UNIVERSITI PUTRA MALAYSIA

GENOTYPE-ENVIRONMENT INTERACTION AND STABILITY ANALYSES IN ADVANCED RICE MUTANTS FOR GRAIN YIELD AND STRAW QUALITY

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IPTSM 2018 1

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By

OLADOSU YUSUFF ABISOLA

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

January 2018

DEDICATIONS

This thesis is dedicated to my father (Alhaji Tajudeen Oladosu) for his boundless love, understanding, encouragement, support and sacrifice throughout my study. And my loving daughter Maryam Bint Yusuff

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

GENOTYPE BY ENVIRONMENT INTERACTION AND STABILITY ANALYSES IN ADVANCED RICE MUTANTS FOR GRAIN YIELD AND STRAW QUALITY

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Chairman: Prof. Mohd Rafii Yusop, PhD
Institute: Tropical Agriculture and Food Security

Genotypes evaluation in diverse environments is a prerequisite for selecting ideal genotype (genotype with high mean yield with a low degree of fluctuations). These evaluations are essential especially when the objective of the breeding programme were to release a new varieties with high adaptability and stability for grain yield and straw quality. The main objective of this study was to assess the performance of selected rice mutant genotypes and check varieties across different growing environments for adaptability and interaction on yield, yield components and straw quality. A set of 15 rice genotypes was tested over 2 planting seasons (main and off season) in 5 locations across Peninsular Malaysia. The genotypes included 6 advanced mutant lines, 6 mutant varieties from Vietnam and Bangladesh, and 3 local commercial varieties as checks. The experiment was carried out in a randomized complete block design with three replications across the environments. Data were collected on vegetative traits, yield and yield component traits and straw quality traits. Analysis of variance revealed a significant difference among the genotypes, locations, seasons and genotype × location × season interaction for all the characters studied except for 100-grain weight, panicle length, crude fibre, neutral detergent fibre, acid detergent fibre and acid detergent lignin. Moderate heritability and genetic advance were also recorded for all the traits except 100-grain weight, panicle length and panicles per hill. Grain yield per hectare showed highly significant and positive correlations with most of the traits under this study at both phenotypic and genotypic level. By contrast, unfilled grains per panicle and plant height had a negative significant association with yield per hectare. Filled grains per panicle exhibited the maximum positive direct effect on yield followed by grain weight per hill, while unfilled grain per panicle had negative direct effect. The maximum indirect effect on yield per hectare was recorded by the tillers per hill through the panicles per hill. The study revealed that tillers per hill and grain weight per hill could be used as selection criteria for improved grain yield. The test environments that measure the discriminative and representative ability of test location reveal that environment Sekinchan (SC) is the best environment, while Kota Sarang

Semut (KS) and Seberang Perai (SP) can also be considered as favourable environment, whereas Serdang (SS) and Tanjung Karang (TK) were the poorest locations for selecting cultivars adapted to the whole region. Based on univariate (b_i, S^2_d, σi^2, Wi^2, YS_i) and multivariate (AMMI and GGE biplot) stability analysis parameters, rice genotypes were classified into three main groups. First group were genotypes having high stability along with high grain yield. These genotypes include ML4 and ML6 and are widely adapted to diverse environmental conditions. The second group is genotype that exhibited high yield per hectare but low stability, this genotype (ML9) is suitable for specific environments. The last group is genotypes with low yield per hectare but high stability which includes genotypes MR220, Binadhan4, and Binadhan7.

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

INTERAKSI GENOTIP DENGAN PERSEKITARAN DAN ANALISIS KESTABILAN TERHADAP TITISAN PADI MUTANT UNTUK HASIL BIJIAN DAN KUALITI JERAMI

