



**UNIVERSITI PUTRA MALAYSIA**

***ENHANCING GRAIN FILLING IN RICE USING GROWTH ENHANCERS  
UNDER WATER STRESS CONDITION***

**ZULKARAMI BERAHIM**

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UNDER WATER STRESS CONDITION**

By

**ZULKARAMI BERAHIM**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra  
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Doctor of Philosophy**

**January 2018**

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## DEDICATIONS

This thesis is dedicated to:

The sake of Allah, my Creator and my Master, My great teacher and messenger, Mohammed (May Allah bless and grant him), who taught us the purpose of life, My great parents, who never stop giving themselves in countless ways, My dearest wife, who leads me through the valley of darkness with light of hope and support, My beloved brothers and sisters, who stands by me when things look bleak, My beloved kids, whom I can't force myself to stop loving, My supervisor and Co-supervisors, who has been always generous during all phases of my research, My friends who encourage and support me, and all the people in my life who touch my heart, I dedicate this research.

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

## **ENHANCING GRAIN FILLING IN RICE USING GROWTH ENHANCERS UNDER WATER STRESS CONDITION**

By

**ZULKARAMI BERAHIM**

**January 2018**

**Chair: Professor Mohd Razi Ismail, PhD**

**Institute: Institute of Tropical Agriculture and Food Security**

Water stress is one of the key limiting factors in rice cultivation across the entire world. It reduces the production of rice, the income of farmers and stockpiles while increasing rice importation for drought stricken countries. Filled grain is the most affected part in rice plant especially during booting stage under water stress. There are various approaches for mitigation of plant under water stress. One of the approaches is through the use of growth enhancers by regulating physiological and biochemical attributes such as stomatal aperture and photosynthesis rate. The response of the rice plant variety MR219 subjected to different water regimes (well watered and water stressed) were investigated under both rain shelter and field condition. The objective of this study was to examine growth, physiological processes, biomass partitioning and yield determinants when rice plants were subjected to water stress condition. Biomass partitioning, harvest index and photosynthesis were reduced by 50% under water stress due to limitation in the efficiency of assimilate translocation. The results from the field study during prevailing drought condition had indicated the severity of yield losses at about 60-90% with drought imposed rice plant compared to the control. In the following studies short term measures to minimize the detrimental effect of water shortage on growth and rice plant development were carried out both under rain shelter and field conditions. The efficacies of growth enhancers (Vita-Grow®, epibrassinolide, spermine and pyroligneous acid) were evaluated on yield production of rice plants subjected to water stress condition. Among the growth enhancers studied, spermine was found to have the potential to mitigate the detrimental effect of water stress on rice plant. Yield and grain filling improvement of spermine treated plants were attributed to improved stomatal conductance, photosynthesis rate and assimilate partitioning. The application of

spermine with double spray was found to be more effective in improving growth and development of water stressed rice plant. Following trials that were conducted under control environment, a series of field trials were conducted to validate the efficacy of spermine in reducing detrimental effects of water stress on yield of rice in different locations, planting seasons and prevailing climates. Application of spermine in three different locations representing our major national granary areas (MADA, KADA, IADA BLS) showed consistently higher rice yield compared to the control. Out of the three granary areas, the highest intensity of water stress was observed in KADA. Application of spermine showed significantly higher grain filling and yield in plant subjected to water stress condition. A trial was conducted under control environment in an attempt to investigate the response of spermine on sink strength and sucrose synthase (SUS) enzyme in relation to the development of rice plant under water stress condition in a control environment. The result suggested that higher grain filling rate and greater grain weight of spikelets were mainly attributed to more sink strength as a result of bigger sink size and high sink activity in spermine treatments.

