UNIVERSITI PUTRA MALAYSIA

EFFECTS OF PARTIAL ROOT DRYING, REGULATED DEFICIT IRRIGATION AND MYCORRHIZA ON GROWTH PERFORMANCE AND PHYSIOLOGICAL RESPONSES OF ROCK MELON (Cucumis melo L.)

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FP 2015 51

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By

HAMDAN BIN MOHD NOOR

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

November 2015

DEDICATION

This achievement is especially dedicated to my beloved wife and loving children. Your patience and prayers is finally rewarded. My only advice and wish is that, you too will find the wisdom and knowledge, so that you too will be successful someday.

My best wishes to my loving children

Muhammad Harith Ashraf

Muhammad Haikal Ashrawi

and Nur Hana Aneesa

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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November 2015

Chairman : Professor Mohd. Razi Ismail, PhD
Faculty : Agriculture

Rock melon (*Cucumis melo* L.), one of the most popular and delicious fruits of Malaysia has great potential for commercial development. Currently, rock melon is most widely cultivated under rain shelter structure using soilless culture. In principle, the partial root drying (PRD) or regulated deficit irrigation (RDI) technique has been used to evaluate the biochemical responses of water deficit without actually disturbing the physiological effects of plant growth under reduced water availability. This study aimed to determine the effects of deficit fertigation on both vegetative and reproductive growth of melon. Two fertigation techniques were used namely: 1) Partial root drying (PRD) and 2) Regulated deficit irrigation (RDI). The experiment comprise the following treatments: 1) Well watered (WW) - watered manually at 100 % SC (substrate capacity); 2) (RDI) at 50 % SC and 3) (PRD) at 50 % SC, split into two compartments alternating wet and dry period once every 2 days. Different deficit irrigation levels had significant effects on dry matter production and yield of melon as compared to controls. Maximum and significant yield of melon was from the WW and RDI plants. Moderate water stress (RDI) did not drastically reduce fresh fruit weight of melon (511.11 g compared to WW with 710.74 g), i.e. only 28 % drop in yield, indicating better utilisation of the available water. Under the PRD treatment, yield was only 144.11 g plant^{-1} i.e. an 80 % drop in yield. Maximum total soluble solids (TSS) of 14.02 ^{o}Brix was from WW treated plants as compared to 13.83 ^{o}Brix of RDI and 5.99 ^{o}Brix of PRD plants respectively. Total proline concentration in leaf at 76 DAT clearly illustrates that the PRD plants is highly stressed by this deficit system with maximum reading of 21.44 µg g^{-1} as compared to only 9.68 and 9.96 µg g^{-1} from WW and RDI plants respectively. In general, plants that experiencing serious water stress tend to produce higher proline concentration. The RDI technique for melon production in soilless culture is recommended for the subsequent experiment with arbuscular mycorrhiza (AM) fungi. Presence of the AM fungi in combination with RDI (RDI+M treatment), significantly enhanced plant growth, dry matter production and yield of melon. At 76 DAT, results obtained from RDI+M plants gave almost similar results to the WW plants for almost all parameters measured. The WW and RDI+M plants produce respectively higher (930 g and 950 g plant^{-1}) and quality fruits, with high Brix Index of 15.05 ^{o} and 15.26 ^{o}Brix respectively. Non mycorrhizal plants (RDI-M) only

produced smaller sized fruit of 670 g $plant^{-1}$ and Brix Index of 14.15 ^{o}Brix. *Cucumis melo* plants showed high dependance 178.53 % on AM fungi, with root colonisation of 97.5 %. The introduced AM inoculum also sporulate abundontly with, ± > 200 spores / 100 g media used at both harvests (31 DAT and 76 DAT), i.e. 191.75 and 222.50 respectively.

