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The effects of organic materials on the growth of *Boesenbergia rotunda*

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Abstract

Boesenbergia rotunda (L.) Mansf. commonly known as temu kunci is a perennial herb which is botanically described as a small herbaceous plant. Temu kunci has a short, fleshy or slender rhizome shape. The rhizomes of *B. rotunda* have been widely used as spices due to their aromatic flavour, which promotes appetite. This herbal plant is also used as flavouring agents, dyes and traditional medicine to cure various kinds of illnesses. Organic materials have been widely used in agriculture development to improve soil quality, increase crop yield, and plant growth performance, and reduce chemical fertilizer usage. The adverse impact of excessive use of chemical fertilizers in conventional agricultural practices is well documented. A field study was conducted to identify the effects of organic materials on the growth of *B. rotunda*. A completely randomized design (CRD) was used which involve seven treatments and four replication including control, chemical fertilizer alone, and 10% additional materials in 5 kg of soil. The organic materials used in this study are biochar, vermicompost, food waste compost, empty fruit bunch compost and lignohumate. In this study, the vermicompost gave a significant increase and highest reading of plant height, number of leaves, rhizome and finger roots fresh and dry weight compared to other treatments. In conclusion, organic materials can give positive effects on the growth of *B. rotunda* and at the same time can reduce the dependencies on chemical fertilizer.

1. Introduction

Medicinal plants as well called medicinal herbs have been discovered and used in traditional medicine practices since prehistoric times. The compounds found in plants are of many varieties, but most are in four major biochemical classes: alkaloids, glycosides, polyphenols and terpenes (Kittakoop *et al*., 2014). Medicinal plants are used to cure many ailments that are either non-curable or seldom cured through modern systems. They are widely used in non-industrialized societies, mainly because they are readily available and cheaper than modern medicines (Awuchi, 2019). Approximately 80% of the world's population depends on medicinal plants for their health and healing (Aliyu *et al*., 2008). Medicinal plants face various threats such as climate change, habitat destruction, and the specific threat of over-collection to meet market demand (Ahn, 2017). Many sources stated that the medicinal plant has a lot of uses and benefits, thus, the market value of this plant was expected to further rise over the coming years (Singh, 2015). There is a promising future for medicinal plants since there are about half a million plants, and most of their medical activities are not yet investigated. Their unknown potential for medicinal activities might be crucial in the treatment of present and future studies (Singh, 2015).

Boesenbergia rotunda is a medicinal and culinary herb that originated in China and Southeast Asia. In Malay, the root has traditionally been called Temu kunci, because the shape of the rhizome resembles fingers growing out of a centre piece. It is a kind of ginger, and it is an annual crop usually growing in tropical rainforests (The plant list, 2010). The phytochemical properties of *B. rotunda* comprise anti-allergic (Madaka

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and Tewtrakul, 2011), antibacterial (Zainin *et al*., 2013; Udomthanadech *et al*., 2015), anti-*Helicobacter pylori* (Bhamarapravati *et al*., 2006), anti-leptospiral (Chander *et al*., 2016), anticancer (Isa *et al*., 2013), anti-inflammatory (Isa *et al*., 2013), antioxidant (Chiang *et al*., 2017), antiulcer (Abdelwahab *et al*., 2011), anti-dengue viral (Chee *et al*., 2010), anti-herpes viral activities (Wu *et al*., 2011) and act as wound healing (Mahmood *et al*., 2010). It rhizome can be used to treat inflammatory diseases such as dermatitis, dental caries, tooth and gum disease, dry cough and cold, diarrhoea, swelling, wounds, dysentery and diuretic (Chuakul and Boonpleng, 2003; Salguero, 2013). It also can be used to heal hepatic disease and also can act as larvicidal and pupicidal activities (Phukerd and Soonwera, 2014).

Organic materials can be used as a fertilizer to supply nutrients for plant growth. The nutrient content of organic fertilizer varies greatly, depending on the source. There are a lot of benefits of organic fertilizer compare to chemical fertilizer such as the nutrient supply is more balanced which helps to keep plants healthy; enhances soil biological activity that can improve nutrient mobilization from organic and chemical sources and decompositions of toxic substances; increase the colonization of mycorrhizae which increases phosphorus (P) supply; improve root growth due to better soil structure; increase the organic matter content in the soil; improving the exchange capacity of nutrients; enhance soil water retention; supporting soil aggregates; buffering the soil against acidity, alkalinity, salinity, pesticide and toxic heavy metals; release nutrients slowly and contribute to the residual pool of organic nitrogen (N) and P fixation; supply micronutrients; supply food and encourage the growth of beneficial microorganisms and earthworms and they help to suppress certain plant diseases, soil-borne diseases and parasites (Leghari *et al*., 2016).

