



Faculty of Resource Science and Technology

**Growth Performance and Yield of *Brassica rapa* var. *chinensis* with
Takakura and Conventional Compost**

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Growth Performance and Yield of *Brassica rapa* var. *chinensis* with Takakura
and Conventional Compost

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



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ABSTRACT

Composted organic waste from food waste and plants is beneficial to enhance crop productivity and agricultural sustainability. Compost added to soil as a soil amendment is rich in a wide range of plant-available nutrients that could significantly enhance the plant growth and yield but there is no specification of different composting methods to produce compost as a soil amendment for crops. Thus, this study aims to evaluate the growth performance and yield of *Brassica rapa* var. *chinensis* (*B. rapa*) cultivated or growing in the medium (topsoil) incorporated with compost varied in composting methods. Additionally, the study also investigates the growth response of *B. rapa* when chemical fertilizer is added during cultivation from third week until harvest. Six treatments were applied, namely cultivation of *B. rapa* with topsoil only (C), topsoil with fertilizer (CF), Takakura compost amendment only (T), Takakura compost amendment with fertilizer (TF), conventional compost amendment only (M) and conventional compost amendment with fertilizer (MF). The results showed that after six (6) weeks of cultivation, the plant height averaged 20 cm with 18 leaves produced across compost amendment treatments, while the treatments with fertilizer with plant height averaged 25 cm with 21 leaves produced. The other growth parameters, namely fresh to dry weight ratio, root to shoot ratio, and light interception percentage, showed no significant differences at $p \leq 0.05$ among all the compost amendment treatments (T, M, TF, and MF) while different with C and CF treatment. The leaf area and total yield of *B. rapa* show significant differences among compost amendment treatments, while the treatment with chemical fertilizer achieved the highest yield of 1173.4 cm² in leaf area and 44.3 t/ha of total yield. From this study, applying different types of compost, either Takakura or conventional composting, positively affects the growth performance of *B. rapa*

plants. Moreover, combining fertilizer and compost amendment during cultivation will promote the increment in *B. rapa* leaf area and yield.

Keywords: Compost amendment, growth and yield, Siew Pek Chai (Pak Choy), Takakura composting and conventional composting, decompose.

Prestasi Pertumbuhan dan Hasil Brassica rapa var. chinensis dengan Kompos Takakura dan Konvensional

ABSTRAK

Sisa organik kompos daripada sisa makanan dan tumbuhan bermanfaat untuk meningkatkan produktiviti tanaman dan kemampunan pertanian. Kompos yang ditambahkan ke tanah sebagai pindaan tanah kaya dengan pelbagai nutrient tumbuhan yang tersedia secara signifikan boleh meningkatkan pertumbuhan dan hasil tumbuhan dengan ketara tetapi tidak ada spesifikasi kaedah pengkomposan yang berbeza untuk menghasilkan kompos sebagai pindaan tanah untuk tanaman. Justeru, kajian ini bertujuan untuk menilai prestasi pertumbuhan dan hasil Brassica rapa var. chinensis (B. rapa) ditanam atau tumbuh dalam medium (tanah atas) yang digabungkan dengan kompos berbeza-beza dalam kaedah pengkomposan. Selain itu, kajian ini juga menyiasat tindak balas pertumbuhan B. rapa apabila baja kimia ditambah semasa penanaman dari minggu ketiga sehingga menuai. Enam rawatan telah digunakan iaitu penanaman B. rapa dengan tanah atas sahaja (C), tanah atas dengan baja (CF), kompos Takakura pindaan sahaja (T), kompos Takakura pindaan dengan baja (TF), pindaan kompos konvensional sahaja (M) dan pindaan kompos konvensional dengan baja (MF). Keputusan menunjukkan bahawa selepas enam (6) minggu penanaman, purata ketinggian tumbuhan adalah 20 cm dengan 18 helai daun terhasil merentasi rawatan kompos pindaan, manakala rawatan dengan baja dengan ketinggian tumbuhan purata 25 cm dengan 21 helai daun. Parameter pertumbuhan yang lain, iaitu nisbah berat segar kepada kering, nisbah akar kepada pucuk, dan peratusan pintasan cahaya, menunjukkan tiada perbezaan yang ketara pada $p \leq 0.05$ antara semua rawatan pindaan kompos (T, M, TF, dan MF) manakala berbeza dengan C. dan rawatan CF. Luas

daun dan jumlah hasil B. rapa menunjukkan perbezaan yang ketara antara rawatan pindaan kompos, manakala rawatan dengan baja kimia mencapai hasil tertinggi iaitu 1173.4 cm² luas daun dan 44.3 t/ha daripada jumlah hasil. Daripada kajian ini, penggunaan pelbagai jenis kompos, sama ada Takakura atau pengkomposan konvensional, memberi kesan positif kepada prestasi pertumbuhan tumbuhan B. rapa. Selain itu, menggabungkan baja dan kompos pindaan semasa penanaman akan menggalakkan penambahan dalam kawasan daun B. rapa dan hasil.

Kata kunci: Pindaan kompos, pertumbuhan dan hasil, Siew Pek Chai (Pak Choy), pengkomposan Takakura dan pengkomposan konvensional, reput.

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LIST OF ABBREVIATIONS

<i>B. rapa</i>	<i>Brassica rapa</i> var. <i>chinensis</i>
ANOVA	Analysis of Variance
BP	banana peel
CG	coffee ground
DOA	Department of Agriculture
ES	eggshell
FAMA	Federal Agricultural Marketing Authority
FAO	Food and Agriculture Organization
FL	fallen leaves
FS	fish scrape
GC	grass clipping
K	Potassium
MCO	Movement control order
N	Nitrogen
P	Phosphorus
PPT	Pusat Penyelidikan Tumbuhan (Plant Research Center)
UNIMAS	Universiti Malaysia Sarawak

CHAPTER 1

INTRODUCTION

1.1 Introduction

Bio-waste is defined as all biodegradable materials either from agriculture, post-harvest loss in farm or plantation, industrial, domestic activities, including kitchens, cafeterias, and restaurants (Chen *et al.*, 2016; Lim *et al.*, 2016; Ghafar, 2017). According to Food and Agriculture Organization (FAO, 2011), approximately 1.3 billion tonnes of food waste are produced globally. In Malaysia, it was reported that 15,000 tonnes of food were wasted daily, of which 3,000 tonnes were still suitable for consumption (Razak *et al.*, 2018). Although waste disposal in landfills is an option for managing food waste in Malaysia, it has become increasingly challenging since many landfills have reached full capacity (Moh & Manaf, 2014). Composting is one of the alternative methods that should be considered to manage waste disposal, especially for bio-waste.

Compost is produced through a process known as composting, which is a low-cost biological decomposition process through the action of different microbial communities that affect the physical-chemical properties of compost. The factors that affect the composting process include temperature, aeration, moisture content, the ratio of carbon to nitrogen, and pH (Kadir *et al.*, 2016). In spite of the fact that composting is a time-consuming process, the end result has been demonstrated to be beneficial as it remediates the soils which boosts the fertility and the microbial activities of the soil ecosystem. In addition, composting has the potential to assist in the resolution of environmental pollution or greenhouse gas effects by transforming the abundance of food waste generated as a result of an increasing population into a rich nutrient soil beneficial for plant growth. Applying compost amendment in agriculture increases the yield of crops (Farrell & Jones, 2009). According to Khalib *et al.* (2014), compost improves

the soil's physical and biological properties, suppresses diseases caused by plant pathogens, and simultaneously reduces a significant amount of waste that would otherwise be directly disposed of at a landfill. Compost can be made from various organic materials, such as food scraps, yard waste, and weeds.

Composting, a widely employed technique in sustainable agriculture, encompasses various approaches, with the conventional method emerging as one of the most prevalent. There are a few composting methods; one of the most common is conventional composting. The conventional or traditional composting method involves systematically layering bio-waste to facilitate its natural decomposition, essential for enhancing soil fertility and promoting ecological balance (Raimi *et al.*, 2020). The conventional composting method begins with carefully stacking organic materials, such as kitchen scraps, yard waste, and other biodegradable matter. These materials are strategically arranged in alternating layers, creating a dynamic microbial activity and decomposition environment. Unlike some contemporary composting methods that rely on introducing specific microbes to accelerate the process, the conventional approach emphasizes the innate decomposition of organic matter without the direct intervention of microbial cultures (Barlóg *et al.*, 2020). The layering technique in conventional composting serves multiple purposes. It promotes optimal aeration, allowing for the exchange of gases crucial for breaking down complex organic compounds.

Additionally, the layered structure provides a balanced carbon-to-nitrogen ratio, fostering a harmonious environment for microorganisms involved in the decomposition process. The absence of external microbial inoculation distinguishes the conventional method, relying instead on the diverse microorganisms naturally present in the environment to initiate and sustain the composting process (Giannakis *et al.*, 2014). It is important to note that while the conventional composting method is widely practiced, variations in climate, waste composition, and local practices may influence its efficacy. Raimi *et al.* (2020) contribute

valuable insights into the dynamics of this traditional composting method, shedding light on its effectiveness in different contexts and offering practical considerations for sustainable agricultural practices.

Takakura composting is currently the most popular method developed by Koji Takakura by producing fermentative microorganisms as compost seed, followed by mixing the fermented compost seed with the available bio-waste in residential areas (Nuzir *et al.*, 2019). The most exciting potential of the Takakura composting method is that it only requires a shorter time, about two weeks to complete the decomposition cycle compared with other composting methods that need months to complete (Nuzir *et al.*, 2019 and Raimi *et al.*, 2020).

There are few studies reported on the composting method and ratio of starting material for composting. Iqbal *et al.* (2010) have studied the effect of three different composting techniques (aerobic, anaerobic and mixed type), while Guidoni *et al.* (2018) used three different ratios of home-based starting material (rice husk and raw fruit and vegetable leftover) for composting. However, the primary emphasis of both studies is placed on the consistency and maturity of compost. Compost use in growing media for crops is still an open question despite the preliminary research and information that has been gathered on various composting methods and different starting materials in compost production. Home-based composting could be challenging because of its inconsistent characteristics (Amiruddin *et al.*, 2020). Using compost as an amendment or combination with a small amount of chemical fertilizer in agriculture instead of fully applying chemical fertilizer will reduce the risks of soil degradation and nutrient leaching while preserving soil quality (Hernández *et al.*, 2016). *Brassica rapa* var. *chinensis*, also known as Pak Choy or Bok Choi (Chinese mustard), is one of the common leafy vegetables that (Stephen & Gobilik, 2022) is commonly used as planting materials in preliminary studies as it is easy to cultivate either farming or home gardening. Despite its ease of cultivation, Malaysia's demand for *B. rapa*, a leafy vegetable, exceeds the local supply,

necessitating imports (Maludin *et al.*, 2019). Home gardening with home compost is a fundamental option for self-consumption of bio-waste that can effectively alleviate this issue. Furthermore, there is a limitation in the studies on the growth performance and yield of *B. rapa* when comparing compost produced through Takakura composting and conventional composting.

Hence, this study was conducted with the main objectives are:

- i. To assess the maturity and quality of compost from home-based waste using Takakura and conventional composting methods produced compost on the seed germination rate of *B. rapa* var *chinensis* seeds.
- ii. To investigate the effect of different composting methods (Takakura and conventional composting) produced compost on the growth performance of *B. rapa* var *chinensis* crops.
- iii. To assess the effect of different composts on soil chemical properties and its suitability for *B. rapa* var *chinensis* crop cultivation.