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

KESAN PENGERINGAN SEPARA AKAR DAN PENGAIRAN DEFISIT TERKAWAL DAN MIKORIZA ATAS PRESTASI PERTUMBUHAN DAN TINDAKBALAS FISIOLOGI TANAMAN ROCK MELON (*Cucumis melo* L.)

Oleh

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Pengerusi : Profesor Mohd. Razi Ismail, PhD
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Tembikai wangi (*Cucumis melo* L.) adalah sejenis buah paling terkenal dan lazat di Malaysia. Ia mempunyai potensi tinggi untuk dihasilkan secara komersial. Kini, tembikai wangi ditanam secara meluas di bawah struktur pelindung hujan menggunakan kultur tanpa tanah. Secara prinsip, teknik pengeringan separa akar (PRD) atau pengairan defisit terkawal (RDI) telah digunakan untuk menilai respon biokimia tanaman ekoran rawatan defisit air tanpa apa-apa gangguan keatas kesan fisiologi pertumbuhan tanaman. Kajian ini bertujuan untuk menentukan kesan fertigasi defisit keatas pertumbuhan vegetatif dan reproduktif tanaman tembikai wangi. Dua teknik fertigasi digunakan iaitu: 1) Pengeringan separa akar (PRD) dan 2) Pengairan defisit terkawal (RDI). Kajian berikut terdiri dari 3 rawatan: 1) WW - tanaman kawalan diberi air 100 % pada muatan substrat (SC); 2) RDI - diberi 50 % air muatan substrat dan 3) PRD - diberi 50 % air muatan substrat, diselang seli pengairan dengan pengeringan setiap 2 hari. Paras pengairan defisit yang berbeza memberi kesan bererti keatas berat kering tanaman dan hasil tembikai wangi berbanding rawatan kawalan. Hasil tembikai wangi tertinggi dan bererti diperolehi dari tanaman WW dan RDI. Ketegasan air sederhana (RDI) tidak menurunkan berat basah buah tembikai wangi (511.11 g) secara mendadak berbanding tanaman WW (710.74 g), iaitu hanya 28 % penurunan hasil menunjukkan penggunaan lebih baik air yang tersedia ada. Di bawah rawatan PRD, hasil hanya mencecah 144.11 g pokok^{-1} iaitu penurunan hasil berjumlah 80 %. Jumlah maksima pepejal mudah larut (TSS) sebanyak 14.02 ^{o}Brix adalah dari rawatan WW berbanding 13.83 ^{o}Brix dari tanaman RDI dan 5.99 ^{o}Brix dari PRD satu-satunya. Jumlah kepekatan prolin dalam daun pada 76 hari lepas tanam (HLT) jelas menunjukkan bahawa tanaman PRD mengalami ketegasan air teramat dengan bacaan 21.44 µg g^{-1} berbanding bacaan 9.68 dan 9.96 µg g^{-1} dari tanaman WW dan RDI satu-satunya. Secara umum, tanaman yang mengalami ketegasan air yang serius akan menghasilkan kepekatan prolin yang tinggi. Teknik RDI untuk penghasilan buah tembikai wangi dalam kultur tanpa tanah disyorkan untuk kajian seterusnya dengan kehadiran kulat mikoriza arbuskul (MA). Kehadiran kulat MA digabungkan dengan RDI (RDI+M) secara bererti meningkatkan pertumbuhan, berat kering tanaman dan hasil tembikai wangi. Pada 76 HLT, keputusan hampir sama diperolehi dari tanaman WW dan RDI+M bagi hampir semua parameter yang diukur. Tanaman WW dan

RDI+M memberi hasil tinggi (930 g dan 950 g pokok^{-1} satu-satunya) dengan buah berkualiti dan tinggi Indek Brix, 15.05 ^{o} dan 15.26 ^{o}Brix satu-satunya. Tanaman tanpa mikoriza (RDI-M) mengeluarkan buah yang lebih kecil, 670 g pokok^{-1} dan nilai Indek Brix 14.15 ^{o}Brix. Tanaman *Cucumis melo* memperlihatkan pergantungan tinggi (178.53 %) ke atas kehadiran kulat mikoriza dengan bacaan kolonisasi akar 97.5 %. Perletakkan inokulum mikoriza arbuskul mengeluarkan spora dengan banyak, ± > 200 spora / 100 g media pada kedua-dua penuaian (31 HLT dan 76 HLT), iaitu 191.75 dan 222.50 satu-satunya.

