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EFFECTS OF FOLIAR APPLICATION OF Moringa LEAF EXTRACT ON DEFICIT IRRIGATION AND TOMATO (Solanum lycopersicum L.) PRODUCTIVITY

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By

ODU ODO AGADA

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

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DEDICATION

This work is dedicated to my LORD and savoir, Jesus Christ who gave me the privilege of life, the opportunity to study, and the space to express myself.

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

EFFECTS OF FOLIAR APPLICATION OF *Moringa* LEAF EXTRACT ON DEFICIT IRRIGATION AND TOMATO (*Solanum lycopersicum* L.) PRODUCTIVITY

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March 2018

Chairman : Siti Aishah bt Hassan, PhD
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Moringa oleifera leaf extract (MLE), known to contain various phytochemicals, has been documented to enhance drought tolerance in crops, presenting a competitive technology in reducing the effect of water stress, enhancing water use efficiency and reducing use of chemical enhancers in crop production. The present study was undertaken to examine the effects of MLE on deficit irrigation and productivity of tomato, *Solanum lycopersicum*, with the objective of enhancing productivity while augmenting water use efficiency. Conducted under a rain-sheltered facility on heat tolerant tomato variety MARDI MT1, treatments consisted of four levels of sustained deficit irrigation (SDI) computed as percentages of field capacity (FC) viz. 39, 53, 68 and 100 % FC, applied on plants growing in media maintained at soil water potential levels of 1351.08, 968.56, 618.76 and 33 KPa respectively, at 2 weeks after transplanting (WAT). Results showed that at 39 % FC, reductions over control included plant height (33.75 %), total leaf area (59.98 %), fruit weight (71 %), net photosynthesis (44 %) and leaf water potential (56 %). Yield water use efficiency (YWUE) showed a linear relationship between full (100 %) irrigation and lowest at 39 % FC. There was no significant difference between the control and the 68 % FC level on growth, fruit weight and water use efficiency, suggesting it as the appropriate SDI level. The study observed the effects of different concentrations of MLE on growth, yield and water use efficiency under 53 % SDI. Four concentrations of MLE (0, 2.2, 3.3 and 6.7 %) were applied weekly at the rate of 25 ml plant^{-1}. The 6.7 % MLE treatment recorded maximum values for relative water content (RWC) (14.91 %), net photosynthesis (17.25 %), fruit weight (18.85 %) and YWUE (28.41 %) over control. MLE at 6.7 % was observed to be the optimum concentration for reducing negative effects of 53% SDI. The effects of seven timing schedules of MLE applications on productivity under SDI were evaluated and was observed that combination timing performed better than single application timing schedules. The control timing schedule gave significantly higher values for the following parameters: plant height, fruit yield, net photosynthesis and catalase enzyme activity. The control timing schedule produced 35.58, 17.46, 21.27, 17.4 and 14.58 % higher fruit weight than the vegetative, flowering, fruiting, vegetative and flowering, and flowering and fruiting timing schedules respectively. The triple combination timing schedule was therefore the optimum timing for MLE applications. In a comparative study, MLE and benzyl amino purine (BAP) were compared under similar conditions. The MLE recorded significant capacity in enhancing water stress tolerance compared to BAP, yielding higher values in fruit yield (21.52 %), Fv/Fm (16.44 %), total chlorophyll content (22.79 %), photosynthesis (11.97 %) and nutrient element accumulation. This suggests that MLE could be used as an alternative to BAP in enhancing growth and productivity. The study concluded that 6.7 % MLE, applied at the vegetative, flowering and fruiting combination timing schedules was the optimum condition for foliar application of MLE in reducing negative effects of SDI on tomato fruit yield and water use efficiency.

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

KESAN EKSTRAK DAUN *MORINGA* MELALUI APLIKASI DAUN KE ATAS PENGAIRAN DEFISIT DAN PRODUKTIVITI TOMATO (*Solanum lycopersicum* L.)