CHAPTER 2

LITERATURE REVIEWS

2.1 *Brassica rapa* var. *chinensis* (Pak Choy)

Brassica rapa is a diverse species within the *Brassicaceae* family that presents an impressive array of delicious and nutritious value. *B. rapa* varieties can be categorized by their edible parts, for example, roots (turnip), inflorescence (Chinese broccoli), and leafy green (*B. rapa* var. *chinensis*) (Cartea *et al.*, 2011). *Brassica rapa* var. *chinensis*, commonly known as Pak Choy (Figure 2.1), is one of the famous leafy vegetables in tropical areas with dark green leaves and fleshy petioles (Palada & Crossman, 1999) which almost whole plant parts are edible. *B. rapa* is a common leafy vegetable that is commonly used in Asian cuisine (Stephen & Gobilik, 2022). It has thick, large leaf stems with spoon-shaped and dark green leaves (Martin, 2008). It is widely known for its tasty, mild, sweet flavour and crunchy texture. According to Artemyeva and Solovyena (2006), *B. rapa* is the primary production and consumption botanical group after potatoes and tomatoes in developed countries due to its nutritional content. It provides dietary fibre, high protein, vitamins and minerals that are low in saturated fat and cholesterol (Tuquero *et al.*, 2018). The *Brassica* genus crops also contain a secondary plant metabolism compound, glucosinolates that promotes health benefits for human consumption (Podsedek, 2007; and Kalisz *et al.*, 2013). Aside from the eating characteristics of *B. rapa*, the main reason for consumers' choice of this vegetable is due to its capability to be a good source of anti-cancer property, which can be developed into health foods to inhibit cancerous transformation and growth, thus controlling the risk of specific cancer (Herr & Buchler, 2010). Based on Cartea and Velasco (2008) and Acikgoz (2016), the glucosinolates content in the *Brassica* genus helps against cancer, promotes an anti-oxidant, anti-bacterial and anti-viral activities that supports the human immune system prevent

cardiovascular disease and aging process. Thus, *B. rapa* is not only consumed fresh but can also be used in other food products, such as pickles, dehydrates chips, juices and dyes (Chen, 2007). *B. rapa* can also be used as animal feed in farms as part of animal diet (Barchiesi-Ferrari & Chihuailaf, 2019).



Figure 2.1: *Brassica rapa* var. *chinensis* (Pak Choy) (Kalisz *et al.*, 2012).

Due to *B. rapa* medicinal eating characteristics, *B. rapa* consumption in Malaysia has increased (Park *et al.*, 2023). During the COVID-19 pandemic in the year 2020, the movement control order (MCO) imposed by the Malaysian government restricted operation of various sectors, including agriculture (WHO, 2021), which led to lack of food supply due to low production of crops and vegetables locally. Hence, the food supplies are dependent mainly on imported foods causing the price of *B. rapa* increased tripled (FAMA, 2021). According to FAMA (2021), the production of *B. rapa* in Malaysia is insufficient for daily consumption. Thus, increased the demand for imported *B. rapa* and eventually increased the price of *B. rapa* tripled in the market from RM3.00 to RM12.00 per kilogram. *B. rapa* is well-known as an easy

to cultivate and fast-growing plant. Reducing the import of *B. rapa* while increasing its local production or home gardening will help to alleviate the supply of *B. rapa* and other leafy vegetables.

B. rapa grows vigorously with enough supplement of NPK and only takes approximately 30 – 40 days to harvest after transplanting (Ram, 2009; Maselesele *et al.*, 2022). *B. rapa* can be planted directly on soil or fields, in modern urban farming like hydroponic and fertigation, and even the most accessible way as pot planting for home gardening. The residential biodegradable waste produced daily can be used for composting and applied for home gardening. Purbajanti and Setyowati (2020) reported that the application of fertilizers like organic fertilizer could improve soil fertility and increase *B. rapa* production. Based on Maselesele *et al.* (2022), macadamia husk compost shows a positive effect on root biomass, root length, number of leaves, leaf biomass and leaf area index of *B. rapa* production. Hence, it is worth examining the compost produced with different starting materials on *B. rapa* growth.

2.2 Synthetic Fertilizer

Synthetic fertilizers or chemical fertilizers are manufactured inorganic compounds used as nutrient supply for plant growth. Often produced as straight or compound fertilizers, the standard nutrient content mainly consists of Nitrogen (N), Phosphorus (P) and Potassium (K). Synthetic fertilizer was introduced during the 19th century and is widely used for modern agriculture production (Sabry, 2015). There are various forms of synthetic fertilizers available in the market. Granular fertilizer is the most common form of synthetic fertilizer easily found in the market which is normally in small pallet size, easy to apply, and spread over a large scale of farm (Šarauskis *et al.*, 2021).

Although cheap, the granular fertilizer releases nutrients slowly over time and provides long-lasting effects, which is unsuitable for plants requiring immediate nutrient uptake. Next, the synthetic fertilizer in liquid form is usually a concentrated solution that must be diluted with water before application. Liquid fertilizer is also easy to apply using a watering can or sprayer, whereby nutrients dissolved in liquid fertilizer have faster plant absorption than granular fertilizer (Summit Fertilizers, 2011). However, liquid fertilizer can be more expensive and unsuitable during the rainy season as it is prone to leaching. Subsequently, foliar fertilizer, is applied directly to the leaves of plants by spraying. Even though the plants can uptake nutrients faster from foliar fertilizer, however, it is unsuitable for all plant types because this form of fertilizer may sometimes cause leaf burn (Babu, 2022). Another fertilizer forms are coated in granules, pellets, or tablets but they have different function from granular fertilizer, which is a slow-release fertilizer. This fertilizer can release nutrients gradually over time, providing consistent nutrition without the risk of over-fertilization. However, it is unsuitable for plants needing immediate nutrient uptake (Savoy, 2012). The last form of synthetic fertilizer is the water-soluble fertilizer. It is in concentrated powder form that must be dissolved in water before application. Water-soluble fertilizers can be used widely, including soil and foliar sprays and even hydroponic systems, which can minimize soil pollution (Sathisha, 2022). Using water-soluble fertilizer requires accurate measuring and handling to avoid overfertilization and is costly compared to liquid fertilizer.

Application of synthetic fertilizer can increase crop yield (Sabry, 2015) and it acts fast to release nutrients absorbed by soil and plants (Zaman *et al.*, 2014). According to Owolabi *et al.* (2016), using inorganic fertilizer on *Jatropha curcas* L. (physic nut) significantly affected plant growth and dry matter yield. Synthetic chemical fertilizers are widely used in agriculture as they are believed to raise soil fertility and increase crop yield significantly. It is a convenient way to retain the production of crops. Despite these benefits, the overuse of chemical fertilizer

negatively affects the ecosystem, causing severe pollution. Overuse of chemical fertilizer can lead to soil acidification that changes soil pH, humus content and organic matter content, which decreases the soil beneficial organism and microorganism activity, resulting in stunting plant growth and yield reduction (Chandini *et al.*, 2019).

Moreover, some fertilizers contain heavy metals that lead to environmental problems such as water, soil and air pollution (Savci, 2012). Overuse of inorganic fertilizer can lead to soil acidification and thus affect soil fertility (Chandini *et al.*, 2019). Soil acidification decreases the soil pH, thereby reducing organic matter, humus, and beneficial organisms and stunting plant growth, even contributing to greenhouse gas release. Zaman *et al.* (2014) stated that the plants treated with chemical fertilizer would not have sufficient time to grow with good roots, solid stems and nutritious products. Such a situation could lead to poor taste of the agricultural products.

The use of synthetic fertilizer in farming helps in improving crop yield. In order to safely use synthetic fertilizer effectively while protecting the environment, the safe use of synthetic fertilizer is required for a balance. In commerce or laboratories, the safe use of synthetic fertilizer can go through soil testing through soil analysis to identify the existing nutrient levels of soil to prevent unnecessary fertilizer application. However, soil testing does not apply to farmers and growers. The safe use of synthetic fertilizer can only be based on their experience of growing crops, whereas fertilizer only applies when considering the growth stage of plants to prevent overfertilization. Among the ways of utilizing synthetic fertilizer appropriately, splitting synthetic fertilizer for safety use to divide the dosage into small applications throughout the growing season to prevent nutrient overload for farmers and growers is often being practiced (Zeng *et al.*, 2013). Nonetheless, to sustain a healthy and safe soil, the most common methods widely used are crop rotation and another one is promoting

organic amendment to save the environment and produce safe and healthy foods for consumption (Urre *et al.*, 2019).

2.3 Organic Amendment

Organic amendment is made from biodegradable organic waste that can be used in agriculture for nutrient supply (Ferreira *et al.*, 2018). Besides the uses of synthetic fertilizers, organic fertilizer and compost are the alternatives to be considered as a nutrient supply in agriculture. Organic amendment is produced through mineralization, which converts organic materials into available nutrients that plants can readily absorb. Compost is a low-cost biological decomposition process that aids with the microbial activity that could influence the compost's physical and chemical properties, including temperature, aeration, moisture content, C: N ratio and pH (Kadir *et al.*, 2016). However, organic fertilizers are often sold as soil conditioners instead of fertilizers as they may improve soil's physical properties (Savoy, 2012). According to El-Haggar (2007), the benefits of organic fertilizer include preserving the environment and ecosystem by continuously supplying organic nutrients, amino acids, fatty acids, vitamins and mineral content to restore unproductive soil. It is eco-friendly to the environment and deficient in production cost. Lin *et al.* (2019) reported that organic fertilizer can enhance crop yield and soil properties while preventing pests and diseases. The authors also reported that using organic fertilizer significantly increases amino acid, pH and microbial composition while reducing heavy metal elements (Cu, As, Pb and Cd) compared with chemical fertilizers.

Different organic materials used in composting to produce substrates for farming contain different chemical compositions and components that supply macro or micronutrients that can enhance plant growth (Castro *et al.*, 2009; Hossain, 2017; Paritosh *et al.*, 2017;

Pagliaccia *et al.*, 2019). Spent coffee grounds are believed to provide several macronutrients, especially nitrogen, to the soil, which supports plant growth (Chalker, 2016). Kasongo *et al.* (2010), Yamane *et al.* (2014), and Cervera *et al.* (2017) reported that the use of spent coffee ground as fertilizer improved soil fertility as it has water retention ability and has the potential to control weeds also serves as liming material (Kasongo *et al.*, 2010; Afriliana *et al.*, 2020). Fish scraps, on the other hand, are considered to have numerous nutrients; among them, nitrogen, phosphorus and calcium contents in fish scraps are higher than in seaweed and pine bark (Lopez *et al.*, 2011). The macro element content in iceberg lettuce (*Latuca sativa* L.) leaves grown using fish scraps is higher than in iceberg lettuce cultivated without fish scrap compost (Radziemska *et al.*, 2018). Similarly, greater fresh matter and dry matter of ice lettuce leaves were obtained from the field/treatment applied with fish compost.

Eggshells used as organic fertilizer enrich the calcium content in the soil, which is vital for plants to build up stronger cell walls to resist plant disease (Habbasha & Ibrahim, 2015). Apart from increasing yield components of cowpea plants, calcium carbonate content in eggshells is considered a source of liming material to soil (Radha & Karthikeyan, 2019). Khairnar (2019) also stated that a mixture of eggshells and fruit peels is suitable for organic fertilizer, enhances soil stiffness, and prevents soil erosion. In addition, Andhare *et al.* (2018) reported that the combination of banana peel, duckweed and eggshells showed better wheat crop growth as it acts as a soil amendment, increasing soil nutrients and improving soil physical, chemical and biological properties. Fruit peels are considered one of the choices to be used in organic farming, especially banana peel, which has high potassium content (Anhwange *et al.*, 2009), while yard trimming or garden waste such as clippings provides nutrients to the soil for plant growth (Cogger *et al.*, 2002).

Even though composting is a timing process, its final product, compost, is proven to be the soil remediation that increases soil quality and productivity. In addition, composting could

help resolve environmental pollution or greenhouse gas effects by converting excessive food waste produced due to increased population into soil-rich nutrients which benefits plant growth (Quni, 2013). Hence, it is worth investigating the effect of compost, as an alternative to chemical fertilizer, on crop growth performance.

