UNIVERSITI PUTRA MALAYSIA

GENOTYPE-NITROGEN-ENVIRONMENT INTERACTION AND STABILITY OF BLAST RESISTANT RICE IN MULTI LOCATIONAL TRIALS

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By

HAMISU ALMU

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATION

This thesis is dedicated to my late beloved parents and their family for their never-ending support, prayers and encouragement.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chairman : Associate Professor Zulkefly bin Sulaiman, PhD
Institute : Tropical Agriculture and Food Security

Rice shortages have become a serious problem due to high demand as a result of increasing world population. To meet the global rice demand by 2030, its production needs to be increased by more than 50% worldwide. In Malaysia, the average rice production of 4.2 t/ha is considered as low largely due to insufficient nutrients and blast disease. The main objective of this study was to identify high yielding, blast resistant and highly stable rice genotypes with high nitrogen efficiency for commercial cultivation in Malaysia. Sixteen blast-resistant rice genotypes were evaluated in three rice granary areas (Tanjung Karang, Selangor; Kota Sarang Semut, Kedah and Seberang Perai, Penang) with five different nitrogen fertilizer levels over two planting seasons (Main and off seasons). Five nitrogen fertilizer levels:- 60, 80, 100, 120 (standard recommendation) and 140 kg N/ha were applied in each location and planting season. The experimental design was a split plot design with three replications, where the nitrogen fertilizer levels was assigned as main plot and rice genotypes as sub-plot. Nitrogen levels had highly significant effects on all the yields and vegetative traits except, panicle length, grain length and grain width. There was also presence of interaction between genotype and nitrogen levels in all the environments on all traits except, number of tillers per hill, number of panicles per hill and filled grain per panicle. In addition, the genotype by nitrogen interaction was highly significant for all traits except unfilled grain per panicle, panicle length, grain length, grain width and yield per hectare. The nitrogen yield efficiency differed significantly with various levels of nitrogen applied. The optimum nitrogen levels for MADA, Seberang Perai and Tanjung Karang were 112, 125 and 105 kg N/ha with yield production of 9.53, 8.99 and 9.48 t/ha, respectively. The results revealed that the ideal environment were ENV6 (Seberang Perai 2), ENV 2 (Tanjung Karang 1) and ENV4 (MADA 2). From the result obtained on stability analyses, two genotypes (Genotype 9 and 16) were found to be highly stable across the environments and produced high yield with 9.39 and 9.13 t/ha, respectively. However, the agronomic

nitrogen yield efficiency across environments for the two genotypes were 6.23% and 2.79%, respectively, at 140 kg N/ha. The two superior genotypes (Genotype 9 and 16) with high yield and stability across environments are recommended for commercial cultivation in Malaysia.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

INTERAKSI GENOTIP-NITROGEN-PERSEKITARAN DAN KESTABILAN GENOTIP PADI RINTANG KARAH DI PERCUBAAN PELBAGAI LOKASI

Oleh

HAMISU ALMU

April 2019

Pengerusi : Profesor Madya Zulkefly Bin Sulaiman, PhD
Institut : Pertanian Tropika dan Sekuriti Makanan

Kekurangan beras telah menjadi masalah yang serius disebabkan peningkatan permintaan akibat dari pertambahan populasi dunia. Untuk memenuhi permintaan beras dunia sehingga 2030, pengeluarannya perlu ditingkatkan melebihi 50% di seluruh dunia. Malaysia, purata pengeluaran padi adalah rendah iaitu 4.2 t/ha yang diakibatkan kekurangan nutrien dan penyakit karah. Objektif utama kajian ini adalah untuk mengenal pasti genotip padi yang berhasil tinggi dan rintang penyakit karah serta genotip yang stabil dengan kecekapan nitrogen yang tinggi untuk penanaman secara komersial di Malaysia. Enam belas genotip rintang penyakit karah telah dinilai di tiga kawasan jelapang padi (Tanjung Karang, Selangor; Kota Sarang Semut, Kedah and Seberang Prai, Penang) dengan lima kadar baja nitrogen yang berbeza pada dua musim penanaman (musim utama dan luar musim). Lima kadar baja nitrogen iaitu, 60, 80, 100, 120 (kadar piawai) dan 140 Kg N/ha digunakan di setiap lokasi dan musim penanaman. Kajian ini dijalankan mengunakan rekabentuk plot berbelah dengan tiga replikasi di mana kadar baja nitrogen sebagai plot utama dan genotip padi sebagai sub plot. Kadar nitrogen telah memberikan kesan yang sangat bererti ke atas semua ciri hasil dan vegetatif kecuali panjang tangkai, panjang dan lebar bijian. Didapati wujud interaksi antara genotip dan kadar nitrogen dikesemua persekitaran ke atas semua ciri-ciri kecuali bilangan anak pokok seperdu, bilangan tangkai seperdu dan bijian bernas setangkai. Tambahan pula, interaksi genotip dengan persekitaran adalah sangat berbeza untuk semua ciri kecuali bijian tak bernas setangkai, panjang tangkai, panjang bijian, lebar bijian dan hasil sehektar. Kecekapan hasil nitrogen adalah berbeza secara bererti dengan kadar baja yang berbeza. Kadar baja yang optimum untuk MADA, Seberang Perai dan Tanjung Karang adalah 112, 125 dan 105 kg N/ha dengan pengeluaran hasil 9.53, 8.99 dan 9.48 t/ha, masing-masing. Keputusan ini juga menunjjukkan persekitaran ideal adalah ENV6 (Seberang Perai 2), ENV 2 (Tanjung Karang 1) dan ENV4 (MADA 2). Keputusan yang diperolehi dari analisa kestabilan, mendapati dua genotip (Genotip 9 dan 16) adalah sangat stabil merentasi persekitaran dan menghasilkan hasil yang tinggi dengan 9.39 dan 9.13 t/ha, masing-masing. Walau

