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Effects of Organic Fertilizer on Growth Performance and Postharvest Quality of Pak Choy (*Brassica rapa* subsp. *chinensis* L.)

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Abstract: Long-term use of inorganic fertilizers on leafy vegetables can increase soil acidity, harmful to the environment and leaving bad effects on human health. Organic fertilizer application is one of the safer alternatives with many beneficial effects by supplying nutrients for plant growth, environmental-friendly and producing an optimum quality of vegetables. Different organic amendment such as vermicompost, biochar and microbial compost has different effect on plant growth performance since good bacteria could improve structure of the soil and nutrient absorption. Therefore, this study aims to evaluate the effects of organic fertilizer on the growth performance and postharvest quality. The experimental design during planting was conducted in randomized completely block design with a factorial arrangement of treatmentswhile for postharvest quality study was conducted in completely randomized design. Organic fertilizer of vermicompost (110 g/plant), biochar (100 g/plant), microbial compost (80 g/plant) and chicken manure (37.5 g/plant) were treated on Pak choy two times on day 10 and day 24 after transplant. This research revealed the plant growth including plant height, leaf number and leaf length of Pak choy in all treatments were increased as growing stage increased. However, at the end of growing stage, microbial compost and vermicompost resulted in the highest of growth characteristics. In terms of postharvest quality, microbial compost showed the highest fresh weight and premium quality. This study proved that microbial compost at 80 g/plant exhibited optimum growth performance and the best postharvest quality of Pak choy.

Keywords: Vermicompost, biochar, microbial compost, organic fertilizer, pak choy, plant growth

1. Introduction

Pak choy, scientifically known as *Brassica rapa* subsp. *chinensis* L. is a leafy vegetable that originated from Southern and Northern China (Xie et al., 2020). Pak choy also known as Chinese cabbage is a popular leafy vegetable that is widely cultivated worldwide (Fatemi et al., 2020). Pak choy has a complete nutritional content and economic value. Existence large number of phytochemicals in the Brassicacea family are mainly phenolic compounds, it provides many health benefits to human, for instance, preventing cancer, inflammatory diseases and scavenging the free radicals (Lee et al., 2018).

In the past 20 years, inorganic fertilizers or chemical fertilizers have been intensively used in the world. There are many types of inorganic fertilizers, such as ammonium nitrate, ammonium phosphate, superphosphate, and potassium sulfate (Bhandari, 2014). Each of thesetypes contributes specific purpose such as easily soluble in water and can increase crop performance and productivity, enhance root growth, flower formation, accelerate harvesting, reinforce the stem and lower the risk of dropping, and increase the size of fruit and seeds (Hasibuan, 2006). However, the excessive of inorganic fertilizers for the long terms use can increase soil acidity due to ammonia accumulation. Inorganic fertilizer application is also harmful to the environment, especially to water sources due to runoff from agricultural areas during rainfall (Liu et al., 2009).

Concern over environmental pollution, food quality and food safety, scientists and policy makers were explored alternatives to current agronomic systems. Formulating the organic fertilizer is one of the good alternatives to replace

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inorganic fertilizer. Organic fertilizers are natural products originating from plants or animals, including livestock manure, green manure, crop residues, household waste, compost and forest litter. The use of organic fertilizers was proved to improveroot growth and nutrient absorption (FFTC, 1998). Pantawat (2012) claimed that organic matterhelps to minimize global warming by reducing greenhouse gas emissions that are usually expose to nitrogen fertilizers.

There are several types of organic fertilizers available in the commercial industry, suchas vermicompost, biochar, microbial compost and the commercial organic fertilizer (NPK 8:8:8) in Malaysia. Previous studies have conducted by using organic fertilizer to evaluate growing performance. The results revealed that potato plots treated with vermicompost at 6 tonnes/ha produced significantly higher yield and fresh weight compared to vermiwash (Ansari, 2008). In another study, application of biochar with the treatment dosage 0 t ha^{-1} (B0), 5 t ha^{-1} (B1), 10 t ha^{-1} (B2), 15 t ha^{-1} (B3) had no significant effect on the growth performanceof Pak choy (Situmeang et al., 2017). However, a positive growth of spinach in terms of plantheight, leaf length and leaf weight were observed under microbial compost using *Bacillus subtilis* and *Bacillus mucilaginosus* (Jing et al., 2020). To date, there is no comprehensive studyon the effects of vermicompost, biochar and microbial compost on plant growth of Pak choy. Thus, this study was carried out to evaluate the effects of organic fertilizers on the growth performance of Pak choy and their effect on postharvest quality (Priadi & Nuro, 2017).

