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EFFECTS OF DIFFERENT QUALITY OF SOIL MIXTURE ON GROWTH DEVELOPMENT OF AN IMPORTANT MEDICINAL PLANT, *Boesenbergia rotunda*

KAMALUDIN A. RASHID[2*], ABU BAKAR MOHD DARAN[1], NORZULAANI KHALID[1], MAHANOM JALIL[1], YUSMIN MOHD YUSUF[1], SHAHRIL EFZUENI ROZALI[1,2] and REZA FARZIN[1]

[1]*Biological Division, Centre for Foundation Studies in Science, University of Malaya, 50603 Kuala Lumpur, Malaysia*
[2]*Institute of Biological Sciences, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia*
[*]*E-mail: kamalrashid@um.edu.my*

ABSTRACT

Growth and morphological development of *Boesenbergia rotunda* grown in different soil mixture were considered to determine the suitable growing media for the species. *B. rotunda* or fingerroot ginger is a highly important medicinal plant belonging to Zingiberaceae family. The rhizome and fingerroot structure of this species contains several bioactive compounds with various functional pharmaceutical activities. It can be vegetatively propagated through cutting rhizome and shows slow growth rate. This study provided some analysis and informative data on how the three types of typical soil (red soil (RS), black soil (BS) and sand (SS) can give important influences on the morphological and physiological development of the species. Fourteen different types of soil mixture with different mix ratio and quality were used as a growth medium. The effects of these treatments were implied based on the growth rate, evaluation in biomass quality of shoots, rhizomes and fingerroots, and photosynthetic pigment analysis. The highest quality growth of *B. rotunda* was established in the medium containing high percentage of RS and BS with low of SS. The growth rate of plant and photosynthetic pigment concentration were increased in the medium containing a high percentage of RS (50-100%) and BS (50-100%). The presence of a high percentage of BS in the medium was also significantly increased the biomass production of rhizome and fingerroots. The soil mixture might not make adverse effects on the shoots biomass except in medium containing more than 50% of SS. The physical characteristics (bulk density, porosity, water holding capacity and electrical conductivity) of the soil mixture were studied to determine the quality of an optimum combination of the growing medium. The synthetically evaluation index of the plant showed that the different type of soil mixture has a significant effect on growth development of *B. rotunda* that necessary in industrialization cultivation study.

Key words: *Calathea crotalifera*, acclimatization, light intensity, growth, leaf morpohlogy, leaf physiological

INTRODUCTION

Boesenbergia rotunda (L.) Mansf. is an important medicinal ginger species that grows in India, Southeast Asia, Sri Lanka and Southern China. This species belongs to the family Zingiberaceae. This species is also known as Chinese key or Fingerroot in English, "Temu kunci" in Malay and Krachai or Krachai-Dang in Thailand. The morphology of this ginger species has been well characterized with the presence of the small globular shaped central subterraneous rhizome. Several slender and long tubers will be sprouting all in the same direction from the rhizome like the fingers, where the local name fingerroot came from (Sirirugsa, 1992). The ethnomedicinal functions of this species are well known to be used as a condiment in food and as a traditional medicine to treat illnesses like rheumatism, muscle pain, gastrointestinal disorder, peptic ulcer and also used to treat inflammatory diseases such as dermatitis, dental caries, dry coughs, wounds, diarrhea, and as a diuretic (Chuakul & Boonpleng, 2003; Salguero, 2003).

Several biological analysis have been conducted to reveal the pharmaceutical and medicinal functions of this ginger and nearly a hundred of bioactive compounds were successfully isolated and elucidated, consisted of flavonoid derivatives, chalcone derivatives, essential oils, ester, kawains, terpenes and terpenoids (Trakoontivakorn *et al*., 2001; Eng-Chong *et al*., 2012). The presence

* To whom correspondence should be addressed.

of pinostrobin had been reported by Fahey & Stephenson (2002) which plays a role in elevating the activity of an antioxidant enzyme, reducing estrogen-induced cell proliferation, mediating reduction of inflammation, decreasing spontaneous contractions of intestinal smooth muscle, elevating the activity of quinone reductase and as anti-spasmodic agent to inhibit aromatase activity (Bail *et al.*, 1998; Wu *et al.*, 2002). This flavone also exhibited cytoprotective effects that induce anti-ulcerogenic property on rat (Abdelwahab *et al*., 2011). The purified flavonoids, chalcones, and cyclohexyl chalcone derivatives extracted from *B. rotunda* exhibited potent antimutagenic effects (Trakoontivakorn *et al*., 2001).

The isolated cardamonin (flavonoid) displayed antiviral activities that can inhibit HIV-1 protease activity (Tewtrakul *et al.*, 2003). The presence of significant flavonoid of panduratin A was found to reduce the development of human breast cancer and human colon adenocarcinoma cell (Kirana *et al.*, 2007), anti-aging activity by treating skin aging affected by UV (Shim *et al.*, 2009), treating obesity and associated metabolic disorder (Kim *et al.*, 2011), anticariogenic agent to prevent cariogenic teeth (Hwang *et al.*, 2004), antioxidant activities in inhibition of lipid peroxidation in brain (Shindo *et al.*, 2006) and have potential as an antibacterial and antiviral agent (Rukayadi *et al.*, 2010; Wu *et al*., 2011). Kiat *et al.* (2006) reported that 4-hydroxypanduratin A and panduratin A extracted from the rhizome could inhibit dengue-2 virus protease activity.

