UNIVERSITI PUTRA MALAYSIA

ENHANCEMENT OF CHERRY TOMATO (Solanum lycopersicum var. *cerasiforme) GROWTH, PHYSIOLOGY, YIELD AND QUALITY IN RELATION TO MEDIA TYPES, SHADING AND ELEVATED CARBON DIOXIDE UNDER DIFFERENT GREENHOUSE SYSTEMS*

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FP 2021 20

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By

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

December 2019

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

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December 2019

Chairman : Associate Professor Siti Zaharah Sakimin, PhD
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Cherry tomato (*Solanum lycopersicum* var. cerasiforme) is crisp and juicy compared to regular tomato. The bite-sized cherry tomato leads to high demand in regular consumption among community for healthy snacking. However, uncertainty weather pattern was determined as one of the factors that can impact to the food production. Due to the climate changes impact around the world, tomato was found to have better growth, yield and good quality if it is been grown under greenhouse conditions. However, the environmental conditions inside the greenhouse such as media types, amount of light intensity and level of carbon dioxide (CO_2) need to be optimised to improve the growth performance, yield production and quality of tomato. Thus, the objectives of this study were to investigate the effect media type, light intensity level and CO_2 elevation on growth performance, physiology changes, yield production and quality of tomato grown under greenhouse conditions. In Experiment 1, seedlings variety Ruby Red cherry tomato was planted using three different types of media [coconut coir dust (CCD), mixed soil, and top soil] under two different greenhouse systems; smart greenhouse system (SGS) and conventional greenhouse system (CGS). The plants were observed at 30, 60 and 90 days after transplant (DAT). The experiment was arranged in randomized complete block design (RCBD). Plant height, total leaf area, shoot and root dry, root to shoot ratio (R:S), photosynthetic rate, stomatal conductance, transpiration rate, and water use efficiency and yield showed the best performance and significantly highest when the plant grown under CCD. In Experiment 2, Ruby Red cherry tomato seedlings was grown using CCD media which was optimized from Experiment 1. The seedling was then shaded using 0, 50% and 70% black netting to allow 100%, 50% and 30% light penetration, respectively. The plant was placed under greenhouses elevated with 800 ppm CO_2 elevation at 8-10 am daily(SGS) and non-elevated CO_2 (CGS) as control. Exposing tomato seedling in

higher CO_2 concentration reduced plant height, total leaf area and total biomass than control. The number of lateral roots increased under SGS compared to CGS and that the length of the roots increased as well. Upon CO_2 enrichment happened, there was a reduction in stomatal conductance and transpiration rate which reduced the loss of water in the atmosphere. Higher concentration CO_2 level can contribute heat stress to the plant due to the increase in temperature up to 52°C. As consequently fruit setting was delayed about 3 weeks as compared to the plant grown under CGS. Nevertheless, tomato plant received 50% of light penetration has the highest lycopene content in both greenhouses compared to other shading level. In conclusion, CCD is recommended as growing media and shading did not help in reducing temperature under elevated CO_2 greenhouse especially in tropical region.

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

PENINGKATKAN PERTUMBUHAN CERI TOMATO (*Solanum lycopersicum* var. cerasiforme), FISIOLOGI, HASIL DAN KUALITI YANG BERHUBUNGAN DENGAN JENIS MEDIA, ARAS TEDUHAN DAN KARBON DIOKSIDA DI BAWAH SISTEM RUMAH LINDUNGAN HIJAU YANG BERBEZA

Oleh

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Tomato ceri (*Solanum lycopersicum* var. cerasiforme) adalah segar dan berair berbanding tomato biasa. Saiz yang kecil membawa kepada permintaan yang tinggi dalam kegunaan berterusan di kalangan masyarakat sebagai makanan ringan yang sihat. Walau bagaimanapun, corak cuaca yang tidak menentu ditentukan oleh salah satu faktor yang memberi kesan kepada pengeluaran makanan. Oleh kerana kesan perubahan iklim di seluruh dunia, tomato didapati mempunyai pertumbuhan yang lebih baik, hasil dan kualiti yang baik jika ia ditanam di bawah keadaan rumah hijau. Walau bagaimanapun, keadaan persekitaran di dalam rumah hijau seperti jenis media, jumlah intensiti cahaya dan tahap karbon dioksida (CO_2) perlu dioptimumkan untuk meningkatkan prestasi pertumbuhan, pengeluaran hasil dan kualiti tomato. Oleh itu, objektif kajian ini adalah untuk mengkaji jenis kesan media, tahap intensiti cahaya dan peningkatan CO_2 terhadap prestasi pertumbuhan, perubahan fisiologi, pengeluaran hasil dan kualiti tomato yang ditanam di bawah keadaan rumah hijau. Dalam Eksperimen 1, anak benih Ruby Red tomato ceri ditanam menggunakan tiga jenis media [habuk sabuk kelapa (CCD), tanah campur, dan tanah atas] di bawah dua sistem rumah hijau yang berbeza; sistem rumah hijau pintar (SGS) dan sistem rumah hijau konvensional (CGS). Tumbuhan ini diperhatikan pada 30, 60 dan 90 hari selepas pemindahan (DAT). Eksperimen itu telah disusun dalam reka bentuk blok lengkap rawak (RCBD). Ketinggian tumbuhan, jumlah keluasan daun, berat kering pucuk dan akar, nisbah pucuk kepada akar (R:S), kadar fotosintesis, konduktansi stomata, kadar transpirasi, dan kecekapan penggunaan air dan hasil menunjukkan prestasi terbaik dan paling tinggi apabila tumbuhan ditanam di bawah CCD. Dalam Eksperimen 2, benih tomato Ruby Red ceri telah ditanam menggunakan media CCD yang dioptimumkan dari Experiment 1. Anak benih kemudiannya telah dinaungi dengan menggunakan jaring hitam 0, 50% dan 70% untuk membolehkan penembusan cahaya 100%, 50%