The standardization of optimum environmental parameters such as light, temperature, water, humidity and nutrition is required by plants to increase their production and improve the quality of the plant in the field. Nutrition which includes both macronutrients and micronutrients is one of the important components required by the plant. These nutrients contain elements and compounds needed by the plant to support its growth, metabolism and external supply. In order to provide sufficient nutrients to the plants, farmers use chemical fertilizer. The usage of chemical fertilizers in conventional agriculture has contributed significantly to the huge increase in the world food production. Even the chemical fertilizer can give positive effects on the production. However, many types can cause adverse impacts from the excessive inputs of chemical fertilizers in conventional agricultural practices as documented by Banerjee *et al*. (2011) and Garai *et al*. (2014). Organic materials can serve as an alternative to reduce the dependencies on inorganic fertilizers for improving soil structure (Dauda *et al*., 2008) and microbial biomass (Leghari *et al*., 2016) that can give positive effects on the development of the plants. Many studies mentioned the good effects of using organic materials as a fertilizer to substitute the dependencies on chemical base fertilizer. However, the effect of organic materials on the growth biomass of *B. rotunda* has not yet been investigated, therefore, this study aimed to determine the effects of organic materials on growth performance of *B. rotunda*.

2. Materials and methods

2.1 Study site and plant materials

This experiment was carried out at Rimba Ilmu, University of Malaya, Kuala Lumpur. Mature rhizomes of *B. rotunda* were obtained from local farmers in Kuantan, Pahang. Prior to starting the experiment, the rhizomes were cut into 5-10 cm lengths, washed under running tap water and sowed into the pot. The pot was placed under a shading area to avoid direct penetration of sunlight for two weeks for germination. After two weeks, the average height and number of shoots were recorded before transplant in the treatment medium as shown in Table 1.

Table 1. Treatment description for *B. rotunda*

Treatments	Coding	Treatments Combination
Treatment 1	T1(C)	2.5 kg black soil and 2.5 kg red soil
Treatment 2	T2(F)	2.5 kg black soil, 2.5 kg red soil and (200:80:100) NPK dose
Treatment 3	T3(B)	2.5 kg black soil, 2.5 kg red soil and 10% biochar
Treatment 4	T4(V)	2.5 kg black soil, 2.5 kg red soil and 10% vermicompost
Treatment 5	T5(CF)	2.5 kg black soil, 2.5 kg red soil and 10% food compost
Treatment 6	T6(CA)	2.5 kg black soil, 2.5 kg red soil and 10% EFB compost
Treatment 7	T7(LH)	2.5 kg black soil, 2.5 kg red soil and 5g lignohumate in 1 L of water

2.2 Experimental design and treatments

The field experiment was arranged using a completely randomized design (CRD) with seven treatments and four replications. Seven treatments were used in this study, control, chemical fertilizer alone, and 10% additional organic materials without chemical fertilizer in 5 kg of soils. The organic materials used in this study are biochar, vermicompost, empty fruit bunch compost, food waste compost and lignohumate. Each polybag was filled with 5 kg of soil from the mixture of 2.5 kg of black soil and 2.5 kg of red soil following the previous study that found the best medium for *B. rotunda*

(Rashid *et al*., 2015). The organic material was applied and mixed into polybag and incubated for one week before transplant. While for lignohumate treatments, it was applied as foliar fertilizer every 15 days followed manufacture recommendation, 15 g of lignohumate was diluted in 1 L of water. For chemical fertilizer treatment, NPK was applied after 1 month of transplant at 200:80:100kg/ha as suggested by Attoe and Osodeke (2009).

Biochar and vermicompost used in this experiment were purchased from the University of Malaya Zero Waste Campaign. Meanwhile, empty fruit bunch EFB compost, lignohumate and NPK fertilizer were purchased from a local seller at Sungai Buluh nursery. The initial height of the seedling during transplanting was 5 cm on average, the plant was grown in polybag with a dimension of 26×13 cm. The experiment was conducted in CRD with four replications for each treatment resulting in 28 plants in total. The plant was watered twice a day between 10.00 am and 5.00 pm to maintain its turgidity and also to prevent water stress. The plants were maintained in the conservatory area under the natural environment with 60% of sunlight and temperature between 24ºC (min.) – 31°C (max.). Plot sizes were 2.5×1.5 m. Row-to-row and plant-to-plant spacing were 30 cm.