B. rotunda is traditionally propagated by the vegetative method through cutting of rhizome that are protracted for large scale multiplication. The conventional method might cause transmission of soil borne pathogens especially endophytic bacterial and fungal that can spread to other plants and farming areas (Balachandran *et al.*, 1990). Production of healthy shoots with the large size of rhizome and tuber are highly demanded for food consumption and extraction, and also as a source for planting materials. There are several *in vitro* studies reported for plant multiplication and mass production of this species through tissue culture technique (Tan *et al*., 2005; Yusuf *et al.*, 2011).

The application of plant biotechnology approach in plant propagation is a simple and cost-effective way to obtain abundant uniform planting materials within a relatively short time (Balachandran *et al*., 1990; Chan & Thong, 2004). However, the standardization of optimum environmental parameters like light intensity, soil media, and also other abiotic stresses are essential for highest yield production with high quality of plants in the field (Farzinebrahimi *et al.*, 2013). The soil quality control such as aggregate stability, mineral contains, pH and salinity were played an important role in determining the growth development of plants (Jayasinge, 2012; Farzinebrahimi *et al*., 2013; Liu *et al.*, 2014). Liu *et al*. (2014) have reported the influence of different substitute media on morphology and physiology changes on the ornamental plant, *Cyclamen persicum* Mill. The report demonstrated various soil media can give significant effects on the development of the potted plant. The effect of various parameters of nitrogen application in the field of different organic fertilizer on the rhizome yield production of *Zingiber officinale* had been summarized by Lee & Asher (1981). Thus, the present paper describes the influence different soil mixture from three different types of typical agricultural soil in Malaysia on biomass production of potted *B. rotunda* in the field.

MATERIALS AND METHODS

Planting material, soil media and environment

Mature plants of *B. rotunda* with 30-40 cm height were bought from local farmers in Shah Alam, Selangor, Malaysia. The fresh weight, average height and number of shoots were recorded before transplant in the pot. The shoots were removed, and the rhizomes were cut into 5-10 cm length. Each rhizome were washed under running tap water and transferred into the pot with different planting medium as in Table 1. The plants were maintained in the conservatory area under natural environment with 60% of sunlight and temperature 24ºC (min) – 31ºC (max), located at Centre for Foundation in Science, University of Malaya. Each plant was watered with tap water at least once a day to maintain the soil moisture.

Table 1. Different types of soil mixture for growing medium

Medium	Coding	Red Soil (R)	Black Soil (B)	Sand (S)
RB50	M1	50%	50%	
BS50	M2		50%	50%
RS50	M3	50%		50%
RS25B50	M4	25%	50%	25%
RB25S50	M5	25%	25%	50%
BS25R50	M6	50%	25%	25%
R75B25	M7	75%	25%	
R75S25	M8	75%		25%
B75S25	M9		75%	25%
B25S75	M10		25%	75%
R25B75	M11	25%	75%	
B	M12		100%	
R	M13	100%		
S	M14			100%

Growth parameters analysis

The data for biomass development were collected and analyzed based on plant survival, shoot number, leaf area, plant height, fresh and dry weight of rhizome and number of tuber (fingerroot). Data for plant height were measured and collected every two months up to ten months for plotting the growth pattern of each sample.

Photosynthetic pigment analysis

Fully expanded one-month-old leaves were used for photosynthetic pigment analysis. The leaves were mashed with 80% acidified acetone and some $CaCO_3$ in the chilled mortar with ratio 1:10. The crude extract was filtered, and the supernatant was collected to be analyzed using UV-V is Spectrophotometer at 480nm, 645nm, and 666nm. The concentration of each pigment was determined using Wellburn Equation (Wellburn, 1994).

Physical characteristics and pH analysis of media

Physical properties of each soil mixture which consist of bulk density, water holding capacity, total porosity, aeration porosity and air space were determined using procedure described by Jayasinge (2012) and a modified ring knife method as described by Zhang *et al.* (2013). The moistened plant substrate was placed in 6.5 cm diameter of a glass jar with volume 350 mL. Each jar was added with tap water until the substrate gets saturated. After determining the weight of the saturated substrate, the jar was covered with gauze placed upside down. The saturated substrates were allowed to drain in 24 hours. Then, the amount of water loss was determined as a result of drainage. Finally, the jar with the substrate was dried until constant weight. The amount of water retained by substrates after draining was determined. The physical characteristics of the soil mixture were calculated using the formula as described by Zhang *et al*. (2013).

Statistical analysis

Statistical analyzes were performed using software of SPSS Version 17.0. The data were analyzed with a one-way analysis of variance (ANOVA). Differences between means were tested with Duncan's Multiple Range Test (DMRT) at $p \leq 0.05$.

RESULTS AND DISCUSSION

Physical characteristics and pH of media

Table 2 shows the main physical properties and pH of the final soil media after planted with the rhizomes. The bulk density was significantly reduced in the medium with a high percentage of red soil and sand as demonstrated in medium M13, M8 and M5 with 0.72, 0.75 and 0.92 g cm^{-3} respectively. The addition of high ratio of black soil in the combination with sand in medium M9 resulted in higher bulk density compared to other soil mixture. The combination of black soil and sand increased the water holding capacity in the medium M2 (741.18 g g^{-1}) and M9 (620.52 g g^{-1}). This combination of soil also has an adverse effect on aeration porosity of the medium as recorded in medium M2, M4, M5, M9, and M10. The percentage reading were lower than the ideal medium (20.00 – 30.00%) (Zhang *et al*., 2013). However, the control medium that was red soil (M13) and sand (M14) also have higher water holding capacity but lower in percentage of aeration porosity.

