UNIVERSITI PUTRA MALAYSIA

POLLEN QUALITY AND SEED YIELD COMPONENT RESPONSES TO PRE-ANTHESIS WATER STRESS IN CULTIVATED AND WEEDY RICE (Oryza sativa)

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By

AMMINI AMRINA SARAGIH

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

May 2013

DEDICATION

This thesis is dedicated to
my beloved father and mother
for their endless love and unlimited support.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia
in fulfilment of the requirement for the degree of Master of Science

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May 2013

Chairman : Associate Professor Adam B. Puteh, PhD

Faculty : Agriculture

Water stress during reproductive growth stage influences seed yield in cereal crops. The study was aimed to evaluate the differences in the effect of water stress prior to anthesis on plant physiological parameters, pollen and seed yield components of cultivated and weedy rice (*Oryza sativa*) in order to identify if there is yield and genotypes differences under water stress. Therefore, the suitable genotypes and management practices particularly concerning with water and weed management in the field can be improved to maximize rice production. The study comprised of two seasons of field experiment on two cultivated rice varieties (MR 219, MR 232) and two weedy rice genotypes (collected in Bertam, Penang and Ketara, Terengganu) that were exposed to water stress prior to anthesis for ten days. Physiological parameters like leaf water potential, canopy temperature, photosynthetic rate, stomatal conductance and chlorophyll fluorescence parameters were measured. Pollen qualities evaluated in this study covered pollen number per anther, pollen viability, pollen load on stigma surface and *in vivo* pollen germination and pollen tube growth, which were observed under fluorescence microscopy. Seed yield components include spikelet number per panicle, spikelet fertility, 100-grains weight and grain yield were determined. Leaf water potential, photosynthetic rate, stomatal conductance and chlorophyll fluorescence parameters reduced significantly in all stressed plants while canopy temperature increased significantly. Pollen number, pollen viability and pollen load of all rice genotypes tested were reduced after experiencing water stress when compared with those in well watered condition. Water stress reduced pollen number by 56-67%. In the first growing season, the reduction in pollen viability was 89-93% in cultivated varieties and 82-85% in weedy rice. In the second season, the reduction in pollen viability was 84-86% and 91-92% for cultivated varieties and weedy rice, respectively. The reduction of pollen load was >80% in both growing seasons for all genotypes. Observation from fluorescence microscopy showed that water stress clearly affects pollen germination and pollen tube growth in both cultivated and weedy rice. Water stress significantly reduced the spikelet number per panicle, spikelet fertility and 100-grains weight of both the cultivated and weedy rice in both growing seasons. The reduction of spikelet number was in the range of 18-21%. Spikelet fertility decreased by 78% for the MR 219, 71% for Bertam weedy rice and 69% for both the MR 232 and Ketara weedy rice. The reduction of 100-grains weight was found to be more sensitive in cultivated rice than the weedy rice. Filled grain or spikelet fertility appears to be the most critical parameter that influenced grain yield in both cultivated and weedy rice if water stress occurs at pre-anthesis. The imposition of water stress for ten days beginning at prior to-anthesis resulting in yields loss in both cultivated and weedy rice. It can be attributed to reduced pollen load and pollen viability which eventually inhibited fertilization. Although both cultivated and weedy rice are critically affected

by pre-anthesis water stress, however, cultivated rice appears to be more sensitive than weedy rice in term of greater reduction in seed yield components and grain yield. The findings imply that water stress can promote soil seed bank depletion, therefore, this treatment can be adapted as a method for controlling weedy rice infestation in rice field.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk Ijazah Master Sains

RESPONS KUALITI DEBUNGA DAN KOMPONEN HASIL BIJI BENIH TERHADAP TEGASAN AIR SEBELUM ANTESIS PADA PADI DAN PADI ANGIN (*Oryza sativa*)

Oleh

AMMINI AMRINA SARAGIH

Mei 2013

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Tegasan air semasa peringkat reproduktif akan mempengaruhi penghasilan benih tanaman bijirin. Kajian ini bertujuan untuk menilai perbezaan kesan tegasan air yang berlainan yang diberikan pada peringkat sebelum antesis terhadap padi yang ditanam dan padi angin (*Oryza sativa*) dari segi fisiologi tumbuhan, debunga dan komponen hasil biji benih padi untuk mengenal pasti jika terdapat perbezaan hasil dan genotip di bawah tegasan air supaya genotip yang sesuai dan amalan pengurusan terutamanya berkaitan dengan pengurusan air dan rumpai di sawah boleh diperbaiki untuk memaksimumkan pengeluaran padi. Kajian lapangan selama dua musim telah dijalankan menggunakan dua varieti padi yang ditanam (MR 219, MR 232) dan dua genotip padi angin dan didedahkan kepada tegasan air sebelum antesis selama sepuluh hari. Parameter fisiologi seperti potensi air daun, suhu kanopi, kadar fotosintesis, konduktans stomata dan parameter klorofil floresens telah diukur. Kualiti debunga yang dinilai dalam kajian ini adalah bilangan debunga pada satu anter, kebernasan debunga, beban debunga pada permukaan stigma dan