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Ekstrak daripada daun *Moringa oleifera* (MLE), yang diketahui mengandungi pelbagai fitokimia, telah didokumentasikan sebagai mempunyai daya dalam mempertingkatkan toleransi kemarau dalam tanaman, Sekali gus MLE menawarkan satu teknologi yang kompetitif dalam usaha mempertingkatkan kecekapan penggunaan air serta mengurangkan kesan tekanan komoditi (air) dan penggunaan kimia penggalak tumbesaran dalam tanaman. Penyelidikan ini telah dilakukan bagi mengkaji kesan MLE ke atas pengairan defisit dan daya produktiviti tomato, *Solanum lycopersicum*, dengan objektif utama iaitu mempertingkat pertumbuhan dan menambahbaik kecekapan penggunaan air bagi tanaman tersebut. Kajian telah dijalankan di bawah satu fasiliti bebas hujan dan menggunakan satu varieti tomato tahan kemarau MARDI MT-1. Kajian mengandungi empat paras pengairan defisit yang mampan (SDI) yang dikira daripada peratusan keupayaan lapangan (FC) iaitu pada 39, 53, 68 and 100 % kelembapan. Rawatan telah dilakukan 2 minggu selepas pengalihan (WAT) anak pokok. Rawatan telah dikenakan ke atas tanaman yang ditanam dalam media yang dikekalkan paras potensi air tanah, masing-masing pada 1351.08, 968.56, 618.76 and 33 KPa. Pada 39% FC, keputusan menunjukkan berlakunya pengurangan daripada sampel kawalan termasuklah dalam parameter ketinggian pokok (34.7 %), jumlah keluasan daun (58.82 %), berat buah (70.65 %), fotosintesis net (43.6 %) dan potensi air daun (55.95 %). Kecekapan penggunaan air terhadap hasil (YWUE) menunjukkan hubungan linear antara pengairan penuh (100 %) dengan 39 % FC. Tiada berbezaan yang ketara telah direkodkan antara kawalan dan paras 68% FC ke atas tumbesaran, berat buah dan kecekapan penggunaan air. Ini mencadangkan bahawa 68 % FC adalah paras SDI yang paling sesuai untuk kajian selanjutnya. Penyelidikan mengkaji kesan pelbagai kepekatan MLE ke atas tumbesaran, hasil dan kecekapan penggunaan air di bawah 53 % SDI. Empat kepekatan MLE (0, 2.2, 3.3 dan 6.7 %) telah digunakan pada kadar 25 ml pokok^{-1} per

minggu. MLE pada kepekatan 6.7 % telah merekodkan nilai tertinggi pada parameter kandungan air relatif (RWC) (14.91 %), fotosintesis net (17.25 %), berat buah (18.85 %) dan YWUE (28.41 %) melebihi kawalan. MLE pada kepekatan 6.7% didapati optimom dalam mengurangkan kesan negatif 53% SDI. Kesan ke atas tujuh jadual penggunaan MLE di bawah SDI telah dinilai dan didapati jadual penggunaan kombinasi adalah yang lebih baik daripada jadual bersendirian.Jadual penggunaan kawalan didapati member nilai yang ketara bagi parameter termasuklah ketinggian pokok, hasi buah, fotosintesis net dan aktiviti enzim catalase. Jadual penggunaan kawalan mencatatkan 35.58, 17.46, 21.27, 17.4 dan 14.58 % lebih tinggi bagi berat buah berbanding masing-masing parameter tampang, pembungaan, pembuahan, tampang serta pembungaan,pembungaan serta pembuahan dan pembuahan. Jadual masa kombinasi tiga kali ganda adalah masa optimom bagi aplikasi MLE. Dalam satu kajian perbandingan, MLE danbenzyl amino purine (BAP) dijalankan di bawah rawatan yang sama. MLE merekodkan keupayaan yang ketara dalam mempertingkatkan toleransi tekanan air berbanding BAP dengan mencatatkan ketinggian hasil buah (21.52 %), Fv/Fm (16.44 %), kandungan klorofil total (22.79 %), fotosintesis (11.97 %) dan pengumpulan unsure nutrien. Hal ini mencadangkan bahawa MLE boleh digunakan sebagai alternative kepada BAP dalam memerangsangkan pertumbuhan dan produktiviti. Kajian ini merumuskan bahawa 6.7% MLE, di aplikasi pada jadual penggunaan kombinasi tampang, pembungaan dan pembuahan adalah optimom bagi aplikasi MLE melalui dedaun dalam usaha mengurangkan kesan negatif SDI ke atas hasil buah tomato dan kecekapan penggunaan air.