2.4 Composting

Composting is a natural process of the biological conversion, transformation, or decomposition of biodegradable waste, through successive mesophilic and thermophilic activities, to humus-like organic matters which enhance physical, chemical, and biological soil properties when incorporated into soil (FAO, 2003; Iyengar & Bhawe, 2006; Pan *et al.*, 2011; Argun *et al.*, 2017). Composting is a procedure crucial in waste management as it produces high-end compost products with great potential for soil amendment (Cerdeira *et al.*, 2017). It is a natural process that turns organic materials into organic matter rich in substances that help in soil conditioning. Composting is the most economical technology for treating waste, which naturally recycles organic matter into the soil to improve soil structure and fertility (Tweib *et al.*, 2011). Its end product, compost, encourages root growth that benefits agriculture, enhances crop yield, and is deemed a successful humus and nutrient provider (Argun *et al.*, 2017). Shuhaimi *et al.* (2019) stated that compost application has promoted the growth of the Roselle plant. Another study by Mensah and Frimpong (2017) reported that higher crop yield and soil quality can be observed when applied with biochar and compost. Different organic materials used in composting to produce substrates for farming contain different chemical compositions and components that supply macro or micronutrients that can enhance plant growth (Castro *et al.*, 2009; Paritosh *et al.*, 2017; Pagliaccia *et al.*, 2019).

Although the compost benefits agriculture sector or industries, its maturity is the most critical aspect that should be considered before it can be applied on used. Compost maturity refers to the composting process's completeness level (Iwegbue *et al.*, 2006). It also refers to the level or amount of composting completion of a compost pile for soil amendment (Bernal *et al.*, 2017). The maturity of compost is essential as the unmatured compost may harm the plants (Ozores *et al.*, 2002). The immature compost may contain phytotoxic chemicals that do not fully decompose. In the meantime, the high microbial activity of composting may compete for the soil's available nutrients that can stunt, damage, or even kill plants when applied in agriculture (Nova Scotia Environment, 2008). Immature compost could lead to high levels of volatile organic acids and ammonia that cause plant injury or mortality (Ozores *et al.*, 2002; Barral & Paradelo, 2011; Sullivan *et al.*, 2018). The immature compost contains phytotoxicity inhibiting plant seed germination and growth. According to Phonsuwan *et al.* (2016), immature compost resulted in an imbalance of some nutrients and hazardous forms of nutrients in the soil when applied. Hence, examining compost maturity at the end of the composting process is essential.

The compost maturity is one of the crucial factors to ensure the safe use of compost. A phytotoxicity test can be conducted to determine the maturity of compost as it may delay seed germination, inhibition of plant growth, or promote any other negative impact on the plant by specific toxic substances or growing conditions (Blok *et al.*, 2008). One of the simple ways to carry out a phytotoxicity test is by using biological seed germination assay and plant growth test, as all crops react differently with compost, yet it does create confidence in a material's suitability as a substrate for a particular crop (Blok *et al.*, 2008).

2.4.1 Types of Composting

Composting is becoming popular in Malaysia, especially for households who produce compost with their household food scraps and other daily organic waste (The Edge Malaysia, 2020). The easiest way for household composting is mixing several materials like food scraps, garden waste and other organic waste in a bin in the yard.

Aerobic composting requires oxygen to decompose organic matter to produce carbon dioxide, ammonia, water, heat and humus (FAO, 2003). The microbes in organic matter use oxygen to establish nutrients in the raw material of compost (Mehta & Sirari, 2018). The composting time of the aerobic process is often shorter due to the heat-generated breakdown of protein, fats and complex carbohydrates such as cellulose and hemicellulose. Furthermore, the heat produced during the thermophilic phase destroyed many microorganisms, pathogens and weed seeds that may affect the growth and development of crops. This process is considered to have a little risk of phytotoxicity as most of the bacteria are killed (FAO, 2003) and unsuitable for use at this stage. The presence of adequate oxygen in aerobic composting is used to reduce the foul odour of the compost. There are many aerobic composting methods; some examples are conventional heap composting and Takakura composting.

Conventional heap composting is also known as the primeval traditional composting that heaps up all the organic materials like rice straw, weeds, vegetable waste, garden waste and animal dung by layers to form a pile (FAO, 2003). Conventional composting is simple: the organic wastes are stacked by layers in yards or bins. The pile is usually stacked with dry branches at the bottom as air cushions to allow oxygen aeration for composting. The pile is generally built with one layer of green material, followed by brown material, until it reaches approximately 1.5 m (Figure 2.2, FAO, 2015). Conventional heap composting is easy to produce by simply stacking organic material with minimum agitation and management.

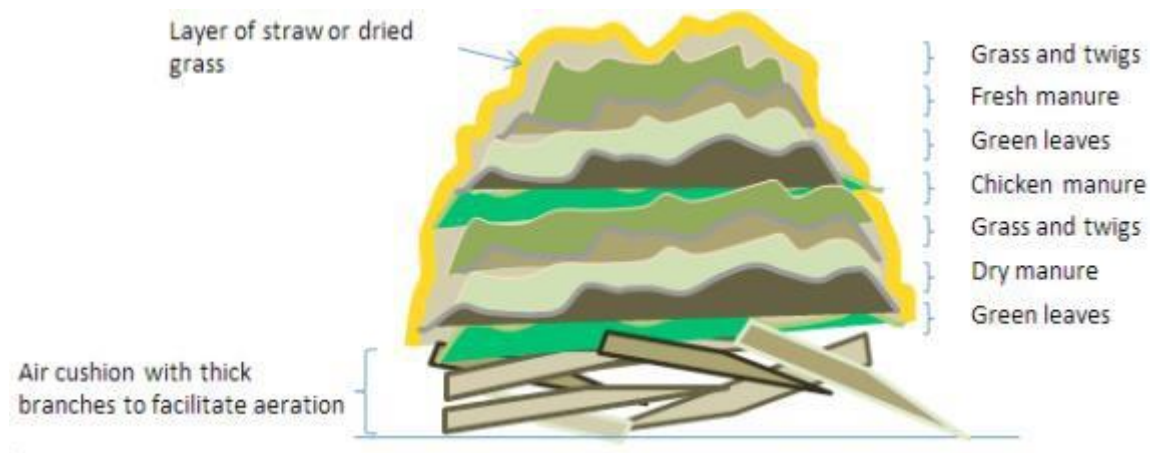


Figure 2.2: Schematic of Pile without Turning (FAO, 2015).

The Takakura composting method was named after a composting expert from Japan (IGES, 2010) and is another popular composting technique. This composting method mainly uses beneficial microorganisms produced from compost seed to decompose organic material (IGES, 2010). To produce seed compost, the salted water and sugared water are brewed with a fermented food like yogurt, fermented soybeans, and yeast to form a fermenting bed (Figure 2.3) before being mixed with other materials for decomposition. Joaquin *et al.* (2018) reported that the Takakura composting method is excellent for transforming food waste into good-quality compost in about six weeks. This composting method has a shorter time to reach a mature compost product due to the effective microbes contained. Based on the study by Abushammala *et al.* (2015), the effective microbes in Takakura compost improved and accelerated the composting process thus decreasing the period of composting (Saad *et al.*, 2013). The effective microbes in the Takakura method enable a large amount of compost production in small areas (IGES, 2010).



Figure 2.3: Making fermenting solution (IGES, 2010).

The comparison of compost results of the conventional heap composting method and the Takakura composting method has not yet been reported. Therefore, related studies are essential to evaluate the decomposition rate of both composting techniques for better-managing food waste and producing compost for further application in cultivation.

2.4.2 Composting Process

At the beginning of the composting process, the organic materials undergo decomposition, including physical breakdown and biochemical transformation of complex organic molecules of dead material into simpler organic and inorganic molecules (FAO, 2005). Soil microorganisms, especially earthworms, play an essential role in nature by breaking down organic material into smaller particles that increase exposure to microbial degradation (Chen

et al., 2011). Mesophilic organisms function best in temperatures 23°C to 45°C and the microbial activity increases in the addition of the available sugars and amino acids (FAO, 2005). The compost pile changes from mesophilic to thermophilic phases within 7 to 14 days (Figure 2.4), where the temperature rises dramatically to 70°C - 80° C (FAO, 2003). When the temperature rises to this point, a few microbial activities are suppressed, while some thermophilic fungi function to kill pathogens, nematodes and weed seeds to obtain quality compost (Gajalakshmi & Abbasi, 2008). The moisture is always maintained at 50% to 60 % as the humidity keeps the microbial activity and reduces the temperature at the thermophilic phase (Gajalakshmi & Abbasi, 2008). Aeration is essential for aerobic composting to minimize heat, water vapour and other gases trapped in the compost pile and supply oxygen to soil microorganisms to increase the process of decomposition (FAO, 2003). The pH value of the composting pile is considered acidic at the range of 4.2 to 5.5 as the production of lactic acids during degradation (Hultman, 2009).

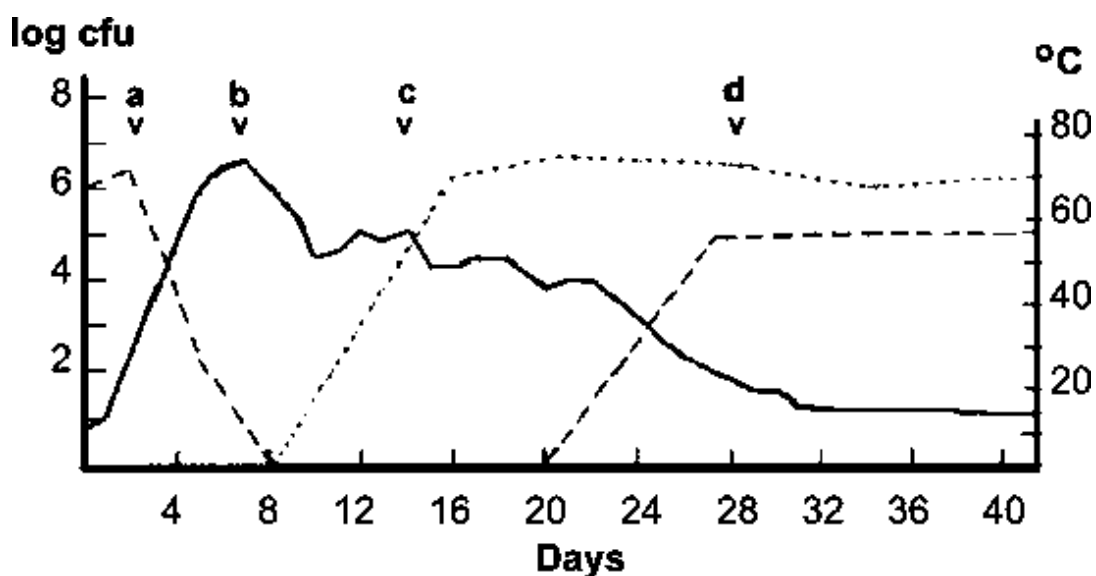


Figure 2.4: Temperature Changes and Fungi Populations in Wheat Straw Compost. Note: Solid Line = Temperature; Broken Line = Mesophilic Fungi population; Dotted Line = Thermophilic Fungi Population; Left y-axis = Fungal population (Logarithm of Colony Forming Units (CFU) per Gram of Compost Plated onto Agar); Right y-axis = Temperature in Centre of Compost; a, b, c and d = heating phases. (FAO, 2003).

After a few months, the compost pile reaches curing or mesophilic phases as the temperature decreases to ambient temperature. The mesophilic organisms recolonize to increase the nutrient content of the compost. When the compost is matured, the pile becomes dark brown to black, and the particle reduces in size and become a soil-like texture. The compost pile increases humus, and pH is neutralized at pH 7 to 8, which is suitable for farming (FAO, 2003).

CHAPTER 3

MATERIALS AND METHODS

3.1 Experimental Location

The composting experiment was conducted in an open environment at ambient conditions at the Faculty of Resource Science and Technology, Universiti Malaysia Sarawak (UNIMAS) (N01°28'09.4", E 110°25'39.3") from June 2020 to December 2020 and January 2021 to July 2021. The planting experiment was conducted in a greenhouse at Plant Research Center (Pusat Penyelidikan Tumbuhan (PPT), Universiti Malaysia Sarawak (UNIMAS) (1°27'56.37"N; 110°26'56.13"E) from June 2022 to December 2022. Data on global solar radiation for the experimental area were obtained from the Malaysian Meteorological Department with temperatures ranging between 26.0°C to 27.1 °C, precipitate with an average of 0.3 inches. The greenhouse's mean monthly temperature and precipitate data were obtained at room temperature with an average temperature of 33.0°C and average humidity of 60 %.