The highest total porosity was recorded in medium M1 with equal ratio of red and black soil. This total porosity percentage was nearly optimum medium (70.00 – 90.00%) (Zhang *et al.,* 2013).

Table 2. Physical characteristics and pH of the different media

Medium	Bulk density (g cm^{-3})	Water holding capacity (g g^{-1})	Total porosity (%)	Aeration porosity (%)	Water holding porosity (%)	Void space (%)	pH
M1	0.89 ± 0.00b	389.77 ± 38.30ab	64.47 ± 0.66h	25.66 ± 1.00ef	38.81 ± 1.30cd	66.72 ± 4.80e	6.65 ± 0.01bc
M2	1.04 ± 0.04def	741.18 ± 62.25f	44.35 ± 1.99b	7.59 ± 0.85a	36.76 ± 2.07c	21.10 ± 2.87a	6.70 ± 0.02cd
M3	1.02 ± 0.02de	455.38 ± 38.82bc	53.15 ± 0.84def	24.41 ± 0.92de	28.74 ± 1.13ab	85.74 ± 5.89f	6.94 ± 0.02gh
M4	0.97 ± 0.01bcd	588.04 ± 21.93d	46.30 ± 0.69bc	16.00 ± 0.50c	30.30 ± 0.19b	52.76 ± 1.32bcde	6.92 ± 0.01fgh
M5	0.92 ± 0.02bc	546.99 ± 56.18cd	49.98 ± 1.10bcd	14.67 ± 1.05c	35.32 ± 2.03c	42.61 ± 4.74b	6.89 ± 0.01fg
M6	1.13 ± 0.06fgh	455.35 ± 77.92bc	50.53 ± 5.23bcd	20.44 ± 3.48d	30.09 ± 1.98b	66.52 ± 8.34e	6.65 ± 0.01bc
M7	0.99 ± 0.01cd	298.69 ± 26.31a	61.12 ± 0.64gh	24.06 ± 1.34de	37.06 ± 0.94c	65.42 ± 5.09de	6.51 ± 0.03a
M8	0.75 ± 0.03a	609.22 ± 27.53de	57.88 ± 1.80efg	20.12 ± 1.30d	37.75 ± 0.85c	53.31 ± 3.11bcde	6.81 ± 0.02e
M9	1.15 ± 0.01gh	620.52 ± 4.71def	45.23 ± 0.39b	15.39 ± 0.21c	29.84 ± 0.40b	51.61 ± 1.15bcd	7.05 ± 0.02i
M10	1.09 ± 0.04efg	870.34 ± 28.93g	52.19 ± 2.45cde	9.30 ± 0.97ab	42.89 ± 2.29de	21.95 ± 2.53a	6.93 ± 0.01gh
M11	1.09 ± 0.03efg	563.13 ± 16.33cd	59.17 ± 2.26fgh	21.70 ± 0.94de	37.47 ± 1.98c	58.53 ± 3.92cde	6.97 ± 0.01h
M12	0.95 ± 0.07bcd	347.93 ± 25.90ab	59.33 ± 2.26fgh	29.47 ± 1.61f	29.86 ± 1.21b	99.08 ± 5.70g	6.64 ± 0.02b
M13	0.72 ± 0.08a	658.99 ± 47.94def	55.75 ± 0.49defg	9.38 ± 2.25ab	46.37 ± 2.10e	21.29 ± 5.88a	6.75 ± 0.01d
M14	1.20 ± 0.02h	716.47 ±16.64ef	37.22 ± 1.22a	12.14 ± 0.80bc	25.07 ± 1.08a	48.85 ± 4.13bc	6.87 ± 0.01f

Values are mean with SE. Means in a column followed by the same letter are not significantly different at $p \leq 0.05$ according to DMRT.

Almost all the soil mixture was approached and within the optimal range of 40-67 for void ratio (Bunt, 1998) except for medium M2, M10, and M13. Values for pH in the substrates ranged from 6.50 to 7.05. Almost all the medium have higher pH value that was higher than pH 6.5. Except for medium M7 that approached the ideal range (5.2 – 6.5) suggested by different reports (Bunt, 1998; Noguera *et al.*, 2003).

Growth pattern and biomass analysis of the plant

The vegetative shoots of *B. rotunda* emerged from the rhizomes after two weeks of planting. The shoots started to produce leaves within four weeks. Rhizomes in M11 have the highest shoot height at the first two months of planting compared to the other medium. The growth pattern of *B. rotunda* was significantly influenced by the growing medium as shown in Fig. 1. Plants in medium M2, M12 and M14 were retarded, and the height was diminished after ten months because most of the old shoots showed necrosis problem and started to die. The highest shoot of *B. rotunda* was achieved in medium M7 followed by M1 and M13, which contained a combination of red and black soil. However, the biomass of *B. rotunda* is not directly proportionated to the growth height of the shoots as shown in Table 3 and Table 4. The highest fresh weight of rhizomes and fingerroots were achieved in medium M7 (54.83 g). The lowest fresh weight with below than 20.0 g was found in medium M2, M3, M5, M9, M10, M11, M12, and M14. These substrates contained a high percentage of sand and black soil. The results revealed that medium M12 and M14 will cause plant retardation and low production of rhizomes after ten months being planted. This medium also caused fingerroot rot after eight months (data not shown).