percambahan debunga *in vivo* dan pertumbuhan tiub debunga, yang diperhatikan di bawah mikroskop pendarfluor. Komponen hasil benih yang ditentukan termasuk nombor spikelet per tangkai, peratusan kesuburan spikelet dan berat 100 bijirin. Potensi air daun, kadar fotosintesis, konduktans stomata dan parameter klorofil floresens menurun dengan ketara, sebaliknya, suhu kanopi meningkat dengan ketara pada tumbuhan yang menerima tegasan air. Bilangan debunga, kebernasan debunga dan beban debunga semua genotip padi yang diuji menurun selepas mengalami tegasan air berbanding dengan padi yang tidak diberikan tegasan air. Tegasan air mengurangkan bilangan debunga sebanyak 56-67%. Pada penanaman musim pertama, pengurangan kebernasan debunga adalah 89-93% pada padi yang ditanam dan 82-85% pada padi angin. Pada penanaman musim kedua, pengurangan kebernasan debunga debunga adalah 84-86% pada padi yang ditanam dan 91-92% pada padi angin. Pengurangan beban debunga adalah >80% dalam kedua-dua musim untuk semua genotip. Pemerhatian melalui mikroskop pendaflor mendapati bahawa tegasan air memberi kesan yang ketara kepada percambahan debunga dan tiub debunga samaada pada padi yang ditanam atau padi angin. Tegasan air mengurangkan bilangan spikelet per tangkai, peratusan kesuburan spikelet dan berat 100 biji benih dengan ketara samaada pada padi yang ditanam atau padi angin dalam kedua-dua musim. Pengurangan bilangan spikelet adalah dalam lingkungan 18-21%. Kesuburan spikelet menurun sebanyak 78% bagi MR 219, 71% untuk padi angin Bertam, dan 69% untuk kedua-dua beras MR 232 dan Padi angin Ketara. Pengurangan berat 100 biji didapati lebih sensitif dalam padi yang ditanam berbanding padi angin. Jika tegasan air berlaku semasa antesis, bijirin berisi atau kesuburan spikelet menjadi parameter yang paling kritikal yang mempengaruhi hasil bijirin padi samaada pada padi yang ditanam atau padi angin. Tegasan air selama sepuluh hari sebelum antesis menyebabkan pengurangan hasil pada padi yang ditanam dan padi angin dan ianya boleh dikaitkan dengan pengurangan beban debunga dan kebernasan debunga yang akhirnya menghalang persenyawaan. Walaupun kedua-dua tanaman padi dan padi angin terjejas secara kritikal oleh tegasan air sebelum antesis, bagaimanapun, padi biasa kelihatan lebih sensitif berbanding dengan padi angin dilihat dari pengurangan komponen hasil biji benih dan hasil bijirin yang lebih besar. Hasil penemuan menunjukkan bahwa tegasan air boleh menggalakkan pengurangan bank biji benih padi angin di dalam tanah dan oleh itu rawatan ini dapat diadaptasi sebagai salah satu method untuk mengawal serangan padi angin di sawah.

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I certify that a Thesis Examination Committee has met on 17 May 2013 to conduct the final examination of Ammini Amrina Saragih on her thesis entitled "Pollen Quality and Seed Yield Component Responses to Pre-Anthesis Water Stress in Cultivated and Weedy Rice (*Oryza sativa*)" 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 Master of Science.

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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 at any other institution.

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AMMINI AMRINA SARAGIH

Date:17 May 2013

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LIST OF ABBREVIATIONS

^0C	Degree celcius
Anova	Analysis of variance
cm	Centimetre
CRD	Complete randomized design
DAT	Day after treatment
DMRT	Duncan's Multiple Range Test
DTB	2,5-diphenyl tetrazolium bromide
et al.	Et alia
g	Gram
ha	Hectare
IKI	Iodine Potassium Iodide solution
IRRI	The International Rice Research Institute
kg	Kilogram
LWP	Leaf water potential
m	Meter
mm	Millimetre
MARDI	Malaysian Agricultural Research and Development Institute
SAS	Statistical Analysis System
PAR	Photosynthetically active radiation
PEA	Plant efficiency analyser
PS II	Photosystem II
s	Second
t/ha	Tons per hectare

CHAPTER 1

INTRODUCTION

1.1 Background

Water plays a crucial role in the plant life. It is the most abundant and at the same time the most limiting factor for agricultural productivity (Taiz and Zeger, 2006). Water deficit is one of the major problems in agriculture. Water deficit can be defined as the absence of adequate moisture necessary for a plant to grow normally and to complete its life cycle (Zhu, 2002). Further, water stress is characterized by reduction of water content, wilting, closure of stomata and the decrease in cell enlargement and growth. Plant growth and development can be inhibited by water stress at any time in crop life cycle. The degree of damage caused by water deficit depends on genotype, duration of the stress and plant growth stage (Farooq *et al.*, 2008; Gonzalez, *et al*., 2008).