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This thesis was submitted to the Senate of the 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:

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LIST OF ABBREVIATIONS

ABA	Abscisic Acid
ANOVA	Analysis of Variance
B	Boron
BA	Benzyl Adenine
BAP	Benzyl Aminopurine
BWUE	Biomass water use efficiency
C	Carbon
C1	Electrical conductivity
Ca^{2+}	Calcium ion
CAT	Catalase
CEC	Cation exchange capacity
Chl a	Chlorophyll a
Chl b	Chlorophyll b
Chla/b	Chlorophyll a to b ratio
CK	Cytokinin
Cl^-	Chloride ion
Cm^2	Centimeter square
Cmolc kg^{-1}	Centimolc per kilogram
CO_2	Carbon dioxide
DI	Deficit irrigation
EBIC	European Biostimulant Industry Council
et al.	And others
ETR	Electron transport rate
FAO	Food and Agricultural Organization
FAOSTAT	Food Agriculture Organization statistics
FC	Field capacity

Fl	Flowering growth stage
Fr	Fruiting growth stage
Fl/fr	Flowering and fruiting growth stage
Fv/Fm	Maximum quantum yield of photosystem II
Fwt/plt	Fresh weight per plant
g	Gram
GAE	Gallic acid equivalent
g g^{-1} Fw	Gram per gram fresh weight
gs	Stomatal conductance
H_2O_2	Hydrogen peroxide
HO_2*	Perhydroxy radical
HO*	Hydroxyl radical
H^+ pump	Proton pump
HSD	Honest significant different
ICBA	International Centre for Biosaline Agriculture
K	Potassium
K^+	Potassium ion
Kg	Kilogram
KPa	Kilo pascal
K_2O	Potassium Oxide
LHC II	Photosystem II light harvesting complex
M	Meter
M^{-3}	Cubic meter
MAPK	Mitogen- Activated Protein Kinase
MARDI	Malaysian Agricultural Research and development Institute
MDA	Malondialdehyde
Mg	magnesium
mg g^{-1} Fw	Miligram per gram fresh weight

mg ha^{-1}	Miligram per hectare
ml/L	Milliter per liter
MLE	Moringa leaf extracts
Mn	Manganese
µmol $m^{-2}s^{-1}$	Micromole per meter square per second
µmol g^{-1} Fw	Micromole per gram fresh weight
µmoles	Micromoles
MPa	Mega pascal
MT 1	MARDI heat tolerant tomato variety
MSI	Membrane stability index
N	Nitrogen
Na	Sodium
NADP+	Oxidized Nicotinamide Adenine Dinucleotide Phosphate
NADPH	Reduced Nicotinamide Adenine Dinucleotide Phosphate
$^1O_2$	Singlet oxygen radical
O_2*	Superoxide radical
P	Phosphorous
PAR	Photosynthetically active radiation
pH	Potential of hydrogen or hydrogen ion concentration
Plt^{-1}	Per plant
Pn	Net photosynthetic rate
P_2O_5	Phosphorous pentoxide
POD	Peroxidase
ppb	Part per billion
ppm	Part per million
PSII	photosystem II
PSI	photosystem I
r^2	Coefficient of determination

RCBD	Randomized Complete Block Design
ROS	Reactive oxygen species
RWC	Relative water content
S	Sulphur
SAS	Statistical Analysis System
SDI	Sustained deficit irrigation
Shoot:Root	Shoot to root ratio
SPAC	Soil-Plant-Atmosphere-Continuum
SOD	Superoxide dismutase
TBA	Thiobarbituric acid
TCA	Tri carboxylic acid
TE	Trace element
$t\ ha^{-1}$	Tons per hectare
TLA	Total leaf area
TLA/fn	Total leaf area to fruit number ratio
Tchl	Total chlorophyll
Tr	Transpiration rate
TSS	Total soluble solid
UNDP	United Nation Development Program
Veg	Vegetative growth stage
Veg/fl	Vegetative and flowering growth stage
Veg/fr	Vegetative and fruiting growth stage
Veg/fl/fr	Vegetative, flowering and fruiting growth stage
V/V	Volume for volume
WAT	Weeks after transplanting
WUE	Water use efficiency
W/W	Weight for weight
YWUE	Yield water use efficiency

Zn	Zinc
ΦPSII	Effective quantum yield of photosystem II
Ψw	Leaf water potential
%	Percentage
°Brix	Degree brix
°C	Degree centigrade
°N	Degree north
°SE	Degree south east
$\pm$	Plus-minus
$\leq$	Less than or equal to
γ	Gamma

CHAPTER 1

INTRODUCTION

Water scarcity is a major challenge to crop production and the attainment of food security goals, especially in Sub-Saharan Africa (Mancosu et al., 2015; Rockstrom et al., 2010). This is usually ascribed to climate change and increased sectoral competition as a result of growing urbanization (Boutraa, 2010). However, Silva et al. (2015) opined that factors such as poor water management which intensify the effect of climate change and urbanization are more critical for crop production. In agreement, Zhang et al. (2017) had submitted that to reduce the effect of water scarcity on productivity there was a need to develop water saving agriculture and improve water use efficiency, which is currently low (Taft, 2015; Calzadilla et al., 2010).

