UNIVERSITI PUTRA MALAYSIA

GROWTH RESPONSE, HEAVY METAL CONTENT, AND HEALTH RISK ASSESSMENT OF Brassica juncea L. AND Amaranthus tricolor L. CULTIVATED IN URBANIZED AND RURAL AREAS

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By

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Urbanization will lead to changes in socioeconomic structures in Malaysia. It may also lead to changes in the quality of agricultural products due to modified ecosystem. The purpose of this study is to observe and to evaluate the plant growth responses and Health Risk Assessment (HRA) on two selected leafy vegetables. *Brassica juncea* L. (*Brassica* sp.) and *Amaranthus tricolor* L. (*Amaranthus* sp.) that were grown under urban ecosystem at Seksyen 24, Shah Alam and the rural (traditional) Field of UPM were compared in terms of their growth performance. Growth parameters such as leaf area ratio (LAR), leaf weight ratio (LWR), and specific leaf area (SLA) were determined from the dry weight of plants' parts that had been oven-dried until constant weight was achieved. Chlorophyll contents were determined using extraction method of fresh leaf in 80% acetone, while photosynthetic parameters (photosynthesis, transpiration rate, and stomatal conductance) were determined using Portable Photosynthesis System (LI-6400XT). Heavy metals such as copper (Cu^{2+}), iron (Fe^{2+}), and zinc (Zn^{2+}) were determined using a dry-ashing method. Health Risk Assessment (HRA) parameters, Estimated Daily Intake (EDI) and Target Hazard Quotient (THQ) were done according to the formula. The results showed that total dry weight of *Brassica* sp. was greater when grown in rural area, and greater for *Amaranthus* sp. when grown in urban area. The LAR values of both species were found to be higher in the samples grown in urban area compared to rural area. The LWR values of *Brassica* sp. were higher in the samples grown in rural area and LWR of Amaranthus sp. were higher when grown in urban area. The values of SLA were higher in both species grown in urban area compared to rural area. Meanwhile, the chloropyhll content in *Brassica* sp. were higher in the samples grown in rural area. However, the chlorophyll contents in *Amaranthus* sp. were higher in the samples grown in urban compared to rural area. All photosynthetic parameters of both species were higher in the samples grown at rural area compared to urban area. Meanwhile, the heavy metals were found to be higher in the samples grown in urban area compared to rural area, except for Zn. HRA assessment showed that no health risk to human when consuming both vegetables grown from both sites since THQ values were

less than 1. Urbanization has significant changes on some of the physiological reactions and contamination that occurs in urbanized area may contribute in exposure to health risk.

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

GERAK BALAS PERTUMBUHAN, KANDUNGAN LOGAM BERAT, DAN PENILAIAN RISIKO KESIHATAN DALAM TANAMAN *Brassica juncea* L. DAN *Amaranthus tricolor* L. DI KAWASAN BANDAR DAN LUAR BANDAR

Oleh

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Perbandaran berupaya membawa kepada perubahan dalam struktur sosioekonomi di Malaysia. Ia juga boleh menyebabkan perubahan dalam kualiti produk pertanian disebabkan oleh ekosistem yang diubahsuai. Tujuan kajian ini adalah untuk menilai tindak balas pertumbuhan oleh tumbuhan dan Penilaian Risiko Kesihatan ke atas dua sayuran berdaun yang terpilih. Perbandingan pertumbuhan dijalankan antara *Brassica juncea* L (*Brassica* sp.) dan *Amaranthus tricolor* L. (*Amaranthus* sp.) yang ditanam di bawah ekosistem bandar di Seksyen 24, Shah Alam dan Ladang UPM luar bandar untuk mengkaji kadar pertumbuhan keduanya. Parameter pertumbuhan seperti nisbah kawasan daun (LAR), nisbah berat daun (LWR), dan kawasan daun spesifik (SLA) ditentukan dari berat kering bahagian-bahagian tumbuhan. Kandungan klorofil ditentukan dengan menggunakan kaedah pengekstrakan daun segar dalam 80% aseton, manakala parameter fotosintesis (fotosintesis, kadar transpirasi, dan konduktansi stomatal) ditentukan dengan menggunakan Sistem Fotosintesis Portable (LI-6400XT). Logam berat seperti tembaga (Cu), besi (Fe), dan zink (Zn) ditentukan menggunakan kaedah kering-debu. Parameter Penilaian Risiko Kesihatan, Anggaran Pengambilan Harian (EDI) dan Target Hazard Quotient (THQ) dilakukan mengikut formula dari literatur. Keputusan menunjukkan bahawa jumlah berat kering *Brassica* sp. adalah lebih berat apabila ditanam di kawasan luar bandar, dan lebih berat untuk *Amaranthus* sp. apabila ditanam di kawasan bandar berbanding di kawasan luar bandar. Nilai-nilai LAR kedua-dua spesies didapati lebih tinggi dalam sampel yang ditanam di kawasan bandar. Nilai LWR *Brassica* sp. adalah lebih tinggi dalam sampel yang ditanam di kawasan luar bandar dan LWR *Amaranthus* sp. lebih tinggi apabila ditanam di kawasan bandar. Nilai SLA adalah lebih tinggi dalam kedua-dua spesies yang ditanam di kawasan bandar berbanding di kawasan luar bandar. Sementara itu, kandungan klorofil dalam *Brassica* sp. adalah lebih tinggi dalam sampel yang ditanam di kawasan luar bandar berbanding di kawasan bandar. Walau bagaimanapun, kandungan klorofil dalam *Amaranthus* sp. adalah lebih tinggi dalam sampel yang ditanam dalam ekosistem bandar berbanding di kawasan luar bandar. Semua parameter fotosintesis kedua-dua spesies adalah lebih tinggi dalam sampel yang ditanam di kawasan luar bandar berbanding di kawasan bandar. Logam berat didapati