Oleh

OLADOSU YUSUFF ABISOLA

Januari, 2018

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Penilaian genotip dalam persekitaran yang pelbagai adalah prasyarat untuk memilih genotip unggul (genotip dengan hasil tinggi dengan tahap perubahan perbezaan yang rendah). Penilaian ini sangat penting terutamanya apabila objektif program pembiakbakaan adalah untuk pengsyoran varieti baharu dengan penyesuaian dan kestabilan yang tinggi untuk hasil bijian dan foder berkualiti. Objektif utama kajian ini adalah untuk menilai prestasi genotip mutan padi terpilih dan varieti kawalan di pelbagai persekitaran penanaman berbeza untuk kesesuaian dan interaksinya ke atas hasil, komponen hasil dan kualiti jerami. Lima belas genotip padi telah diuji sebanyak 2 musim penanaman (musim utama dan luar) setiap lokasi di 5 lokasi di Semenanjung Malaysia. Genotip tersebut termasuk 6 titisan mutant maju, 6 varieti mutan dari Vietnam dan Bangladesh, dan 3 varieti komersial tempatan sebagai kawalan. Eksperimen ini dijalankan mengunakkan Reka Bentuk Blok Penuh Rawak (RCBD) dengan tiga replikasi di setiap lokasi. Pengumpulan data adalah meliputi ciri-ciri vegetatif, hasil dan komponen hasil, dan ciri-ciri kualiti jerami. Analisis varians menunjukkan terdapat perbezaan ketara di antara genotip, lokasi, musim dan interaksi genotip × lokasi × musim untuk semua ciri yang dikaji kecuali berat 100-bijian, panjang tangkai, gentian mentah, gentian detergen neutral, gentian detergen asid dan lignin deterjen asid. Nilai heritabiliti dan kemajuan genetik yang sederhana telah didapati untuk semua ciri kecuali berat 100-bijian, panjang tangkai dan bilangan tangkai serumpun. Hasil bijian sehektar menunjukkan korelasi fenotip dan genotip yang sangat signifikan dan positif dengan kebanyakan ciri-ciri yang dikaji. Sebaliknya, bijian tidak bernas per tangkai dan tinggi pokok mempunyai perhubungan yang negatif dengan hasil per hektar. Bijian bernas per tangkai menunjukkan kesan langsung positif yang maksimum keatas hasil diikuti dengan berat bijian serumpun, manakala bijian tidak bernas per tangkai mempunyai kesan langsung secara negatif. Kesan tidak langsung yang maksimum ke atas hasil sehektar telah direkodkan oleh bilangan anak pokok serumpun melalui ciri bilangan tangkai serumpun. Kajian ini menunjukkan bahawa ciri bilangan anak pokok serumpun dan berat bijian serumpun boleh digunakan

sebagai kriteria pemilihan untuk mendapatkan hasil bijian yang lebih baik. Persekitaran yang telah diuji berdasarkan ukuran diskriminatif dan representatif lokasi menunjukkan persekitaran Sekinchan (SC) adalah persekitaran yang terbaik, dan dikuti Kota Sarang Semut (KS) dan Seberang Perai (SP), sedangkan Serdang (SS) dan Tanjung Karang (TK) adalah lokasi yang kurang sesuai untuk memilih kultivar untuk mewakili persekitaran yang boleh beradaptasi bagi seluruh persekitaran. Berdasarkan kepada parameter analisis kestabilan (b_i, $S^2{}_d$, σi^2, Wi^2, YS_i) dan multivariat (AMMI dan GGE biplot), genotip padi tersebut dapat diklasifikasikan kepada tiga kumpulan utama. Kumpulan pertama adalah genotip yang mempunyai kestabilan tinggi serta hasil bijian yang tinggi. Genotip kumpulan ini adalah ML4 dan ML6 iaitu boleh beradaptasi dengan keadaan persekitran yang pelbagai. Kumpulan kedua adalah genotip yang memberikan hasil tinggi per hektar tetapi kestabilan rendah, genotip ini (ML9) sesuai untuk persekitaran tertentu. Kumpulan terakhir adalah genotip dengan hasil per hektar yang rendah tetapi kestabilan yang tinggi iaitu genotip MR220, Binadhan4, dan Binadhan7.

ACKNOWLEDGEMENTS

This thesis is a result of interaction between this author and many distinguished professionals, colleagues, fellow graduate students, and staff. It is indeed a difficult job to keep this list of acknowledgements short. First and foremost, all praise and thanks to Allah the exalted, for the grace bestowed upon me to start and complete my research in not-too-far period. My honest appreciation to the chairman of my supervisory committee Prof. Dr. Mohd Rafii Yusop, for his patience, tireless support, willingness to help, encouragement, kindness and guidance throughout the research and during the preparation of the thesis. I am very much indebted to the members of my supervisory committee namely Prof. Dr. Norhani Abdullah, Dr. Asfaliza Ramli, and Dr. Ghazali bin Hussin for their support and advice during my research. I really enjoyed every of my moment with you all.

