GROWTH AND YIELD PERFORMANCE OF CHILI (*Capsicum annum* L.) INFLUENCED BY GREYWATER ORGANO MINERAL LIQUID FERTILIZER

By

TAN SI LI

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

October 2021

FP 2021 70

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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Chair : Associate Professor Susilawati binti Kasim, PhD
Faculty : Agriculture

Over the years, the increase in greywater disposal coincides with the rapidly growing world population. Current literature shows a high valuable fertilizing potential of laundry greywater owing to its salts and nutrients contents. Thus, the objectives of this research were to formulate a potential liquid organo mineral fertilizer (OMF) from laundry greywater (LW) and vegetable wastes (VW) and to investigate the effects of organo mineral fertilizer on the growth and yield performance of chili plants in fertigation system. In the first experiment, vegetable waste was dissolved in laundry greywater at 3 ratios (1:10, 1:15, and 1:20) and shaken to obtain a biological suspension. Then, samples were subjected to an incubation period of 0, 3, 6, 9, 12 and 15 days respectively. Data on pH, electrical conductivity (EC), the concentration of nutrients (N, P, K, Ca, Mg, Mn, Cu, Zn, and Fe) of each sample were recorded at the end of the experiment. In second experiment, selected OMF from previous experiment was tested on chili plants in five treatments including 100 % AB fertilizer (ABF), 75 % ABF + 25 % OMF, 50 % ABF + 50 % OMF, 25 % ABF + 75 % OMF and 100 % OMF on 10 chili plants each in separate fertigation systems under the rain shelter. Growth measurements along with yield performance as well as the proximate compositions of fruits and microorganism count were analysed. Both experiments were laid out in a Completely Randomized Design (CRD). Data collected was analysed using SAS and the treatment means were compared by using Tukey test at a 5 % significant level. At a lower ratio (1:10) of VW:LW with an incubation period of 9 to 15 days, the best quality of liquid OMF was produced. Moreover, the combined use of ABF and OMF resulted in better growth of chili plants and their fruits. The sole application of OMF produced statistically similar chili fruits as commercial ABF in terms of fruit quality. Thus, it is recommended to enhance the growth and yield performance of chili by mixing ABF and OMF at a ratio of 50:50. As the product is produced from waste, OMF may considerably reduce fertilization costs and improve the sustainability of the farming system. Meanwhile, further studies on the enhancement of phosphorus content in the

fertilizer and microorganism activities related to the application of fertilizer are needed to improve the overall performance of fertilizer.

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

PERTUMBUHAN DAN PENGHASILAN CHILI (*Capsicum annum* L.) SEBAGAI YANG DIPENGARUHI OLEH BAJA CECAIR ORGANO MINERAL AIR KELABU

Oleh

TAN SI LI

Oktober 2021

Pengerusi : Profesor Madya Susilawati binti Kasim, PhD
Fakulti : Pertanian

Selama bertahun-tahun, peningkatan pembuangan air kelabu bertepatan dengan populasi dunia yang berkembang pesat. Literatur semasa menunjukkan potensi pembajaan yang tinggi pada air kelabu mesin basuh disebabkan oleh kandungan garam dan nutriennya. Oleh itu, objektif penyelidikan ini adalah untuk menghasilkan baja organo mineral cair (OMF) yang berpotensi dari air kelabu mesin basuh (LW) dan sisa sayuran (VW) dan untuk mengkaji kesan baja organo mineral terhadap pertumbuhan dan penghasilan tanaman cili dalam sistem fertigasi. Dalam eksperimen pertama, sisa sayuran dilarutkan pada 3 nisbah yang berbeza (1:10, 1:15 dan 1:20) dan digoncangkan untuk mendapatkan suspensi biologi. Kemudian, sampel diambil pada 0, 3, 6, 9, 12 dan 15 hari. Data pH, kekonduksian elektrik (EC), kepekatan mikronutrien (N, P, K, Ca, Mg, Mn, Cu, Zn dan Fe) pada setiap sampel dicatatkan pada akhir eksperimen. Dalam eksperimen kedua, OMF terpilih telah diuji pada tanaman cili dalam lima rawatan termasuk 100 % baja AB, 75 % baja AB + 25 % OMF, 50 % baja AB + 50 % OMF, 25 % baja AB + 75 % OMF dan 100 % OMF. Setiap rawatan dikenakan pada 10 tanaman cili dalam sistem fertigasi yang berasingan di bawah rumah lindungan hujan. Pengukuran pertumbuhan bersama dengan prestasi hasil serta anggaran komposisi dan jumlah mikroorganisma pada hasil-hasil cili telah dianalisis. Kedua-dua eksperimen tersebut disusun dalam Reka Bentuk Rawak Sepenuhnya (CRD). Data yang dikumpulkan dianalisis menggunakan SAS dan rawatan dibandingkan dengan menggunakan ujian Tukey pada tahap signifikasi 5%. Pada nisbah yang lebih rendah (1:10) VW: LW dengan tempoh inkubasi 9 hingga 15 hari, OMF yang berkualiti terbaik telah dihasilkan. Selain itu,

