Chapter 3
CHAPTER 3
THE EFFECT OF SOIL TYPE ON GROWTH
OF L. LEUCOCEPHALA

3.1 Introduction

Soil is the primary growth medium for plants. Attributes of the soil system such as soil temperature, moisture and acidity, *inter alia*, are important environmental factors that affect plant growth and microbial activity in the soil. Soil also provides plant with physical support, inorganic nutrients and water. A close relationship exists between soil properties and plant growth. It is also reported that bulk density, saturated hydraulic conductivity, and soil water retention affect the growth and development of the plant (Laboski *et al.*, 1998). In relation to physical support, the development of the root is influenced by soil factors including soil properties and soil shear strength (Raven, 1992). Hence, it is essential to study the relationship between soil properties and the growth of *L. leucocephala*.

In this chapter, the experiment to determine the best soil type for the growth of *L. leucocephala* is described. The species studied was grown in different types of soil and its physiological criteria were also examined. The aim of this preliminary project is not to evaluate the potential criteria of *L. leucocephala* as a slope coloniser but to obtain base data of its growth performance given the best soil condition. It was reported that the species studied can establish in a wide range of soil type conditions (Tham *et al.*, 1977). Thus, the reason for choosing a range of soil types, fertile (sandy-loam) to infertile (slope soil), is to compare the growth performance of the plant in each soil type.
3.2 Materials and Methods

3.2.1 Soil and Plant Materials

Five different types of soil were chosen in this experiment viz. light coloured sandy loam (Sungai Buluh Nursery), peat (Jasa Berbakti Enterprise, Banting, Selangor), slope soil (Rimba Ilmu, Universiti Malaya), clay (Jasa Berbakti Enterprise, Banting, Selangor) and sand (Jasa Berbakti Enterprise, Banting, Selangor). Each type of soil was filled into a 15 x 40 cm polythene bag in ten replications. Seeds were inoculated with specific *Rhizobium* (Rubber Research Institute of Malasyia) and germinated at 20 seeds per container (60 x 45 x 15 cm). After three weeks, at an average height of 30 cm, the seedlings were transferred to the glasshouse, Rimba Ilmu, University Malaya. The experiment was carried out for 100 days after transferring (DAT) under glasshouse conditions (temperature, 21-32°C, maximum PAR 2100 µE m⁻² s⁻¹ and relative humidity of 60-90%) in a completely randomised design (CRD). The plants were watered twice a day to maintain turgidity.

3.2.2 Morphological Studies

Increment of plant height, number of leaf and leaflets were measured at 7-day intervals for 56 DAT. The plant growth rate was calculated as [(final height – initial height)/initial height] x 100%. Nodulation frequency and weight were observed at the end of the experimental period (day 100).

3.2.3 Physiological Studies

(a) Photosynthetic Rate and Chlorophyll Content

Photosynthetic rate was measured for 42 DAT using the portable photosynthetic system (PPSystem, CIRAS-1, USA). Chlorophyll content for 56 DAT was also measured with a portable chlorophyll meter (SPAD-502, Minolta, Japan). Both parameters were measured
at 14-day intervals. The six youngest fully expanded leaves of each treatment were measured randomly.

(b) **Dry Weight Partitioning and Biomass**

Biomass of stem, leaf and root were obtained at the end of each treatment. All parts were oven-dried (80°C) to constant weight.

**3.2.4 Statistical Analysis**

Statistical analysis was performed using STATGRAPHIC Plus 3.0. The one way ANOVA was applied to evaluate the significant difference of the parameters studied in the five different soil treatments (one factor). LSD (p=0.05) was calculated using the error mean squares of the analysis of variance.