One of the strategies that is been used to improve water use efficiency in agriculture is the application of deficit irrigation (Tejero et al., 2011). There are several advantages on the use of this strategy including better water use efficiency (WUE) through reduced evapotranspiration, improved produce quality, lower weed and pest problems (Chapagain et al., 2011). However, there is a major limitation to its use as it has being reported to reducecrop growth and yield. According to Fereres and Soriano (2007), reducing crop water use without a loss in crop productivity is a difficult task since evaporation from crop canopy is tightly associated to CO_2 fixation. Shahein et al. (2012) and Igbadun et al. (2012) had recorded 17.16 and 23.0 % reduction in tomato and onion yield respectively with deficit irrigation (DI). It is therefore, pertinent that strategies be developed to mitigate this inadvertent effect of DI (Akhtar et al., 2014). Attempts in this direction included the use of organic amendments such as manure, biosolids, mulch and compost. According to Hirich et al. (2014) the use of organic amendments in corn production improved yield performance by 10% under deficit irrigation conditions. Biological agents such as mycorrhiza, plant growth rhizobia, and plant growth enhancers have also been used to reduce the effect of DI induced stress.

Plant growth enhancers refer to substances which are capable of stimulating productivity and crop vigor. There use was inspired by the ability of plants to produce, accumulate or alter the relative abundance of certain metabolites in response to stress conditions. Such metabolites include hormones, antioxidants and compatible solutes. One important strategy of manipulating metabolites to imrove stress tolerance is the development of improved or transgenic varieties (Verbruggen and Herman, 2008). However, Ashraf and Foolad (2007) opined that transgenic plants suffer from an inability to accumulate enough of the target metabolites under stress. A second and alternative approach is the exogenous application of stress mitigating metaboliteswhich act as growth regulators, scavengers, and osmoprotectants. Whereas a wide range of synthetic chemicals have been evaluated and found useful in terms of their efficacy and predictability, their use is limited by their ralative high cost as well as concerns relating to environmental and consumer safety (Ashraf et al., 2008). As an alternative, a number of natural sources, including extracts of algae, humic acid, and plants such as *Moringa oleifera*are being evaluated for use.

Moringa leaf extracts is an important source of botanical biostimulants in agriculture (Yakhin et al., 2017). It has been used as a plant growth enhancer in the cultivation of different crops and in alleviating the effect of stress on crop productivity due to its rich content of bioactive compounds such as vitamin A, α-tochopherol, K, Ca, Mg, Zn, Zeatin and antioxidants (Biswas et al. 2016; Rady and Mohamed, 2015). Mvumi et al. (2012) had reported that the application of moringa leaf extract increased the yield of tomato by 150 % over untreated plants. In addition, farmers in arid regions can easily grow moringa as the plant is drought tolerant and requires low maintenance. Also the leaves can be processed into extracts for foliar spray using simple technologies (Yasmeen 2011; Moringanews/Moringa association of Ghana, 2010). Moringa leaf extracts can therefore be used as part of a low cost water management strategy in water scarce regions to reduce the effect of deficit irrigation on crop productivity.

Although much work has been done on the use of different concentrations of moringa leaf extracts to alleviate the effect of abiotic stress on crops, no attention has been paid to the optimization of concentration with timing of application under sustained deficit irrigation conditions. This study is therefore designed to optimize the concentration and timing of application of moringa leaf extracts for tomato production under sustained deficit irrigation.

1.1 General objective

The general objective is to evaluate effect of moringa leaf extracts (MLE) on stress-induced reduction in growth, physiology and yield of tomato cultivated under deficit irrigation technology.

1.2 Specific objectives

1. To developan effective sustained deficit irrigation level for tomato production under hot and humid low land condition
2. To determine the optimum concentration of moringa leaf extract (MLE) required for optimum growth, physiology and fruit yield of tomato under sustained deficit irrigation condition.
3. To study effects of applying the optimum MLE concentration at different growth stages of tomato on growth, physiology and yield of tomato under sustained deficit irrigation (SDI)
4. To compare and assess the effect of applying moringa leaf extracts (MLE) and benzyl amino purine (BAP) on growth, physiology, and yield of tomato under sustained deficit irrigation (SDI)

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