EFFECTS OF CONCENTRATION AND FREQUENCY OF PACLOBUTRAZOL APPLICATION ON GROWTH, YIELD AND QUALITY OF WATERMELON (*Citrullus lanatus* (Thunb.) Matsum. & Nakai]

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

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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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Chairman : Associate Professor Siti Zaharah binti Hj. Sakimin, PhD
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Watermelon (*Citrullus lanatus*) excessively grows and has an abundantly branching habit, resulting in a requirement of continual pruning to control vegetative growth and trigger reproductive development. Paclobutrazol (PBZ) is a plant growth regulator commonly used in agriculture to control plant height and increase yields. Previous studies have shown that PBZ can significantly reduce plant height. However, the effect of PBZ on the growth and yield of watermelons grown under a greenhouse is unknown. Thus, the objectives of this study were to investigate the effects of PBZ different concentration, watermelon varieties, and frequency of PBZ application on growth performance, yield production, and quality of watermelon grown under greenhouse conditions. In the first experiment, the effects of five concentrations (0, 250, 500, 750, and 1000 mg/L) of PBZ were applied as a foliar spray on three varieties of watermelon: Mellow oblong (GE344), Red Delight (GE341), and Oval Yellow (SSH348) and their growth and yield were evaluated. The experiment was arranged in a factorial Randomized Complete Block Design (RCBD) with three replications. Among the PBZ treatments, the reduction in plant height for 250 mg/L was almost 14.26% compared to the non-treated plants, while watermelon applied with 1,000 mg/L PBZ showed extremely lowest plant height. This study shows that the variety GE344 Mellow oblong was better, and produced significantly the highest relative chlorophyll content, TSS%, fruit weight, number of the female flower, and root volume compared to other treatments. The highest relative chlorophyll content, percentage of TSS, fruit diameter, and root fresh and dry weights, root diameter was found in the application of 250 mg/L PBZ as compared to other PBZ concentrations. The application of 250 mg/L of PBZ increased relative chlorophyll content, number of the female flower, root fresh weight, root dry weight, root diameter, and fruit diameter rate by 61.12%, 71.63%, 51.49%, 42.12%, 48.38%, 57.20%, and 18.83%, respectively, compared to the non-treated plants. In the second experiment, the treatment involved the best variety from Experiment 1 (Mellow oblong), and three frequencies of PBZ application: T0 = control (without PBZ application), T1 = single application of 250 mg/L applied at 15 DAT, and T2 = 125 mg/L

of PBZ applied twice at 15 and 30 DAT were used. Watermelon plant received T1 treatment resulted the highest lycopene content compared to T2 and T0. Watermelon plant treated with T1 obtained the highest chlorophyll a, relative chlorophyll content, lycopene content, total phenolic content and increased by 30.22%, 39.14%, 35.15%, and 119.58%, and significantly decreased by 21.48% of plant height, respectively than control. T2 treatment decreased leaf area, leaf dry weight, and fruit weight by 14%, 15%, and 38.32%, respectively, compared to the non-treated plants. In conclusion, the application of T1 (250 mg/L of PBZ and single frequency) as a foliar spray controls growth, improved yield and quality as well as the physiological process of watermelon crop.

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

KESAN KEPEKATAN DAN KEKERAPAN PACLOBUTRAZOL APLIKASI TERHADAP PERTUMBUHAN, HASIL DAN KUALITI TEMBIKAI (*Citrullus lanatus* (Thunb.) Matsum. & Nakai]