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

**MENINGKATKAN PENGHASILAN PADI BERISI MENGGUNAKAN  
PENGALAK TUMBESARAN DIBAWAH KEADAAN STRES AIR**

Oleh

**ZULKARAMI BERAHIM**

**Januari 2018**

**Pengerusi: Profesor Mohd Razi Ismail, PhD**  
**Institut: Institut Pertanian Tropika dan Keselamatan Makanan**

Kekangan air adalah salah satu faktor penghad dalam tanaman padi di seluruh dunia. Ia akan mengurangkan penghasilan tanaman padi, pendapatan petani dan simpanan beras negara di samping meningkatkan pengimportan padi bagi negara-negara yang mengalami masalah kemarau. Padi berisi adalah bahagian yang paling terjejas pada pokok padi terutamanya pada fasa padi bunting semasa kekangan air. Terdapat pelbagai kaedah untuk mengurangkan kekangan air pada tumbuhan di kenalpasti. Salah satu cara adalah melalui penggunaan penggalak tumbesaran dengan mengawal selia ciri-ciri fisiologi dan biokimia seperti pembukaan stomata dan kadar fotosintesis. Tindakbalas varieti padi MR219 berada dalam keadaan kekangan air yang berbeza (keperluan air secukupnya dan kekangan air) telah di siasat di dalam rumah teduhan dan juga di lapangan. Tujuan kajian ini adalah untuk memeriksa pertumbuhan, proses-proses fisiologi, pembahagian biomas dan penentuan hasil apabila tanaman padi berada dalam keadaan kekangan air. Pembahagian biomas, indeks tuaian dan kadar fotosintesis telah berkurang sebanyak 50% di bawah kekangan air kerana kecekapan penghasilan dan pemindahan fotosintesis adalah terhad. Keputusan daripada kajian telah menunjukkan kehilangan hasil padi yang serius iaitu sebanyak 60-90% semasa keadaan kemarau berbanding petak kawalan. Pada kajian berikutnya, kaedah jangka masa pendek untuk meminimumkan kemudaratan pada pertumbuhan dan pembangunan tumbuhan akibat kekurangan air telah dijalankan di kedua-dua rumah teduhan dan juga di lapangan. Kecekapan penggalak pertumbuhan (Vita-Grow®, epibrassinolide, spermin dan pyroligneous acid) telah di siasat pada hasil tanaman padi di bawah kekangan air. Di antara penggalak pertumbuhan yang di kaji, spermin di dapati sangat berpotensi untuk

mengurangkan kesan buruk terhadap tanaman padi akibat kekangan air. Penambahbaikan hasil dan padi berisi oleh rawatan spermin dikaitkan dengan aliran stomata, kadar fotosintesis dan asimilasi pembahagian. Penggunaan spermin dengan dua kali semburan di dapati lebih efektif dalam penambahbaikan pertumbuhan dan pembangunan tumbuhan dalam keadaan kekangan air. Berikutan daripada kajian pada persekitaran terkawal, dua siri ujian lapangan telah dijalankan untuk mengesahkan keberkesanan spermin dengan cara mengurangkan kesan buruk kekangan air pada hasil tanaman padi di beberapa lokasi, musim tanaman padi dan cuaca. Penggunaan spermin di tiga lokasi yang berbeza mewakili jelapang padi utama negara (MADA, KADA, IADA BLS), menunjukkan peningkatan hasil padi yang konsisten berbanding kawalan. Daripada tiga kawasan jelapang padi, tahap kekangan air yang tertinggi di dapati di KADA. Kesannya, penggunaan spermin menunjukkan peningkatan padi berisi dan hasil yang ketara. Kajian dijalankan di dalam keadaan persekitaran terkawal sebagai percubaan untuk menyiasat tindak balas spermin terhadap kekuatan pendedapan dan enzim sukrosa sintase dalam pembentukan penghasilan padi di bawah keadaan kekangan air. Keputusan kajian menunjukkan kadar padi berisi dan berat spikelet yang tinggi menyumbang kepada kekuatan pendedapan yang tinggi disebabkan oleh pendedapan yang lebih besar dan pendedapan aktiviti yang tinggi dalam rawatan spermin.



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I certify that a Thesis Examination Committee has met on 4 January 2018 to conduct the final examination of Zulkarami Berahim on his thesis entitled "Enhancing Grain Filling in Rice using Growth Enhancers under Water Stress Condition" 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.

Members of the Thesis Examination Committee were as follows:

**Mohd Rafii bin Yusop, PhD**

Professor  
Institute of Tropical Agriculture and Food Security  
Universiti Putra Malaysia  
(Chairman)

**Yahya bin Awang, PhD**

Associate Professor  
Faculty of Agriculture  
Universiti Putra Malaysia  
(Internal Examiner)

**Uma Rani a/p Sinniah, PhD**

Professor  
Faculty of Agriculture  
Universiti Putra Malaysia  
(Internal Examiner)

**Muhammad Ashraf (S.I), PhD**

Professor  
University of Agriculture  
Pakistan  
(External Examiner)



---

**NOR AINI AB. SHUKOR, PhD**

Professor and Deputy Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date: 26 April 2018

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

**Mohd Razi Ismail, PhD**

Professor  
Faculty of Agriculture  
Universiti Putra Malaysia  
(Chairman)

**Halimi Mohd Saud, PhD**

Associate Professor  
Faculty of Agriculture  
Universiti Putra Malaysia  
(Member)