lebih tinggi dalam sampel yang ditanam di kawasan bandar berbanding dengan kawasan luar bandar, kecuali Zn^{2+}. Akhir sekali, penilaian HRA menunjukkan bahawa tiada risiko kesihatan kepada manusia apabila memakan kedua-dua sayur-sayuran yang ditanam di kedua-dua tapak tersebut kerana nilai THQ adalah kurang daripada 1. Perbandaran mempunyai perubahan ketara terhadap beberapa reaksi fisiologi dan pencemaran yang berlaku di kawasan bandar boleh menyumbang kepada pendedahan kepada risiko kesihatan.

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The thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted a fulfillment 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 Members of Supervisory Committee:

This is to confirm that:

- The researched conducted and the writing of this thesis was under our supervision;
- Supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

cm	centimetre
Cu	Copper
Dw	dry weight
EDI	Estimated Daily Intake
et al.,	and other
Fe	Iron
g	gram
HCl	Hydrochloric acid
HNO3	Nitric acid
Km2	Kilometre squared
mg/kg dw	miligram per kilogram dry weight
ml	millilitre
ParIn	In-chamber quantum sensor (µmol m-2s-1)
ppm	parts per million
RfD	Oral Reference Dose
Tblock°C	Temperature of cooler block (C)
THQ	Target Hazard Quotient
Zn	Zinc
°C	degree Celsius
%	percent

CHAPTER 1

INTRODUCTION

1.1 Introduction

Classifications of urban and rural areas are based on the several points such as population density, ecosystem natural richness, and social groups. Dijkstra & Poelman (2014) defined three degree of urbanisations which are rural area (populations of above 100 inhabitants per km^2 but with less than 50 thousand inhabitants), towns and suburban (300 inhabitants per km^2 and a minimum population of 5 thousand), and urban cities (populations of 500 inhabitants per km^2 with more than 50 thousand inhabitants) based on their respective population. In other country like Japan, the classification of rural area is based on specific population threshold of an area (eg: 500 persons per square kilometer (km^2)) so that the difference to other denser area can be clearly understand (Pizzoli & Gong, 2007). In reference to natural richness, rural area is classified as an area of agricultural land, forests or hill that leads to limitation of human activities other than agriculture, and urban area offered more opportunities to the population around (Gallego, 2004; Vard, 2005).

Urbanization can be described as the process occurring along transitional change of an allocated area from rural area to sub-urban area, and lastly to urban area (Chaolin et al., 2012). In rural area, there are limited numbers of buildings and population, while urban area is monopolized by cities of concrete jungle along the roads (Zhang & Ramaswami, 2016). The development of settlements in urban area can be characterized with the presence of various centres for economy and social such as education institution and international ports for trades, as can be observed in Southeast Asia due to its strategic location along the maritime crossroads (Han & Beisi, 2016). In the other hand, population is more crowded in urban area, where migration is occurring from time to time due to job availability and for education purpose (Grant, 2012). Urban expansion settlements such as apartments and condominiums are dominant in urban cities where the demand increases over years causing more cropland area to be explored (d'Amour et al., 2017), while traditional detached settlement are remained in rural area with only several rebuilding procsses done over years (Heinonen & Junnila, 2011).

The urbanization process was driven by various factors including migration, lifestyle, and mainly economic positive achievement (Small et al., 2018). Migration occurs due to job availability with large network of speciality, where grouped of specialist work on specific functions are important to be practice since the urban trade are developing (Turok & McGranahan, 2013). In addition, lifestyle directed people to have a living in urban area with emergence of efficient developed technologies for daily lives such as systematic sewage treatments and public infrastructures such as hospitals and universities (Martine et al., 2008). The development of economic sector in urban area produces large labour pool to participate and rely to each other in developing new economic achievement by idea-sharing (Cooke et al., 1998).