Oleh

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Tembikai (*Citrullus lanatus*) tumbuh secara berlebihan dan mempunyai tabiat bercabang yang banyak, sehingga memerlukan pemangkasan berterusan untuk mengawal pertumbuhan vegetatif dan mengaruh perkembangan pembiakan. Paclobutrazol (PBZ) ialah pengawal selia pertumbuhan tumbuhan yang biasa digunakan dalam pertanian untuk mengawal ketinggian tumbuhan dan meningkatkan hasil. Kajian terdahulu telah menunjukkan bahawa PBZ boleh mengurangkan ketinggian tumbuhan dengan ketara. Walau bagaimanapun, kesan PBZ terhadap pertumbuhan dan hasil tembikai yang ditanam di bawah rumah hijau tidak diketahui. Oleh itu, objektif kajian ini adalah untuk mengkaji kesan kepekatan PBZ, varieti, dan kekerapan penggunaan PBZ terhadap prestasi pertumbuhan, perubahan fisiologi, pengeluaran hasil, dan kualiti tembikai yang ditanam di bawah keadaan rumah hijau. Dalam eksperimen pertama, kesan lima kepekatan (0, 250, 500, 750, dan 1000 mg/L) PBZ digunakan sebagai semburan daun pada tiga jenis tembikai: Mellow bujur (GE344), Red Delight (GE341), dan Oval Yellow (SSH348) dan pertumbuhan serta hasil mereka dinilai. Eksperimen telah disusun dalam Reka Bentuk Blok Lengkap Rawak (RCBD) faktorial dengan tiga replikasi. Di antara rawatan PBZ, pengurangan ketinggian tumbuhan untuk 250 mg/L adalah hampir 14.26% berbanding tumbuhan yang tidak dirawat, selain itu tembikar yang dirawat dengan 1,000 mg/L PBZ menunjukkan ketinggian tumbuhan yang sangat rendah. Kajian ini menunjukkan bahawa varieti GE344 Mellow bujur adalah lebih baik, dan menghasilkan kandungan klorofil relatif tertinggi, TSS, berat buah, bilangan bunga betina, dan isipadu akar secara signifikan berbanding rawatan lain. Kandungan klorofil relatif tertinggi, peratusan TSS, diameter buah, dan berat segar dan kering akar, diameter akar telah diperolehi dalam penggunaan 250 mg/L PBZ berbanding kepekatan PBZ yang lain. Penggunaan 250 mg/L PBZ meningkatkan klorofil relatif, bilangan bunga betina, berat segar akar, berat kering akar, diameter akar, dan kadar diameter buah sebanyak 61.12%, 71.63%, 51.49%, 42.12%, 48.38%, 57.20 %, dan 18.83%, masing-masing, berbanding tumbuhan yang tidak dirawat. Dalam eksperimen kedua, rawatan melibatkan varieti terbaik daripada Eksperimen 1 (Mellow bujur), dan tiga frekuensi aplikasi PBZ: T0 =

kawalan (tanpa aplikasi PBZ), T1 = penggunaan tunggal 250 mg/L digunakan pada 15 DAT dan T2 = 125 mg/L PBZ digunakan dua kali pada 15 dan 30 DAT. Tanaman tembikai yang menerima rawatan T1 menghasilkan kandungan likopen tertinggi berbanding T2 dan T0. Tanaman tembikai yang dirawat dengan T1 memperoleh klorofil a tertinggi, kandungan klorofil relatif, kandungan likopen, jumlah kandungan fenolik dan meningkat sebanyak 30.22%, 39.14%, 35.15%, dan 119.58%, dan menurun dengan ketara sebanyak 21.48% ketinggian tumbuhan, masing-masing berbanding kawalan. Rawatan T2 mengurangkan luas daun, berat kering daun, dan berat buah masing-masing sebanyak 14%, 15%, dan 38.32%, berbanding tumbuhan yang tidak dirawat. Kesimpulannya, penggunaan T1 (250 mg/L PBZ dan frekuensi tunggal) sebagai semburan daun mengawal pertumbuhan, peningkatan hasil dan kualiti serta proses fisiologi tanaman tembikai.

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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

PBZ	Paclobutrazol
ABA	Abscisic Acid
mg/L	Milligram per litre
%	Percentage
°C	Degree Celsius
mL	Millilitre
cm	Centimetre
mm	Millimetre
cm^2	Centimetre square
cm^3	Centimetre cubic
Mg	Magnesium
g	Gram
mg	Milligram
Kg	Kilogram
GA	Gibberellin
ppm	Part per million
RCBD	Randomize complete block design
LSD	Least significant difference
ANOVA	Analysis of variance
CV	Coefficient determination
mg g^{-1} FW	Chlorophyll unit
pH	Measurement for hydrogen ion concentration
min	Minute
A_{503nm}	Optical density at wavelength 503 nanometer
nm	nanometre

