Effects of Different Quality of Soil Mixture on Growth Development of an Important Medicinal Plant, Boesenbergia Rotunda

Article in Malaysian Applied Biology · October 2015
EFFECTS OF DIFFERENT QUALITY OF SOIL MIXTURE ON GROWTH DEVELOPMENT OF AN IMPORTANT MEDICINAL PLANT, Boesenbergia rotunda

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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 morphology, 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
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 ant-uicerogenic property on rat (Abdelwahab et al., 2011). The purified flavonoids, chalcones, and cyclohexyl chalcone derivatives extracted from B. rotunda exhibited potent antimutagenic effects (Trakoonvivakorn 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 that have not yet been reported.

### 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 was 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 24°C (min) – 31°C (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

<table>
<thead>
<tr>
<th>Medium</th>
<th>Coding</th>
<th>Red Soil (R)</th>
<th>Black Soil (B)</th>
<th>Sand (S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RB50</td>
<td>M1</td>
<td>50%</td>
<td>50%</td>
<td>0%</td>
</tr>
<tr>
<td>BS50</td>
<td>M2</td>
<td>50%</td>
<td>50%</td>
<td>0%</td>
</tr>
<tr>
<td>RS50</td>
<td>M3</td>
<td>50%</td>
<td>50%</td>
<td>0%</td>
</tr>
<tr>
<td>RS25B50</td>
<td>M4</td>
<td>25%</td>
<td>50%</td>
<td>25%</td>
</tr>
<tr>
<td>RB25S50</td>
<td>M5</td>
<td>25%</td>
<td>25%</td>
<td>50%</td>
</tr>
<tr>
<td>BS25R50</td>
<td>M6</td>
<td>50%</td>
<td>25%</td>
<td>25%</td>
</tr>
<tr>
<td>R75B25</td>
<td>M7</td>
<td>75%</td>
<td>25%</td>
<td>0%</td>
</tr>
<tr>
<td>R75S25</td>
<td>M8</td>
<td>75%</td>
<td>0%</td>
<td>25%</td>
</tr>
<tr>
<td>B75S25</td>
<td>M9</td>
<td>75%</td>
<td>25%</td>
<td>0%</td>
</tr>
<tr>
<td>B25S75</td>
<td>M10</td>
<td>25%</td>
<td>75%</td>
<td>0%</td>
</tr>
<tr>
<td>R25B75</td>
<td>M11</td>
<td>25%</td>
<td>75%</td>
<td>0%</td>
</tr>
<tr>
<td>B</td>
<td>M12</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>M13</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>M14</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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 CaCO₃ 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 ≤ 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>
<thead>
<tr>
<th>Medium</th>
<th>Bulk density (g cm⁻³)</th>
<th>Water holding capacity (g g⁻¹)</th>
<th>Total porosity (%)</th>
<th>Aeration porosity (%)</th>
<th>Water holding porosity (%)</th>
<th>Void space (%)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>0.89 ± 0.00b</td>