bagaimanapun, kecekapan hasil agronomi nitrogen merentasi persekitaran untuk dua genotip tersebut adalah 6.23% dan 2.79%, masing-masing pada kadar 140 kg N/ha. Kedua genotip unggul ini (Genotip 9 dan 16) dengan hasil tinggi dengan kestabilan merentasi persekitaran yang tinggi adalah disyorkan untuk ditanam secara komersial di Malaysia.

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Declaration by graduate student

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LIST OF ABBREVIATIONS

%	Percentage
^0c	Degree Celsius
βi	Parkins and jinks beta
σi^2	Shukla's variance
AEC	Average environment coordinate
AMMI	Additive main effect and multiplicative interaction effect
ANOVA	Analysis of variance
bi	Regression slope
CM	Centimeter
G	Gram
G×E	Genotype × environmental interaction
GGE	Genotype main effect plus genotype × environmental interaction model
GGL	Genotype plus genotype by location interaction
H_20_2	Hydrogen peroxide
HCL	Hydrochloric acid
IRRI	International Rice Research Institute
L	Liter
LSD	Least significant difference
M	Trait mean
MET	Multiple environmental trials
Mg	Milligram
Min	Minute
NACL	Sodium chloride
PC	Principal component
P_i	Lin and Binns pi

S^2_d	Deviation from regression
SAS	Statistical analysis
SASG×G	SAS genotype × environment interaction analysis program
SVD	Singular value decomposition
SVP	Single value pertitionon
Wi	Wricke's ecovalence
YSi	Kang's yield stability statistics
ENV1	Tanjung Karang 1
ENV2	Tanjung Karang 2
ENV3	MADA 1
ENV4	MADA 2
ENV5	Seberang Perai 1
ENV6	Seberang Perai 2

CHAPTER 1

INTRODUCTION

1.1 Genaral Introduction

Rice (*Oryza sativa*) is one of the most important staple foods for more than half of the world's population (Muthayya *et al.,* 2014). Food shortages has become a serious problem due to increasing population (Brown and Funk, 2008*;* Takeda and Matsuoka, 2008). The continuous increase in human population and demand for more food on less land is calling for steping up the current production through development of high yielding variety. The most important primary objective of rice breeding is to improve yield. Therefore, many studies have focused on the improvement and inheritance of agronomically important yield-related traits for achieving higher yield (Gravois and Ronald, 1993; Samonte *et al,* 1998). Many researchers have stated that in order to meet the global food demand for rice, production has to be increased by more than 50% worldwide by 2030 (Khush*,* 2005; Chukwu et al., 2019). It is a tremendous task for the development of high yielding rice varieties with tolerance to biotic and abiotic stresses (Selvarag *et al.,* 2011). However, the potential yield of rice is more than 10 t/ha whereas an average of 5 t/ha is obtained globally (Khush and Jena, 2009). This yield gap is largely due to management practice coupled with biotic and abiotic stresses.