ACKNOWLEDGEMENTS

Alhamdulillahi Rabbil 'alamin, praise to the Almighty Allah SWT for giving me strength and courage that finally enable me to accomplish my graduate study. My selawat and salam to His messenger, Prophet Muhammad SAW. I would like to express my sincere thanks and profound appreciation to the chairman of my supervisory committee, Professor Dr. Mohd. Razi Ismail who has contributed much effort in guiding me through the entire course of this study. Special thanks and appreciation are also extended to the supervisory committee members, Dr. Puteri Edaroyati Megat Wahab for the invaluable and constructive criticisms and encouragement which made this study a success.

I am also greatly indebted to Associate Prof. Dr. Radziah Othman for the valuable support in permitting me to run part of this research in her laboratory, and for providing me with all the facilities needed. My acknowledgement is also extended to Dr. Ahmad Selamat, for his encouragement and guidance on statistical analysis. I also like to extend my honest appreciation and sincere thanks to the staff of the Institute Tropical of Agriculture, Crop Science Department and Soil Management Department in the Faculty of Agriculture, UPM and to Mr. Ibrahim Wasiu Arolu, Mr. Mohd Shafar Jefri Mokhtar, Dr. Hanim Ahmad, Mr. Saiful Zaimi Jamil, Dr. Zulhazmi Sayuti, Ms. Farahzety Abdul Mutalib, Mr. Camillus Benno and Ms. Golnaz Sharifianpour who had contributed in one way or another to this work.

Last but not least, I would like to take this opportunity to dedicate this Master thesis to my beloved wife Ms. Azidah Mohd Yusuf and loving children, Muhammad Harith Ashraf, Muhammad Haikal Ashrawi and Nur Hana Aneesa for their encouragement and moral support, which made life easy throughout my studies. My only advice and wish is that, you too will find the wisdom and knowledge, so that you too will be successful someday. Finally, my special appreciation and gratitude to my family and Professor Dr. Azizah Hashim for being the source of encouragement, and always ready to offer a helping hand.

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

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

ABA	Abscisic Acid
ANOVA	Analyses of Variance
ANON	Anonymous
cm^2	Square centimetre
C.V.	Coefficient of Variation
DOA	Department of Agriculture
EC	Electrical Conductivity
ET	Evapotranspiration
Etc	Evapotranspiration of crop
et al.	And Friends
e.g	Example
Fm	Maximum fluorescence
Fo	Minimal fluorescence
Fv	Variable fluorescence
Fv/Fm	Maximum quantum efficiency of PSII system
FAMA	Federal Agricultural and Marketing Authority
FAO	Food and Agriculture Organization
gs	Stomata conductance
H_2SO_4	Sulfuric acid
H_2O_2	Hydrogen peroxide
JPM	Jabatan Perdana Menteri
Kc	Crop coefficient
LAI	Leaf Area Index
$LSD_{0.05}$	Least Significant Difference at 5% level
Mc	Moisture content
MPa	Mega Pascal
MT	Metric Tonnes
NH^{4+}	Ammonium
ns	Not Significant
NAR	Net Assimilation Rate
p	Probability
Pn	Net photosynthesis
PSII	Photosystem II
RCBD	Randomised Complete Block Design
RGR	Relative Growth Rate
RH	Relative Humidity
RM	Ringgit Malaysia
SAS	Statistical Analysis System
UPE	Unit Perancangan Ekonomi

CHAPTER 1

INTRODUCTION

Agriculture has always been an important component in the Malaysian economy since the 1950's. This sector under the Ministry of Agriculture and Agro-Based Industry (MOA) has been identified to be 'the third engine of growth' after the industrial and services sectors. Agriculture in fact provides the much needed employment opportunities to the rural community contributing significantly to the national revenue (Anon, 2004a).