<td>389.77 ± 38.30ab</td>
<td>64.47 ± 0.66h</td>
<td>25.66 ± 1.00ef</td>
<td>38.81 ± 1.30cd</td>
<td>66.72 ± 4.80e</td>
<td>6.65 ± 0.1bc</td>
</tr>
<tr>
<td>M2</td>
<td>1.04 ± 0.04def</td>
<td>741.18 ± 62.25f</td>
<td>44.35 ± 1.99b</td>
<td>7.59 ± 0.85a</td>
<td>36.76 ± 2.07c</td>
<td>21.10 ± 2.87a</td>
<td>6.70 ± 0.02cd</td>
</tr>
<tr>
<td>M3</td>
<td>1.02 ± 0.02de</td>
<td>455.38 ± 38.82bc</td>
<td>53.15 ± 0.84def</td>
<td>24.41 ± 0.92de</td>
<td>28.74 ± 1.13ab</td>
<td>85.71 ± 5.88f</td>
<td>6.94 ± 0.02gh</td>
</tr>
<tr>
<td>M4</td>
<td>0.97 ± 0.01bcd</td>
<td>598.04 ± 21.93d</td>
<td>46.30 ± 0.69bc</td>
<td>16.00 ± 0.50c</td>
<td>30.30 ± 0.18b</td>
<td>52.76 ± 1.32bcde</td>
<td>6.92 ± 0.01gh</td>
</tr>
<tr>
<td>M5</td>
<td>0.92 ± 0.02bc</td>
<td>546.99 ± 56.18c</td>
<td>49.98 ± 1.10bcd</td>
<td>14.67 ± 1.05c</td>
<td>35.32 ± 2.03c</td>
<td>42.61 ± 4.74b</td>
<td>6.89 ± 0.01fg</td>
</tr>
<tr>
<td>M6</td>
<td>1.13 ± 0.06gh</td>
<td>455.35 ± 77.92bc</td>
<td>50.53 ± 5.23bcd</td>
<td>20.44 ± 3.48d</td>
<td>30.09 ± 1.98b</td>
<td>66.52 ± 8.34e</td>
<td>6.65 ± 0.10bc</td>
</tr>
<tr>
<td>M7</td>
<td>0.99 ± 0.01cd</td>
<td>298.69 ± 26.31a</td>
<td>61.12 ± 0.64gh</td>
<td>24.06 ± 1.34de</td>
<td>37.06 ± 0.94c</td>
<td>65.42 ± 5.09de</td>
<td>6.51 ± 0.03a</td>
</tr>
<tr>
<td>M8</td>
<td>0.75 ± 0.03a</td>
<td>609.22 ± 27.53de</td>
<td>57.88 ± 1.80efg</td>
<td>20.12 ± 1.30d</td>
<td>37.75 ± 0.85c</td>
<td>53.31 ± 3.11bcde</td>
<td>6.81 ± 0.02a</td>
</tr>
<tr>
<td>M9</td>
<td>1.15 ± 0.01gh</td>
<td>620.52 ± 4.71def</td>
<td>45.23 ± 0.39b</td>
<td>15.39 ± 0.21c</td>
<td>29.64 ± 0.40b</td>
<td>51.61 ± 1.18bcde</td>
<td>7.05 ± 0.02d</td>
</tr>
<tr>
<td>M10</td>
<td>1.09 ± 0.04efg</td>
<td>870.34 ± 28.93g</td>
<td>52.19 ± 2.45cde</td>
<td>9.30 ± 0.97ab</td>
<td>42.89 ± 2.92de</td>
<td>21.95 ± 2.53a</td>
<td>6.93 ± 0.01gh</td>
</tr>
<tr>
<td>M11</td>
<td>1.09 ± 0.03efg</td>
<td>563.13 ± 16.33c</td>
<td>59.17 ± 2.26gh</td>
<td>21.70 ± 0.94de</td>
<td>37.47 ± 1.98bc</td>
<td>58.53 ± 3.92cde</td>
<td>6.97 ± 0.01h</td>
</tr>
<tr>
<td>M12</td>
<td>0.96 ± 0.07bcd</td>
<td>347.93 ± 25.90ab</td>
<td>59.33 ± 2.28gh</td>
<td>29.47 ± 1.61f</td>
<td>29.86 ± 2.12b</td>
<td>99.08 ± 5.70g</td>
<td>6.64 ± 0.02b</td>
</tr>
<tr>
<td>M13</td>
<td>0.72 ± 0.08a</td>
<td>658.99 ± 47.94def</td>
<td>55.75 ± 0.49defg</td>
<td>9.38 ± 2.25ab</td>
<td>46.37 ± 2.10e</td>
<td>21.29 ± 5.88a</td>
<td>6.75 ± 0.01d</td>
</tr>
<tr>
<td>M14</td>
<td>1.20 ± 0.02h</td>
<td>716.47 ± 16.64f</td>
<td>37.22 ± 1.22a</td>
<td>12.14 ± 0.80b</td>
<td>25.07 ± 1.08a</td>
<td>48.85 ± 4.13bc</td>
<td>6.87 ± 0.01f</td>
</tr>
</tbody>
</table>