µg/ml	Microgram per millilitre
GAE	Gallic acid equivalents
µL	Microliter
FAO	Food and Agriculture organization
DOA	Department of agriculture of Malaysia
DAT	Days after Transplanting
WAT	Weeks after treatment
<	Less than
>	More than
H	Hour
UPM	Universiti Putra Malaysia
USA	United States of America

CHAPTER 1

INTRODUCTION

1.1 Background

Watermelon (*Citrullus lanatus* (Thunb.)) is an important commercial fruit that is widely planted and consumed around the world (Liu et al., 2018). Global watermelon production in 2020 was 101,620,420 tons with China (59.13%), Turkey (3.44%), and India (2.74%) among the largest producers according to the FAO (FAOSTAT, 2022). Watermelons are major crops of the gourd family cucurbitaceae (Kamarubahrin et al., 2019). The centre of origin of the dessert watermelon is North-eastern Africa, that over 4,000 years ago, watermelons were domesticated for food and water, and Around 2,000 years ago, sweet dessert watermelons first emerged in the Mediterranean area (Paris, 2015). Watermelon is an annual, monoecious herb with long, hairy, ridged stems that are scandent or trailing on the ground, with curly and bifid tendrils (Lim, 2012). The tall, highly branched stems can reach up of 914.5 cm. (Wehner, 2008). It grows very vigorous and requires continues pruning (Huang et al., 1989).

Plant growth retardants are synthetic substances that are used to shorten the size of a plant's stems in a controlled manner without altering developmental patterns or causing phytotoxicity (Rademacher, 2000). Utilizing inhibitors of gibberellin (GA) biosynthesis will help fruit trees stay more compact, reducing pruning costs and achieving a better ratio between vegetative growth and fruit production, which also reduces the amount of space required in a greenhouse for production (Rademacher, 2015). Paclobutrazol (PBZ) is a synthetic plant growth regulator (PGR) that has been used to improve the economic yields of various tree crops by controlling vegetative growth and improving flowering and fruiting patterns (Davis et al., 2011). Paclobutrazol [(2RS, 3RS)-1-(4-chlorophenyl)-4, 4-dimethyl-2-(1H-1, 2, 4-trizol-1-yl)-pentan-3-ol], is one of the members of triazole family containing growth regulating characteristics (Soumya et al., 2017). Paclobutrazol was first reported as a new and incredibly powerful PGR by Lever et al. (1982). One of commercial product of PBZ is also known as PP333 under the trade names of Bonzi, Clipper, Cultar or Parlay is under active development as plant growth retardants (Davis et al., 2011). The inhibitory impact of PBZ produces through the inhibition of the oxidation steps of ent-kaurene to ent-kaurenoic acid in the pathway of GA biosynthesis (Hedden & Graebe, 1991).

Enhances in flowering and fruiting of PBZ-treated plants could result from the inhibition of GA biosynthesis, which changed the sink source relationship by reallocating the carbohydrate source forwards other parts of plants than the stem apex (Rai et al., 2003). Tolerance to various biotic and abiotic stresses is induced by PBZ. (Baninasab & Ghobadi, 2011). In watermelon seedlings applied with 150 ppm PBZ caused 23.4% and 16.2% reduction of height and leaf area, respectively and increase the chlorophyll content in the four crop species of squash, cucumber, watermelon, and melon (Flores et al., 2018). Foliar spraying with high concentrations of 400 and 600 mg/L of PBZ reduced terminal growth of lettuce, whereas the soil drench of PBZ significantly reduced vegetative growth traits and total soluble solids (TSS) and dry matter content were