Fruit production plays a dominant role in the agro-based food sector. Statistical data published by the Department of Agriculture (2015) had stated that more than 1.5 million metric tons (MT) of fruits were produced in year 2013. Value of production increased from RM3.63 billion in 2009 to RM4.57 billion in 2013. However, as a result of urbanization, the area under fruits has decreased from 249,994 hectares in 2009 to 202,593 hectares in 2013 (Anon, 2008; 2014). In spite of this, the growth of the fruit industries in this country is bright due to the increase in domestic consumption of both fresh and processed products as a result of the rise in the standard of living and the increasing awareness on health. The demand is also expected to increase in consistent with the world demand for tropical fresh and processed foods. Hence Malaysian agriculture sector focuses towards greater commercialization of our agriculture produce and agro based industry products. A total of 10 fruit industries has been given priority by our Ministry of Agriculture and Agro-Based Industry (MOA) namely: papaya, pineapple, watermelons, starfruit, mango, durian, jackfruit, citrus, guava and rambutan (Anon, 2013).

Rock melon (*Cucumis melo* L.) has become one of the important fruits in the Entry Point Projects (EPP) besides; papaya (Eksotika), pineapple (MD2), star fruits (B10) and banana (Cavendish) (Anon, 2010). This has been clearly stated in the Agriculture National Key Economic Areas (NKEA) and EPP. The government aims to double agriculture sector's contribution to the Gross National Income (GNI) by upgrading capabilities to produce fruits for the premium markets respectively. Recently, rock melon has gained popularity both in the local and export market. They are mainly grown using the fertigation system in soilless culture under rain shelter. Under this system, calculated quantities of macro nutrient elements from chemical fertilizers are applied hence reducing unnecessary loss of fertilizers into the soil using conventional methods.

Irrigated agriculture makes a major contribution to food security, producing nearly 40% of the food and agricultural commodities on 17% agricultural land (FAO, 2011). Irrigated areas have almost doubled in the recent decades and contributed much to the growth in agricultural productivity over the last 50 years. More than 70% of the irrigated agriculture uses water from rivers and in developing countries, the proportion exceeds 80 percent.

The scope for further development to meet food requirements in the coming years is, however, severely constrained by decreasing water resources and growing competition for clean water. While on a global scale water resources are still ample, serious water shortages is becoming rampant in the arid and semi-arid regions as existing water resources reach full exploitation. The situation is exacerbated by the decline in water quality and soil resources hence affecting food supply while increasing rural poverty (Shock and Feibert, 2002). The great challenge for the coming decades therefore will be the task of increasing food production using less water, particularly in countries with limited water and land resources.

Water stress affects crop growth and productivity in many ways. Most of the responses have a negative effect on production. Maximum crop productivity is achieved from high-yielding varieties with optimal water supply and high soil fertility levels (Hossain *et al*., 2014). It is therefore of great importance to develop an effective irrigation technique of increasing water productivity for various crops without causing a severe drop in crop yield.

Currently, inoculation of plants with the arbuscular mycorrhiza has been proven to be able to enhance crop production in most countries in the tropics, some even under limited water supply (Azizah, 2015 personal comm).

In view of the above, the current project conducted aims to:

i. Evaluate the effectiveness of two techniques of irrigation: regulated deficit irrigation (RDI) and partial root drying (PRD) on growth performance and yield of rock melon,
ii. Determine the role of arbuscular mycorrhizal (AM) fungi in enhancing growth and yield of rock melon under the best irrigation system obtained from experiment 1 above.

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