gabungan baja AB dan OMF menghasilkan pertumbuhan tanaman cili dan buah yang lebih baik. Penggunaan OMF semata-mata menghasilkan buah cili yang tidak berbeza secara bererti dengan baja AB dari segi kualiti buah. Oleh itu, pencampuran baja AB dan OMF pada nisbah 50:50 dicadangkan untuk meningkatkan pertumbuhan dan hasil tanaman cili. Oleh kerana produk tersebut dihasilkan dari sisa organik, OMF dapat mengurangkan kos pembajaan dan meningkatkan kelestarian pertanian. Walaupun bagaimanapun, kajian lanjutan mengenai peningkatan kandungan fosforus dalam baja cecair dari air kelabu mesin basuh dan aktiviti mikroorganisma yang berkaitan dengan penggunaan baja perlu dikaji untuk meningkatkan prestasi keseluruhan baja

ACKNOWLEDGEMENTS

The completion of this study could not have been possible without the expertise of my supervisory committee. My sincere gratitude goes first to my supervisor, Dr. Susilawati binti Kasim, for the continuous support of my research, for her patience, motivation, and knowledge. Never forget to pay my deep sense of gratitude to my co-supervisor, Dr. Martini Mohammad Yusof and Dr. Syaharudin Zaibon. Their constructive suggestions during the planning and development of this research work are appreciated.

My appreciation also extends to my teammates Nur Sirah, Natrah Azirah, Shariff, and Fatal for lending me their hands and the enthusiastic encouragement throughout the research.

I am glad and grateful for the love given by my parents, my siblings, and other family members throughout my master' study and my life in general.

Above all, to Mr. Liew Dao Zhung, thank you for the unceasing encouragement, support, and attention.

Lastly, I would like to place on record my sense of gratitude to one and all who directly or indirectly lent me their hand in this venture.

Thank you.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the Master of Science (Land Management). The members of the Supervisory Committee were as follows:

Susilawati binti Kasim, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Martini binti Mohammad Yusof, PhD
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

Syaharudin bin Zaibon, PhD
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

_____
ZAILAH MOHD SHARIFF,PhD
(Professor and Dean)
School of Graduate Studies
Universiti Putra Malaysia

Date: 11 May 2023

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Signature:	
Name of Chairman of Supervisory Committee:	Associate Professor Dr. Susilawati binti Kasim
Signature:	
Name of Member of Supervisory Committee:	Dr. Martini binti Mohammad Yusof
Signature:	
Name of Member of Supervisory Committee:	Dr. Syaharudin bin Zaibon

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LIST OF ABBREVIATIONS

%	percent
°C	Degree Celsius
µS cm^{-1}	Micro Siemen per centimeter
µg	Microgram
AAS	Atomic absorption spectroscopy
Al^{3+}	Aluminium ion
ANOVA	Analysis of variance
C	Carbon
Ca	Calcium
cfu g^{-1}	Colony-forming unit per gram
cfu ml^{-1}	Colony-forming unit per milliliter
cm	Centimeter
CRD	Completely Randomized Design
Cu	Copper
DAT	Days after transplanting
df	Diluting factor
DOSM	Department of Statistics Malaysia
dS cm^{-1}	Decisiemen per centimeter
EC	Electrical Conductivity
EPA	United States Environmental Protection Agency
FAO	Food and Agriculture Organization of United Nations
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
Fe	Iron