Malaysia also undergoes urbanization transformation decades ago with development in urban settlement and growth within that period of developing (Ahmad et al., 2009). The trends of urban growth can be observed in Federal Territory of Kuala Lumpur and Penang where cities are developing with more dense population due to migration and establishment of housing capacities (Yaakob et al., 2010). These two cities evolved from the British colonization where commercial centres and exports hub develop around the Malacca City and later to Kuala Lumpur when the British intervention takes place (Sendut, 1965). Besides, urban community are usually from the government officer and industrial workers that settled down in the nearest area for their service, where only less of them settled down in rural area with the urban settlers have higher income compared to rural settlers (Siwar et al., 2016). In rural area, the community are mainly the villagers and folks that actively involved in agriculture (Thompson, 2004) and other rural production such as handcrafts and food product.

The emergence of new industrial sectors in main districts invites immigrants to migrate. In Kuala Lumpur and Johor Bahru, job offers mainly attracts people to migrate and living in large cities. In Malaysia, Shah Alam is located at Klang Valley area consists of second highest urban population in Malaysia (Karim, 2009). Shah Alam is a highly urbanized area with the presence of industrial centres (Dominic et al., 2012) providing large opportunity of job that drives migration to urban area. Also in Shah Alam, there were the presence of urbanized civilization of highways, housing areas, and industrial areas (Kalana, 2010).

Urbanization has both positive and negative attributes to social and environment. Environmentally, in urban area, the original ecosystem is damages and new landscape of ecosystem introduced (Gren & Andersson, 2018). The main changes can be observed mainly on soil condition and its physical characteristics of the texture, high pH, and lower organic matter (Li et al., 2013). These soil conditions are no longer suitable for previous crops and may be suitable for other crops.

In urban area, air quality is decreasing due to air pollution and haze (Liu et al., 2015). Pollutants originating from the factory smoke and from the large various number of transportations are releases into the atmosphere, as observed in Indonesia (Hunt & Wu, 2017). Transportation is mainly important in urban area for transporting goods from the industrial centres, other than for the human transportation itself (Russo & Comi, 2012). Meanwhile in rural area, the numbers of industrial transportation were less than the one in urbanized area due to less overcrowded settlements and presence of short-distance small scale trading. Other than that, combined-effect between transportation and factories wastes causes the concentrations of carbon dioxide in urban area elevates, by releasing their wastes in the air (Heinonen & Junnila, 2011).

Due to the growing populations from year to year, continuous food supply is a must to meet the demand for food (Hanjra & Qureshi, 2010). However, due to depleted land area in urbanized area, urban crop production becomes the solution where the available land is completely utilized for food production (Olsson et al., 2016). In Malaysia, agricultural development was stressed on 10th and 11th Malaysian Plans (Rafindadi & Ozturk, 2015). This was suggested in order to produce sufficient food supply such as vegetables, fruits, livestock, and aquaculture by implementing urban farming for food production and also developing the abandoned land areas by for solution to less area for agriculture (DOA, 2015).

Industrial wastes such as in urban areas leads to soil pollution and indirectly polluted the water systems from the runoffs (Goonetilleke et al., 2005). The pollutants later transported into the plants, exposing people to health risk if edible plants are affected. As an example, heavy metals contamination in soils was common pollution occurs in urban soils due to industrialization (Gratao et al., 2005). The extraction of specific pollutants such as heavy metals from the soil of polluted ecosystem can be done by bioremediation process called phytoremediation where plants decontaminate soil by eliminate, transfer, or degrade contaminants in the soil (Ashraf, 2013). Specifically, phytoextraction process is the process where metals or organics extracted from contaminated soil and water by plant roots and translocate them to shoots (Morikawa & Erkin, 2003). Examples of plants that can accumulate high heavy metals were *Aspalathus linearis* (presence of specialized cluster roots) that can remove excess aluminium (Kanu et al., 2013) and sunflower, *Helianthus annuus* L. is the best phytoremediation agent to remove lead (Seth et al., 2011).

1.2 Objectives

There are three objectives of this study as follows:

1) to compare the physiological responses of *Brassica* juncea L. and *Amaranthus tricolor* L. grown in urban area and rural area of Selangor, Malaysia.
2) to determine the concentration of heavy metals (Cu, Fe, Zn) in *Brassica* juncea L. and *Amaranthus tricolor* L. grown in urban area and rural area in Selangor, Malaysia.
3) to determine the Health Risk Assessment from the consumption of *Brassica* juncea L. and *Amaranthus tricolor* L. grown in urban area compared to rural area.

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