2.3 Growth performance of Boesenbergia rotunda

The growth performance of *B. rotunda* from all treatments was measured weekly. Plant height was measured using a meter ruler from the bottom of the shoot which is at the surface of the soil to the tip of the tallest leaf of the plant. The number of leaves was counted manually. The yield was harvested four months after planting. The fresh weight of the rhizome and roots from each treatment were measured using a weighing balance after harvesting. Meanwhile, the dry weight was obtained by wrapping the rhizome and roots from all treatments in an aluminum foil and drying it in an oven at 38˚C until a constant weight was obtained.

2.4 Statistical analysis

Statistical analysis was done using IBM SPSS Statistics 26 software. One-way ANOVA was used to analyse the significant differences in all the treatments. The post-hoc test was conducted using Tukey's test. Results were subjected to analysis of variance (ANOVA) and central tendency analysis. Differences were considered statistically significant at a level of P<0.05.

3. Results

3.1 Effects of organic materials application on plant height and number of leaves of Boesenbergia rotunda

The application of organic materials' effects on the height and number of leaves of *B. rotunda* are presented in Table 2. Out of five organic materials tested, vermicompost, EFB compost and lignohumate showed better effects on the plant height of *B. rotunda.* The highest plant height and number of leaves were found in T4 (V) with 52.71 cm and 7.64 respectively. The lowest plant height and number of leaves were found in T3(B) with only 36.65 cm and 4.53 respectively.

Table 2. The mean plant height and the number of leaves of *B. rotunda* grown with different types of organic materials and chemical fertilizer.

Treatments	Plant height (cm)	Number of leaves
Control	44.53^{ab}	5.56^{abc}
Chemical fertilizer	45.00^{ab}	5.31^{ab}
Biochar	36.65^{a}	4.53^{a}
Vermicompost	52.72^{b}	7.64^{c}
Food waste compost	44.23^{ab}	6.74^{bc}
EFB Compost	50.20^{b}	7.36^{bc}
Lignohumate	47.54^{b}	6.24^{abc}

Values with different superscripts within each row are significantly different at P<0.05 according to Tukey's test.

3.2 Effect of organic materials application on fresh and dry weights of rhizome and fingerroot of Boesenbergia rotunda

The fresh and dried weight of rhizome and finger roots of *B. rotunda* after harvested has a significant difference between treatments as presented in Table 3. T3 (B) shows a significant decrease among the other treatment in the fresh weight of rhizome and finger roots. The treatment that has the highest fresh weight was obtained from T4(V) with 210 g and the lowest was found in T3(B) with only 41.25 g. The application of vermicompost showed the best effect on fresh weight. The best dry weight was also obtained by T4(V) with

Table 3. The mean of fresh and dry weight of rhizome and finger roots grown with different types of organic materials and chemical fertilizer.

Treatments	Fresh weight (g)	Dry weight (g)
Control	86.25^{ab}	8.63^{ab}
Chemical fertilizer	90.00^{ab}	9.92^{ab}
Biochar	41.25^{a}	4.04^{a}
Vermicompost	52.71^{d}	16.53^{c}
Food waste compost	121.75^{bc}	11.47^{bc}
EFB Compost	157.50^{cd}	13.82^{bc}
Lignohumate	210.00^{d}	7.73^{ab}

Values with different superscripts within each row are significantly different at P<0.05 according to Tukey's test.

16.53 g and the lowest was also found in T3(B) with

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Figure 1. Effect of organic materials treatments on fresh weight of rhizome and finger roots of *Boesenbergia rotunda*. (a) control, (b) chemical fertilizer, (c) biochar, (d) vermicompost, (e) food waste compost, (f) EFB compost and (g) lignohumate.

Figure 2. Effect of organic materials treatments on the dry weight of rhizome and finger roots of *Boesenbergia rotunda*. (a) control, (b) chemical fertilizer, (c) biochar (d) vermicompost (e) food waste compost (f) EFB compost and (g) lignohumate at weeks 17 . The photo was taken after 72 hrs oven-dried.

only 4.043 g. Vermicompost shows the best effects on all parameters measured compared to other treatments. This can conclude that the vermicompost application gave the best results for plant growth and development. Figure 1 and Figure 2 show the effect of organic materials treatments on fresh and dried weight respectively.