Reproductive phase has important economic and social impacts because the reproductive phase products are the key components of economic yield and the source of the world food supply (Boyer and Westgate, 2004; Thakur *et al*., 2010). However, sensitivity to water stress is particularly acute during the reproductive stage. If water stress occurs during this stage, yield will be affected and can lead to reproductive failure (Li *et al*., 2006). It is because water stress occurring during the reproductive growth has a great impact on the reproductive organ and development of crops and consequently on final seed yield (Thakur *et al*., 2010; Boyer and Westgate, 2004; Saini, 1997).

Rice (*Oryza sativa* L.) is a major food crop in many regions of the world, especially in Asian countries. It is widely grown in tropical and subtropical regions (Olszyk *et al.*, 1999). Rice may grow as a dry land or upland crop, but it usually grows as a low land crop (Grist, 1986). The low land rice crop is a semi-aquatic plant and has been identified as water deficit susceptible crop (Cha-um *et al.*, 2010). Since rice production is a water intensive system, the drought marked by water stress becomes one of the major problems for the rice production worldwide. It is reported that more than 50% of the 40 million hectares of rainfed lowland rice area in South and Southeast Asia is affected by drought annually (Wu *et al*, 2011). Limitation of available water becomes a serious threat for rice cultivation since it may contribute to significant yield losses.

In rice, the sensitive stage to water deficit is around flowering (Liu *et al.*, 2006). The effects of water stress around anthesis which reduces grain yield in major cereal crops and rice in particular are well documented (Hong and Serraj, 2012; Nguyen and Sutton, 2009). During water stress condition, pollen quality appears to be a limiting factor that often impairs successful pollination. Water deficit interrupts pollen quality, which results in pollen not performing well and as a consequence the disturbance to pollination and fertilization occurs and then leads to failure or reduction in grain set (Jagadish *et al.*, 2010; Prasad *et al.*, 2006; Khan and Abdullah, 2003).

The degree of yield reduction due to water deficit does not only depend on the timing of the stress but also varies among species. Water stress also will have different effects on different plant species. Nowadays, the weedy rice problem has been reported in many rice growing areas of the world. Weedy rice is an annual grass and locally known in Malaysia as *padi angin*. It is the weedy form of rice which is morphologically similar to cultivated rice and usually grows in the same field (Mansor *et al*, 2012) with an early and easy seed shattering as its main characteristic (Akasaka *et al*, 2011). Currently, it appears as one of the noxious weed in rice cultivation due to its similar morphology and trait to cultivated rice varieties (Londo and Schaal, 2007). Weedy rice infests rice growing areas worldwide (Prathepha, 2009; Hashim *et al*., 2007; Londo and Schaal, 2007; Ferrero, 2003; Gealy *et al*., 2002) and the infestation can cause up to approximately 60-70% of yield loss (Karim *et al.* 2004).

Although many reports indicated that water stress during anthesis reduces seed set in rice and other cereal crops have been documented and extensively reviewed (Saini and Westgate, 2000; Zou *et al*., 2005; Barnabas *et al*., 2008; Serraj *et al*., 2009). However, information regarding the effect of water stress on weedy rice in tropical region at flowering stage is limited.

Weedy rice with similarity in growth pattern and morphology to cultivated rice potentially shows the same response to water stress. However, the earlier study by Puteh *et al.* (2009) reported that weedy rice produced more filled grain after experiencing short duration of water stress (<5 days) while at the same time that short period of water stress could reduce filled grain of cultivated rice. The increase of this yield component in weedy rice is possibly associated with the higher pollen production. The results indicated that a short period of water stress enhances soil seed bank of weedy rice that contributes to higher incidence of weedy rice infestation in the rice field for the next growing season.

Based on that finding, a hypothesis is set up that there are different responses to the degrees of water stress between cultivated rice and weedy rice which leads to differences in yield.

Thus, to confirm the effect of water stress on cultivated and weedy rice, a study needed to be conducted in which the stress duration is lengthened and then the pollen and seed yield component responses after experiencing stress are evaluated in order to identify if there is yield and genotypes differences under water stress. Therefore, the suitable genotypes and management practices particularly concerning with water and weed management in the field can be improved to maximize rice production.

1.2. The Objectives of the Study

Based on the background mentioned above, the objective of the study in general is to evaluate the differences in the effect of water stress on pollen and seed yield components in cultivated and weedy rice in order to identify if there is yield and genotypes differences under water stress.

Specifically, the objectives of the study are to evaluate the effect of water stress prior to anthesis on physiological parameter, pollen quality, yield and seed yield components in cultivated and weedy rice.

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