**Monjurul Alam Mondal, PhD**

Research Fellow  
Faculty of Agriculture  
Universiti Putra Malaysia  
(Member)

---

**ROBIAH BINTI YUNUS, PhD**

Professor and Dean  
School of Graduate Studies  
Universiti Putra Malaysia

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Signature: \_\_\_\_\_

Name of Chairman of

Supervisory Committee: Professor Dr. Mohd Razi Ismail

Signature: \_\_\_\_\_

Name of Member of

Supervisory Committee: Associate Professor Dr. Halimi Mohd Saud

Signature: \_\_\_\_\_

Name of Member of

Supervisory Committee: Dr. Monjurul Alam Mondal

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## LIST OF ABBREVIATIONS

SSL	self-sufficiency level
PGRs	Plant growth regulators
ADP-phosphorylase	Adenosine diphosphate-phosphorylase
SS	Starch synthase
EPI or BRs	Epibrassinolide
PA	Pyroligneous acid
SPM	Spermine
CWS 10 days	Cyclic water stress at 10 days intervals
DAS	Days after sowing
DAT	Days after transplanting
DPA	Days after anthesis
KADA	Kemubu Agricultural Development Authority
MADA	Muda Agricultural Development Authority,
IADA BLS	Integrated Agriculture Development Area Barat Laut Selangor
ABA	Abscisic acid
ROS	Reactive oxygen species
H <sub>2</sub> O <sub>2</sub>	Hydrogen peroxide
NO	Nitric oxide
CO <sub>2</sub>	Carbon dioxide
Ca <sup>2+</sup>	Calcium
ADP	Adenosine diphosphate
AGPase	Adenosine diphosphate-glucose pyrophosphorylase
SS	Starch synthase
SUS	Sucrose synthase enzyme
SUS1-4	Sucrose synthase 1-4 gene
CV	Coefficient variance
DMM	Department meteorological Malaysia
BCR	Benefit cost ratio
GFR	Grain filling rate
GW	Grain weight
HI	Harvest index
P <sub>n</sub>	Photosynthesis rate

## CHAPTER 1

### INTRODUCTION

Rice (*Oryza sativa* L.), the staple food of half the human population is a cereal crop that is susceptible to soil water deficit, which causes huge yield losses in many Asian countries (Noorzuraini et al., 2012; Alimullah Miyan, 2015). Plants adapt to drought stress or water shortage by altering physiological, biochemical and molecular processes (Bohnert and Jensen, 1996; Vij and Tyagi, 2007). Severe stress such as drought leads to significant difference in actual and potential rice yield. Tuong and Bouman (2003) predicted that by 2025, 15–20 million hectares of irrigated terrain will endure water shortage resulting in water stress that can affect the development and yield of rice (Xu et al., 2010; Lobell et al., 2011) especially if it occurs during grain filling.

Several measures are available to mitigate the impact of drought on rice which include improved irrigation facilities in all granary areas, breeding programme and simple agronomic manipulation. The drawback of rice breeding programme is it is a long-term approach that is unable to increase productivity under normal growing conditions. Undoubtedly, managing rice under limited water availability is highly desired to ensure crop survival while enhancing yield in general for the given situation. Foliar application of growth enhancer such as polyamines that are economical, feasible, easy to apply and readily available to the farmers could be a possible solution for rice growing in water stress environment (Farooq et al., 2009; Alcázar et al., 2011).

A high grain yield in rice plants can be attained only when a appropriate combination of variety, suitable environment, and appropriate agronomic practices is obtained. Understanding the physiological processes involved in grain production, such as vegetative growth, the formation of storage materials and grain filling, helps to improves in grain yield under varies condition (Paul, 2017).

At present, the roles of growth enhancers on local rice variety in relation to the grain filling and yield of rice under water stress are not widely examined. Furthermore, earlier findings were mainly reported from the studies of foliar growth enhancers under normal conditions (Ishimaru et al., 2005; Mohapatra et al., 2011; Sekhar et al., 2015). Therefore, the main objective of the study is to examine the efficiency of growth enhancers to alleviate the effect of water deficit on growth and yield of rice plant. The specific objectives of the study undertaken were as follows;

1. to examine growth, physiological processes, biomass partitioning and yield determinants when rice plants were subjected to water stress condition.
2. to evaluate the efficacy of growth enhancers on yield production of rice plant subjected to water stress condition.
3. to validate the efficacy of selected growth enhancer at different locations, planting seasons and prevailing climates on yield of rice plant under field conditions.
4. to investigate the response of selected growth enhancer on sink strength and sucrose synthase (SUS) enzyme in relation to the development of rice under water stress condition in a control environment.



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