UNIVERSITI PUTRA MALAYSIA

IMPOSITION OF BENEFICIAL WATER STRESS FOR IMPROVEMENT OF POSTHARVEST QUALITY OF LOWLAND TOMATO FRUITS (Lycopersicon esculentum Mill.)

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By

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

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IMPOSITION OF BENEFICIAL WATER STRESS FOR IMPROVEMENT OF POSTHARVEST QUALITY OF LOWLAND TOMATO FRUIT (*Lycopersicon esculentum* Mill.)

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Chairman : Mahmud Tengku Muda Mohamed, PhD
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Water stress affects crop performance by influencing nutrient availability and crop functionality. There is a lack of information on utilization of deficit irrigation strategies in manipulating the growth rates, yield and quality of low land tomato plant in Malaysia. Present study was indicated to investigate the effects of different level of water stress on plant growth, yield and postharvest qualities. Two greenhouse experiments were conducted at Field 15, Faculty of Agriculture, Universiti Putra Malaysia. Experiment 1 was conducted to describe the effect of limiting strategically the water supply during plant development on plant growth, yield and postharvest quality, with the aim of identifying the best deficit schedule for the plants under low land tropical conditions. Three- week old MT1 tomato seedlings from the trays were transplanted into polybags filled with mixture of coco peat and paddy husk (2:1 V/V). After 40 days, the seedlings were treated with T1 control (daily watering to field capacity), T2 (restoring water supply to field capacity every two days) and T3 (restoring water supply to field capacity every four days). At harvest, plant height, leaves number, stem diameter, leaf area, dry shoot and root fresh and dry weight, fruit weight and fruit number were measured. In addition, data were collected on the following fruit quality parameters: firmness, total soluble solids, titratable acidity, pH, ascorbic acid and lycopene. The deficit irrigation applications increased soluble solids concentration significantly at T3 in the first experiment and at T4 (fruiting growth stage) in the second experiment. However, the rates of increment was not significantly different in titratable acidity, ascorbic acid, lycopene content, pH and firmness. The T2 (restoring water supply to field capacity every two days) promoted total fruit weight. Water stress treatments decreased plant heights, leaves number, leaf area, trusses number and both fresh and dry shoot and root weight. The leaf relative water content was reduced by 22.2% in the most stressed plants T3 (four days deficit irrigation) compared to the control. Whilst experiment 2 was conducted to identify the most critical phenological (plant growth stages) and fruit maturity stages to impose deficit irrigation and their effects on growth, yield and postharvest quality of tomato. Three weeks old seedlings were transplanted into polybags. Then, the seedlings were exposed to four water stress treatments: T1 (control), T2 (deficit irrigation every four days at the vegetative stage), T3 (deficit irrigation every four days at the flowering stage) and T4 (deficit irrigation every four days at the fruiting stage). All growth, yield and postharvest parameters were determined as in Experiment 1. The plants that subjected to deficit irrigation levels produced similar plant height and number of leaves to the control plants (full irrigation). However, fruit weight and number of fruit increased significantly under T3 (flowering stage) but not significantly different from those in control plants. In addition, water deficit irrigation at T4 (deficit imposed during fruiting stage) significantly reduced fresh and dry weight of shoots and root compared to the other treated and control plants. In conclusion, the optimum yield of tomato could be obtained at T3 (deficit imposed at flowering stage). The vegetative and flowering growth stages could be considered as the most tolerant to deficit irrigation, and the fruiting growth stage could be considered the most critical stage. Imposition water stress at flowering growth stage on tomato produced better plants condition, while using the water stress during fruiting stage retards plant growth by decreased plant growth and rate of yield. Fruits quality such as fruit firmness, pH of fruit, SSC, TA, AA and lycopene were affected significantly by deficit irrigation treatments. T4 (fruiting stage) fruits had the highest SSC in those harvested at the turning maturity fruit stage; high SSC improves both paste yield per unit of fresh fruit and overall processing efficiency. While the highest lycopene content was observed with those treated during vegetative stage harvested at the red maturity fruit stage. On the other hand, fruits harvested from T2 (vegetative stage) plants at turning maturity fruit stage gave the highest firmness. Highest pH fruit was obtained with T3 plants at red fruit maturity index. However, the results demonstrated that different deficit irrigation regimes did not affect TA and AA contents of tomato fruits, indicating that the results from of this study can enhance and maintaining post-harvest quality, also deficit irrigation strategy can help in the development of water management system for tomato production in the scenario of reduced water availability and enable the tomato growers to produce tomato with optimum yield by allowing little water stress without substantial yield reduction.

