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SMART VERTICAL GARDEN SYSTEM DESIGN AND PERFORMANCE FOR INDOOR VEGETABLE PRODUCTION

MUNIRAH HAYATI BINTI HAMIDON

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SMART VERTICAL GARDEN SYSTEM DESIGN AND PERFORMANCE FOR INDOOR VEGETABLE PRODUCTION

By

MUNIRAH HAYATI BINTI HAMIDON

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

SMART VERTICAL GARDEN SYSTEM DESIGN AND PERFORMANCE FOR INDOOR VEGETABLE PRODUCTION

By

MUNIRAH HAYATI BINTI HAMIDON

January 2019

Chair : Associate Professor Samsuzana Abd Aziz, PhD
Faculty : Engineering

Vertical garden systems have the potential to increase vegetables production in the urban areas in Malaysia. The purposes of this research were to design and develop a compact and smart vertical garden system for urban agriculture and to study the growth of lettuces in the developed vertical system. The development of the smart vertical garden system was divided into two main components: i) the development of vertical garden system and ii) the monitoring system for nutrients solutions. The main parts of the structure comprised of water tank, extendable pole as the support, irrigation line and five stacks of planting pots with each pot had eight planting pockets. The gravity-fed irrigation method was used to irrigate all the lettuces in the vertical garden. The water quality monitoring system consisted of EC and pH sensors that integrated with Arduino Uno microcontroller. The growth of lettuce (*Lactuca sativa*) was observed at the different stacks of the vertical garden system. Besides, the plant growth development in the designed vertical garden was compared with a commercialized conventional hydroponic system.

As for the plant growth development in the vertical garden between stacks, the result showed that the maximum lettuces height, leaves width and number of leaves were found at the most bottom stack (stack 5). From the overall ANOVA results, only lettuce height was observed to be significantly difference ($P < 0.0001$) at the different stacks while no significant difference was observed in the overall number of leaves produced ($P = 0.0002$) and leaves width ($P = 0.0046$) at the different level of stacks. The growth development of the lettuces at each of the stacks was varied due to different amount of water and light exposure.

While comparing the development of plants grown in vertical garden and commercialized conventional hydroponic system, there was no significant difference in each of the lettuces growth parameters (lettuce height ($P = 0.4997$);

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number of leaves (P = 0.5325); and width leaves (P= 0.5231)). To conclude, the designed vertical garden performed similarly as the commercial conventional hydroponic system. Hence, the vertical garden has a great potential to be as one of the planting alternative system especially in limited space area.

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

REKA BENTUK DAN PEMBANGUNAN SISTEM TAMAN VERTIKAL PINTAR DAN PRESTASINYA UNTUK PENGELUARAN SAYURAN DALAMAN

Oleh

MUNIRAH HAYATI BINTI HAMIDON

Januari 2019

Pengerusi : Profesor Madya Samsuzana Abd Aziz, PhD
Fakulti : Kejuruteraan

Sistem taman menegak mempunyai potensi untuk meningkatkan pengeluaran sayuran di kawasan bandar di Malaysia. Tujuan utama kajian ini adalah untuk mereka bentuk dan membangunkan sebuah sitem taman menegak yang lengkap dan sesuai untuk pertanian bandar serta mengkaji prestasi tumbesaran tanaman salad menggunakan sistem taman menegak yang direka. Penghasilan sistem taman menegak ini terbahagi kepada dua komponen utama: i) pembangunan sistem taman menegak dan ii) sistem pemantauan cecair nutrien. Bahagian utama taman menegak yang direka terdiri daripada tangki air, tiang boleh laras, sistem pengairan dan lima tingkat pasu tanaman di mana setiap pasu mempunyai lapan poket tanaman. Kaedah pengairan graviti digunakan untuk mengairi kesemua salad di taman menegak. Sistem pemantauan kualiti cecair nutrient yang dibina terdiri daripada sensor kekonduksian elektrik (EC) dan pH yang diprogramkan pada pengawal mikro Arduino Uno. Perkembangan tumbesaran salad (Lactuca sativa) di setiap tingkat sistem taman menegak diperhatikan. Selain itu, perkembangan tumbesaran tanaman yang ditanam pada sistem yang dibina juga dibandingkan dengan tanaman yang ditanam menggunakan sistem hidroponik konvensional yang dikomersialkan.