I would like to extend my deepest and sincere appreciation to Universiti Putra Malaysia who supported my candidature and International Atomic Energy Agency (IAEA), for providing research grant to support this study under Coordinated Research Project (CRP) for Food and Feed (CRP Code D2.30.30) for enhancing sustainable rice production in Malaysia.

I am extremely grateful to all my family members for their love, prayers and encouragement during my studies. My incomparable parents, I thank you for giving me the liberty to pursue my wish; I thank you for the discomfort you had to go through to give me the best. To all my siblings Musa, Daud, Maryam, Nefisat, Medinat, Khadijah, Ibrahim, Aishat and Zainab, thanks for being there for me.

I am Thankful to my friends, colleagues, all Prof Rafii students and staff at Institute of Tropical Agriculture and Food Security, UPM for making my life as a graduate student at UPM a wonderful experience. Thanks to Oladipo Kolapo, Ahmed Muhideen, Usman Magaji, Kolapo Kaseem, Dr. Ibrahim Arolu, Dr. Salisu Monsur and Adewoyin Malik for being there throughout my journey. Nasrudeen Abdulhafeez, Oladejo Olayinka, Ayanlaja Lukman, Dr. Afolabi Luqman, Tajudeen Qoseem and Folohunsho Kaseem, thanks for your incredible friendship.

Finally, thanks to my beloved wife. I thank you for your prayer, support, encouragements, and motivations.

I certify that a Thesis Examination Committee has met on 11 January 2018 to conduct the final examination of Oladosu Yusuff Abisola on his thesis entitled "Genotype-Environment Interaction and Stability Analyses in Advanced Rice Mutants for Grain Yield and Straw Quality" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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This is to confirm that:

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- Supervision responsibilities as slated in Rule 41 in Rules 2003(Revision 2012-2013) were adhered to.

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LIST OF ABBREVIATIONS

%	Percentage
^{0}C	Degree Celsius
AEC	Average environment coordinate
AMMI	Additive main effect and multiplicative interaction effect;
ANOVA	Analysis of variance
b_i	Regression slope
cm	Centimeter
G	Gram
G×E	Genotype × environmental interaction
GGE	Genotype main effects plus genotype × environmental interaction model
GGL	Genotype plus genotype by location interaction
H_2O_2	Hydrogen peroxide
HCL	Hydrochloric acid
IRRI	International Rice Research Institute
L	Liter
LSD	Least significant difference
M	Trait mean
MET	Multiple environment trials;
Mg	Milligram
Min	Minute
NaCl	Sodium Chloride
PC	Principal Component
Pi	Lin and Binns Pi
S_2d	Deviation from regression
SAS	Statistical analysis software
SASG×E	SAS genotype × environmental interaction analysis program
SVD	Singular value decomposition;
SVP	Singular value partition
Wi	Wricke's ecovalence
YSi	Kang's yield stability statistics
βi	Perkins and Jinks beta
σi_2	Shukla's variance

CHAPTER 1

INTRODUCTION

1.1 General introduction

Rice (*Oryza sativa L.*) is the third most important food crop after wheat and maize, which serves as staple food for nearly half of the world's population. It is an essential source of carbohydrate that accounted for 23% of calories consumption of people mostly from Africa, Asia, and Latin America (Brar and Khush, 2002). In Malaysia, rice is the most important food, covering about 0.6 million hectares of land. About 60% of the total rice areas in Malaysia are provided with extensive irrigation and drainage facilities while the remaining are mainly rain-fed areas. Malaysia produces 2.6 million tons of rice annually which can only meet 70% of the requirement, and the 30% shortfall met by importation (Department of Agriculture Peninsular Malaysia, 2012).

The continuous increase in the gaps between rice production and its demand rises on a daily basis, which necessitates the need to step up the current yield in rice production with national average of 4.03 t/ha. Subsequently, large efforts have been undertaken towards development and high yielding variety and technology improvement. Beginning in 1972, the use of induced mutations such as gamma rays for rice improvement was initiated in Malaysia (Mohamad et al., 2006) and more research is continuously carried out until today. Mutation breeding in rice is used to complement conventional breeding since the technique is very effective in improving major traits. Yield increase has to be achieved through the development of high yielding genotypes. A genotype with high yield with a low degree of fluctuations in yield in diverse environments is considered stable and desirable in any breeding program. However, breeders face a lot of difficulties in selecting this ideal genotype because of high genotype by environment (G×E) interactions for grain yield (Dia et al., 2016). Genotyping evaluation in multi-locations is a costly step that requires a high level of prediction prior to the recommendation as a new variety. These evaluations are extremely important, especially when the objective of the breeding program is to select and release rice genotype with high yield stability and adaptability.

