
CRD	Complete Randomized Design
DAS	Days after seeding
DNMRT	Duncan Multiple Range Test
GSR	Grain/ Straw ratio
HI	Harvest index
HYVs	High yielding varieties
IRRI	International Rice Research Institute
LAI	Leaf area index
LNC	Leaf nitrogen content
MADA	Muda Agricultural Development Authority
MARDI	Malaysian Agricultural Research and Development Institute
MIT	Mineralization-immobilization turn over
Mt	Midtillering
NRE	Nitrogen recovery efficiency
NUE	Nitrogen use efficiency
PAN_5	Number of panicles for the 5-hill samples/pot
PI	Panicle Initiation
PM	Physiological maturity
SPAD	Soil Plant Analysis Development
SSNM	Site-specific nutrient management

RTNM	Real-time Nitrogen management
UAN	Urea-ammonium-nitrate
UPM	Universiti Putra Malaysia
WPGs	Weak-potential grains

CHAPTER 1

INTRODUCTION

1.1 Background Information

Rice plays a critical role in contributing to food and nutritional security, income generation, poverty alleviation and socio-economic growth of people. Rice yield must be improved by 43% in 30 years from 2000 to meet the demands of population growth in the world (Cassman, 1999). Considering the current trend in population growth rate, further improvement in rice productivity is needed in order to overcome the challenges of poverty and hunger.

Low soil fertility, and particularly deficiency of Nitrogen, is an important constraint on grain yield in rice growing countries. In many countries, governments invest heavily in fertilizer subsidies, and make improvements to irrigation facilities, infrastructure and rice price support mechanisms that makes rice intensification economically attractive especially for commercial farmers.

Nutrient management mostly relies on approaches that do not account for the dynamic nature of crop response to the environment. Because 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 (Dobermann and Cassman, 2002).

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. More than 20% of N fertilizer produced worldwide is used in the rice fields of Asia, but N recovery efficiency in most farmers' fields is only about 25-40% of applied N (Dobermann and Fairhurst, 2000).

In paddy fields, N is easily lost due to denitrification, leaching and volatilization. These substantial losses tend to affect the optimization of rice yield. Use of urea fertilizer in flooded rice is one of the key sources of N loss through denitrification and volatilization. Moreover, N loss is economically and environmentally undesirable. Nitrogen loss as denitrification represents the loss of a valuable plant nutrient and hence an economic cost to agriculture.

Over the past decade, global prices for N fertilizers continue to increase and have become increasingly difficult for average farmers to meet their fertilizer requirements. In Malaysia urea price increased from RM1500/ton in 2007 to RM3200/ton in 2008. This situation calls for concerted action so that the fertilizer can be used in most effective and efficient way.

In the new global economy, increasing rice production has become a central issue in overcoming the growing menace of poverty. One of the most significant current discussions is to improve both the genotype and agronomic efficiency of rice production systems. Improving fertilizer management and overall N efficiency of rice is a critical component of addressing global food crises.