3.2 Preparation of Home-based Compost

The home-based waste used in this experiment was fish scraps (FS), grass clippings (GC), banana peel (BP), coffee ground (CG), eggshells (ES), and fallen leaves (FL). The study used the Takakura method and the Conventional Method of composting. In Takakura composting, a compost seed was produced first from fermented solutions and fermented bed for 1 week following the Takakura method (Bobeck, 2010) in bins. Another composting method is the conventional composting method, in which the home-based waste was stacked layer by layer to form a heap in bins. The collected home-based waste material was added based on the recommended brown (1 ES and 3 FL) to green (1 FS, 1GC, 1 BP and 1 CG) ratio

of 1:1 in volume by Alves *et al.* (2019). The balancing of greens and browns is crucial for creating a healthy and efficient compost pile as green material (nitrogen wet materials) provides nutrients and moisture while brown material (carbon dry materials) provides energy, structural strength and is used for absorbing excess moisture in compost pile (Schwarz & Bonhotal, 2011). The collected materials were composted naturally in a 20-gallon enclosed container with holes for air circulation in an open environment at ambient conditions for 30 weeks at the Faculty of Resource Science and Technology, Universiti Malaysia Sarawak (UNIMAS). The composting materials in both methods were turned weekly for air circulation, and the compost containers were checked weekly. The physicochemical properties of Takakura and conventional produced compost are as Table 3. follows:

Table 3.1: The physiochemical properties of Takakura and conventional produced compost.

Compost Physiochemical Properties	Takakura	Conventional
pH	6.57	6.60
Electroconductivity ($\mu\text{S cm}^{-1}$)	2700	3280
Moisture content (%)	51.77	35.60
Total Carbon (g kg^{-1})	291.70	150.73
Total Nitrogen (g kg^{-1})	36.21	20.36
Available Phosphorus (mg Pkg^{-1})	554.10	560.4

3.3 Seed Germination Bioassay

After the composting process, the phytotoxicity of the two different composts (T and M) was evaluated using seed germination bioassay according to Mengistu *et al.* (2017) to identify the stabilization and maturation of different composting methods with home-based

waste. According to Oktiawan *et al.* (2018), the germination bioassay method to test compost maturity is highly reproducible and direct to test compost readiness's stabilization and maturity.

Ten grams of compost sample was shaken with 100 mL of distilled water for an hour. After that, the suspension was centrifuged at 3,000 rpm for 15 minutes and the supernatant was filtered through a Whatman No. 42 filter paper. The filter paper was placed inside the sterilized plastic bottle and wetted with 5 mL of each compost extract water. Distilled water (5 mL) was used as the control. *B. rapa* seeds (15 seeds) were placed inside each sterilized plastic bottle for germination, with six replicate bottles per treatment. The plastic bottle was kept in the dark for 7 days at ambient temperature. The percentage of seed germination (%), percentage of relative seed germination (%), root elongation (%), and germination index (GI) were calculated using the following formulas (Mengistu *et al.*, 2017:

$$\text{Seed germination (\%)} = \frac{\text{No. of germinated seeds}}{\text{No. of total seeds}} \times 100$$

$$\text{Relative Seed germination (\%)} = \frac{\text{No. of seed germinated in compost extract}}{\text{No. of seeds germinated in control}} \times 100$$

$$\text{Relative root elongation (\%)} = \frac{\text{Mean root length in compost extract}}{\text{Mean root length in control}} \times 100$$

$$\text{Germination Index (GI)(\%)} = \frac{\text{Seed germination (\%)} \times \text{Root elongation (\%)}}{100}$$

3.4 Experimental Design and Crop Growth Maintenance

Brassica rapa seeds were sown in a plastic tray filled with coco peat for seedling establishment for approximately three (3) weeks. The seedlings of *B. rapa* were transplanted into poly pots using six (6) treatments with ten (10) replicates for each treatment, as presented in Table 3.2.

Table 3.2: The growing media used for planting *Brassica rapa* var. *chinensis* (Pak Choy) for each treatment

No.	Treatment	Growing Media
1	Control (C)	Topsoil only
2	Control with fertilizer (CF)	Topsoil with fertilizer*
3	Takakura (T)	Takakura compost amendment with topsoil
4	Takakura with fertilizer (TF)	T treatment with fertilizer application*
5	Conventional (M)	Conventional compost amendment with topsoil
6	Conventional with fertilizer (MF)	M treatment with fertilizer application*

*Amount of fertilizer application of 150 kg/ha or, at 2 g/pot (N: P: K 15: 15: 15) once standardized against surface area in the media pots according to the recommended rate for *B. rapa* cultivation by Maludin *et al.* (2019).

The *B. rapa* seedlings were then arranged in a greenhouse to receive full sunlight in a completely randomized design at the Plant Research Center (PPT), UNIMAS. The plants in the pots were irrigated with water twice a day. The growth experiment was conducted with compost to soil mix of 1:6. The general soil properties of the planting media used: sandy clay loam soil (Silt 10 % to 30 %; Clay 20 % to 30 %; and Sand 50 % to 70 %), pH (H₂O) ranged from 5.85 to 6.99, soil electroconductivity ranged between 120 $\mu\text{S cm}^{-1}$ to 970 $\mu\text{S cm}^{-1}$, C:N ratio ranged from 4.5 to 160.7. For fertilizer treatment plants, the fertilizer (NPK 15:15:15)

was applied as a top dressing in the third week after transplants. The application of chemical fertilizer in the experiment mainly served as the positive control. In addition, fertilizer is applied to test the growth of *B. rapa* by using compost alone, fertilizer alone, or with a combination of both compost and fertilizer. The crops were harvested after six (6) weeks after transplanting for further assessment.

3.5 Growth performance measurement of *Brassica rapa* var. *chinensis*

3.5.1 Plant Height

Plant height is the distance between the bases of the plant, excluding roots, to the tip of the highest leaf of an individual plant. Plant height was measured at seven (7) days intervals using a measuring tape.

3.5.2 Number of Leaves

The total number of leaves produced was recorded every seven days until the plants entered the matured phase.

3.5.3 Leaf Area

The plants were cut at the ground level with a pair of secateurs at harvest. The leaf area of the plants was measured using a Leaf Area Meter.

3.5.4 Total Light Interception

The light interception was measured using a light meter at the reproductive phase of the *B. rapa* crops. The reading of the solar radiation above and below the canopy was taken and light interception was calculated using the formula (de Aquino & de Melo, 2014):

$$\text{Light Interception (\%)} = 1 - \frac{\text{Light below canopy (Klux)}}{\text{Light above canopy (Klux)}}$$

3.5.5 Determination of Vegetable Biomass (Fresh Weight, Dry Weight, Fresh Weight: Dry Weight Ratio and Root: Shoot Ratio)

The weight of *B. rapa* plants was measured with a weighing balance and recorded. The biomass of *B. rapa* plants was determined using the destructive method at the harvest phase at the end of the experiment. The plants were harvested carefully and cleaned under tap water to remove dirt. The roots and shoots of plants were then cut to separate shoot and root. The different parts of the plant period taken for each plant were blotted to remove any free surface moisture and immediately weighed, and the value obtained was recorded before being dried in the oven for 72 hours at a fixed temperature of 60 °C in the drying oven, then the plants were cooled at room temperature for dry weight measurement.

The formula used to calculate the fresh: dry ratio was as follows (Park & Kim, 1993):

$$\text{Fresh weight to dry weight ratio} = \frac{\text{Fresh weight of plants (g)}}{\text{Dry weight of plants (g)}}$$

The formula used to calculate the root: shoot ratio was as follows (Rogers *et al.*, 1996):

$$\text{Root to shoot ratio} = \frac{\text{Dry weight of root (g)}}{\text{Dry weight of shoot (g)}}$$

3.6 Compost and Soil Analysis

The home-based compost produced with both Takakura and conventional composting was analyzed. Observations were recorded for pH, electrical conductivity, moisture content, total carbon (C), Nitrogen (N) and Phosphorus (P). For soil physicochemical properties, pH, electrical conductivity, moisture content (MC) percentage, organic matter (OM), total carbon (C), Nitrogen (N) and Phosphorus (P) were observed for the potting mix before and after planting. All soil samples obtained from each treatment from the pots were air-dried for a week and sieved through a 2.00 mm and 0.425 mm mesh sieve before subjected to analysis of the soil physicochemical properties. In addition, the roots and plant debris in the samples were removed.

3.6.1 pH (H₂O)

Initially, the pH meter was calibrated with pH 7.00, pH 4.01 and pH 10.01 buffer solution. After that, approximately 10 g of soil samples were weighed and transferred into a 100 mL beaker. Next, 20 mL of distilled water was added and stirred well with a glass rod. The solution was then left for 30 minutes with intermittent stirring. Subsequently, the pH meter electrode was immersed into the soil water suspension in the beaker while the pH value was recorded. Then, the electrode of pH was rinsed with deionized water to minimize errors before the pH reading was recorded for other samples.

3.6.2 Electrical Conductivity (EC)

Soil-to-water suspension at 1:5 volume ratios was prepared and mechanically shaken at room temperature for 1 hour at 180 rpm. The soil was allowed to precipitate for about 15 minutes. In the meantime, the EC meter was calibrated according to the manufacturer's

instructions for Hanna's instrument. In the present study, the electrode was dipped into the supernatant without touching the soil precipitation. The reading was taken once the system had stabilized. Similarly, the electrode was then rinsed with the deionized water to minimize error before the EC reading was recorded for other samples.

3.6.3 Moisture Content (MC)

The empty crucible was placed in a drying oven at 75°C for 24 hours before being used in the experiment. The empty crucible (W_c) was labeled, weighed and recorded. After that, 5g of compost was filled in the crucible. The weight of the crucible with or without wet sample (W_{csw}) was recorded. The crucible filled with the wet sample was placed in the drying oven at 105°C for 24 hours. Before the crucible and dry sample (W_{csd}) was weighed and recorded. The moisture content was calculated with this formula:

$$\text{Moisture Content (MC)} = \frac{(W_{csw} - W_{csd})}{(W_{csw} - W_c)} \times 100$$

3.6.4 Organic Matter and Carbon Content

Volatile solids are equivalent to the organic matter content. It is measured as the carbon-based material in soil which burns when heated to a high temperature. The remaining material is known as ash or non-volatile solids. Organic matter is vital for soil structure, nutrient availability, and water-holding capacity. The Total C was determined using the loss on ignition method.

Next, similar procedures as in section 3.6.3 were applied for dry samples. Then, the crucible filled with dry samples was placed in a furnace at 550°C for 8 hours. The weight of

the crucible and ashed sample (W_{ca}) was weighed and recorded. The mineral content was calculated using this formula:

$$\text{Mineral content (\%)} = \frac{(W_{ca} - W_c)}{(W_{cs} - W_c)} \times 100$$

The percentage of organic matter (OM%) was calculated as follow:

$$\text{Organic matter (\%)} = 100\% - \text{Mineral content \%}$$

The soil organic carbon values have been converted into estimations of soil organic matter using a conversion factor of 1.72, assuming that organic matter is composed of 58 % carbon (Pribly, 2010). The carbon percentage was calculated as follows:

$$\text{Carbon (\%)} = \frac{\text{Organic matter (\%)}}{1.72}$$

3.6.5 Soil Total Nitrogen (N)

The total available nitrogen was determined by Kjeldahl acid digestion (Kjeltec machine DR900).

3.6.6 Soil Total Phosphorus (P)

The total available phosphorus was qualified by the Bray II method, where soil samples were extracted with solvent extraction (1 M Ammonium fluoride (NH_4F) and 0.5 M

hydrochloric acid (HCl)). Colour developing reagent was added and available phosphorus was determined by absorbance reading with a UV spectrophotometer at a wavelength of 710 nm.