The production of fingerroot was higher in medium M7, M8 and M13, which contained a high percentage of red soil (Fig. 2). The size and diameter of the fingerroots were also bigger with either cylindrical or globular structure. The different soil mixture might not give adverse effect to the shoot biomass of *B. rotunda.* The average shoot number in each medium was almost similar, but the lowest yield with less than two shoots was found in medium M2, M3, M4, and M14. Shoots in medium M14 was found had the lowest leaf number, leaf area and stem diameter compared to the other medium. Burn shoot tips problem was also demonstrated in this medium. Rhizome in medium M7 and M11 produced a higher number of shoot as shown in Fig. 2.

Based on the results, the biomass production of *B. rotunda* was significantly affected by the physical characteristics of the soil mixture. The bulk density is closely related to the porosity of media where an inappropriate aeration porosity and water holding capacity values can limit air exchange or water retention of growth media. This phenomenon thereby can disrupt plant growth (Hicklenton *et al.*, 2001). The combination of a high percentage of black soil and sand in the substrate medium decreased the yields production of rhizome and fingerroot of *B. rotunda* (Table 3). This combination

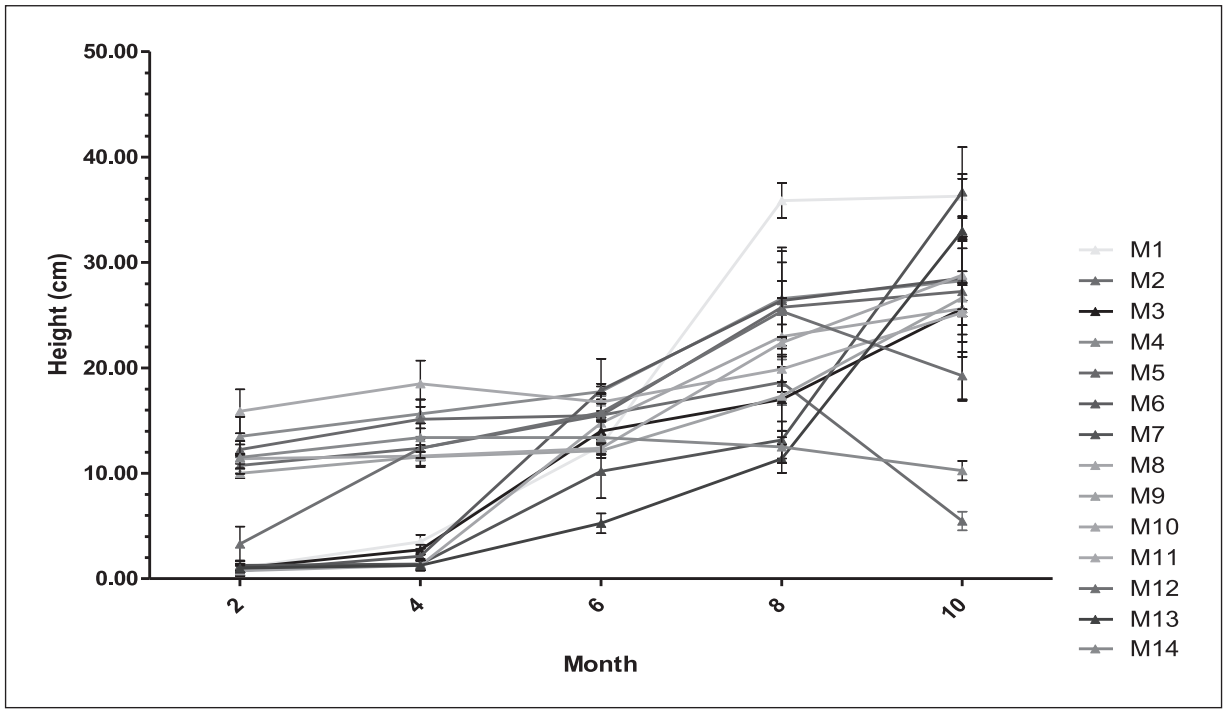

Fig. 1. Effect of different growth medium on growth rate of *Boesenbergia rotunda* in ten months cultivation.

Table 3. Biomass (fresh and dry) of rhizomes and fingerroots of *Boesenbergia rotunda* as affected by different growth medium