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

PENGENAAN TEGASAN AIR YANG BERMANFAAT BAGI PENAMBAHBAIKAN KUALITI PASCA TUAI BUAH TOMATO TANAH RENDAH (*Lycopersicon esculentum* Mill.)

Oleh

MOHAMMED HASSAN NAMA

Januari 2018

Pengerusi : Profesor Mahmud Tengku Muda Mohamed, PhD
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Tegasan air memberi kesan terhadap prestasi tanaman dengan mempengaruhi ketersediaan nutrien dan fungsi tanaman. Terdapat kekurangan maklumat mengenai penggunaan sistem pengairan defisit dalam memanipulasikan kadar pertumbuhan, hasil tuai dan kualiti tanaman tomato tanah rendah di Malaysia. Kajian ini dijalankan bagi mengkaji kesan perbezaan tahap ketegasan air terhadap pertumbuan pokok, hasil dan kualiti pasca tuai. Dua kajian dalam rumah hijau telah dijalankan di ladang 15, Fakulti Pertanian, Universiti Putra Malaysia. Eksperimen 1 telah dijalankan untuk menerangkan kesan mengehadkan bekalan air secara strategik semasa pertumbuhan tanaman terhadap tumbesaran, hasil tuai dan kualiti pasca tuai tanaman, dengan sasaran untuk mengenalpasti jadual defisit air terbaik untuk tanaman pada kondisi tanah rendah tropika. Anak benih tomato MT1 yang berusia tiga minggu telah dipindahkan dari dulang semaian ke dalam polibeg berisi sabut kelapa dan sekam padi (2:1 V/V). Selepas 40 hari, anak benih dirawat dengan T1, kawalan (pengairan harian ke kapasiti lapangan), T2 (memulihkan air kepada kapasiti lapangan setiap dua hari) dan T3 (memulihkan air kepada kapasiti lapangan setiap empat hari). Pada peringkat penuaian, tinggi pokok, bilangan daun, diameter batang, luas daun, berat segar dan kering pucuk dan akar, berat buah dan bilangan buah diukur. Di samping itu, data parameter kualiti buah: ketegasan, jumlah pepejal terlarut, asid tertitrat, pH, asid askorbik dan kandungan lycopene turut dikumpulkan. Pengairan defisit pada T3 dalam eksperimen pertama dan T4 (peringkat pembuahan) dalam eksperimen kedua meningkatkan kepekatan pepejal terlarut secara bererti, tetapi kadar peningkatan asid tertitrat, asid askorbik, kandungan lycopene, pH dan ketegasan adalah tidak berbeza bererti di antara rawatan. T2 (pemulihan sumber air kepada kapasiti lapangan setiap dua hari) menggalakkan jumlah berat buah. Rawatan tegasan air mengurangkan ketinggian tumbuhan, bilangan daun, luas daun, bilangan tangkai dan kedua-dua berat segar dan kering pucuk dan akar. Kandungan relatif air pada daun berkurang kepada