dan 30%. Tumbuhan telah diletakkan di bawah rumah hijau yang telah ditingkatkan 800 ppm CO_2 pada 8-10 pagi setiap hari (SGS) dan tidak ditingkatkan CO_2 (CGS) sebagai kawalan. Pendedahan anak benih tomato dalam kepekatan CO_2 yang lebih tinggi mengurangkan ketinggian tumbuhan, jumlah daun dan jumlah biomas dari kawalan. Bilangan akar sisi meningkat di bawah SGS berbanding dengan CGS dan panjang akar meningkat juga. Apabila pengayaan CO_2 berlaku, terdapat pengurangan kadar konduktansi stomata dan transpirasi di mana menghindarkan kehilangan air di udara. Tahap kepekatan CO_2 yang lebih tinggi boleh menyumbang tekanan haba kepada tumbuhan kerana peningkatan suhu sehingga 52°C. Oleh itu, penghasilan buah telah ditangguhkan sekitar 3 minggu berbanding dengan tumbuhan yang ditanam di bawah CGS. Walau bagaimanapun, tumbuhan tomato yang menerima 50% penembusan cahaya mempunyai kandungan lycopene tertinggi di kedua rumah hijau berbanding dengan tahap naungan yang lain. Kesimpulannya, CCD disyorkan sebagai media penanaman dan teduhan tidak dapat menurunkan suhu dan kelembapan relatif di bawah rumah hijau yang ditingkatkan CO_2 terutamanya di kawasan tropika.

ACKNOWLEDGEMENTS

Alhamdulillah, thanks to Allah Almighty for His mercy and blessing that giving me opportunity and time to complete my Master study.

I would like to express my sincere gratitude to my supervisor, Associate Professor Dr. Siti Zaharah bin Sakimin for her guidance, patience, motivation, enthusiasm, and immense knowledge throughout my study period. I am also thankful to my committee member, Dr. Ahmad Suhaizi bin Mat Su for his insightful comments and encouragements. May ALLAH SWT bless all of you here and hereafter, Insha Allah.

Special thanks towards my supportive friends especially in Postgraduate Room 2, Aimi, Zarina, Farahin, Rabiatul, Ilya, Huda, Iffah, Arina and Anna for giving me strength physically and spiritually to complete my study. Not to forget, Aiman, Liza, Fahida, Yi and Elmira for helping me lots during running the experiment. I would also like to thank all the staffs and everyone who have helped me for all their patience and support. May ALLAH SWT bless your life and happiness here and hereafter, Insha Allah.

I am also thankful to Ministry of Education for giving me opportunity, financial support and study leave under Hadiah Latihan Persekutuan Scholarship.

Last but not least, my deepest appreciation goes to my husband, Muhammad Termizi bin Hasni for giving me blessing to pursue my study and support me during the trials and turbulence during this study. I am also thankful to my son, Judd Muhammad bin Muhammad Termizi for always being so easy, kind and understanding during my study period. Special thanks to my parents, parents in law, siblings, siblings in law for giving me full support, faith and unconditional love. May ALLAH SWT grant all of you Jannah, Insha Allah.

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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This is to confirm that:

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LIST OF ABBREVIATIONS

AA	Auto Analyzer
AAS	Atomic Absorption Analyzer
ANOVA	Analysis of variance
CCD	Coconut coir dust
CGS	Conventional Greenhouse System
CO_2	Carbon dioxide
DAT	Day after transplant
DOA	Department of Agriculture
DPPH	2,2-diphenyl-1-picrylhydrazyl
GH	Greenhouse
IPCC	Intergovernmental Panel on Climate Change
LSD	Least significance different
PPM	Parts per million
SGS	Smart Greenhouse System
TSS	Total soluble solid
WUE	Water use efficiency

CHAPTER 1

INTRODUCTION

Malaysian tropical climate characteristic is favourable for production of various fruits and vegetables. However, Malaysia is vulnerable to climate change which is threating agriculture industry. Under climate changes phenomenon, conventional open field cultivation was seen not effective to increase the agriculture productivity. Heavy rainfall was recorded during November to February especially in East Coast Peninsular Malaysia caused negatively effect on soil nutrient deficiency leads to poor growth of plant. In addition, the increasing temperature was recorded between 37 to 40^{o}C especially in West Coast Peninsular Malaysia during Mac until May 2019 enhanced evapotranspiration that leads to reduce water availability and also disturbing flower setting of plant. Therefore, protected cultivation was introduced in Malaysia to avoid any circumstances especially in climate changes.