3.7 Statistical Analysis

In the germination bioassay of *Brassica rapa* var. *chinensis* seeds among the parameters recorded include mean shoot length, mean root length, seed germination, relative seed germination, relative root elongation and germination index. Besides, all growth performance measurements were also observed like plant height, number of leaves, leaf area index, total light interception, plant weight, fresh weight to dry weight ratio and root to shoot ratio of *B. rapa*. Moreover, the soil physicochemical properties of the growing media before and after planting like pH, electroconductivity, total carbon, total nitrogen and available phosphorus were also analyzed using Analysis of Variance (ANOVA) IBM SPSS Software Version 25.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Germination Bioassay of *Brassica rapa* var. *chinensis* (Pak Choy)

Table 4.1 shows the seed germination assessment of *B. rapa* seeds in each compost extract and the control. The mean of shoot length of *B. rapa* seedlings grown on both compost extracts after 7 days of germination was significantly different ($p < 0.05$) among all treatments (Figure 4.1).

Table 4.1: Seed Germination Assessment of *Brassica rapa* var. *chinensis* (Pak Choy) Seeds at Two Different Compost Treatments.

Growth Assessment	Treatments		
	Control	T	M
Seed Germination (%)	82.8 $\pm$ 1.92 a	83.3 $\pm$ 2.78 a	85.0 $\pm$ 2.74 a
Mean shoot length (cm)	1.67 $\pm$ 0.12 a	2.97 $\pm$ 0.13 b	2.65 $\pm$ 0.09 b
Mean root length(cm)	1.66 $\pm$ 0.14 a	2.68 $\pm$ 0.15 c	2.45 $\pm$ 0.17 bc
Relative seed germination (%)	1.00 $\pm$ 0.02 a	1.01 $\pm$ 0.03 a	1.03 $\pm$ 0.03 a
Relative root elongation (%)	1.00 $\pm$ 0.08 a	1.60 $\pm$ 0.08 c	1.48 $\pm$ 0.11 bc
Germination Index (%)	1.00 $\pm$ 0.09 a	1.60 $\pm$ 0.07 b	1.54 $\pm$ 0.14 b

Means with the same letter are not significantly different at 0.05 % significance level.

The highest shoot length of *B. rapa* seedling was recorded in the compost treatments (T treatment) at an average of 2.97 cm (Figure 4.1b), but it was not significantly different compared to other compost extract (M treatment) at an average of 2.65 cm (Figure 4.1c).

Meanwhile, the lowest shoot length was observed in control treatment at an average of 1.67 cm. Comparison for mean shoot length of *B. rapa* seedlings growing in all tested treatments were illustrated in Figure 4.1d. Similarly, the *B. rapa* seeds root length at compost treatment gave the highest length at 2.68 cm (T treatment). This data was significantly different from the root length in the control (1.66 cm) but not substantially different from the M treatment. As stated, the mean shoot length and root length of *B. rapa* treated with compost extract water showed the highest shoot and root length compared to control treatment with only distilled water. The shoot and root length could respond to differently in various water extracts (Gvozdenac *et al.*, 2013) and the compost extracts produced may contain certain compounds content in the compost produced such as nitrogen and phosphorus (Table 4.3) that boost the *B. rapa* shoot and root length.

The relative seed germination is the highest at 1.03 % at M treatment. According to the statistical analysis, the seed germination percentage of *B. rapa* among the three treatments promoted no significant difference ($p > 0.05$), as shown in Table 4.1. The relative root elongation percentage at the control treatment records the lowest average value at 1.00 %. Meanwhile, the T treatment compost showed the highest value in relative root elongation percentage at 1.60 %, but it was not significantly different from the relative root elongation in M treatment (1.48 %).

Relative seed germination and relative root elongation are commonly and easily applied as valid phytotoxicity tests, and they have several benefits, including sensitivity, simplicity, low cost, and compatibility for unstable compounds or materials (Wang *et al.* 2001, Munzuroglu and Geckil, 2002). In this study, the assessment of relative seed germination among various *B. rapa* seedlings treatments yielded consistent results, revealing no significant differences. This suggests that the initial stages of seedling development, from germination to seedling emergence, were not notably influenced by the specific treatments applied. However,

a noteworthy contrast emerged when examining the relative root elongation in response to different treatments. Specifically, the compost extract water treatments exhibited a significantly higher value in relative root elongation than the control treatment. The increase in root elongation percentage in the treatments incorporating compost extract implies a stimulatory effect on the root growth of *B. rapa*. According to Eudoxie and Martin (2019), this phenomenon could be attributed to the unique compounds present in the compost extract, which may act as bioactive substances promoting the overall root development of plants. These compounds, likely derived from the decomposition of organic matter during the composting process, seem to play a crucial role in enhancing the physiological processes associated with root elongation. Both composts extracted water treatments performed similarly for their seed germination bioassay assessment as both composting materials used are similar. The addition of compost seeds in Takakura composting method does not vary from the conventional composting method as the raw material used for both composting involved fish scraps which act as bio-activators that contain effective microorganism (Dewilda *et al.*, 2021) that helps in the early development of plants.

The higher root elongation percentage in the compost extract treatments compared to control treatment suggests a positive correlation between applying compost-derived compounds and promoting root growth in plants (Baldotto *et al.*, 2016; Pasqualone *et al.*, 2021). This finding underscores the potential agricultural significance of utilizing compost extracts as a natural and sustainable means to enhance the growth and development of crop plants (Jindo *et al.*, 2012). Further investigation into the specific compounds responsible for this growth-promoting effect may provide valuable insights into the application of compost in optimizing crop production and sustainable agriculture practices.

The *B. rapa* seedlings that have the lowest germination index in control treatment (1.00 %), showed significantly different ($p < 0.05$) from all compost extract treatments. However,

the germination index for seeds grown in T treatment was not significantly different compared to the germination index in M treatment (1.54 %). The germination index is used to evaluate the maturity and phytotoxicity of compost at specific composting stages (Jakubus and Bakinowska, 2018). It seems the seeds germinated well in all the compost extracts which indicated the absence of phytotoxicity in the composts. Barral and Paradelo (2011) reported that a percentage germination value below 50% indicates high phytotoxicity, from 50 % to 80 % indicates moderate phytotoxicity, and values above 80 % show no phytotoxicity. Both the compost in different composting methods and ratios reveal positive results that enhance the shoot and root growth of *B. rapa* seeds (Figure 4.1d).

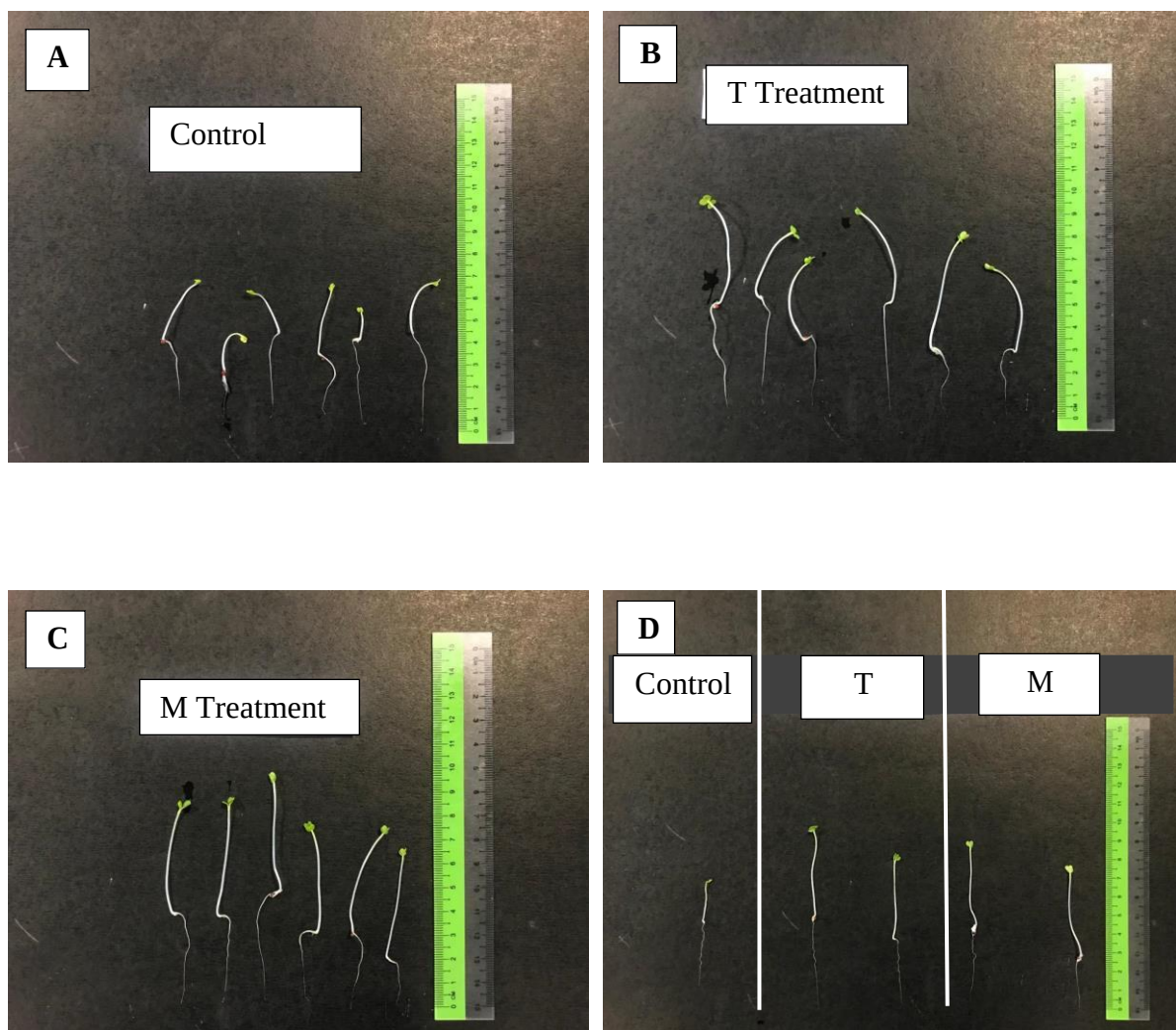


Figure 4.1: Germination bioassay of *B. rapa* seeds treated with (A) control (distilled water only), (B) T (Takakura composting produced compost) treatment, (C) M (conventional composting produced compost) treatment (D) comparison of 3 different treatments after 7 days of sowing.

4.2 Growth Performance of *Brassica rapa* var. *chinensis* (Pak Choy) with compost

Table 4.2 shows the growth performance of *B. rapa* 6 weeks after transplanting to the potting media with compost produced from different composting methods. All treatments applied with compost amendments (T and M) showed better growth performance than the control treatment (C). The plant height for *B. rapa* with compost amendment treatments is 20.0 cm, and the number of leaves is an average of 18 per plant (Figure 4.2). Meanwhile, the leaf area in both compost amendments ranges from 466 cm² to 504 cm². The fresh-to-dry ratio ranges from 9.19 to 9.47, and the root-to-shoot ratio averages 0.14. The light interception for both compost to soil ratio ranges from 59.2 % to 61.0 %. According to Kaleri *et al.* (2020), the Chinese cabbage (Pak Choy), *B. rapa* growth with compost-amended soil showed an improvement in plant growth in terms of plant height, leaf number, leaf area, fresh-to-dry ratio, and root to shoot ratio when compared to topsoil only. According to Shuhaimi *et al.* (2019), a positive growth response was achieved when the tested plant was cultivated in media containing additional food waste compost which was in contrast to the plants grown without compost addition. When comparing the growth performance of *B. rapa* to that of home-based compost, this study found that similar tendencies in plant growth were observed. Various studies have reported that the use of compost not only improves soil physical properties that enhance soil health but also improves soil properties that boost the growth and development of plants (Cahyono *et al.*, 2020; Goldan *et al.*, 2023; Wright *et al.*, 2022). Rich nutrient content in the compost might be produced and used in plant growth and development for an extended period, thus reducing the application of chemical fertilizer use (Goldan *et al.*, 2023; Sanchez *et al.*, 2017).

Table 4.2: Growth assessment of *Brassica rapa* var. *chinensis* (Pak Choy) for all treatments.