In Malaysia, rice is the most important food, cultivated in 12 rice growing areas across the country, covering about 0.6 million hectares of land. About 2.6 million tons of rice is produced annually which accounted for 70% of self-sufficiency level while the remaining 30% shortfall is met by importation from neighboring countries (Khazanah Research Institute, 2019). The rice production has to increase in order to fill the gap between rice production and its demand. Rice production can be increased by expanding the cultivated area or increasing the current crop yield potential. Expansion of cultivated area is no longer feasible because of environmental concern and urbanization. Increasing yield potential, combine effort on plant breeding, physiology, agronomic and management practices are prerequisite for achieving set goals. The green revolution has shown the significant contribution of optimum nitrogen management for increasing rice yield (Zorilla *et al.,* 2012). Application of nitrogen fertilizer either in excess or less has a significant effect on growth, yield and grain quality of rice. Therefore, it is important to apply optimum rate of nitrogen fertilizer according to each variety, planting density and soil type requirement (Awan *et al.,* 2011; Wu *et al.,* 2013*)*. Grain yield is influenced by many factors including the genotype, fertilizers, such as nitrogen, water management and location. Hence, selection of genotype should be based on fertilizer use efficiency and high stability with consistent performance across a wild range of environments.

The presence of genotype-by-environment (G×E) interaction in multi-location trial usually complicates the interpretation of results obtained and reduces efficiency in selecting the best genotypes (Annicchiarico and Perenzin, 1994). This G×E interaction is the result of changes in cultivar's relative performance across environments, due to differential responses of the genotypes to various edaphic, climatic and biotic factors (Dixon and Nukenine, 1997*)*. Information on G×E interaction leads to a successful evaluation and selection of stable genotype across environments, which could be recommended for cultivation in diverse locations.

Yield is a complex quantitative character and is greatly influenced by environmental fluctuations; hence, the selection for superior genotypes based on yield solely at a single location in a year may not be very effective (Shrestha *et al.,* 2012). Thus, evaluation of genotypes for the stability performance under different environmental conditions for yield has become essential before releasing any new rice variety. Variation in yield is a result of genotype, environment and G×E interaction (Dingkuhn *et al*., 2006). The interaction between these explanatory variables gives insight for identifying genotype suitable for general and specific environments (Blanche *et al.,* 2009).

1.2 Problem Statement

Rice is a staple food crop in Malaysian and for ensuring food security, the yield production has to be increased from the current average yield. In addition, over 150,000 local farmers depend exclusively on rice cultivation for their overall sustenance (Najim *et al.,* 2007). The Institute of Tropical Agriculture and Food Security has developed 13 blast resistant rice genotypes that are highly potential for commercial cultivation (citation required). However, these newly developed varieties have to be evaluated in multi-locational trial and under different nitrogen fertilizer levels. Genotypic differences in nitrogen use efficiency has been reported repeatedly under well-watered intensive lowlands condition (Broadbent *et al.,* 1987, de Datta and Broadbent. 1990 and Ladha *et al.,* 1998). Therefore, evaluation of the 13 blast resistant genotypes in diverse environments under different levels of nitrogen fertilizer application will be use as selection criteria for stable and high yielding as well as nitrogen use efficiency genotypes for commercial cultivation in Malaysia.

1.3 Main Objective

This study was conducted with the main objective of identifying stable, high-yielding and nitrogen use efficiency rice genotypes across environments for commercial cultivation.

1.4 Specific Objectives:

i. To determine the optimum nitrogen fertilizer rates for high production in each location
ii. To estimate and quantify the level of G×E interaction and heritability values for vegetative, yield and yield components traits.
iii. To identify stable genotypes across locations and estimate the G×E interaction for all traits in the study
iv. To quantify the path of influence and relationship of various traits on the yield using genotypic and phenotypic path coefficient analysis.

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LIST OF PUBLICATIONS

Hamisu Almu, Zulkefly Sulaiman, Mohd Rafii Yusop, Mohd Razi Ismail, Abdul Rahim Harun, Asfaliza Ramli, Mohd Yusoff A.S. and Jamilu Halidu (2019). Genetic Variability and their Relationship among Yield and Yield Related Traits in Tropical Environment, International Journal of Plant Breeding and Crop Science (Published)

Hamisu Almu, Zulkefly Sulaiman, Mohd, Rafii Yusop, Mohd. Razi Ismail, Abdul Rahim Harun, Asfaliza Ramli, Usman Magaji, Yusuff Oladosu, Mohd. A.S Yusoff Muhammad Buhari (2019). Phenotypic correlation and heritability estimates of some quantitative characters in 16 varieties of rice (Oryza sativa L.) influenced by different nitrogen fertilizer levels, Chilean Journal of Agricultural Research (under Review)

Hamisu Almu, Zulkefly Sulaiman, M. Y. Rafii, Mohd Razi Ismail, Abdul Rahim Harun, Asfaliza Ramli, Jamilu Halidu, and Mohd A.S. Yusoff (2019). GENETIC VARIABILITY AND SELECTION CRITERIA IN ADVANCED BLAST RESISTANT RICE LINES AS REVEALED BY QUANTITATIVE CHARACTERS, International Journal of Agronomy (under Review)

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