Medium	Fresh Weight (FW)(g)	Dry Weight (DW)(g)	Ratio (DW/FW)	Water Content (g)	Percentage of Water Content (%)
M1	30.49 ± 8.37ab	8.22 ± 2.15bcd	0.27 ± 0.01a	22.27 ± 6.22ab	72.96 ± 1.13a
M2	12.14 ± 1.06a	2.92 ± 0.27a	0.24 ± 0.01a	9.22 ± 0.82a	75.89 ± 0.97a
M3	11.10 ± 0.93	3.00 ± 0.26a	0.27 ± 0.01a	8.09 ± 0.68a	72.92 ± 0.67a
M4	21.78 ± 4.13ab	5.57 ± 1.21abc	0.25 ± 0.02a	16.21 ± 2.93ab	75.40 ± 1.94a
M5	13.71 ± 1.59a	3.23 ± 0.26ab	0.24 ± 0.02a	10.48 ± 1.47a	75.59 ± 2.21a
M6	17.32 ± 2.78ab	4.64 ± 1.19abc	0.27 ± 0.08a	12.67 ± 2.59ab	72.58 ± 7.71a
M7	54.83 ± 7.92c	12.65 ± 1.59d	0.24 ± 0.02a	42.18 ± 6.81c	75.98 ± 2.37a
M8	38.63 ± 9.41bc	9.18 ± 2.11cd	0.24 ± 0.01a	29.45 ± 7.36bc	76.04 ± 0.95a
M9	16.25 ± 3.19ab	4.29 ± 0.88ab	0.26 ± 0.02a	11.96 ± 2.33ab	73.91 ± 1.77a
M10	17.08 ± 4.19ab	3.67 ± 0.83ab	0.24 ± 0.03a	13.41 ± 3.74ab	76.18 ± 3.29a
M11	19.08 ± 2.14ab	4.07 ± 0.50ab	0.22 ± 0.02a	15.01 ± 1.91ab	78.08 ± 2.44a
M12	11.66 ± 2.03a	2.60 ± 0.45a	0.23 ± 0.02a	9.06 ± 1.62a	77.37 ± 1.74a
M13	52.75 ± 20.60c	10.91 ± 4.07d	0.21 ± 0.03a	41.84 ± 16.60c	78.99 ± 2.79a
M14	11.57 ± 2.81a	2.24 ± 0.14a	0.22 ± 0.03a	9.33 ± 2.70a	77.92 ± 2.83a

Values are mean with SE. Means in a column followed by the same letter are not significantly different at $p \leq 0.05$ according to DMRT.

Table 4. Shoot number, leaf number per shoot, length and diameter of leaf, and stem diameter of *Boesenbergia rotunda* as affected by different growing medium

Medium	Shoot Number	Leaf Number per Shoot	Leaf Length (cm)	Leaf Diameter (cm)	Leaf Area (cm2)	Stem Diameter (cm)
M1	2.50 ± 0.56ab	5.17 ± 0.54	19.75 ± 0.87c	7.33 ± 0.36d	85.07 ± 9.14d	0.97 ± 0.07
M2	1.50 ± 0.22a	3.50 ± 0.34abc	12.43 ± 0.76ab	4.93 ± 0.27abc	46.36 ± 4.51abc	0.60 ± 0.05
M3	1.83 ± 0.31a	3.00 ± 0.86ab	10.17 ± 1.14ab	4.12 ± 0.32ab	32.51 ± 5.97ab	0.58 ± 0.05
M4	1.50 ± 0.22a	3.83 ± 0.60abc	14.58 ± 0.98bc	5.40 ± 0.24bc	59.75 ± 6.62bcd	0.82 ± 0.12
M5	3.33 ± 0.33abc	3.50 ± 0.34abc	15.47 ± 1.33bc	5.20 ± 0.40bc	61.62 ± 8.33bcd	0.72 ± 0.11
M6	2.83 ± 0.40abc	3.67 ± 0.42abc	14.82 ± 1.04bc	5.85 ± 0.30c	66.12 ± 7.39bcd	0.83 ± 0.08
M7	3.83 ± 0.91bc	4.33 ± 1.20bc	14.63 ± 2.62bc	5.17 ± 0.54bc	61.98 ± 17.16bcd	0.80 ± 0.11
M8	3.00 ± 0.58abc	3.50 ± 0.62abc	14.93 ± 2.75bc	5.87 ± 0.88c	73.15 ± 19.03cd	0.83 ± 0.14
M9	2.50 ± 0.43ab	3.30 ± 0.42abc	11.27 ± 2.11ab	4.35 ± 0.52abc	40.68 ± 11.04abc	0.63 ± 0.12
M10	2.83 ± 0.54abc	3.67 ± 0.42abc	11.12 ± 1.89ab	4.42 ± 0.45abc	39.56 ± 8.47abc	0.57 ± 0.08
M11	3.83 ± 1.05bc	3.33 ± 0.61abc	10.92 ± 1.16ab	4.40 ± 0.37abc	37.27 ± 6.71abc	0.57 ± 0.02
M12	2.33 ± 0.21ab	3.67 ± 0.56abc	13.20 ± 1.00ab	4.97 ± 0.32abc	50.26 ± 6.71abcd	0.58 ± 0.10
M13	4.50 ± 0.76c	3.33 ± 0.80abc	15.25 ± 3.11bc	5.07 ± 0.90bc	68.01 ± 21.71bcd	0.75 ± 0.11
M14	2.00 ± 0.63ab	2.17 ± 0.31a	8.15 ± 0.50a	3.45 ± 0.17a	21.36 ± 2.26a	0.48 ± 0.03

Values are mean with SE. Means in a column followed by the same letter are not significantly different at $p \leq 0.05$ according to DMRT.

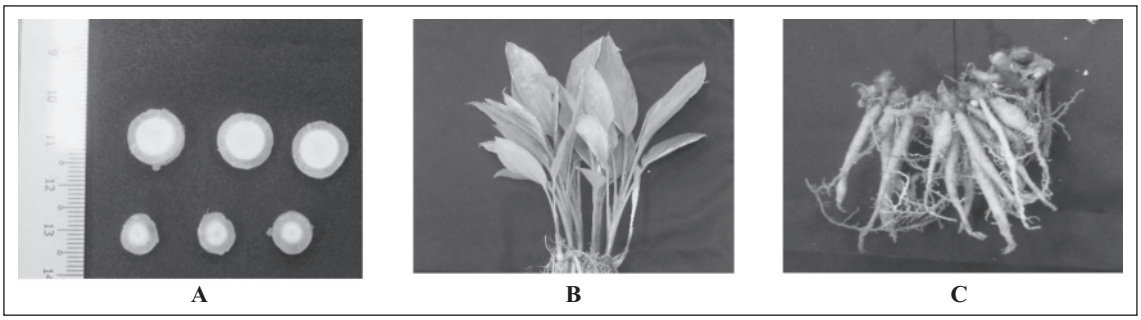

Fig. 2. Development of *Boesenbergia rotunda* in a different type of soil mixture. (A) Different size of diameter for a cross section of fingerroot in medium M7 and medium M14. (B) High production of shoot number in medium M11. (C) High production of rhizome and fingerroots in medium M7.

