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DEVELOPMENT OF CUT CHRYSANTHEMUM (Chrysanthemum morifolium Ramat.) PRODUCTION IN SUBSTRATE CULTURE UNDER RESTRICTED ROOT VOLUME

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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 Doctor of Philosophy

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DEVELOPMENT OF CUT CHRYSANTHEMUM (*Chrysanthemum morifolium* Ramat.) PRODUCTION IN SUBSTRATE CULTURE UNDER RESTRICTED ROOT VOLUME

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The effects of three different substrate volumes (34, 73, 140 cm^3) and three different substrates (coconut peat 100 %, burnt rice husk 100 % and coconut peat+burnt rice husk 50:50) grown at 64 plant/m^2 were investigated. Plant height and the total leaf area of chrysanthemums reduced significantly when substrate volume decreased regardless of substrate type but chrysanthemum grown in substrate volume of 140 cm^3 being produced at the highest plant height. Chrysanthemums grown in a substrate volume of 140 cm^3 had the largest root surface area. The relative water content and macro elements in leaves did not differ significantly between treatments. Chrysanthemums grown in restricted root volume had high proline levels throughout growth period. Root:shoot ratio did not differ between treatments. Plants grown in substrate volume of 140 ml showed the highest number of flower of 17.79 and flower diameter of 20.82 cm.

The effects of two substrate volumes (73 and 140 cm^3) and three irrigation frequencies (4, 6, 8 times/day) were investigated to determine a suitable irrigation frequency for the growth and flowering of cut chrysanthemum grown under restricted root volume. There was interaction between irrigation frequency and substrate volume on plant height of chrysanthemum. The tallest plant of 109.25 cm was obtained from chrysanthemum, grown at 140 cm^3 irrigated 6 times/day. Chrysanthemum irrigated 6 and 8 times/day had significantly higher phosphorus content in leaf than being irrigated 4 times/day. The total dry weight of chrysanthemum irrigated 6 and 8 times/day was higher than 4 times/day 32% and 23% consequently. Chrysanthemum_irrigated 8 times per day had the highest number of flower, indicated at 20.44. In conclusion, chrysanthemum grown in substrate volume of 140 cm^3 had better growth and flower quality than in 73 cm^3. The growth and flowering of chrysanthemum irrigated 6 and 8 times/day were better than 4 times/day.

The effects of two chrysanthemum varieties (‘New White’ and ‘New Yellow’) and three different plant densities (64, 81 and 99 plants/m^2) were investigated to determine a suitable plant density for the growth and flowering to determine financial possibility. For instance, the plant grown at 81 plants/m^2 had higher leaf area index than at 64 plants/m^2. The pedicel length of plant density of 99 plants/m^2 was longer than of 64 plant/m^2 18.33% and the stem fresh weight and total dry weight did not differ between three plant densities. Plant densities also did not significantly affect photosynthesis rate, transpiration rate, stomatal conductance, and Fv/Fm. Other than that, chrysanthemum grown at 99 plants/m^2 had the highest plant height but at the same time did not significantly differ from other two plant densities. Plant densities did not significantly affect the day of flowering, the number of flower, flower diameter, inflorescence diameter, flower color and vase life. These results indicated that under root restriction, chrysanthemum could be grown at high plant densities up to 99 plants/m^2. From the gross profit analysis, chrysanthemum ‘New White’ and ‘New Yellow’ grown at 81 plants/m^2 provided highest margin.

The last experiment investigated the growth and flowering, perception of growers, distributors and consumer and financial feasibility of chrysanthemum cultivated in the tray and the trough system. Furthermore, the growth and flowering of chrysanthemum produced in the tray system almost did not differ from the trough system. However, the yield of chrysanthemum produced in the trough system was higher than of the tray system significantly. Besides that, the quality of chrysanthemum produced in the tray and the trough system received very good scores from growers, distributors and consumers in almost all characteristics. From the gross profit analysis, the tray system had higher profit than the trough system but both of them were lower than that of soil-based system.