Hasil kajian terhadap tanaman yang ditanam di taman menegak menunjukkan salad yang mepunyai ketinggian paling tinggi, lebar daun yang besar dan bilangan daun yang terbanyak berada pada tingkat paling bawah (tingkat 5). Secara keseluruhannya, analisi varians (ANOVA) menunjukkan hanya ketinggian salad mempunyai perbezaan ketara ($P < 0.0001$) di antara setiap tingkat manakala tiada perbezaan yang ketara ditemui pada keseluruhan bilangan daun ($P = 0.0002$) dan lebar daun ($P = 0.0046$) di setiap tingkat. Perbezaan tumbesaran salad di setiap tingkat adalah disebabkan jumlah air dan pendedahan cahaya yang berbeza.

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Ketika membandingkan tumbesaran pokok yang ditanam di taman menegak dan sistem hidroponik konvensional, tiada perbezaan ketara pada setiap parameter tumbesaran pokok (ketinggian salad (P = 0.4997); bilangan daun (P = 0.5325); dan lebar daun (P= 0.5231). Kesimpulannya, sistem taman menegak yang direka memberikan prestasi yang sama dengan sistem hidroponik konvensional. Oleh itu, taman menegak mempunyai potensi yang besar untuk menjadi salah satu alternatif sistem penanaman terutama di kawasan ruang yang terhad

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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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Declaration by Graduate Student

I hereby confirm that:

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
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LIST OF ABBREVIATIONS

AC	Alternating current
ANOVA	Analysis of variance
CAD	Computer-aided drafting
DC	Direct current
DMRT	Duncan's Multiple Range test
EEPROM	Electrically erasable programmable read-only memory
LCD	Liquid-crystal display
SAS	Statistical analysis system

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CHAPTER 1

INTRODUCTION

1.1 Background

By the year of 2025, it is estimated that almost 30% of global population will live in the urban areas. This trend is expected to continue in line with the population growth and rapid urbanization. In Malaysia, until 2015, around 74 % of the citizens live in urban areas, and that figure is projected to increase gradually by 2025 (Muhammad and Rashid, 2015). This phenomenon is due to land scarcity, the migration of rural people to the city and economic factors.

The migration of rural people to the city increased the population density of urban areas and this led to a competing access of food supplies, nutrition and food security to the population (Pandey and Seto, 2015). Nowadays, Malaysia is more dependent on food supply, particularly fruits and vegetables from other countries, especially Thailand and China. In Malaysia food imports increase over the years and this showed that the country is facing the problems of food supply (Muhammad and Rashid, 2015).

On the other hand, the food preferences have changed due to the increase in per capita income, occupational changes and global linkages. These trends along with the rises of population over the years become a challenge to agricultural sector in Malaysia for producing more and better food. Changes in the global environment and climate increase the challenge and had become indispensable topic for those who concerned about their health and environment (Smit and Parnell, 2012). In this regard, the prosumer concepts came out to help urban areas in many of the countries to increase the production and its sustainability (Ahamed et al., 2014). The prosumer concept is a practice where people could produce their own food using the available resources and consume the produce by themselves or share it with their community.

However, there are some limitations to increase the productivity of agriculture if we still employ the current conventional techniques. The recent issues such as land scarcity, threat to environment sustainability and health due to dependence on chemical fertilizers and pesticides are the major constraints that affect the food production and quality.

New innovations in agriculture are inevitably needed and these innovations should be integrated with the main streams of agriculture. Thus, one way to achieve the sustainable urbanization and food security is by practicing the urban agriculture (Zezza and Tasciotti, 2010). The practice of urban farming seems to be very significant and relevant to serve the needs of the urban residents,

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particularly those which are more vulnerable to the food crisis compared to rural consumers.