Multilocation trial in most rice breeding programs focused on yield and yield related parameters, as a result, there are limited studies on genotype by environment interaction on the nutritional quality of rice straws. Santos et al. (2010), Vadiveloo, (1995) and Vadiveloo, (2003) reported a wide variation observed in the nutritive quality between different varieties of rice straw evaluated in different locations. The observed variability in the nutritional value and digestibility of rice straw could be in line with the influence of genotype or environmental factors (Vadiveloo, 1995). As genotypic variation can be moderated by the environment, the present study was conducted to ascertain the influence of environmental factors, season and location on yield and nutritional quality of rice straw.

1.2 Problem Statement

As Malaysia is determined to reduce her dependency on rice importation from other countries, the development of stable and high yielding rice varieties for local cultivation is of prime important for enhancing self-sufficiency's and compacting climatic changes. At present, the current average yield of rice in Malaysia stands at 4.03 t/ha (USDA, 2017). Therefore, in order to attain self-sufficient level, the productivity of paddy fields must be increased from the current 4.03 to 10 t/ha. Yield increase has to be achieved through development of high yielding genotypes.

Rice generates a relatively large amount of crop residues. Only approximately 20% of rice straw is used for industrial (e.g. fertilisers, paper and ethanol) and domestic purposes (animal feeds). The remains of rice straw are most burnt in-situ causing environmental pollution by increasing the amount of greenhouse gas in the air (El-Gammal and Shakour, 2001). The potential use of these crop residues as livestock feed is of great important in integrated crop/livestock farming systems which can be used to meet a portion of the nutrient requirements of ruminants. Although, rice straw is usually categorised as poor quality roughage but its feeding value can vary over a wide range (Nori et al., 2009). Vadiveloo and Phang, (1996) reported a wide variation observed in the nutritive quality between different varieties of rice straw evaluated in different location. Since rice is primarily grown for grain, and to date, little or no attention has been given to the nutritional quality of the straw in breeding because of the present emphasis on increasing grain yield. Therefore, there is a greater need to evaluate breeding lines for the nutritional value of the straw. All other traits being equal, plant breeders could then select lines with better nutritional quality of straw.

The observed phenotypic trait is a mixture of genotype (G) and environment (E) components and interactions (G×E) between them. Genotype tends to expresses differently in a diverse environment. These genotypic and environmental interactions (G×E) lead to inconsistency in yield and quality of crop production. Also, G×E reduces the genetic progress in plant breeding programs through minimizing the association between phenotypic and genotypic values (De leon et al., 2016), making it complicated to select genotypes with superior performance. Hence, G×E must either be exploited by selecting superior genotype for each specific target environment or by selecting widely adapted and stable genotype across a wide range of environments (De leon et al., 2016).

1.3 Significance of the Study

The continuous increase in rice demand justifies the need to step up the current yield output through the development of high yielding variety. This is so because: (i). The phenotypic response to change in environment is not the same for all the genotypes leading to G×E interaction (ii). Yield stability performance differs across environments (iii). Released varieties differ in adaptation and consistency performance in yield across the various environments. Therefore, it is great opportunity to identify genotype with high stable yield and well adapted to a wide range of environment suitable to Malaysia and to determine the influence of environment on the nutritive value of rice straw. This study will be a significant endeavor in promoting the approach of rice mutation breeding in Malaysia. In addition, the developed varieties from this study will add to the genetic diversity of the existing rice varieties in Malaysia.

1.4 Research Objectives

Main objective

To assess the response of selected rice genotypes across different growing environments for yield and adaptability and their interaction on yield, yield components and straw quality.

Specific objectives:

(i) To evaluate the response and stability of selected mutant rice genotypes under ten different rice growing environments for grain yield and straw quality.
(ii) To determine the genetic variability, heritability and paths of influence among various yield components of selected rice genotypes and their contribution to grain yield.
(iii) To determine the effectiveness of different stability analyses methods for identifying genotypes with consistent yield performance.
(iv) To identify locations having high discriminative and representative ability among test locations.

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