22.2% pada tanaman paling tinggi tegasan, T3 (pengairan defisit setiap empat hari) berbanding rawatan kawalan. Manakala eksperimen 2 telah dijalankan untuk mengenalpasti peringkat fonologikal dan kematangan buah paling kritikal untuk mengenakan pengairan defisit dan kesannya terhadap tumbesaran, hasil dan kualiti pasca tuai tomato. Anak benih berusia tiga minggu dipindahkan ke dalam polibeg. Kemudian, anak benih ini didedahkan kepada empat rawatan tegasan air: T1 (kawalan), T2 (pengairan defisit setiap empat hari pada peringkat pertumbuhan vegetatif), T3 (pengairan defisit setiap empat hari pada peringkat pembungaan) dan T4 (pengairan defisit setiap empat hari pada peringkat pembuahan). Semua parameter tumbesaran, termasuklah hasil dan pasca tuai telah dikenalpasti seperti dalam Eksperimen 1. Tanaman dengan tegasan air menunjukkan tinggi pokok dan bilangan daun yang sama dengan tanaman kawalan (pengairan penuh). Walau bagaimanapun, berat dan bilangan buah meningkat secara bererti pada T3 (peringkat pembungaan) tetapi tidak bererti berbanding tanaman kawalan. Di samping itu, pengairan defisit air mengurangkan berat segar dan kering pucuk dan akar pada T4 (defisit pada peringkat pembuahan) berbanding tanaman kawalan dan rawatan lain. Kesimpulannya, hasil tuai tomato yang optimum boleh dicapai pada T3 (pengairan defisit pada peringkat pembungaan). Peringkat tumbesaran vegetatif dan pembungaan boleh dianggap sebagai peringkat paling toleran kepada pengairan defisit air, dan peringkat tumbesaran buah boleh dianggap sebagai peringkat paling kritikal. Pengenaan tegasan air pada peringkat pembungaan tomato menghasilkan tanaman yang baik, manakala pengenaan tegasan air pada peringkat pembuahan merencat pertumbuhan pokok dengan mengurangkan tumbesaran pokok dan kadar hasil tuai. Kualiti buah-buahan seperti ketegasan buah, pH, kepekatan pepejal terlarut, asid tertitrat, asid askorbik dan lycopene terjejas dengan ketara terhadap rawatan pengairan defisit. Buah-buahan T4 (peringkat pembuahan) mengandungi kepekatan pepejal terlarut tertinggi berbanding hasil lain yang dituai pada peringkat pertukaran kematangan buah; tinggi kepekatan pepejal terlarut meningkatkan kedua-dua hasil pes per unit buah segar dan kecekapan pemprosesan keseluruhan. Manakala kandungan lycopene tertinggi pada hasil tuai dengan rawatan di peringkat vegetatif dituai pada peringkat kematangan buah merah. Sebaliknya, buah-buahan yang dituai dari tanaman T2 (peringkat vegetatif) memberikan kepejalan buah tertinggi pada peringkat pertukaran kematangan. Selain itu, pH buah tertinggi telah dicapai melalui tanaman T3 pada indeks kematangan buah merah. Walau bagaimanapun, hasil kajian menunjukkan perbezaan rejim pengairan defisit tidak menjejaskan kandungan asid tertitrat dan asid askorbik buah-buah tomato, menunjukkan bahawa keputusan dari kajian ini dapat menambah dan mengekalkan kualiti pasca tuai, strategi pengairan defisit juga dapat membantu dalam pembangunan sisem pengurusan air untuk pengeluaran tomato dalam senario pengurangan sumber air dan membolehkan pengusaha tomato untuk menghasilkan tomato dengan hasil yang optimum dengan membenarkan sedikit ketegasan air tanpa mengalami pengurangan hasil.

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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 Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

^0C	Degree celcius
AA	Ascorbic acid
Anova	Analysis of variance
cm	Centimetre
DAT	Day after treatment
DI	Deficit Irrigation
Dw	Dry weight
ET	Evapotranspiration
ETc	Crop Evapotranspiration
FC	Field Capacity
Fw	Fresh weight
g	Gram
ha	Hectare
kg	Kilogram
LRWC	Leaf Relative Water Content
LSD	Least Significant Difference
LWP	Leaf water potential
M	Molarity
m	Meter
MARDI	Malaysian Agricultural Research and Development Institute
MC	Moisture content
mg	Milligram
mm	Millimetre
Ms	Fruit maturity stage

PRD	Partial root zone drying
RCBD	Randomized Complete Block Design
RDI	Regulated deficit irrigation
SAS	Statistical Analysis System
SSC	Soluble Solids Concentration
TA	Titratable Acidity
USDA	United State Department of Agriculture
WUE	Water Use Efficiency

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is a member of the night shade family, Solanaceae (Costa and Heuvelink, 2005). It is a highly versatile crop and is among the most widely consumed vegetables. The fruits are rich in vitamins and minerals and contains the valuable carotenoid, lycopene, which is a vital factor in cardiovascular protection and relief of oxidative stress (Abete et al., 2013). Along with total soluble solids (TSS), a valuable attribute for the fruit processing industries, the aforementioned properties constitute part of tomato's important quality parameters that are usually the target of enhancement or maintenance strategies, either at the pre- or postharvest end of the value chain (Ilahy et al., 2011).

According to Arpaia (1994), a postharvest physiologist is interested in maximizing the postharvest quality of horticultural commodities. However, it has been suggested that optimum postharvest quality of vegetables is intrinsically tied to pre-harvest processes or factors. According to Meaza et al., (2007) cited in Sibomana et al. (2015), pre-harvest factors such as the crop genetic status, cultural practices and environmental conditions influence the post-harvest quality of crops. Workneh et al. (2012), reported improved postharvest quality and storability when tomato plants were subjected to pre-harvest treatments that included natural growth enhancers. However, Silva, (2011) reported that the effects of pre-harvest factors are not usually factored into the planning of post-harvest programmes, thereby overlooking a very significant aspect. Whereas post-harvest programmes aim to maintain the quality of produce until they are utilized by consumers, a major determinant of those qualities is the conditions and management practices to which the crop was subjected while in the field. Such factors as irrigation scheduling, including its adequacy and timeliness, fertilization, cultural practices such as weeding, pest control, plant population etc, which influence crop growth and development invariably affect the development and quality of the harvest. It must be noted that nothing can be added to the quality attained at harvest during postharvest treatment. It is therefore pertinent that pre-harvest factors are carefully planned and manipulated with a view to influencing postharvest quality and shelf life (Silva, 2011).