Growth Assessment	Treatment without fertilizer			Treatment with fertilizer		
	C	T	M	CF	TF	MF
Plant Height (cm)	11.1 ± 1.1 a	20.0 ± 1.3 bc	20.5 ± 1.8 bcd	18.2 ± 6.4 b	24.4 ± 1.9 cd	26.1 ± 1.2 d
No. of Leaves	9 ± 1 a	18 ± 2 b	18 ± 3 b	12 ± 3 a	21 ± 1 b	22 ± 1 b
Leaf Area (cm ²)	119 ± 50 a	466 ± 125 bc	504 ± 38 c	288 ± 121 ab	1041 ± 105 d	1173 ± 114 d
Fresh: Dry Ratio	8.35 ± 2.28 a	9.47 ± 2.32 ab	9.19 ± 1.62 ab	11.45 ± 2.60 ab	12.61 ± 1.95 ab	13.31 ± 2.95 b
Root: Shoot Ratio	0.36 ± 0.09 b	0.14 ± 0.05 a	0.13 ± 0.03 a	0.15 ± 0.13 a	0.11 ± 0.04 a	0.11 ± 0.04 a
Light interception (%)	29.8 ± 7.0 a	59.2 ± 5.6 b	61.0 ± 14.0 b	57.6 ± 13.4 b	75.2 ± 9.5 b	76.0 ± 5.8 b
Total Yield Production (t/ha)	1.7 ± 0.9 a	18.1 ± 4.9 c	16.5 ± 1.2b c	6.6 ± 2.8 ab	41.3 ± 8.9 d	44.3 ± 8.1 d

*Means ± standard deviation. All data presented are on an average basis per plant. Different letter indicates significant differences among treatment at 5% using Tukey's test (p <0.05). C: topsoil only (control), T: Takakura compost amendment, M: Conventional compost amendment, CF: topsoil (control) + fertilizer, TF: Takakura compost amendment + fertilizer, and MF: Conventional compost amendment + fertilizer.

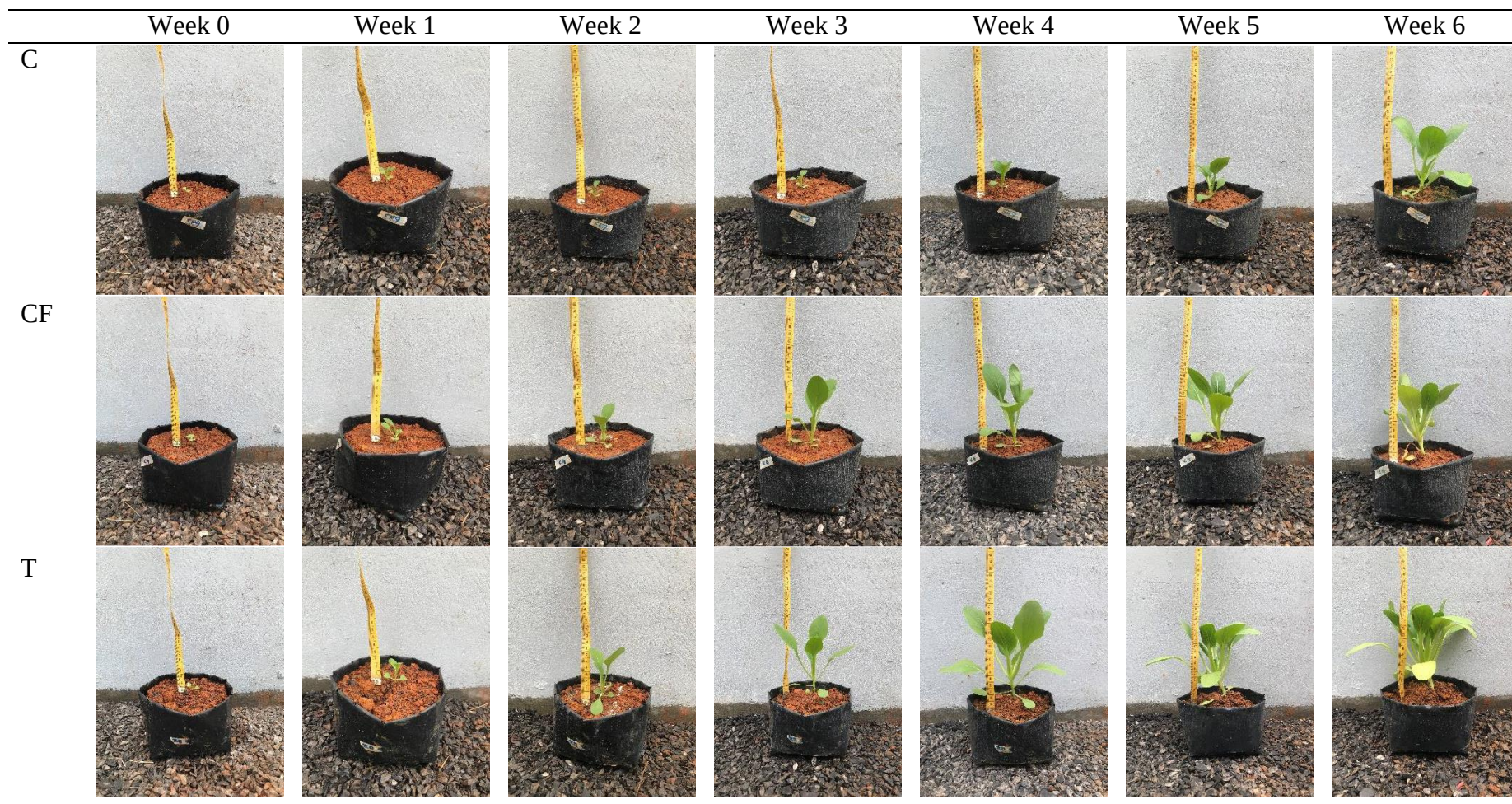
According to the result of the root-to-shoot ratio (Table 4.2), it is observable that the *B. rapa* treated with either T or M treatment performs a lower root-to-shoot ratio than the control. The root-to-shoot ratio of plants is supposed to be a smaller value for better plant growth as the related increase of plant shoots or leaf area of plants (Bonifas *et al.*, 2005; Lopez *et al.*, 2023; Oliveria & Viani, 2020) as there might have sufficient nutrient content in the compost produced from both T and M composting method with the home-based waste used in this study. Regarding *B. rapa* growth, the percentage of light interception of *B. rapa* is higher for treatment T and M than the control treatment. The compost added to the growing media might provide sufficient nutrients to *B. rapa*; increasing the number of leaves and leaf area produced for each plant contributes to a higher light interception percentage (Eifediyi *et al.*, 2022; Ndzeshala *et al.*, 2023). The higher number of leaves produced and larger leaf area lead to higher light interception for more photosynthetic capacity (Eifediyi *et al.*, 2023) of *B. rapa*, hence providing more production of crops.

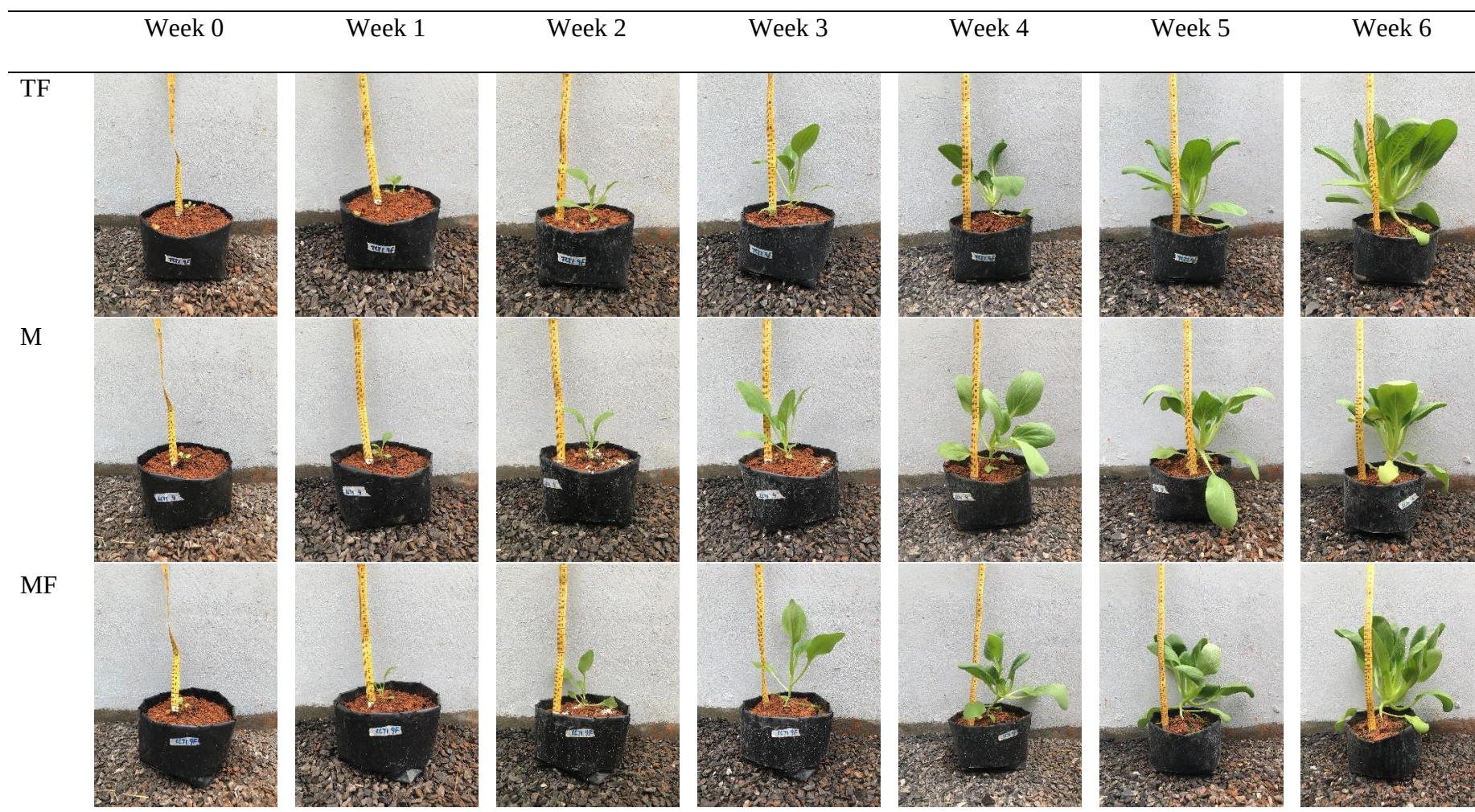
Nevertheless, when the chemical fertilizer was added to *B. rapa* in the experiments with compost amendment (TF and MF), no significant differences were observed between TF and MF instead noticeable differences with control treatment in most plant growth. The plant height of *B. rapa* in TF and MF showed increment ranges of 24.4 cm to 26.1 cm, respectively. Meanwhile, the leaf area and total yield of *B. rapa* production for TF and MF treatments showed a double increment from control. Elfeel and Abohassan (2016) reported that the NPK fertilizer used for plants has a higher leaf area index value. The higher value of leaf area indicates higher plant weight that affects the results of yield obtained. According to Ouda and Mahadeen (2008), organic compost amendment used in *B. oleraceae* (Broccoli) performed better in all growth assessments with additional compost and chemical fertilizer

application. Similar studies by Liu *et al.* (2016) reported that the combined application of organic and inorganic fertilizers improved the yield and quality of Pak Choy.