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

PERKEMBANGAN PENGELUARAN BUNGA KERATAN KEKWA (*Chrysanthemum morifolium* Ramat.) DALAM KULTUR SUBSTRAK DI BAWAH ISIPADU AKAR TERSEKAT

Oleh

TAWEESAK VIYACHAI

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Pengerusi : Profesor Madya Thohirah Lee Abdullah, PhD
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Kesan tiga isipadu media (34, 73, 140 cm^3) dan tiga jenis media berlainan (tanah gambut sabut kelapa 100%, sekam padi bakar 100% dan tanah gambut sabut kelapa 50:50) dengan kepadatan tanaman 64 pokok/m^2 telah dikaji. Ketinggian pokok dan jumlah luas permukaan daun kekwa berkurang dengan nyata apabila isipadu media berkurangan tanpa mengira jenis media tetapi kekwa yang ditanam dalam isipadu media 140 cm^3 mencatatkan tinggi pokok dan jumlah luas permukaan akar yang paling banyak. Kandungan air bandingan dan unsur makro pada daun tidak menunjukkan perbezaan yang nyata antara rawatan. Kekwa yang ditanam di bawah isipadu akar yang terhad mengandungi paras proline yang tinggi sepanjang tempoh pertumbuhan. Nisbah akar: pucuk tidak berbeza antara rawatan. Kekwa yang ditanam dalam isipadu media 140 cm^3 menghasilkan bilangan bunga (17.79 bunga) dan diameter bunga (20.82 cm) yang paling tinggi.

Kesan dua isipadu media (73 dan 140 cm^3) dan tiga kekerapan pengairan (4, 6, 8 kali/hari) telah dikaji untuk menentukan kekerapan pengairan yang sesuai untuk pertumbuhan dan pembungaan kekwa yang bertujuan untuk dijadikan bunga keratan yang ditanam di bawah isipadu akar yang terhad. Interaksi antara kekerapan pengairan dan isipadu media ke atas tinggi pokok kekwa telah diperhatikan. Kekwa yang paling tinggi (109.25 cm) telah diperoleh menggunakan isipadu media dan kekerapan pengairan 6 kali/ hari. Daun kekwa yang disiram 6 dan 8 kali/hari mengandungi paras fosforus yang nyata lebih tinggi berbanding dengan 4 kali/ hari. Jumlah berat kering kekwa yang disiram 6 dan 8 kali/ hari adalah lebih tinggi berbanding 4 kali/ hari 32% dan 23% masing-masing. Kekwa yang disiram 8 kali/hari menghasilkan bilangan bunga yang paling banyak (20.44 bunga). Kesimpulannya, kekwa yang ditanam dalam isipadu media 140 cm^3 menunjukkan pertumbuhan dan kualiti bunga yang lebih bagus berbanding

dengan isipadu media 73 cm^3. Kekwa yang disiram 6 dan 8 kali/hari menunjukkan pertumbuhan dan pembungaan yang lebih bagus berbanding dengan 4 kali/hari.