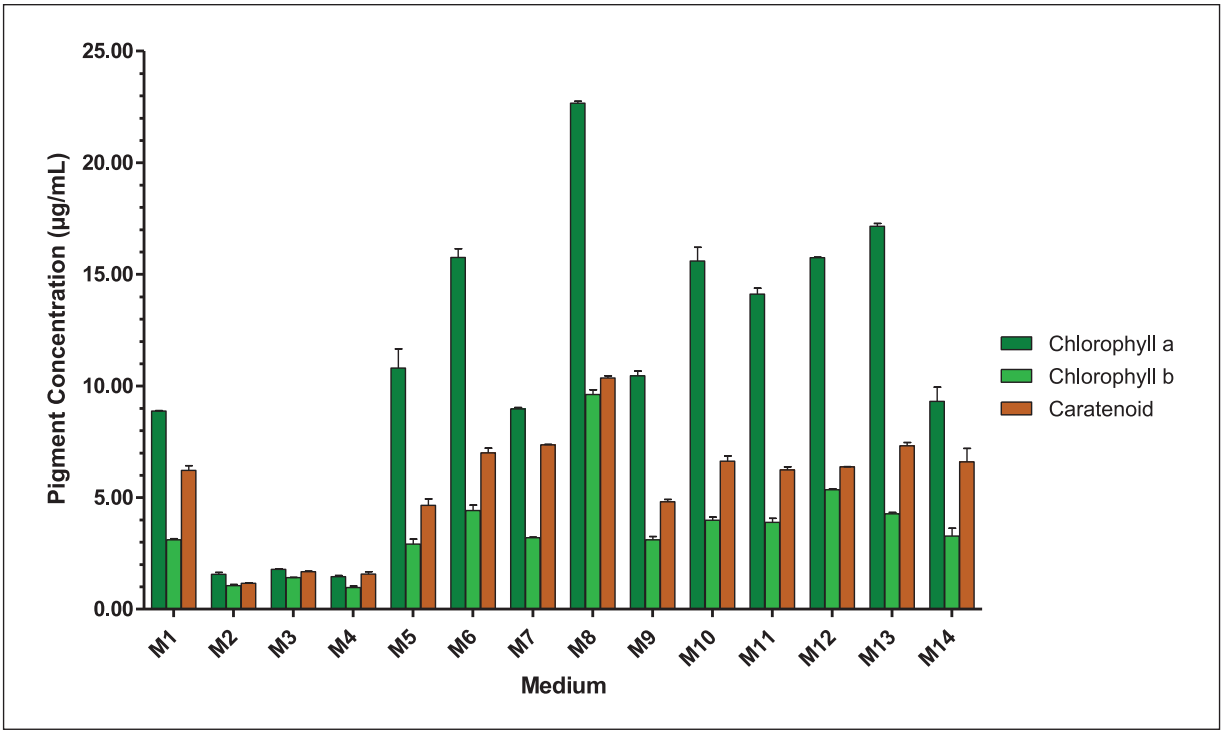

Fig. 3. Effect of different growth medium on photosynthetic pigment concentration in leaf of *Boesenbergia rotunda* after four months cultivation.

was reduced the aeration porosity of the medium that is lower than the optimum range (Zhang *et al*., 2013).

The void ratio value was also necessary to determine the effectiveness of soil mixture for gas exchange and water retention and drainage. The high value of void ratio demonstrates a low ability to retain water whereas a ratio that is too low shows the potential for retaining too much water for plant growth (Benito *et al.*, 2005). The lowest void ratio was observed in medium M2 and has retained too much water within the planting period which caused the presence of rotten problem on the rhizomes and fingerroots due to fungal and indigenous bacterial infections (Balachandran *et al*., 1990). The same problem was also found in medium M10 (data not shown). The better aeration porosity with the ideal void space retention in the medium will enhance the root growth and development of the plant (Zhang *et al*., 2013). The better growth of root development was observed in medium M11 (data not shown).

Photosynthetic pigment analysis

Based on Fig. 3, the combination of a high percentage of red soil in medium M8 produced the highest concentration of photosynthetic pigment (chlorophyll a, chlorophyll b and carotenoid). Similar results were also observed in medium M6, M12 and M13 with values more than 15.00 µg/ml. The results demonstrated that the highest percentage of red and black soil in the potting medium could enhance the production of photosynthetic pigments in the leaves. The concentration of chlorophyll b in each medium was lower than the other pigments. Medium M2, M3, and M4 resulted in the lowest concentration of photosynthetic pigment in the leaves. Photosynthetic pigment concentration was found higher in the medium with a high percentage of red soil and also organic constituents from the black soil especially in medium M8, M6 and M13 potentially enhanced the Fe, Mg and other nutrient contents in that soil mixture. (Lallawmsanga *et al.*, 2012) reported that Mg and Fe are required for pigment biosynthesis and are thought to be involved in the chloroplast formation via protein synthesis.