4. Discussion

In general, the plant growth performance was much affected by the organic material up to three-month observations (Figure 3). The best treatment was found in vermicompost treatment. In this study, vermicompost showed the best results in improving plant height, number of leaves, fresh and dry weights of rhizome and finger roots of *B. rotunda*. For optimum plant growth, nutrients must be available in sufficient and balanced quantities. A lot of earlier studies also showed that the application of vermicompost helps in improve plant growth performance (Zaller, 2007; Blouin *et al.*, 2019). As a result, the finding of this study which was the combination of organic materials mainly vermicompost with soil mixture suggested by Rashid *et al*. (2015) gives the best results in improving the growth performance of *B. rotunda*. They also indicate that the combination of 50% black soil and 50% red soil can increase the productivity of rhizomes and finger roots and maintain healthy growth of shoots where the biomass production of *B. rotunda* was significantly affected by the physical characteristic of the soil mixture. In order to enhance the development of the plant, not only nutrient management is important but the soil physical also plays an important role in determining the development of the plant. Good soil quality can help the plant absorb nutrients from the soil. The usage of this soil mixture plus vermicompost increases the soil porosity to avoid the bulk density of the soil because of the good physical characteristic of vermicompost. The bulk density is closely related to the porosity of the media where inappropriate aeration on porosity and water holding capacity can limit air exchange and water retention on growth media.

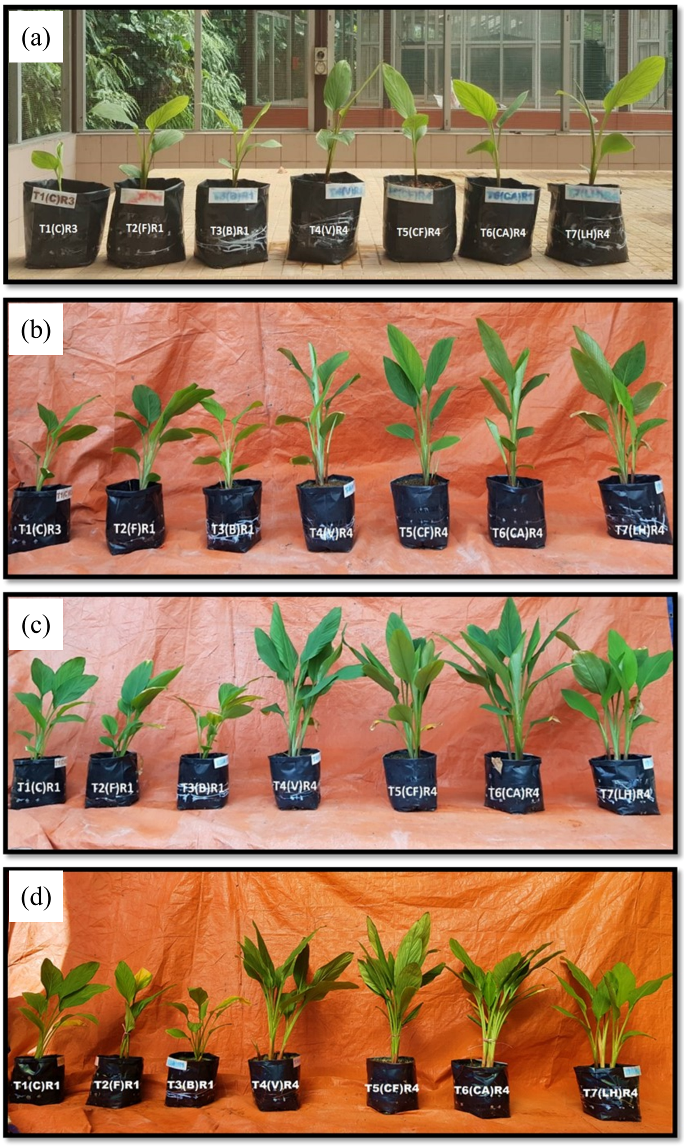

Figure 3. Effect of organic materials on growth performance of *B. rotunda* (a) growth after 30 days. (b) growth after 60 days. (c) growth after 90 days. (d) growth after 120 days in different organic material and chemical fertilizer treatments.