Values are mean with SE. Means in a column followed by the same letter are not significantly different at p < 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 Boesenbergia 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 Boesenbergia 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 Boesenbergia rotunda was achieved in medium M7 followed by M1 and M13, which contained a combination of red and black soil. However, the biomass of Boesenbergia 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 Boesenbergia 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 Boesenbergia 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 Boesenbergia rotunda (Table 3). This combination

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![Fig. 1](image_url)  
**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

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

Values are mean with SE. Means in a column followed by the same letter are not significantly different at $p < 0.05$ 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

<table>
<thead>
<tr>
<th>Medium</th>
<th>Shoot Number</th>
<th>Leaf Number per Shoot</th>
<th>Leaf Length (cm)</th>
<th>Leaf Diameter (cm)</th>
<th>Leaf Area (cm$^2$)</th>
<th>Stem Diameter (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>2.50 ± 0.56ab</td>
<td>5.17 ± 0.54</td>
<td>19.75 ± 0.87c</td>
<td>7.33 ± 0.36d</td>
<td>85.07 ± 9.14d</td>
<td>0.97 ± 0.07</td>
</tr>
<tr>
<td>M2</td>
<td>1.50 ± 0.22a</td>
<td>3.50 ± 0.34abc</td>
<td>12.43 ± 0.76ab</td>
<td>4.93 ± 0.27abc</td>
<td>46.36 ± 4.51abc</td>
<td>0.60 ± 0.05</td>
</tr>
<tr>
<td>M3</td>
<td>1.83 ± 0.31a</td>
<td>3.00 ± 0.86ab</td>
<td>10.17 ± 1.14ab</td>
<td>4.12 ± 0.32ab</td>
<td>32.51 ± 5.97ab</td>
<td>0.58 ± 0.05</td>
</tr>
<tr>
<td>M4</td>
<td>1.50 ± 0.22a</td>
<td>3.83 ± 0.60abc</td>
<td>14.58 ± 0.98bc</td>
<td>5.40 ± 0.24bc</td>
<td>59.75 ± 6.62bcd</td>
<td>0.82 ± 0.12</td>
</tr>
<tr>
<td>M5</td>
<td>3.33 ± 0.33abc</td>
<td>3.50 ± 0.34abc</td>
<td>15.47 ± 1.33bc</td>
<td>5.20 ± 0.40bc</td>
<td>61.62 ± 8.33bcd</td>
<td>0.72 ± 0.11</td>
</tr>
<tr>
<td>M6</td>
<td>2.83 ± 0.40abc</td>
<td>3.67 ± 0.42abc</td>
<td>14.82 ± 1.04bc</td>
<td>5.85 ± 0.30c</td>
<td>66.12 ± 7.39bcd</td>
<td>0.83 ± 0.08</td>
</tr>
<tr>
<td>M7</td>
<td>3.83 ± 0.91bc</td>
<td>4.33 ± 1.20bc</td>
<td>14.63 ± 2.62bc</td>
<td>5.17 ± 0.54bc</td>
<td>61.98 ± 17.16bcd</td>
<td>0.60 ± 0.11</td>
</tr>
<tr>
<td>M8</td>
<td>3.00 ± 0.58abc</td>
<td>3.50 ± 0.62abc</td>
<td>14.93 ± 2.75bc</td>
<td>5.87 ± 0.88c</td>
<td>73.15 ± 19.03c</td>
<td>0.83 ± 0.14</td>
</tr>
<tr>
<td>M9</td>
<td>2.50 ± 0.43ab</td>
<td>3.30 ± 0.42abc</td>
<td>11.27 ± 2.11ab</td>
<td>4.35 ± 0.52abc</td>
<td>40.68 ± 11.04abc</td>
<td>0.63 ± 0.12</td>
</tr>
<tr>
<td>M10</td>
<td>2.83 ± 0.54abc</td>
<td>3.67 ± 0.42abc</td>
<td>11.12 ± 1.89ab</td>
<td>4.42 ± 0.45abc</td>
<td>39.56 ± 8.47abc</td>
<td>0.57 ± 0.08</td>
</tr>
<tr>
<td>M11</td>
<td>3.83 ± 1.05bc</td>
<td>3.33 ± 0.61abc</td>
<td>10.92 ± 1.16ab</td>
<td>4.40 ± 0.37abc</td>
<td>37.27 ± 6.71abc</td>
<td>0.57 ± 0.02</td>
</tr>
<tr>
<td>M12</td>
<td>2.33 ± 0.21ab</td>
<td>3.67 ± 0.56abc</td>
<td>13.20 ± 1.00ab</td>
<td>4.97 ± 0.32abc</td>
<td>50.26 ± 6.71bcd</td>
<td>0.58 ± 0.10</td>
</tr>
<tr>
<td>M13</td>
<td>4.50 ± 0.76bc</td>
<td>3.33 ± 0.80abc</td>
<td>15.25 ± 3.11bc</td>
<td>5.07 ± 0.90abc</td>
<td>68.01 ± 21.71bcd</td>
<td>0.75 ± 0.11</td>
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<tr>
<td>M14</td>
<td>2.00 ± 0.63ab</td>
<td>2.17 ± 0.31a</td>
<td>8.15 ± 0.50a</td>
<td>3.45 ± 0.17a</td>
<td>21.36 ± 2.26a</td>
<td>0.48 ± 0.03</td>
</tr>
</tbody>
</table>

Values are mean with SE. Means in a column followed by the same letter are not significantly different at $p < 0.05$ 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.
DIFFERENT QUALITY OF SOIL MIXTURE OF MEDICINAL PLANT, Boesenbergia rotunda

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 fingerroots tuber.

ACKNOWLEDGEMENTS

The author acknowledged University of Malaya, Kuala Lumpur, Malaysia for the financial support and research facilities. This research is funded by University of Malaya Research Grant (RP003-2012C).

REFERENCES