FOMCA	Federation of Malaysian Consumers Associations
g	Gram
H^+	Hydrogen ion
H_2SO_4	Sulphuric acid
HCl	Hydrochloric acid
IP	Incubation Period
K	Potassium
kcal	kilocalorie
kg	Kilogram
KOH	Potassium hydroxide
LW	Laundry Greywater
mg	Milligram
Mg	Magnesium
mg ℓ^{-1}	Milligram per liter
mm	Millimetre
Mn	Manganese
MOA	Ministry of Agriculture
N	Nitrogen
Na	Sodium
NaOH	Sodium hydroxide
NH_4^+	Ammonium
NO_3^-	Nitrate
OMF	Organo mineral fertilizer
P	Phosphorus
SAS	Statistical Analysis System

UPM	Universiti Putra Malaysia
USDA	United States Department of Agriculture
VW	Vegetable waste
WHO	World Health Organization's (WHO)
Zn	Zinc

CHAPTER 1

INTRODUCTION

1.1 Introduction

Greywater occurs as one of the wastewaters generated due to urbanization and industrialization. Wastewater arises from domestic washing operations, including baths, showers, hand basins, washing machines, and kitchen sinks (Jefferson *et al.*, 2004; Ledin *et al.*, 2001). Laundry greywater (LW) is the effluent discharged clothes washing process. The utilization of soap, soda, and detergent in the washing process gives rise to dirt, grease, and starch stained from clothing (Nemerow and Dasgupta, 1991). LW mainly composes of cations, namely calcium, magnesium, and potassium, as well as anions such as nitrate, sulphate, carbonate, and chloride, along with organic micropollutants (OMPs) raised from the detergents (Mohamed *et al.* 2013, 2014; Chan *et al.* 2014).

The reusing of greywater is leading a trend to cope with the water scarcity problem worldwide. Greywater, especially untreated LW was suggested as a potential water resource for irrigation of household lawns and gardens (Al-Joyyousi, 2003). Moreover, LW application in planting plants with sodium removal ability can prevent sodium accumulation in soil without affecting plant growth (Misra *et al.*, 2010). In recent years, greywater reusing potential in food production was investigated on various vegetables. The biomass of tomato plants irrigated with LW was significantly higher than tap water irrigated ones (Mirsa *et al.*, 2010). Besides, irrigation with greywater (from the bath, hand basin, laundry, and dishwashing) produced significantly greater stem heights and total yield overtimes for green peppers than nutrient-irrigated and tap-water-irrigated ones (Salukazana *et al.* 2005). Household greywater irrigation enhanced the growth and yield performance of carrots and Swiss chard and was associated with plant nutrient content improvement (Rodda *et al.*, 2011). However, a study revealed that liquid detergent caused lesser damage to the soil properties than powdered laundry detergent. Long-term irrigation with powdered laundry detergent water will result in drought resilience of LW-irrigated soils (Hardie *et al.*, 2021).

Over the years, the wide use of chemical fertilizers to meet global food security resulted in environmental pollution. Nevertheless, the continuous application of chemical fertilizers degrades soil health and quality (Chandini *et al.*, 2019). On the other hand, organic fertilizer can diminish soil nutrient leaching. Yet, the usage of organic fertilizer is associated with problems like inadequate availability, transportation, handling problem, high C:N ratio, heavy metal pollution, and slow nutrient release (Ayeni *et al.*, 2010). Hence, organo mineral fertilizer, the combination of both fertilizers, was suggested as a new source of nutrients. Organo mineral fertilizer (OMF) is a mixture of organic fraction and mineral

fraction that offers both chemical fertilizer and organic fertilizer characteristics (Ramos *et al.*, 2017; Moraes *et al.*, 2017).

In the past few years, research on OMF has shown better yield performances than the single use of chemical and organic fertilizer. The application of OMF together with inhibitors on corn (Zea mays) and wheat (Triticum aestivum) crops performed the best in terms of total grain yield as compared to single-use of urea or organic fertilizer (Juliano *et al.*, 2016). The synergistic effect of organic and inorganic matrices mixture raised both yield and yield components of okra and soil improvement (Jaja and Ibeawuch, 2015). OMF consisting of calcium sulphate, ground rice bran, and humic acid improved the growth and fruit performance of tomato (Solanum lycopersicum L.) plants in reclaimed saline soil (Rady, 2012). The highest fresh and dry root biomass obtained from cherry tomato plants was applied with formulated fertilizer and powder or granular OMF. Additionally, these treatments increased the nutrition concentrations of phosphorus, potassium, magnesium, sulphur, sodium, chloride, and aluminum in cherry tomatoes (Bautista *et al.*, 2020). OMF mixture of green waste compost, elemental sulphur, and humic acid showed increased growth, proline, photosynthetic efficiency, and nutrient contents of eggplant (Solanum melongena L.) grown in reclaimed saline calcareous soil (Semida, *et al.*, 2014).