**3.3 Results and Discussion**

**3.3.1 Plant Growth Performance**

Increments in height, leaf and leaflet numbers were observed in all treatments until 42 DAT (Fig. 3.1). Amongst the treatments, sandy-loam plants exhibited the highest increments in the parameters studied. However, leaflet number in the slope soil showed an inconsistent rate of increment, followed by rapid reduction after 42 DAT. This is possibly attributed to leaf drop due to nutrient deficiencies. After 42 DAT, the percentage of increment decreased in all parameters studied in all soil treatments. A high growth rate of *L.leucocephala* was observed in both sandy-loam and clay soils, 112.3% and 120.5%, respectively (Fig. 3.2). This implies that these soil mediums are more suitable for the growth of *L.leucocephala* compared to other soils used in the experiment. More aspects of growth are discussed in the following section.
**Figure 3.1:** Increment in (H) height (%), (LN) leaf number (%) and (LLN) leaflet number (%) of *L. leucocephala* in five different types of soil
Figure 3.2: Growth rate (%) of *L. leucocephala* in five different types of soil (SL=sandy-loam, P=peat, C=clay, SLO=slope, S=sand)
3.3.2 Photosynthetic Rate and Chlorophyll Content

Photosynthetic rate of *L. leucocephala* showed significant differences amongst the treatments (Fig. 3.3). In fact, the photosynthetic rate of plants grown in sandy-loam at 42 DAT exhibited almost double the value of that in other soils \( \text{LSD}_{p,0.05}=1.30 \). The high value observed indicates high efficiency of gaseous exchange in plants grown in this type of soil.

The species studied showed a similar trend in chlorophyll content to that of photosynthetic rates, displaying a significant difference amongst all treatments \( \text{LSD}_{p,0.05}=2.7 \); Fig. 3.4). Except at 42 DAT, *L. leucocephala* displayed the highest in sandy-loam treatment on all measuring days. The average chlorophyll content of *L. leucocephala* in sandy-loam was 22.0 g/l (33.2 SPAD) which is about 63% of the mature *L. leucocephala* grown on slopes. This observation implies high photosynthetic rate observed in plants grown in sandy-loam.

3.3.3 Dry Weight Partitioning

*L. leucocephala* in sandy-loam and clay treatments have significantly high leaf and stem biomass compared to the others (Fig. 3.5). All parameters i.e. root, leaf and stem biomass show a significant difference with \( \text{LSD}_{p,0.05} = 1.64, 1.50 \) and 1.32, respectively (Fig. 3.5). In fact, the total leaf and leaflet number in both treatments were amongst the highest (Fig. 3.6). This result may reflect a higher photosynthetic rate in these soil types. This consequently lead to high partitioning of carbon at the vegetative tissues e.g. leaf and stem. In addition, plants grown in sandy loam also displayed the highest root biomass amongst the other treatments. However, the results show that the plant grown in sandy-loam has the lowest ratio of root to shoot (leaf) amongst the treatments (Table 3.1). The highest value was observed in sand followed by slope soil (Table 3.1). This result implies high carbon partitioning in root compared to leaf in less fertile soils such as sand and slope soil. Plants
Figure 3.3: Photosynthetic rate of *L. leucocephala* in five different types of soil (vertical bars represent LSD$_{p<0.05}$)
Figure 3.4: Chlorophyll content of *L. leucocephala* in five different types of soil (vertical bars represent LSD$_{p<0.05}$)
Figure 3.5: Dry weight partitioning of *L. leucocephala* (stem, leaf and root) in different types of soils (SL=sandy-loam, P=peat, C=clay, SLO=slope, S=sand). Vertical line on the bar represents standard deviation. Vertical bars represent LSD<sub>p<0.05</sub> stem (st) = 1.3, leaf (lf) = 1.5 and root (rt) = 1.6.
Figure 3.6: (a) Total leaf number, (b) leaflet number and (c) total biomass *L. leucocephala* in soil type treatment (SL=sandy-loam, P=peat, C=clay, SLO=slopel and S=sand)
Table 3.1: Root / shoot ratio of *L. leucocephala*