Moreover, regarding the difference between the compost produced by the composting method Takakura composting (T) and conventional composting (M), the growth assessment of *B. rapa* shows no significant difference. Takakura composting uses a fermenting bed, which reduces composting time and increases plant growth parameters (Sharma *et al.*, 2017). Nonetheless, the results of this study could be attributed to aerobic composting because both composts were produced in bins with holes, and the compost was turned weekly for aeration. Adediran *et al.* (2003) used two different partially aerated composting methods on two vegetable crops, showing similar effects on crop growth and improving yields. Moreover, the starting material ratio used in this study may also lead to the results obtained as no previous documentation was reported about the combination of home-based materials. The fish scraps added to the compost bins possibly contributed specific microbes and nutrients, resulting in an equal amount of beneficial microbes in both composting methods and no difference in plant growth assessment among the compost treatments in this study. According to Thendral and Geetha (2017), a study on the application of fish waste in *Vigna radiata* cultivation identified a high rhizobacterial and rhizobium population in liquid fish waste fertilizer, and the microbial population's contents contribute to seed germination and root and shoot growth and development. The produced compost is used for home gardening, especially for horticulture, and currently expands in crop planting for self-consumption. In addition, home-based waste is usually collected and composted in the yard or garden at home area without any testing or analysis of its nutrient content. Chang *et al.* (2023) reported that compost's chemical and biological analysis could be time-consuming and costly, and it would be difficult to determine the nutrients after one cycle of

compost production since the nutrients largely depend on the source of materials used. In the case of home farming, it is targeted to grow clean and safe crops for daily consumption and, most importantly, to produce sufficient yield for one household. If using home-made compost is a viable alternative that is also effective, this would reduce the dependence of home gardening on inorganic fertilizers that are effective for crop production. In this study, the home farming simulations were carried out for preliminary testing of the home-based waste on *B. rapa* growth with different composting methods.





*C: topsoil only (control), T: Takakura compost amendment, M: Conventional compost amendment, CF: topsoil (control) + fertilizer, TF: Takakura compost amendment + fertilizer, and MF: Conventional compost amendment + fertilizer.

Figure 4.2: The growth of *B. rapa* with different compost treatment with topsoil from Week 0 to Week 6.

4.3 Yield Production of *Brassica rapa* var. *chinensis* (Pak Choy) with Compost

According to the statistics by the Department of Agriculture (2021), *B. rapa* production yield for 2020 to 2021 is 13.9 t/ha. As shown in Figure 4.3, the combination of fertilizer and compost amendment with compost to soil (TF and MF) showed better yield than control treatment and other compost amendments without chemical fertilizer with double yield production. Such conditions indicated that the cooperation of chemical fertilizer and compost amendment is needed for rapid nutrient uptake of *B. rapa*. Moreover, the compost amendment treatments without fertilizer treatments (T and M) still achieved the recommended yield proposed by DOA with a total mean yield of 18.1 t / ha and 16.5 t / ha, respectively. Consequently, the designed starting material and the composting method used to produce the compost for this study suit the growth of *B. rapa* crop.

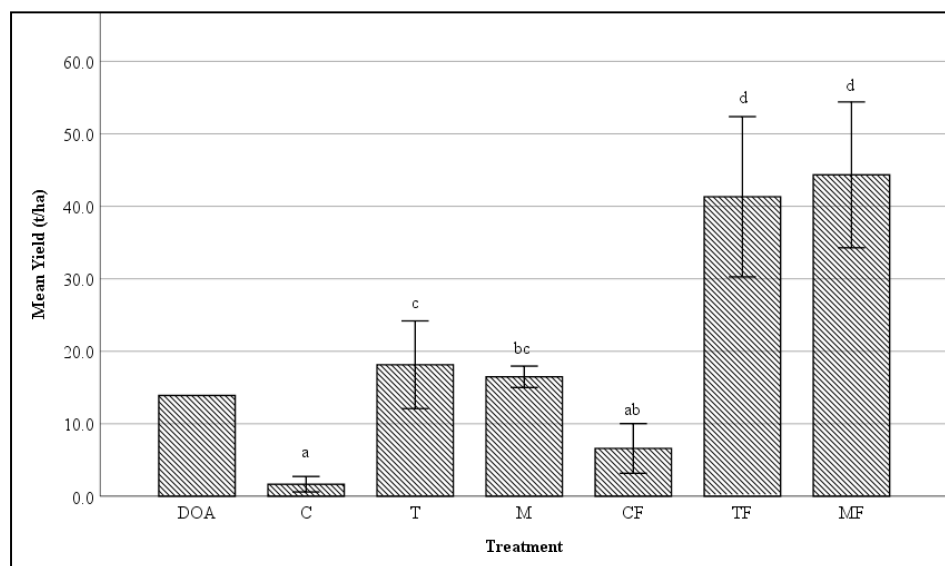


Figure 4.3: Total yield of *B. rapa* for all treatments. Different letter indicates significant differences among treatment at 5 % using Tukey's test ($p < 0.05$). DOA: Department of Agriculture, Malaysia suggested yield for *B. rapa*, C: topsoil only (control), T: Takakura compost amendment, M: Conventional compost amendment, CF: topsoil (control) + fertilizer, TF: Takakura compost amendment + fertilizer, and MF: Conventional compost amendment + fertilizer.

For *B. rapa* crops growing, the essential agronomic factors are the number of leaves, leaf area, and plant yield (Nasution *et al.*, 2021). Overall, the experiment for different composting methods (T and M) produced compost as an amendment for *B. rapa* growing, showing almost similar data collection for all parameters. In contrast, the fertilizer applied for both treatments (TF and MF) had a double increment in leaf area and plant weight. Incorporating compost amendment and fertilizer in agriculture could help improve crop yield and quality (Khan *et al.*, 2017).

Besides the composting method, the ingredients or materials used to prepare compost may affect the result as different materials applied may have other nutrient profiles. According to Parwada *et al.* (2020), different types of manure compost used show different total dry matter production of Baby Spinach. The poultry manure compost performs better results while the use of fertilizer shows better total dry matter production than cattle manure compost. Another study by Nursuhaida *et al.* (2021) stated that microbial compost on *B. rapa* obtained the highest fresh weight during harvest compared with vermicompost, biochar compost and fertilizer. However, few studies show similar results when testing compost with different materials. Based on Prado (2006), the growth of *B. rapa* with vermicompost, conventional compost, and fertilizer shows no significant difference in the growth assessment obtained. Uwumarongle *et al.* (2012) reported that empty fruit bunches compost, poultry compost, and cattle manure compost also present no significant difference in the vegetative growth performance of oil palm seedlings. Although neither study found a substantial difference in the compost used for crop growth, compost is still recommended because it helps reduce the overapplication of inorganic fertilizer during cultivation. Furthermore, using compost will employ long-term practices to improve soil health and reduce reliance on chemical fertilizers (Nursuhaida *et al.*, 2021).

Compost maturity could additionally affect crop growth and yield. Immature compost produced from nitrogen-rich material may contain high ammonium levels, resulting in low compost pH and high electroconductivity, which is phytotoxic to crop growth (Ko *et al.*, 2008; Phonsuwan *et al.*, 2016). According to Phonsuwan *et al.* (2016), immature compost produces poor lettuce plant growth. In addition, Russell and Leon (2022) noted that using green compost stunned lettuce germination. Although the maturity of the compost in this study is only determined by chemical parameters such as pH, electric conductivity, and C: N ratio, further research should be conducted to determine the biological parameters that determine compost maturity.

The application rate of compost influences the growth performance of plants. Previous studies by Zerga and Tsegaye (2019) examined the effect of different rates of compost application on the growth of carrots, with the results indicating that increasing the compost application rate from 0 t/ha to 75 t/ha nearly tripled the vegetative growth of carrots. Izilan *et al.* (2022) conducted a similar study on Choy Sum and found that increasing the biochar compost application rate increased the biomass of Choy Sum. Aji *et al.* (2021) reported similar results, in which the biomass of dwarf crape jasmine increased when applied compost rose from 0% to 20%. Despite this, Aji *et al.* (2021) found that increasing compost application from 30% to 100% decreased dwarf crape jasmine biomass. When an excessive amount of compost is applied, it is not necessarily beneficial to crop growth and yield; consequently, it is essential to prioritize the optimal amount of compost added to achieve optimal nutrient management.

Given that excessive chemical fertilizer application can harm the environment (Chandini *et al.*, 2019), compost can be a more sustainable alternative or supplementary material to reduce the amount of chemical fertilizer applied for crop production (Kizito *et*

al., 2019). Although it may be challenging to produce consistently adequate compost to enhance crop growth and yield, compost is a natural product that can be produced from home waste, making it a more sustainable option for improving crop growth performance and yield, particularly for *B. rapa*.

4.4 Soil Physicochemical Properties before Planting and after Planting of *Brassica rapa* var. *chinensis* (Pak Choy)

Table 4.3 presented the results of soil physicochemical properties analysis for the soil samples collected from the control treatment (C), treatments with the application of compost (T and M), treatment with the application of fertilizer (CF), and treatments with the application of compost cooperated with fertilizer (TF and MF) before and after planting of *B. rapa*.

The pH readings among the treatments before planting range between 5.76 to 6.18. Among the treatments, the growing media with the most significant increase is M treatment. On the other hand, analysis of soil properties of the control, T, CF, TF and MF treatments after planting showed increasing in pH, although not as great as in the M treatment. The T treatment shows such results could be caused by adding compost seed in Takakura composting methods that introduce more fermentation that causes low oxygen in the compost leading to a drop in pH (Haroun *et al.*, 2004). However, there is not much difference in pH after the experiment. According to DAFF (2013), the average optimum pH level of growing media suitable for vegetables is from 5.50 to 7.60. Based on this study, the pH levels among all the treatments ranged in between the optimum pH level recommended. The plant nutrient uptake from the growing media for this study is effective as the pH of the growing media is suitable for vegetable growth (Shobri *et al.*, 2016).

Regarding to electrical conductivity (EC), the soil EC for control and CF treatment after planting were ranged between $120 \mu\text{S cm}^{-1}$ to $970 \mu\text{S cm}^{-1}$. The increase of EC in the treatments with cooperation of fertilizer (CF, TF and MF) could be due to an increase in the mineral salt content of growing media, leading to higher readings (Mendez-Cifuentes *et al.*, 2023). Soil EC is greatly influenced by a combination of physio-chemical properties, including soluble salts, clay content and mineralogy, soil water content, bulk density, organic matter, and soil temperature (Corwin & Lesch, 2005). After 6 weeks of planting, the soil EC for all the treatments is relatively low, ranging from $360 \mu\text{S cm}^{-1}$ to $930 \mu\text{S cm}^{-1}$. According to the United States Department of Agriculture (2011), for all soil textures, the degree of salinity ranging from $0 \mu\text{S cm}^{-1}$ to $2000 \mu\text{S cm}^{-1}$ is considered non-saline for all soil textures. The non-saline nature of the growing media in this study is claimed to be unaffected by most plant and soil microbial processes suitable for planting use (USDA, 2014).

Next, the total carbon content of all the growing media ranges from 34.24 g/kg to 42.67 g/kg. The increase in total carbon increase led to the root exudates during *B. rapa* planting, microorganisms' activities of the growing media, chemical fertilizer added in treatments and decomposition of matured compost (USDA, 2009) added to the growing media, especially for compost amendment treatments. Compost is commonly used as an addition of external carbon source to soil as it helps to maintain and enhance soil properties (Biala, 2011 & Krull *et al.*, 2004). The T and M treatments have slightly higher total carbon content due to the organic material used for composting especially the green waste like fish scraps, coffee ground, and grass clipping contributes to the carbon released.

Table 4.3: General soil physicochemical properties of the media used in this study.

Treatments	Soil Physicochemical Properties					
	pH	EC ($\mu\text{S cm}^{-1}$)	Total Carbon (g kg^{-1})	Total Nitrogen (g kg^{-1})	C:N ratio	Available Phosphorus (mg P kg^{-1})
<u>Before experiment</u>						
Control	6.18 ± 0.03	120 ± 7	25.70 ± 1.25	0.21 ± 0.15	119.9 ± 81.8	22.2 ± 0.1
T	5.90 ± 0.05	620 ± 127	35.70 ± 0.46	0.99 ± 0.70	36.2 ± 25.4	53.6 ± 14.0
M	5.76 ± 0.10	970 ± 106	41.67 ± 0.32	1.36 ± 0.09	30.7 ± 1.7	61.3 ± 7.1
<u>After experiment</u>						
Control	6.87 ± 0.04	360 ± 106	34.24 ± 0.14	0.21 ± 0.15	160.7 ± 114.0	22.7 ± 0.3
T	6.84 ± 0.06	380 ± 28	41.16 ± 0.48	0.84 ± 0.09	48.8 ± 4.7	67.0 ± 23.7
M	6.99 ± 0.09	410 ± 7	39.42 ± 0.25	1.83 ± 0.40	21.55 ± 4.7	173.6 ± 8.2
CF	6.70 ± 0.01	810 ± 141	34.01 ± 0.42	0.43 ± 0.30	80.0 ± 57.0	267.2 ± 4.8
TF	6.81 ± 0.09	580 ± 78	41.18 ± 0.15	9.14 ± 0.94	4.5 ± 0.4	421.9 ± 0.4
MF	6.80 ± 0.10	930 ± 191	42.67 ± 0.07	1.27 ± 0.21	33.5 ± 5.8	330.4 ± 13.3

* Mean (standard deviation). EC: Electrical Conductivity. Control: topsoil only, T: Takakura compost amendment with topsoil, M: Conventional compost amendment with topsoil, CF: Topsoil (control) with fertilizer, TF: T treatment with fertilizer application, MF: M treatment with fertilizer application.