2. Literature Review

Organic farming is one of the broad spectra of production methods that are supportive of the environment. The demand for organic food is steadily increasing both in developed and developing countries, with an annual average growth rate of 20-25% (Ramesh et al., 2005). Organic farming is advantageous to the agriculture sector because it offers a foundation for nutritious and healthy food. Organic products are safe to eat because they contain substantially less or no pesticide residues and taste good (Ohazurike et al., 2003).

Organic fertilizers are natural materials derived from plant or animal origin, including livestock manure, green manure, residues from plant processing, sewage waste, compost and forest litter. There are several positive values for using organic fertilizers, for instance, soil value, crop value, biological value, environmental value, economic value, human health and soil quality (Haruna et al., 2020). Overstreet & DeJong-Hughes (2010) stated the addition of organic matter to soil could enhance aggregate stability and soil compaction resistance, increase fertility and minimize nutrient leaching, increase biological activity, improve water retention, efficiency and reduction of greenhouse gas emissions by soil.

Vermicompost is a nutrient-rich organic waste produced from earthworms that is beneficial for soil improvement and has been observed to improve crop yield and quality. Ndegwa & Thompson (2000) reported that earthworms have the capacity to decay organic waste and to eliminate waste particles by up to 60%. Earthworms with a weight of up to 0.6 g can consume waste close to their weight and produce between 50% of the waste every day. They are also responsible for changes in soil properties that are both biological and chemical. The moisture retention varies from 32% to 66%, with a pH of 7.0. Nagavallemma et al. (2004) described thatvermicompost has an excellent structure with high porosity and drainage that allows plant wateruptake. Besides, it also great in the water holding capacity (WHC) to store a lot of water that rice needs and have good aeration.

Biochars are materials rich in carbon created by pyrolysis processes, consisting of the incorporation of biomass (such as wood or manure) in a closed container and heating with little or no available air (Janus et al., 2015). Mohan et al. (2018) explained that incorporating biochar generated at low pyrolysis temperatures increases the physico-chemical properties of soil including pH, cation exchange capacity (CEC) and WHC and provides essential plant nutrients for improving crop performance. Lehmann & Joseph (2009) stated the char takes the denomination of "biochar" when it was developed to be added to soil to enhance soil characteristics like productivity or conservation of carbon. Some biochars were not wholly carbonized.

Microbial compost refers to bacterial fertilizers, organic fertilizers and microbial inoculants containing beneficial microorganisms that offer fertilization for crops by their activities (Shen et al., 2011). Compost fertilizer can enhance physical properties, chemistry andbiology. By using compost, the soil structure becomes crumb and the soil becomes looser. As indicated by Alori & Babalola (2018) and Singh et al. (2011), microbes alone or in a consortium of microbes could boost the output farming systems. It is crucial because microbes and plants have been evolutionarily cooperative.

In previous study, the maximum plant height of Pak choy can be achieved until 28.00±0.62 cm by using vermicompost with the rate of 100 g/plant (Ramnarain et al., 2018). In relation to organic farming, Zucco et al. (2015) found that soils with higher vermicompost rates produced a higher number of leaves than lower vermicompost. Nisa (2010) mentioned the treatment of organic fertilizer composition of urban waste has a significant impact on the variable number of Pak choy plants after 35 days of planting by using 25 % weight of planting media. The total fresh weight of Pak choy by using organic compost gives a significant impact with the treatment of 20 tonnes per hectare by obtained the highest total fresh weight 23.33 g (Situmeang et al., 2017). Bahadur et al. (2006) stated that combining organic manures and biofertilizers increases the yield and quality attributes of vegetables.

3. Methodology

3.1 Experimental Site

This study was involved in a fieldwork experiment that conducted at the farm, Kampung Pangkal Pisang, Peringat, Kota Bharu, Kelantan (geographical coordinates: 6°00′28.6″ North, 102°16′29.5″ East, Malaysia) from March 2021 until April 2021.

3.2 Planting Materials and Preparation

Four package of Pak choy seed was purchased from Gardenic company. Each pack of seed was tested on germination rate prior to sow. The seeds of Pak choy were sown in two germination trays (30 cells/tray) containing cocopeat as substrate. After two weeks of germination, the healthy and vigorous seedlings with 3 to 4 leaves were transplanted into 64 polybags (8'x12'). The polybag medium has contained a mixture of topsoil: organic matter: sand in a ratio of 3:2:1. The distance between polybags was 30 cm. Plant was watered twice a day using a watering can.