CONCLUSIONS

This paper is the first to report on the effects of a different mixture of typical agriculture soil in Malaysia on the growth development of the important medicinal plant, *B. rotunda*. The results revealed that the different types of soil mixture significantly influenced yield production of rhizome and fingerroots tuber that were essential for bioactive compound extraction. The paper also provides general and new information concerning the effects of physical characteristics of soil mixture for the cultivation of this rhizomatous species. The use of a high percentage of red and black soil with

differing ratios of sand soil could enhance the growth productivity of the *B. rotunda*. The combination of black soil and sand was not recommended for the cultivation of this species in the pot. The best results were obtained with a combination of 75% red soil and 25% black soil in medium M7 and the combination of 50% red soil and 50% black soil in medium M1. The findings indicate that the combination of both types of soil can increase the productivity of rhizomes and fingerroots and maintain healthy growth of shoots. These results are necessary for evaluation of different type of nutrient source or some abiotic stress including present of heavy metal, light intensity, mineral composition and drought stress on the accumulation of an important bioactive compound in the rhizome and fingeroots tuber.

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REFERENCES

Abdelwahab, S.I., Mohan, S., Abdulla, M.A., Sukari, M.A., Abdul, A.B., Taha, M.M.E. and Lee, K.-H. 2011. The methanolic extract of *Boesenbergia rotunda* (L.) Mansf. and its major compound pinostrobin induces anti-ulcerogenic property in vivo: Possible involvement of indirect antioxidant action. *Journal of Ethnopharmacology,* **137(2)**: 963-970. doi: http://dx.doi.org/10.1016/j.jep.2011.07.010

Bail, J.C.L., Aubourg, L. and Habrioux, G. 2000. Effects of pinostrobin on estrogen metabolism and estrogen receptor transactivation. *Cancer Lett.,* **156**: 37-44.

Balachandran, S.M., Bhat, S.R. and Chandel, K.P.S. 1990. *In vitro* clonal multiplication of turmeric (*Curcuma* spp.) and ginger (*Zingiber officinale* Rosc.). *Plant Cell Reports,* **8(9)**: 521-524. doi: 10.1007/BF00820200

Benito, M., Masaguer, A., Antonio, R.D. and Moliner, A. 2005. Use of pruning waste compost as a component in soilless growing media. *Bioresour. Technol.,* **96**: 597-603.

Bunt, A.C. 1998. *Media and mixes for container grown plants: a manual on the preparation and use of the growing media for growing pot plants* (2nd ed.). London: Unwin Hyman Ltd.

Chan, L.K. and Thong, W.H. 2004. *In vitro* propagation of Zingiberaceae species with medicinal properties. *J. Plant Biotechnol.,* **6**: 181-188.

Chuakul, W. and Boonpleng, A. 2003. Ethnomedical uses of Thai Zingiberaceous plant *Journal of Medicinal,* **10(1)**: 33-39.

Eng-Chong, T., Yean-Kee, L., Chin-Fei, C., Choon-Han, H., Sher-Ming, W., Li-Ping, C.T. and Yusof, R. 2012. *Boesenbergia rotunda*: from ethnomedicine to drug discovery. *Evidence-Based Complementary and Alternative Medicine*. doi: 10.1155/2012/473637

Fahey, J.W. and Stephenson, K.K. 2002. Pinostrobin from honey and Thai ginger (*Boesenbergia pandurata*): a potent flavonoid inducer of mammalian phase 2 chemoprotective and antioxidant enzymes. *J. Agr. Food Chem.,* **50**: 7472-7476.

Farzinebrahimi, R., Taha, R.M. and Rashid, K.A. 2013. Effect of light intensity and soil media establishment and growth of *Curculigo latifolia* Dryand *Journal of Applied Horticulture,* **15(3)**: 224-226.

Hicklenton, P.R., Road, V. and Warman, P.R. 2001. The effectiveness and consistency of source-separated municipal solid waste and bark compost as components of container growing media. *Sci. Hort.,* **91**: 365-378.

Hwang, J.-K., Chung, J.-Y., Baek, N.-I. and Park, J.-H. 2004. Isopanduratin A from *Kaempferia pandurata* as an active antibacterial agent against cariogenic *Streptococcus mutans*. *International Journal of Antimicrobial Agents,* **23(4)**: 377-381. doi: 10.1016/j.ijantimicag.2003.08.011

Jayasinge, G.Y. 2012. Synthetic soil aggregates as a potting medium for ornamental plant production. *Journal of Plant Nutrition,* **35**: 1441-1456.

Kiat, T.S., Pippen, R., Yusof, R., Ibrahim, H., Khalid, N. and Rahman, N.A. 2006. Inhibitory activity of cyclohexyl chalcone derivatives and flavonoids of fingerroot, *Boesenbergia rotunda* (L.), towards dengue-2 virus NS3 protease. *Bioorganic & Medicinal Chemistry Letters,* **16(12)**: 3337-3340. doi: http://dx.doi.org/10.1016/j.bmcl.2005.12.075

Kim, D., Lee, M.S., Jo, K., Lee, K.E. and Hwang, J.K. 2011. Therapeutic potential of panduratin A, LKB1-dependent AMP-activated protein kinase stimulator, with activation of PPARα/δ for the treatment of obesity. *Diabetes, Obesity and Metabolism,* **13(7)**: 584-593. doi: 10.1111/j.1463-1326.2011.01379.x

Kirana, C., Jones, G., Record, I. and McIntosh, G. 2007. Anticancer properties of panduratin A isolated from *Boesenbergia pandurata* (Zingiberaceae). *Journal of Natural Medicines,* **61(2)**: 131-137. doi: 10.1007/s11418-006-0100-0

Lallawmsanga, Kumar, D.J.M., Balakumaran, M.D., Kumar, M.R. and Jeyarathi, J. 2012. Ameliorating effects of vermicompost and cow dung compost on growth and biochemical characteristics of *Solanum melongena* L. treated with paint industrial effluent. *Ann. Biol. Res.,* **3**: 2268-2274.