In addition to the carbon content, the nitrogen content in the soil plays an essential role for leafy vegetables such as *B. rapa*. This is because nitrogen primarily enhances chloroplast activity, thereby increasing photosynthetic productivity (Fathi, 2022). Based on the results in Table 4.3, most of the treatments show that the total nitrogen content of the growing media increases after planting, especially for the treatments that cooperated with fertilizer. Adding NPK fertilizer to the growing media increases the total nitrogen content in the growing media. As a result, the MF treatment demonstrates a reduction in the overall nitrogen content following planting. This can be attributed to the improved nutrient use efficiency of *B. rapa*, which enhances the vegetative growth of the crop, as evidenced by parameters such as plant height, number of leaves, and leaf area, as shown in Table 4.2.

Nevertheless, the findings also indicated that the addition of NPK fertilizer along with compost led to an increase in overall nitrogen content in the planting medium, resulting in significantly enhanced plant growth (Table 4.2). The total nitrogen content of TF treatment after planting resulted in 9.14 g kg^{-1} which raised almost 9 times the total nitrogen content when compared with other treatments which only raised a small amount of total nitrogen content. The used of Takakura composting method involves the addition of a fermenting bed formed with sugar and salt solution that contains extra nutrients provided to the growing media. When the combination of topsoil, Takakura composting produced compost and cooperation with fertilizer possibly improves the microbial activity of the growing media that indicates a high amount of the total nitrogen content for TF treatment. This is the synergistic effect of the combination of compost amendment and NPK fertilizer which helps to improve the physical and biological properties of soil at the same time improves soil structure and microbial activity leading to better nutrient uptake by plants (Naka *et al.*, 2015; Oyetunji *et al.*, 2022). Besides, the application of compost reduces the

need for chemical fertilizer by supplying nutrients, leading to cost savings and reduced environmental impact. However, according to Passoni and Borin (2009), using different composts showed no significance in crop yield and nitrogen use efficiency due to the short term of observation. Based on the soil physicochemical properties obtained from Table 4.3, the total nitrogen content in TF treatment growing media is required to be reused for the next growing cycle without the addition of fertilizer, which not only saves the raw material but also develops a safe and clean food produced for consumption in future.

In general, the total available phosphorus contents in growing media after planting were higher as compared to before planting of *B. rapa*. This condition is likely a result of the application of organic compost and NPK fertilizer, which has led to an increase in the nutrient content of the soil. While the treatments with the cooperation of NPK fertilizer have a higher total phosphorus content (Table 4.3), the use of compost, whether Takakura or conventional method, in growing media, shows better growth performance in T treatment and M treatment compared to CF treatment, as shown in Table 4.2 and Figure 4.3. According to Verma (2013), the effect of compost on soil may be influenced by the particle size of the compost, as it impacts the decomposition rate. Based on the compost produced from Takakura and conventional composting in this study, although both particle sizes used for composting are the same, the Takakura composting method produced the finest compost compared to conventional composting. When both composts were added to the soil in this study, the M treatment compost with large particle size might decompose again to form the phosphate-solubilizing bacteria that convert immobilized phosphorus into available phosphorus in soil for plant uptake (Cheng *et al.*, 2023 & Pang *et al.*, 2024), thus resulting in higher phosphorus content in the soil. Conversely, compost and NPK fertilizer utilization led to a greater overall phosphorus content in the growing media, resulting in greater growth

performance compared to all other treatments. According to FAO (2022), the nutrient content in growing media like nitrogen, phosphorus and potassium is lost after planting due to nutrient uptake of the crops that contribute to higher yield production of treatments with the application of compost and fertilizer. However, some treatments show increased nutrient content in growing media after planting. The presence of unused phosphorus in the cultivation of *B. rapa* in this experiment can be attributed to the use of smaller pots. Aragao *et al.* (2020) found that using smaller pot sizes can decrease soil leaching during cultivation, leading to better retention of nutrients, particularly nitrogen and phosphorus, in the planting media. The available phosphorus is one of the major macronutrients known to help in cell development, especially for plant root development (Shen *et al.*, 2011). The soil physicochemical properties result in Table 4.3; except for the control treatment, the other treatments served available phosphorus ranging between 67.0 mg Pkg⁻¹ to 421.9 mg Pkg⁻¹. Based on the growth performance results in Table 4.2, the root-to-shoot ratio parameter well explained the root development of *B. rapa* in this study whereas the use of Takakura and conventional composting produced compost and cooperation with fertilizer enhanced the soil available phosphorus that improved *B. rapa* root growth for better structure, water uptake and nutrient absorption for other macronutrients and micronutrients of *B. rapa* hence to the great degree of other growth performance parameter like leaf area and leaf numbers as both of the parameters are essential towards *B. rapa* yield. Nonetheless, the main factor influencing the soil physicochemical properties of the growing medium for *B. rapa* might be the starting material or home-based waste used to produce the compost in this study. The home-based waste material that contributes most of the nitrogen source for the end product of compost is grass clippings, coffee grounds, eggshells and fish scrapes. Both types of home-based waste are considered green as they are commonly fresh and moist, which makes

the compost decompose faster and rich in nitrogen content (Smith, 2011). In addition, the fish scrapes stacked for the compost pile in this study not only the unwanted fish flesh but also included the fish's organs like gills and intestines of the fish which would believe that the fish's organ content of specific beneficial microbe and fish protein (Ahuja *et al.*, 2020) that improve the compost quality and at the same time the end product helps in better *B. rapa* plants growth performance in this study. Furthermore, home-based materials like banana peels are considered green, too, but they are well-known to provide high potassium and phosphorus to the soil and help improve soil nutrients (Panwar, 2015). The combination of these home-based waste materials to produce compost, either Takakura composting or conventional composting and used it with topsoil (sandy clay loam soil) as growing media to plant *B. rapa* is recommended as the preliminary experiment of this study shows positive growth performance of *B. rapa*.

The C: N ratio of the growing media after planting ranges between 4.5 to 160.7 among all the treatments. According to Fog (1988), based on the interpretation of the C: N ratio, the M treatment is categorized as a medium C: N ratio (20:1 to 25:1), which is the ideal range for most soil that balance supports moderate decomposition, sufficient nitrogen release and healthy microbial activity. For TF treatment, it is considered a low C: N ratio (< 15: 1) as the incorporation of the Takakura compost and chemical fertilizer possibly triggers the microbial activities that lead to high nitrogen availability. In the other treatments (C, T, CF and MF), the C: N ratio is more than 30: 1, categorized as a high C: N ratio, indicating the nutrient use efficiency when planting *B. rapa* with topsoil and compost. However, *B. rapa* growth with only topsoil or fertilizer is still insufficient for the media to supply sufficient nutrients for *B. rapa* as the C: N ratio is very high, showing low nutrient content in soil with poor growth performance (Table 4.2). The lower C: N ratio in soil indicates a higher amount

of nitrogen availability and nitrogen mineralization in soil (Norman *et al.*, 1990 & Briggs, 2008) leading to a quick nitrogen supply for TF treatment resulting in better growth performance of *B. rapa*.

Based on the results of germination bioassay of different composting produced compost (Table 4.1), growth performance of *B. rapa* with different composting methods produced compost (Table 4.2), yield of *B. rapa* with different composting methods produced compost (Figure 4.3) and soil physicochemical properties before and after experiment (Table 4.3), both the Takakura composting and conventional composting produced compost shown similar effects toward the *B. rapa* seeds germination, growth performance and yield of *B. rapa* crops which is significant. The growing of leafy vegetables like *B. rapa* requires a higher amount of nitrogen content (Motseki, 2008). In this study, both composting methods were produced using home-based materials and an equal ratio of material ratio. Thus, the soil physicochemical properties of both composts showed no significant differences in the nutrient content. However, the Takakura composting method involved the production of compost seed and composting bed before adding waste material that used extra material that is believed to have extra nutrient content, which could provide the crops with better growth. According to Al-Khadher *et al.* (2021), the Takakura composting method produces compost that can be ready within a short duration. Yet, the home-based waste used in this study, especially fish scraps, could be the reason for a beneficial microbe that results in both composting methods showing similar decomposition in the period. For planting *B. rapa* for home gardening, conventional composting compost is recommended because the composting method is simple and direct compared to the Takakura composting method, which requires preparing the fermentative liquid and bed

following a specific ratio. The Takakura composting compost could grow better crops besides leafy vegetables such as legumes or fruits.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The analysis in this experiment shows that using different composting methods, either Takakura composting or conventional composting, produced compost with selected home-based waste for the preliminary study of *B. rapa*, which positively affects the growth performance of *B. rapa* plants. In addition, the results suggested that the growth performance and production of *B. rapa* plants were high when cultivated in combination with compost with chemical fertilizer. Based on this study, although the parameters between treatment T and M compost amendment treatments showed no significant effect on growth performance, treatment M compost performed better growth performance and yield for *B. rapa* plants. However, certain aspects should be revisited, particularly the current ratio of both Takakura and conventional compost, for consistent observation regarding the different ratios of compost added to growing media for *B. rapa* growth. The use of organic fertilizers like compost helps enhance plant growth. Hence, the combination of compost amendment and chemical fertilizer is recommended for home farming as using only small areas and small pots with the combination of compost amendment and fertilizer indicated the best growth performance and yield. When producing compost, the total amount of waste in the environment can be reduced and reused for specific purposes, and at the same time, it benefits the plant's growth. Meanwhile, the use of compost made from home-based waste is not only for production but also handy to Do-It-Yourself (DIY) at home to grow your own foods that are clean and safe for consumption. Basically, the Takakura composting method uses compost seed content of microbes that help accelerate the decomposition of compost

which is suitable for use on small scales like home farming to save space and, at the same time produce efficient compost. The conventional composting method has low cost and easy management of its composting while the decomposition of this method would need a large scale or space for the composting in order to obtain the efficient decomposition and its final product. Thus, both composting methods would be selected based on the materials' quantity and available space to show a better decomposition rate and its final product.

5.2 Recommendations

The aforementioned conclusions are subject to certain limitations. Firstly, the waste material collections do not adequately determine the extent of compost production, which limits the generalization of the experimental results. Therefore, the limited quantity of compost generated restricts the size of the pots chosen for the experiments, potentially affecting the results of *B. rapa*. Larger pots provide more nutrients and space for the growth of *B. rapa*. Nevertheless, *B. rapa* continues to exhibit favorable outcomes. Additionally, other factors may influence the growth performance of *B. rapa*, such as weather conditions. Despite the presence of an air circulation system in the greenhouse, the air circulation system only allows air to flow in, while the outflow of air is not functioning. Nevertheless, the system will automatically cease operation after a specific duration. Consequently, the temperature within the greenhouse is not adjustable and is contingent upon the prevailing weather conditions.

Hence, it is imperative to conduct further research in order to investigate the efficacy of increasing waste collection for composting. This research should involve more precise experiments in larger containers or under field conditions. In addition, the increased production of compost may facilitate future research on various types of crops, such as

cucumber and long bean, to test the effectiveness of different compost formulations. The temperature is one of the critical factors to consider when growing *B. rapa* plants in a greenhouse in order to achieve optimal crop yields.

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