3.3 Preparation of Organic Fertilizer Treatment

Four types of organic fertilizer vermicompost, biochar, microbial compost and chicken manure at the recommended rate by supplier were applied two times on Pak choy plant on day 10 and day 24 after transplant. The organic fertilizer of 8-8-8 (chicken manure) was served as control. The rate for each organic fertilizer is tabulated in Table 1.

Table 1: The Rate of Organic Fertilizer Application

Organic fertilizer	Suggested rate application (g/plant)
Control (chicken manure, NPK 8:8:8)	37.5
Vermicompost	110
Biochar	100
Microbial compost	80

3.4 Determination of Plant Growth

The data of each plant growth were evaluated every week for five weeks based on plant height, the number of leaves and leaf length.

Plant Height: The plant height of Pak choy from ground level to the tip of the tallest leaf was measured using the measuring tape in centimeter (cm) unit.

Number of Leaves: The number of leaves was counted for each treated plant. The number of leaves was calculated when a new shoot emerged to recognize the maximum number of leaves for every treatment suggested.

Leaf Length: The length of the leaves was randomly measured on three outer layer leaves per head using a measuring tape in a cm unit.

3.5 Determination of Postharvest Quality

The data of postharvest quality were measured at 35 days after transplanting on fresh weight and rating quality scale.

Fresh Weight: The basal stem of Pak choy was cut with a sharp and clean knife to remove it from the growing medium. Then, it was washed using running tap water and blotted dry with a soft paper towel for any free surface moisture. The digital balance scale was used to measure the fresh weight and expressed in the gram unit.

Rating Quality Scale: Rating quality scales were observed by grading, based on color, size, and extent of defects on the leaves based on grading specification of Pak choy (FAMA) description.

Table 2: Grading Specification of Pak Choy

Grade	Specifications	Relaxation (maximum)
Premium	Pak choy must be of the same variety, fresh, clean and has a good stem shape and leaves. Must be free of defects or damage. The number of petioles (branches) is more than five	Fresh ≤ 5% Damaged ≤ 5% Injury ≤ 5% Size uniformity ≤ 5%
1	Pak choy must be of the same variety, fresh,clean and have a good stem and leaf shape. Must be relatively free of defects or damage and	Fresh ≤ 5% Damaged ≤ 5% Injury ≤ 10%

	number of petioles 3-5	Size uniformity ≤ 10%
2	Pak choy should be of the same variety, fresh, clean and has a stem shape and good leaves. Must be quite free from defects or damage and number petiole is 3-5.	Fresh ≤ 10% Damaged ≤ 10% Injury ≤ 10% Size uniformity ≤ 10%

(Source: FAMA, 2001)

3.6 Experimental Design and Statistical Analyses

For plant growth of Pak choy, the experimental design in randomized completely block design with a factorial arrangement of treatments and four replications. The factorial treatments comprised four types of organic fertilizer x five growing stages. The postharvest quality experimental design is a completely randomized design with four replications. The data were analyzed using analysis of variance,and when the treatments are significant, means were separated by least significant difference (LSD) at $P \leq 0.05$.

4. Results and Discussion

4.1 Plant Growth of Pak Choy

Plant Height. The results indicated microbial compost and vermicompost treatments showedthe highest in plant height (Fig. 1a) of Pak choy at the final harvesting stage (35 DAT). Meanwhile, the plant height of biochar and control were not significantly different. The variation of plant height performance was probably due to Pak choy plant can adapt to the nutrient content of the microbial compost and vermicompost fertilizer and the dose are meet the nutrient elements. Effective microbes in compost hasten the plant growth by secreting important trace elements, antioxidants, bioactive compounds and exopolysaccharides (Naik et al., 2020). Nasution et al. (2014) reported the balance of nutrients received by plants is critical in supporting plant growth. Excess nutrients can be toxic to plant tissues, whereas a nutrient deficiency can result in stunted growth. Moreover, Yan et al. (2017) discovered that using microbial fertilizer could significantly increase the plant height of Pak choy. Besides microbial compost, the current study also found that vermicompost exhibited the highest in plant growth. These results were consistent with the findings of Pant et al. (2009).