Chili (*Capsicum annum* L.) is in the family of Solanaceae, cultivated worldwide as a spice and a fruit vegetable (Dias, 2013; Wahyuni *et al.*, 2013). It is one of the most important vegetable crops, as its role as a spice, condiment, and culinary supplement (Huq and Arshad, 2010). In Malaysia, the import dependency ratio (IDR) of chili increased from 55.1 % in 2016 to 72.4 % in 2020. Chili was highly dependent on imports to meet domestic demand, and recorded the highest IDR in 2020, about 66,294.9 tonnes (DOSM, 2021a). The cost of fertilizer is one of the constraints among chili growers apart from seed improvement (Rajput, 2007). The production of chili in micro-irrigation and fertigation achieves higher fertilizer use efficiency than conventional irrigation in chili production (Manohar, 2002). However, the production cost of chili in the fertigation system is higher because of the high water-soluble fertilizer cost compared to conventional fertilizers (Chandramohan and Hebbar, 2018). Current research aims to produce a potential liquid OMF from LW-disposed and biodegradable vegetable waste (VW). VW is a biodegradable material that includes rotten, peels, shells, and scraped portions of vegetables or slurries (Singh *et al.*, 2012). It contains fiber, nitrogen, potassium, phosphorus, and other nutrients (Stella and Sashikala, 2016). Despite the nutrient in LW and vegetable waste, the product is expected to pose great potential in improving chili plants' performance from their gradual release of nutrients.

1.2 Problem Statement

In Malaysia, several regions face water-stress problems due to the temporal or spatial seasonal rainfall. States like Perlis, Kedah, and Selangor, which used to support large-scale agriculture (paddy production) experienced productivity loss due to water demand shortage during drought (National Water Resources Study, 2011). A rapid increase in water supply-demand is estimated in domestic and industry sectors by 2050 and beyond. Besides, issues regarding water shortages during drought periods and low irrigation water use efficiency had raised in Malaysia (Abdullah *et al.*, 2016). The Federation of Malaysian Consumers Association (FOMCA), Water and Energy Consumers Association of Malaysia (WECAM), and Forum Air Malaysia (FAM) urged Malaysia to take action over the unorganized management and unsustainable water resources usage that lead to water scarcity in the country (Krishnan, 2021).

In recent years, consideration of the potential of greywater reusing, particularly utilizing LW in plant irrigation, to resolve water scarcity problems in certain regions such as New Zealand, Japan, Australia, and the United States (Gorgich, 2016). In Malaysia, LW made up the second highest which is 22 % of the average water usage distribution of 1972 families (FOMCA, 2010).

On the other hand, the Food and Agriculture Organization (FAO, 2011) reported that approximately one-third of the food produced for human consumption is lost or wasted worldwide, which is about 1.3 billion tonnes a year. Meanwhile, fruit and vegetables show the highest wastage rates, about 45 % of any food product. The production of valuable fertilizer and soil amendment from vegetable waste is encouraged. The waste-produced fertilizer is essential to replenish plant nutrients, sustain soil health, and control possible pollution and diseases caused by a large amount of vegetable waste (Chatterjee et al., 2014).

Yet, the utilization of chemical fertilizers in agricultural production indicated a significant increment over the years. These fertilizers brought severe pollution to our environment and degraded soil's physical properties. Hence, several studies were carried out on possible fertilizers to substitute the chemical fertilizers to diminish the adverse effects caused and to replenish soil nutrient content. Hence, this research prioritized the transformation of greywater from washing machines with a suitable ratio of biodegradable VW into safe and low heavy metal content liquid OMF, which increases the productivity of sustainable farming. As the usage of OMF is an efficient farm input in crop production, a better understanding of the physical properties related to their production, handling, and performance on plants is needed.

1.3 Objectives

The overall objective of this research was to develop a potential OMF from the mixture of LW disposed of washing machine and biodegradable VW. The three extended objectives of this research were as follows:

- To determine a suitable ratio for LW and biodegradable VW to formulate a potential liquid OMF.
- To identify a suitable period to incubate LW and biodegradable VW to formulate a potential liquid OMF.
- To investigate the effects of OMF compared with commercial AB fertilizer on the growth and yield of chili plants in a fertigation system.

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