increased as compared to control (Abed, 2018). Orabi et al. (2010) observed that after one week of transplanting applying PBZ at the rate of 25 or 50 mg/L decreased the plant height and increased chlorophyll a, b, and carotenoids in cucumber seedlings. In watermelon, zucchini squash, and cucumber, Wang (1985) noted that PBZ increased resistance to low temperatures while simultaneously reducing plant height and stem length. Height of watermelon was decreased by PBZ compared to non-treated. Mohammed et al. (2017) found that foliar PBZ sprayed on *Lagerstroemia indica* plants produced more flowers and leaves and decreased internode length, leaf dry weight, leaf area, and stem dry weight in comparison to those produced by the soil drenched plants. Paclobutrazol improved root diameter by expanding width of the cortex and by promoting the production of more secondary xylem lvessels, depending on the plant species and the dosage, PBZ either encouraged or inhibited root growth (Tsegaw et al., 2005). Paclobutrazol per meter canopy span having bigger fine roots volume relative to the non-PBZ treated control in coffee (Ramos, 2019). Paclobutrazol application also effectively increased both the fresh weight and dry weights of roots of cucumber (Baninasab & Ghobadi, 2011). Both the fresh and dry weight of the roots in watermelon seedlings was significantly increased by the application of PBZ (Baninasab, 2009). Number of root tips, length, and diameter were improved, but hypocotyl length was decreased in seed of cucumber treated with PBZ (Ramin, 2009). Bottle gourd plants treated with PBZ to fruit or plant, fruit weight, fruit diameter, TSS and dry matter content were increased while length was decreased and caused early appearance of female flowers on the nearest node (from bottom) (Rai et al., 2003). Paclobutrazol increased number of female flowers over control plants in pumpkin (Gerdakaneh et al., 2018). Eliwa et al., (2005) found that PBZ increased TSS (%) in peach fruits compared with the control. The application of 5 and 10 mg of PBZ caused 60.9% and 85.85% increased lycopene content compared to control were observed in tomato, respectively (Suja & Anusuya, 2018). In mango lycopene content was only marginally influenced by PBZ (Reddy, 2013). Method of PBZ application also make different on the biochemical content to the plant. It was found that application of 10 and 5 mg/L of PBZ using soil drenching technique recorded the maximum quantity of ascorbic acid and phenolic content, respectively in *Brassica rapa* (Yusop et al., 2018).

1.2 Problem Statement

Under normal planting conditions (in open area), watermelon seedlings grow huge vigorously and have an abundantly branching habit resulted in a continuous pruning to control the vegetative growth and reproductive development. It is a time-consuming process and hence high labour cost (Huang et al., 1989). To control plant growth, PBZ inhibits the production of gibberellins, a hormone responsible for stem elongation in plants. Furthermore, the previous studies revealed that PBZ was used to control vegetative growth and reproductive development in watermelon (Huang et al., 1989). Under marginal land or arid conditions, fresh produce (vegetable or fruit) is produced under greenhouse production. To increase the efficiency of greenhouse production, plant vigorous growth has to be controlled to optimise the profit. Vegetable seedlings have a difficulty with quality losses when temperatures are high and humidity levels are low during the winter and spring seasons, or when temperatures are high during the summer (Ozgur, 2011).

Watermelon requires high input during its cultivation period. Under greenhouse condition during the night, the ventilation to allow gas exchange with the outside environment is turned off. The inclosure limits gas exchange with the external environment, including the release of carbon dioxide (CO_2), a byproduct of plant respiration. As a result, CO_2 concentrations in greenhouse can be significantly higher than in open fields. This caused the watermelon to grow vigorously to open field resulting in a requirement of highly pruning activity to control the vegetative growth and to improve the quality and fruit set. Pruning is time-consuming, high labor cost and need skilled workers. To control the massive vigorously branch off habit and pruning cost and improve the fruit quality and reproductive development of watermelon plants is the use of growth retardants. It is well known that PGRs can improve the functional and qualitative aspects of several plants by reducing longitudinal stem growth. Paclobutrazol is a GA biosynthesis inhibitor which inhibits growth and stem extension in inclusive variety of crops. The PBZ has been tested on several fruit tree species and shown an optimum dose of PBZ will produce good plant growth and reproductive development. However, the effect of PBZ has not been studied intensively on growth, yield and fruit quality of watermelon under greenhouse condition in Malaysia.

1.3 Objectives

1. To evaluate the effects of different concentration of PBZ on vegetative growth, yield and fruit quality of watermelon *(Citrullus lanatus)* var. Mellow oblong (GE344), Red Delight (GE341), and Oval Yellow (SSH348) an under greenhouse condition.
2. To determine the efficacy of PBZ frequency of application on growth, yield and quality of selected watermelon (from objective 1) under greenhouse condition.

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