Kesan dua varieti kekwa (‘New White’ dan ‘New Yellow’) dan tiga kepadatan penanaman (64, 81 dan 99 pokok/m2) telah dikaji untuk menentukan kepadatan penanaman yang sesuai untuk pertumbuhan dan pembungaan kekwa dan juga untuk menentukan kebolehlaksanaan kewangan. Kekwa yang ditanam pada 81 pokok/ m^2 mencatatkan indeks luas daun yang lebih tinggi iaitu berbanding dengan kekwa yang ditanam pada 64 pokok/m^2. Kekwa yang ditanam pada kepadatan tanaman 99 pokok/ m^2 mencatatkan tangkai bunga 18.33% lebih tinggi berbanding dengan kepadatan tanaman 64 pokok/m^2. Berat basah batang dan jumlah berat kering tidak berbeza antara ketiga-tiga kepadatan tanaman tersebut. Kepadatan tanaman tidak mempengaruhi fotosintesis, transpirasi, kekonduksian stomata dan Fv/Fm. Kekwa yang ditanam pada 99 pokok/m^2 mencatatkan tinggi pokok yang paling banyak (61.28 cm) tetapi ianya tidak berbeza secara nyata daripada dua kepadatan tanaman lain yang dikaji. Kepadatan tanaman tidak mempengaruhi secara nyata hari pembungaan, bilangan bunga, diameter bunga, diameter kelompok bunga, warna bunga dan jangka hayat jambangan. Keputusan yang diperoleh menunjukkan bahawa di bawah pertumbuhan akar yang terhad, kekwa boleh ditanam pada kepadatan yang tinggi sehingga 99 pokok/m^2. Daripada analisa keuntungan bersih, kekwa ‘New White’ dan ‘New Yellow’ ditanam pada kepadatan 81 pokok/m^2 memberikan kepulangan yang paling tinggi.

Kajian yang terakhir mengkaji tentang pertumbuhan dan pembungaan, persepsi penanam, pengedar dan pembeli kekwa dan juga kebolehlaksanaan kewangan kekwa yang ditanam dalam sistem tray dan sistem palung. Pertumbuhan dan pembungaan kekwa dalam sistem tray hampir tidak berbeza daripada sistem palung, tetapi hasil kekwa yang ditanam dalam sistem palung adalah lebih tinggi secara nyata berbanding dengan sistem tray. Kualiti kekwa dalam hampir kesemua aspek yang dihasilkan melalui sistem tray dan sistem palung mendapat sambutan yang menggalakkan daripada penanam, pengedar dan pengguna. Melalui analisa keuntungan bersih, sistem tray berkeupayaan untuk menjana lebih banyak keuntungan berbanding sistem palung tetapi keuntungan yang dijana oleh kedua-dua sistem tersebut adalah lebih rendah berbanding sistem menggunakan media.

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

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%	Percentage
°C	Degree celsius
ANOVA	Analysis of variance
B	Boron
bar	Bar
C	Carbon
Ca	Calcium
Chl	Chlorophyll
cm	Centimeter
cm^2	Square centimeter
C/N	Carbon/Nitrogen
CRD	Completely Randomize Design
Cu	Copper
cv.	Cultivar
d	Day
e.g.	For example
EC	Electrical conductivity
et al.	And friends
etc.	et cetera
FAA	Formalin Acetic Acid
Fe	Iron
g	gram
h	Hour

K	Potassium
kPa	Kilopascal
l	Litre
LAI	Leaf Area Index
m	Meter
MARDI	Malaysian Agricultural Research and Development Insititue
m^2	Square meter
mg cm^{-2}	milligram per square centimeter
mg L^{-1}	Milligram per litre
Mg	Magnesium
ml	Milliliter
mol	Mole
µg	Microgram
µmol	Micromole
Mn	Manganese
MPa	Mega Paskal
Mo	Molybdenum
mS/cm	Milli-Siemens per centimeter
N	Nitrogen
nm	nanometre
ns	Not significant
p	Probability
P	Phosphorus
pb	Bulk density
pH	Measurement of Acidity/Alkalinity

RCBD	Randomized Complete Block Design
RM	Ringgit Malaysia
RWC	Relative Water Content
s	Second
SD	Standard deviation
USA	United States of America
Zn	Zinc