Number of Leaves. Microbial compost of Pak choy resulted in the highest number of leaves,followed by vermicompost, biochar and control (Fig. 1b). By comparing with control, at 14 DAT, both microbial compost and vermicompost Pak choy showed a greater number of leaves.Starting from 21 DAT up to the end of growth stage, these two treatments were maintained higher in number of leaves compared to others, but both were no significantly different. This could be due to composting component. According to Situmeang et al. (2017), the increase in leaves number and size was depend on the supplied nutrition. The nutrient absorption capacity of the plant enhanced root development and increased translocation of carbohydrates from source to the growing points. With good nutrients and conditions, plant was progressing from earlier to the later stage by cell division and enlargement with the increasing of growing stage (Mauseth, 2014). The nutrient analysis by Pant et al. (2012) found that vermicompost contained greater soluble mineral nutrients and microbial by-product such as humic acid, fulvic and organic acids to the plant compared to control (chicken manure).

Leaf Length. Fig. 1c depicted that among the type of organic fertilizer, the treatment of microbial compost and vermicompost had a significant difference from the treatment of biochar and control. The data analysis of growing stage tabulated that the plant length was constantly increased as the elapsed, but with significant changes. Chantal et al. (2010) stated that good microbes could be fostering the nutrients to the plants that enhanced biomass production and overall growth performance. Beneficial bacteria and fungi present in compost improve soil conditions and accelerate plant growth (Shen et al., 2013). Meanwhile, vermicompost increases the level of available water and induction of nitrogen, phosphorus and potassium exchange that cause growth speeding (Manivannan et al., 2009). The findings were consistent with Ramnarain et al. (2018), who discovered that the effect of vermicompost on Pak choy improvesthe physical structure of the soil. Previous work has demonstrated that vermicompost in multiple soil types can increase growth rate and yield in Pak choy compared to control (Pant et al., 2012).

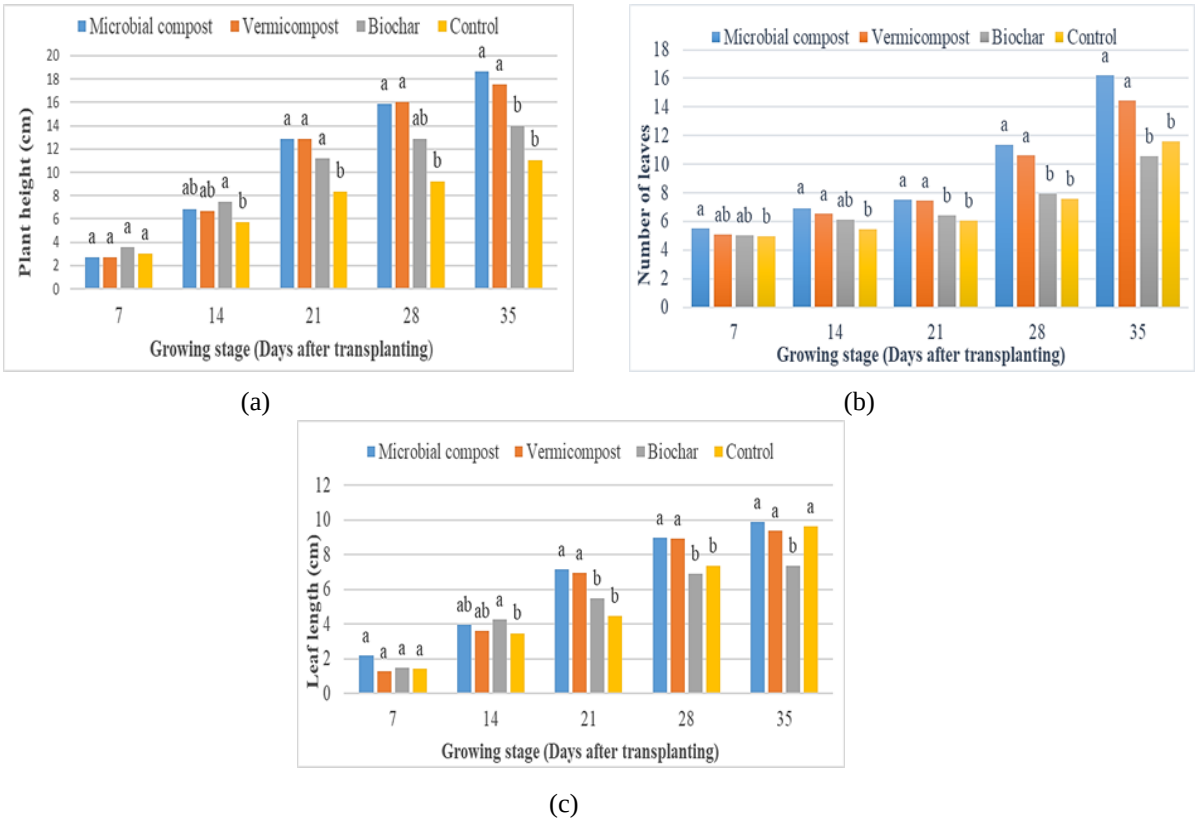

Fig. 1: Effect of organic fertilizer at seven days interval after transplanting on plant height (a), number of leaves (b), and leaf length (c) of Pak choy. Means with the same letter within organic fertilizer are not significant different at $P>0.05$ using the LSD test