Urban agriculture is known as a cultivation practice beyond strictly for home consumption or educational purposes such as cultivating, producing, processing, distributing, and marketing food and other products within the cities and existing town areas (Shamsudin et al., 2014). It is getting popular in many regions across the world. New York, London and Tokyo are the leading cities from the developed countries which emphasize the various practices of urban agriculture. Malaysia's neighbouring country, Singapore who has limited space available for farming, started to apply urban farming system and able to contribute almost 25% of their food supply.

However, one engaging with urban farming has to deal with several constraints such as spaces and water, management system and farm maintenances in the high-density populated areas. Therefore, by integrating the vertical farming or gardening technique in urban agriculture system seems to be promising in solving those constraints (Eigenbrod and Gruda, 2015). The vertical garden also is one of the solutions for the shortage in both food and arable land due to the crops grow in a vertical structure, thus more production can be made possible in the limited land spaces (Despommier, 2009).

Vertical garden is defined as plants growing system that uses an assortment of support structures that stand upright and make the small space being utilized for more production. By contrast, growing plant in horizontal system takes up most of the room or space. In addition, while other plants are typically grown at ground level, the vertical garden stand tall and upright, which makes harvesting crops a simple task (i.e, limited bending and kneeling). Figure 1.1 summarizes the concept of vertical garden system.

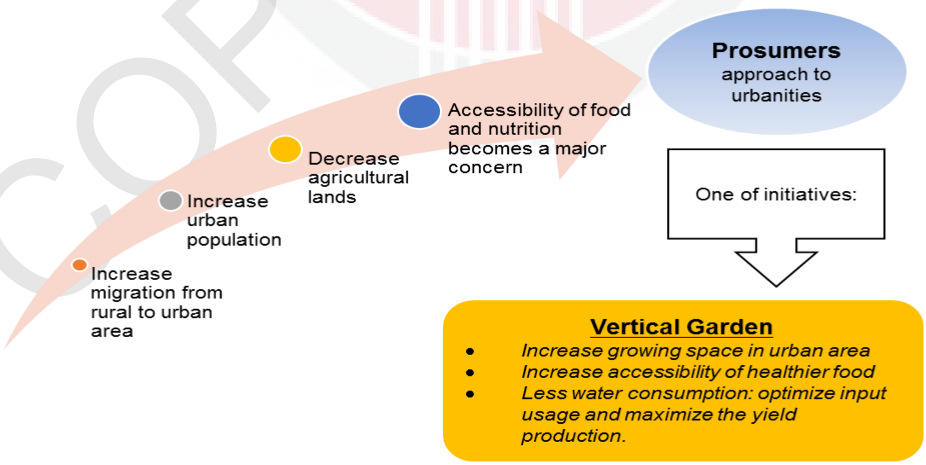

Figure 1.1: The concept of vertical garden

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Urban agriculture has drawn attention in Malaysia as a response to the rise of urban poverty, food security, and sustainable development. As population grows, the need to provide adequate nutritious, safe, acceptable and cost-effective food to the urban dwellers becomes more complex both economically and physically. By that reasons, The Government of Malaysia has started to promote the urban agriculture program especially to those who are living in the developing cities. They were encouraged to have their own edible garden in the house area (Ruban, 2015). This program increased the attention of home grower markets and households in Malaysia towards growing their own food such as vegetables, herbs and fruits. By growing own food, it allow them to ensure the freshness of the produces and also can help to cut the cost of grocery bill (Rezai et al., 2016a).

Recently, Universiti Putra Malaysia had also initiated the urban agriculture program in its effort to support the government campaign to encourage city dwellers to carry out modern farming activities in the limited spaces of their homes as a guaranteed source of food for the nation by 2020. The development of urban agriculture is important nowadays as we need to take care of our constrained resources especially land, water and biodiversity. Additionally, growing plants in vertical structure by controlling and monitoring the temperature, humidity, fertilizer formulation especially in liquid form and water is a very good agriculture and food production for future (Khairul, 2013).