CHAPTER 1

INTRODUCTION

Chrysanthemum is a popular cut flower which is produced worldwide. The cultivation of cut chrysanthemum around the world is still mainly in soil (Blok and Vermeulen, 2012). Many flowers such as rose, gerbera, anthurium and cymbidium have changed to soilless cultivation (Erik *et al.* 2008). Several countries such as Holland and Israel have widely cultivated cut flower in soilless substrate for many years (Marta, 2001). Many countries such as Brazil, Canada, Europe, Morocco, Tanzania, USA and Colombia have used substrate culture for flower production to reduce the environmental problems from soil treatment by methyl bromide (Marta, 2012). Soilless culture system can improve the yield and quality of crop plants even in non- arable areas (Gruda, 2009).Soilless culture was a choice for flower production because it can avoid soil-borne pests and diseases that became hard to control. Soil problems such as soil degradation, soil contamination and poor soil structure were also difficult to manage in floriculture (Marta, 2007). Lim *et al*. (1998) reported that accumulation of nematodes and soil-born diseases were a problem for cut flower production which were produced in the same area continuously.

Chrysanthemum production in soilless culture system has been studied and developed for more than 30 years. In 1980, Van Os developed a nutrient film system for growing chrysanthemum. Production of chrysanthemum in nutrient film systems can increase yield up to 24 % when compared with soil culture (de Visser and Hendrix, 1986). Buwalda *et al*. (1994) reported that chrysanthemum grown in ebb and flow system had higher productivity than soil cultivation. Growing chrysanthemum also was tested in aeroponics system (de Kreij and Paternotte, 1999). Some systems showed disadvantages such as deep flow technique which produced shorter and weaker stem than soil (Sakamoto *et al*. 2001). However, chrysanthemums grown in solution system were prone to infection by *Pythium* (Liptay and TU, 2003). Even, the use of ultra violet treatment cannot decrease *Pythium* root rot (Liu *et al*. 2007). Chrysanthemums grown hydroponically had severe root rot problem and this inhibited chrysanthemum production in hydroponic systems (Sutton *et al*. 2006)

Substrate culture was another area of interest for producing chrysanthemum. Coarse grade peat can be use as a substrate for cultivate chrysanthemum all year round (Verhagen, 1993). High quality chrysanthemums can be produced with expanded clay, perlite, pumice and pumice mixed with peat in bag culture without any physiological disorder (Marlogio *et al.*1994). Wilson and Finlay (1995) reported that chrysanthemums can be produced in a sand-based system with higher stem length and heavier stem than soil grown without any sterilization for seven crop cycles. Wrigth *et al*. (2008) found that pine tree substrate can be used for chrysanthemum production in a greenhouse as a peat-lite medium.

Even though, substrate cultures seem to be a possible way for growing chrysanthemums with less problems on root disease, but the disadvantage of this system was the high production cost due to high expense for replacing substrate (Buwalda *et al*. 1994). Blok and Vermeulen (2012) developed substrate systems for growing chrysanthemum such as a sand base system, peat base system and cassette base system to compare with soil grown. They found that all systems were unprofitable. Growing chrysanthemums with the optimum substrate may have the potential to obtain economic production and could be an alternative to solve soil degradation and soil-born diseases. However, the use of small container will increase root restricted condition experienced by the plants. Reduce rooting volume caused many physiological and morphological change (NeSmith and Duval, 1998). *Altering* amount in a *substrate* will *change* roof performance through influencing *plant growth* (Young *et al*. 2014). Beside, plants grown in small volume are very sensitive to the variation on the moisture and nutrient level in the root zone, which can affect growth performance and quality of plants (Xianfeng *et al*. 2010).

This study will conduct to investigate the growth and flowering of chrysanthemum under root restricted conditions in association with the financial analysis of chrysanthemum production in the developed system. The objectives of this study were:

1. To determine the effects of substrate types and substrate volumes on the growth and flowering of chrysanthemum.
2. To determine the effects of irrigation frequencies on the growth and flowering of chrysanthemum grown under restricted root volume.
3. To determine the effects of plant density on the growth and flowering of chrysanthemum grown under restricted root volume.
4. To survey the perception of growers, distributors and consumers on the flower quality of chrysanthemum grown under restricted root volume, and the economic possibility of chrysanthemum production.

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