The main purpose of using protected cultivation in tropical region especially Malaysia is to avoid extreme temperature, wind and pests (Shamsiri, 2014). In the mid-1980's, Tropical Lowland Greenhouses (TLG) was introduced by using plastic cover rain shelters (Hawa, 1998). The performance of TLG showed significant potential in crop productivity (Hawa, 1990) by increasing the yield production of tomato, sweet pepper and celery between 10 – 15 times more than open cultivation with optimal temperature (27^{o}C) and CO_2 enrichment (Hawa, 2003). Greenhouse as defined as covered structure not only protect crop from extreme weather, it is also protecting crop from pest and diseases. Therefore, planting media play as a key role to boost growth performance of every plants inside greenhouse. The main functions of media are to support plant growth physically, applicable for maximizing root growth to improve the uptake of nutrients and water. Growth media should have good aeration, proper drainage, high water holding capacity, right cation exchange capacity and lack of weed seeds, pests and diseases and other harmful materials that can distract the plant growth (Mirseyed, 2017; Mitchell et. al., 1991; Gaur et. al., 1990).

One of the priorities in greenhouse installation is microclimate condition to achieve optimal growing environment. The incorrect maintenance of temperature, relative humidity, light penetration and CO_2 concentration can adversely affect plant growth thereby reduced productivity. The temperature inside TLG was reported could be increased about 20 – 30^{o}C higher than the outside due to solar radiation (Shamsiri, 2016). The increasing of temperature inside greenhouse caused by heat which is transferred by solar radiation. According to Jones (2007), the minimum requirement of solar radiation for tomato plant is about 2.34 kWh/m^2/day. In addition, the reduction of light level less than 15% causes significantly reduced in fruit yield (Anderson, 1996). In Malaysia, the average of solar radiation is about 4.32 kWh/m^2/day (TNBR, 2012). High solar radiation was found to decrease tomato fruit quality in term of cracking and sunscald injuries. Therefore, shading was suggested to reduce and prevent heat transfer from excessive light inside greenhouse. In addition, the implementation of shade could enhance crop growth and production (Ilic et. al., 2015).

Ozer (2017) found that, the usage of 50% shading could increase the rate of photosynthesis, stomatal conductance and chlorophyll content compared to open cultivation.

On the other hand, CO_2 concentration inside greenhouse significantly reduced below outside level due to the dense of crop growth. An odorless and colorless gas was observed plays important role in photosynthesis. The stimulation of CO_2 enrichments in photosynthesis depends with different plant either C_3 or C_4. According to Li et. al. (2013), the elevated CO_2 greenhouse could improve the efficiency of crops due to decrease stomatal conductance and water use-efficiency. Nonetheless, CO_2 enhancement was found associated with temperature. The positive effect of elevated CO_2 greenhouse was negatively found when crops were grown in high temperature (Benlloch-Gonzalez et. al., 2014). Thus, proper ventilation needs to be installed in greenhouse which elevated CO_2 to provide favourable condition for crop growth (Shamsiri, 2013).

Cherry tomato (*Solanum lycopersicum* var. cerasiforme) is one of the most widely cultivated vegetable inside greenhouse. It is highly demand because of the crunchier taste compared to regular tomato. The favourable microclimate for cultivating cherry tomato inside greenhouse is moderate to warm climate with appropriate light setting to improve fruit development and yield. According to Heauvelink (2005), the optimal temperature for tomato germination is recommended to be at 25^{o}C while seedling growth should be grown between 16 – 18.5^{o}C (Jones, 2013). Moreover, the air temperature reaching 32^{o}C is progressively reduced tomato production (Adam et.al, 2001). In Malaysia, major tomato cultivation is in highlands such as Pahang (Cameron Highland), Kelantan (Lojing) and Sabah (Kundasang). However, the demand of tomato shows increments due to increase population, level of income and food consumption changes. Therefore, Malaysia needs to import almost 60% of tomato from Thailand to fulfill the demand (Hengky, 2016). The shift of tomato cultivation from highland to lowland cause adversely affect the growing due to climate factors.

Therefore, the objectives of this research work were;

1. To investigate the growth performances, physiological changes, yield and quality of cherry tomato in relation to media type under different greenhouse system.
2. To determine the growth performances, physiological changes, yield and quality of tomato in relation to shading level and CO_2 elevation in different greenhouse systems grown using optimized media.

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PUBLICATION

Hairin, N. E. M., Sakimin, S. Z., Ramlan, M. F., Baghdadi, A., Mat Su, A. S., & Dahlanand, N. Y. (2018). Growth Performance and Yield Production of Cherry Tomato as Affected by Media Types and Grown under Different Greenhouse Systems. *Proceedings of the 8th International Agriculture Congress 2018 & 6th International Symposium for Food & Agriculture 2018*. Malaysia.

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