Lee, M.T. and Asher, C.J. 1981. Nitrogen nutrition of ginger (*Zingiber officinale*) *Plant and Soil,* **62**: 23-34.

Liu, Q.C., Wang, K.L., Liu, Q.H., Pan, H.T. and Zhang, Q.X. 2014. Effects of substitute media on development of potted *Cyclamen percicum* Mill. *Journal of Northeast Agricultural University,* **21(2)**: 28-37.

Meckers, M., Paz, D., Acosta, J. and Mata, R. 1998. The effects of chrysin and pinostrobin, two flavonoids isolated from *Teloxys graveolens* leaves, on isolated guinea-pig ileum. *Phytomedicines,* **5**: 459-463.

Noguera, P., Abad, M., Puchades, R., Maquieira, A. and Noguera, V. 2003. Influence of particle size on physical and chemical properties of coconut coir dust as a container medium *Commun. Soil Sci. Plant Anal.,* **34**: 593-605.

Rukayadi, Y., Han, S., Yong, D. and Hwang, J.K. 2010. *In vitro* antibacterial activity of panduratin A against enterococci clinical isolates. *Biol. Pharm. Bull.,* **33**: 1489-1493.

Salguero, C.P. (2003). A Thai herbal. In L. Barton (Ed.), *Traditional recipes for health and harmony*. Forres, Scotland: Findhorn Press.

Shim, J.-S., Han, Y.-S. and Hwang, J.-K. 2009. The effect of 4-hydroxypanduratin A on the mitogen-activated protein kinase-dependent activation of matrix metalloproteinase-1 expression in human skin fibroblasts. *Journal of Dermatological Science,* **53(2)**: 129-134. doi: 10.1016/j.jdermsci.2008.09.002

Shindo, K., Kato, M., Kinoshita, A., Kobayashi, A. and Koike, Y. 2006. Analysis of antioxidant activities contained in the *Boesenbergia pandurata* Schult. rhizome. *Bioscience, Biotechnology, and Biochemistry,* **70(9)**: 2281-2284. doi: 10.1271/bbb.60086

Sirirugsa, P. 1992. A revision of the genus *Boesenbergia* Kuntze (Zingiberaceae) in Thailand. *Natural History Bulletin of the Siam Society,* **40**: 67-90.

Tan, S.K., Pippen, R., Yusof, R., Ibrahim, H., Rahman, N. and Khalid, N. 2005. Simple one-medium formulation regeneration of fingerroot [*Boesenbergia rotunda* (L.) Mansf. Kulturpfl.] via somatic embryogenesis. *In Vitro Cellular & Developmental Biology - Plant,* **41(6)**: 757-761. doi: 10.1079/IVP2005695

Tewtrakul, S., Subhadhirasakul, S., Puripattanavong, J. and Panphadung, T. 2003. HIV-1 protease inhibitory substances from the rhizomes of *Boesenbergia pandurata* Holtt. *Songklanakarin J. Sci. Technol.,* **25**: 503-508.

Trakoontivakorn, G., Nakahara, K., Shinmoto, H., Takenaka, M., Onishi-Kameyama, M., Ono, H. and Tsushida, T. 2001. Structural analysis of a novel antimutagenic compound, 4-hydroxypanduratin A, and the antimutagenic activity of flavonoids in a Thai species, fingerroot (*Boesenbergia pandurata* Schult.) against mutagenic heterocyclic amines. *J. Agric. Food Chem.,* **49**: 3046-3050.

Wellburn, A.R. 1994. The spectral determination of chlorophyll-a and chlorophyll-b, as well as total carotenoids, using various solvents with spectrophotometers of different resolution. *J. Plant Physiol.,* **144**: 307-313.

Wu, D., Nair, M.G. and Witt, D.L.D. 2002. Novel compounds from *Piper methysticum* Forst (kava kava) roots and their effect on cyclooxygenase enzyme. *J. Agr. Food Chem.,* **50**: 701-705.

Wu, N., Kong, Y., Zu, Y., Fu, Y., Liu, Z., Meng, R. and Efferth, T. 2011. Activity investigation of pinostrobin towards herpes simplex virus-1 as determined by atomic force microscopy. *Phytomedicine,* **18(2–3)**: 110-118. doi: http://dx.doi.org/10.1016/j.phymed.2010.07.001

Yusuf, N.A., Annuar, M.S.M. and Khalid, N. 2011. Rapid micropropagation of *Boesenbergia rotunda* (L.) Mansf. Kulturpfl. (a valuable medicinal plant) from shoot bud explants. *Afr. J. Biotechnol.,* **10(7)**: 1194-1199.

Zhang, L., Sun, X.Y., Tian, Y. and Gong, X.Q. 2013. Effects of brown sugar and calcium superphosphate on the secondary fermentation of green waste. *Bioresour. Technol.,* **131**: 68-75.