According to Hicklenton *et al*. (2001), this phenomenon can disrupt plant growth. Soil medium is the most important factor for plant growth, soils amended with vermicompost products have the ability to retain moisture, improve soil structure and cation exchange capacity, have a higher rate of plant growth hormones and humic acids, higher microbial population and activity, and less root pathogens or soil borne diseases (Atiyeh *et al*., 2002; Postma *et al*., 2003; Perner *et al*., 2006) and overall improvement in plant growth and yield (Kale *et al*., 1992; Arancon *et al*., 2004). Other than good physical characteristics, the application of vermicompost showed a good result because it is an organic source of plant nutrients, contains a higher percentage of nutrients necessary for plant growth in readily available forms (Atiyeh *et al*., 2000; Nagavallemma *et al*., 2004; Zaller, 2007) support the fact that vermicompost has potential for improving plant growth and dry matter yield when added to the soil. Vermicompost showed a positive effect on diverse types of plants. Previous studies finding out that vermicompost plays a major role in improving the growth and yield of different field crops, including vegetables, flowers and fruits crops, for example, the applications of vermicompost gave higher germination (93%) growth and yield of mung bean (*Vigna radiate* L.) compared with the control (84%) (Nagavalemma *et al*., 2004; Blouin *et al*., 2019). Another report suggested that the application of 30% vermicompost produced the most flowers on the Marigold (*Tagetes erecta* L.) plants in pot culture experiments, and the largest flower diameter was produced in soil amended with 40% vermicompost (Sangwan *et al*., 2010). They also indicated that the amount of vermicompost had a significant effect not only on the growth and flowering of marigold plants but also on the plant shoot and root biomass, plant height and diameter of the flowers.

Many researchers stated the benefit and positive effects of biochar application on the physical and chemical properties of soil and lead to the good effects on the growth and development of plants (Herath *et al*., 2013; Hamzah and Shuhaimi, 2018). However, this study found that the treatment using biochar showed the lowest value of all measured parameters compared to other treatments. The results obtained from this study were in accordance with the previous study that the size of biochar used will affect the growth and development of the plant (Herath *et al*., 2013; Helliwell, 2015). The smaller particle size of biochar retains more water than larger particles since small biochar particles can easily mix and interact with soil particles to form aggregates than large biochar particles (Herath *et al*., 2013). The application of small size biochar will show a positive effect compared to the larger size. Furthermore, these aggregates contribute to an increase in water retention which is more suitable for the development of the rhizome and finger roots. The greater and lesser interaction of biochar with the soil matrix may have a direct effect on its chemical, physical and hydrological properties (Barnes *et al*., 2014) thus, the usage of large particles is not effective in plant growth and development. This interaction is dependent on biochar particle size and therefore can influence the physical and hydraulic properties of soil (Blanco-Canqui, 2017). In another study, Głąb *et al.* (2016) found that as bulk density decreased, total porosity increased, plant available water content decreased, and water repellence decreased with an increase in the biochar size from 0.5 to 2.0 mm. (Rashid *et al*. (2015) mentioned that the used of sand also give the bad effect to the growth and development of *B. rotunda* species. The sand will cause plant retardation and low production of rhizomes after ten months of planting because the physical characteristic of sand will reduce water retention. The studies also conclude that the combination of a high percentage of black soil and sand in the substrate medium decreased the yield production of rhizome and finger roots of *B. rotunda*. Other than the biochar particle size, the effects on the chemical and physical properties of soil are dependent on the biochar amount, pyrolysis temperature and biomass type (Liu *et al*., 2012; Blanco-Canqui, 2017; Wang *et al*., 2018).

The control treatment shows the normal growth compared to biochar treatments because the soil medium used in this study was 50% of red soil and 50% of black soil which gave positive effects on the growth and development even without the addition of any fertilizer or organic material. Other than fertilizer application, the important thing to make sure the good development of the plant is the fertility of the soil. Soil is generally considered fertile when it has a good physical structure, balanced nutrients and sufficient biotic activity (Mäder *et al*., 2002). The absence or imbalance of any one of these factors as a limiting factor also can affect plant growth (Theunissen *et al*., 2010). To increase the yield of crops, fertilization is essential, and the adequate amount of fertilizer to be applied to boost rhizome yields should be known to avoid oversupply and wastage. Adequate amount of fertilizer rates significantly increase the rhizome yield in the Zingiberaceae family, such as in turmeric (*Curcuma longa* L.) and ginger (*Z.officinale*) (Akamine *et al*., 2007; Akhter *et al*., 2013). In addition, the planting medium containing an adequate supply of nutrients is good for plants to achieve optimum growth and development (Mehmood *et al*., 2013). Three major nutrients which are nitrogen (N), phosphorus (P), and potassium (K) play a very important role in plant growth, yield and plant quality (Ivonyi *et al*., 1997). The

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application of the organic matter in this study help to improve the plant growth and yield of this species and at the same time reduce the usage of chemical fertilizer.

4. Conclusion

Boesenbergia rotunda needs good soil with good holding capacity and aeration that is suitable for use as a growing medium. This study showed that the application of organic materials has increased the growth performance of *B. rotunda*, which were the number of leaves, plant height, fresh and dry weight of rhizome and finger roots. The use of a suitable planting medium and application of organic materials especially vermicompost can help in the growth and development of *B. rotunda* compare to other organic materials treatment and application of chemical fertilizer.

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