Two major pre-harvest factors that influence post-harvest qualities are watering and maturity fruit harvesting stages (Sibomana et al. (2015); Kader, (1997). According to Sibomana et al. (2015), water supply is a critical determinant of fruit yield and the crop is sensitive to soil moisture level during growth and development. It significantly affects fruit weight, firmness, total soluble solids and titratable acidity. According to Boamah et al. (2010), water deficit reduced tomato growth, fruit yield and quality while Cantore et al. (2012) held that too much water may result in root hypoxia which invariably reduces yield. Mpelasoka et al. (2001) on the other hand enthused that deficit irrigation (DI) enhanced fruit total soluble solid and firmness as well as their maintenance during storage at 0˚C. Dorji et al. (2005) also reported enhanced fruit quality and postharvest quality with DI treatment. They found that the total soluble solid of pepper was higher than control by 8 %. The DI treatment also modified the performance of different quality parameters at different maturity stages. For example, Dorji et al. (2005) found that TSS was 10.2 % for DI at the firm red stage as against 8.4 % for control and 5.0 % at the matured green stage as against 4.5 % in control. From the foregoing, it can be concluded that proper water management for crop growth and yield is not just an important crop management factor but also an important strategy for maintaining post-harvest quality. It would therefore be beneficial to determine the level of water supply that would result in better quality and storability. In this regard a paradigm shift from a principle of adequate water supply to optimum water supply becomes necessary.

This becomes even more pertinent when taken together with the fact that meeting agricultural water demand is increasingly been complicated by its growing scarcity. Globally, water resources have been observed to be declining at an alarming rate, leading to fear of future wide spread scarcity. According to Escobar (2010), by 2025 about half of the population of the world would be facing water scarcity. Water deficit or drought is, globally, the most common stress condition and it is increasingly of concern worldwide (Reddy et al., 2004; Mahajan & Tuteja, 2005). Absolute water stress is found most notably in arid and semi-arid regions with high population densities such as parts of India, China and the Middle East/North Africa (MENA) region. The MENA region is increasingly unable to produce the food required locally due to increasing water stress from a combination of population increase, economic development and climate change, and will have to rely more and more on food (and virtual water) imports. In arid and semi-arid regions, water availability is often a key limiting input.

Tomatoes are very sensitive to drought stress, initially during vegetative development and, later, when the tomato is in the reproductive stage (Wudiri & Henderson, 1985). Poor management is, in most cases the real culprit of water was related to low productivity in agriculture and also a major factor in the growing scarcity of water. In line with this opinion, Boutraa, (2010a) reported that only about 50 % of all water extracted for agricultural purposes are utilized. What is required then is deft management of water resources in such a way as to enhance crop productivity. Water management practices are the tools which can serve to protect our natural capital in water resources and avoid the critical situation for the survival and sustainability of agriculture and economic activities which would ensue from their decline (Postel, 2000). Although the development of irrigation has contributed greatly to increased crop productivity as well as improvement in overall agricultural performance (Hussain and Wijerathna. 2004), it is not without its cost, including negative environmental and health consequences such as increased water logging, scarcity, salinization and water-borne diseases. Some of these problems could be remedied by better management. One management strategy in use is deficit irrigation. Geerts & Raes, (2009) had recommended it as a water saving technology in arid regions and other water scarcity prone areas.

This study, will describe the effects of limiting water supply to emulate water stress during plant development on postharvest qualities of tomato fruits with the aim of identifying the best deficit irrigation program and also the effects of water stress on tomato fruits at different phenological stages of tomato plant development on yield and quality of different fruit maturity stages. This will enable us to look at the benefits that can be derived with controlled stress imposed as a management practice. Even numerous studies were performed on beneficial DI effects on tomato, but with the current variety used, this study was deemed with merit.

The objectives of this study were to examine the soil moisture depletion that can be allowed in irrigating tomatoes with a view to investigate the effects of different level of water stress on plant growth, yield and postharvest qualities as well as determined water stress effects on lycopene content and tomato fruit quality in the lowland under tropical conditions. The specific objectives of this study were to:

i. Determine the best water stress level for optimum tomato productivity.
ii. Determine the effects of water stress at different phenological stages on plant growth and yield of tomato plant development, and quality of fruits at different fruit stages.

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