However, most of the people that live in the congested area have very limited or no land for plant cultivation or gardening. Thus, by applying vertical garden system could be one of the farming alternatives due to less space is needed if compared to growing plant conventionally. In Malaysia the idea of growing plants in the vertical garden is still in its infancy stage. There is still a lack of relevant and site-specific design and database to support and invest in vertical gardening system. These data include the appropriate design, suitable types of plant growth, conditions needed for healthy growth, construction and maintenance of farming facilities and also the implementing and production budget (Khairul, 2013). Besides that, there are very limited commercialized vertical gardens in Malaysia if compared to other developed countries such as Singapore, United States, Japan and Korea where they already have several established designs of vertical gardens. These issues become one of major limitations for the urbanites in Malaysia to start their own garden where they do not have enough space and infrastructures.

1.2 Problem Statement

Although there are several vertical garden systems have been developed, there is still very little information about the plants performance growth in the vertical garden system. To date, there is no known research being reported on the plant growth performance or difference if the plants are grown in the different stacks or levels of vertical garden system. It is very important to determine the uniformity of the plant growth if growing in the vertical garden because it can

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identify whether the plants can adapt and survive well in the condition of the growing in different stacks of the vertical garden.

Most of the vertical gardens are fully integrated with hydroponic system. The hydroponic vertical garden system is a method of growing plants using water and nutrient solutions, without soil in vertically stacked layers. Therefore, monitoring and maintaining the water quality such as its pH and electrical conductivity (EC) of the hydroponic vertical garden are crucial for the plants growth. Currently, the quality of nutrient solution monitoring process of vertical garden has to be carried out manually and can be inconvenient especially for urban people who always busy and wanted a simple complete planting system.

Based on the highlighted studies, this project is proposed to design and develop a smart vertical garden system that could provide consumers either for individual and community used with the ability to grow the edible vegetables, herbs or fruits easily especially in the cities. A very simple water nutrient monitoring system is also required to develop and implement in the system to monitor the status of nutrients, especially its pH and EC for growing healthy plants and producing high yields. In addition, the vertical garden also will be suitable as a kit for educational purpose to attract the young generation in urban agriculture.

1.3 Objectives

The overall goal of this research was to design and develop a compact and smart vertical garden system for urban agriculture initiative in Malaysia. The specific objectives of this project were as follows:

1. To design and develop a hydroponic vertical garden system together with nutrient status (pH and EC) monitoring system for optimum plants growth.
2. To determine the leaf lettuce (*Lactuca sativa*) growth developement at the different stack heights of vertical hydroponic system.
3. To evaluate the plant growth development of lettuce (*Lactuca sativa*) planted using the vertical garden and conventional hydroponic system.

1.4 Scope and Limitations

1. The system is designed and targeted to be used by the households, hobbyist, community garden, or as the educational purposes for schools or universities.

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2. The vertical garden system is designed for the indoor usage either in the shaded or covered area where the irrigation is automatically carried out.

3. The plant used in this study is green leaf lettuce (*Lactuca sativa*).

1.5 Thesis Layout

The thesis is divided into five main chapters. Chapter 1 is the introduction, which presents general information about the research topic; whereby problems, motivation, objectives, and scope of the work are briefly discussed. Chapter 2 is the literature review, whereas in this chapter, some previous studies have been reviewed regarding the urban agriculture system and vertical gardening techniques to provide the readers with an understanding into the basic knowledge and concept. Chapter 3 explains the materials and methods, the design and develop the system of the vertical garden. Besides, how the experiment has been conducted is also briefly discussed in this chapter. Meanwhile, Chapter 4 presents the results obtained from the experiment done in this project. In addition, this chapter discusses and explains the biophysical parameters of plant growth. The thesis is concluded in chapter 5 which summarizes the work done in the project. Recommendations for further improvement are also discussed in this chapter.

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LIST OF PUBLICATIONS

Journal

Hamidon, M. H., Aziz, S. A., Ahamed, T., Mahadi, M. R. (2019). Design and Development of Automatic Vertical Garden System for Urban Agriculture Initiative in Malaysia. *Jurnal Teknologi (Sciences & Engineering)* No 82: 1 January 2020.

Conferences

Hamidon, M. H., Aziz, S. A., Ahamed, T., Mahadi, M. R. (2017). Vertical Garden System for Urban Agriculture Initiative in Malaysia- Poster Presentation. *Ag-ESD Symposium*, University of Tsukuba Japan.

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