4.2 Postharvest Quality of Pak choy

Fresh Weight. The fresh weight of Pak choy plant has significant difference ($P\leq0.05$) after treated with different types of organic fertilizer (Fig. 2). The fresh weight was found the highest for microbial compost, vermicompost as the second and followed by control and biochar. The increase of fresh weight after microbial compost application enhanced the physical properties, chemistry, and biology of the soil. The findingwas corroborated with Situmeang et al. (2017) who found that by microbial compost application will change the soil structure and loosens the soil. Macronutrients (N, P, K, Ca, Mg) and micronutrients (Mn, Fe, Cu, Zn) are necessary for more available plants, soil cation exchange capacity and microorganism activity in the soil are increasing (Novizan, 2007). Unno et al. (2005) reported that, an effective microbe play a part to plant nutrition by liberating phosphorus from organic compounds such as phytates, thereby indirectly increasing of plant fresh weight. In the present study, biochar fertilizer application impacted lower fresh weight of Pak choy compared to others. The nutrient composition and fertilizer rate among the fertilizer types in this study could be the reasons of varied quality on Pak choy. In contrast, Nisa (2010) found that biochar is more compatible in soil than other organic ingredients that allow nutrient retention and sustain soil fertility longer.

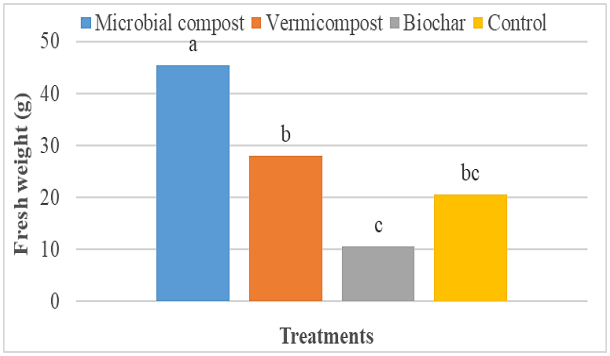

Fig. 2: Effect of organic fertilizers on freshweight of Pak choy. Means with the same letter within organic fertilizer are not significantly different at $P>0.05$ using the LSD test

Rating Quality Scale. Rating quality scale for organic fertilizer Pak choy was depicted on Fig. 3. Among the treatments, the highest premium quality was obtained by microbial compost Pak choy and the second highest was vermicompost Pak choy. Quality of vegetable is a combination characteristic attributes and properties that putting the commodity at higher price. Rating quality scale are classified as external and internal factors. In terms of marketing, external criteria may be regarded as being of the utmost importance. It included fresh weight, firmness, and color appearance. Treatment of microbial compost gave the best results on the rating quality scale. It is presumed that the use of microbial compost will increase the plant's fertility and vegetative growth. Verma et al. (2014) stated that biofertilizers containing microbes treatment could improve the leafy vegetable quality.

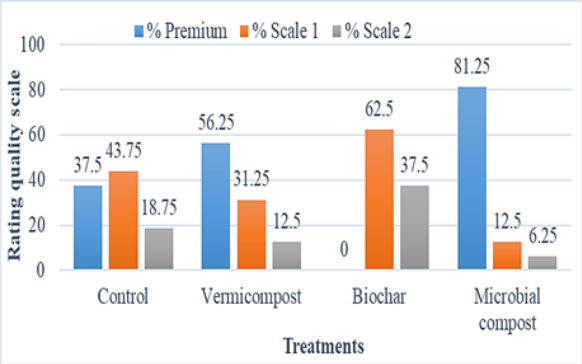

Fig. 3: Effect of organic fertilizers on rating quality scale of Pak choy

5. Conclusion

The study revealed that different types of organic fertilizers with different rate application had significant effect on the plant height, number of leaves, leaf length, fresh weight and rating quality scale of Pak choy. Among organic fertilizers, microbial compost treatment at application 80 g/ plant exhibited optimum growth performance and the best postharvest qualityof Pak choy.

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