in all soil treatments.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy-loam</td>
<td>1.72</td>
</tr>
<tr>
<td>Peat</td>
<td>1.79</td>
</tr>
<tr>
<td>Clay</td>
<td>2.15</td>
</tr>
<tr>
<td>Slope soil</td>
<td>2.30</td>
</tr>
<tr>
<td>Sand</td>
<td>2.40</td>
</tr>
</tbody>
</table>
grown in slope soil displayed the lowest performance in all dry weight partitioning parameters (Fig. 3.5 and 3.6). Plants in sandy loam showed the greatest total biomass, 30.3%, followed by peat (21.9%) and clay (21.6%). Plants in sandy loam had a total biomass thrice the value of those plants in slope soil (Fig. 3.6).

3.3.4 Nodulation

There was a significant difference (LSD_p<0.05=8.74) observed amongst the treatments. Nodule frequency of *L. leucocephala* in sandy-loam treatment was almost double of that recorded for the clay treatment (second highest). On the other hand, plants in the sand treatment showed the lowest nodulation frequency (Fig. 3.7), implying that nodulation of the young seedlings (100 DAT) in the species studied is theoretically low in less fertile soil. The present experiment also showed that nodule frequency is directly related to soil pH (Fig. 3.8). This finding is in line with the report of Smolander and Sarsa (1990) that positive correlation was observed between nodulation and soil pH, indicating that soil pH is one of the main factors that influence nodulation potential of a species. It is also reported that nodulation capacity appears to be most closely related to soil properties including pH and fertility level of the soil (Martin *et al.*, 2003). A positive relationship was also observed between nodule frequency and root biomass \( r = 0.61 \) as well as shoot biomass \( r = 0.70 \) (Fig. 3.9). The results suggest that high above ground biomass indicate high nodule frequency of the species studied and therefore possibly a high capacity of water absorption.

3.3.5 Ranking Analysis of Physiological Parameters

Ranking analysis was based on the importance value of the parameters studied on plant growth and development. In this evaluation, each parameter was given a weighted value of a minimum of 1 to a maximum of 4. Chlorophyll was given the lowest value, 1, as this
Figure 3.7: Nodule frequency of *L. leucocephala* in five treatments (SL=sandy-loam, P=peat, C=clay, SLO=slope and S=sand). Vertical line on the bar represents standard deviation. Vertical bar represents LSD$_{p<0.05}$.
Figure 3.9: The relationship between nodules frequency and (a) root biomass and (b) shoot biomass
parameter is less significant in terms of affecting growth. Moreover, this parameter can be much influenced by other environmental and man-made factors e.g. rainfall, technique and rate of fertilisation. On the other hand, photosynthetic is a vital process in plants and closely related to plant growth. This parameter is one of the most highly integrated and regulated metabolic processes to maximise the use of available light, to minimise the damaging effects of excess light and to optimise the use of limiting carbon and nitrogen resources. Therefore, this parameter was given the highest value, 4, as it involves numerous functions of the plant. High photosynthesis implies that the plant is more efficient in utilising light for enhancing growth. Therefore, the plant is also more likely to grow faster. This is an essential criterion for a slope soil coloniser. Growth rate depends on the photosynthetic process and it has been reported that an interrelationship exists between these two parameters rather than a one-way relationship (Paul and Foyer, 2001). Due to this close relationship, the growth rate parameter was also given the highest value of 4.

Nodulation is another important factor especially when dealing with leguminous plant like *L.leucocephala*. Choosing the suitable soil medium is vital as this has a close relationship with species capable of fixing nitrogen. Furthermore, nitrogen status has a close relationship with photosynthetic regulation. It has been reported by Geiger *et al.* (1999) that high CO$_2$ with a high nitrogen supply would keep up the growth rate. In view of this, high nodule frequency is an essential criterion for slope plants as such plants is envisaged to improve soil fertility of the slope. Thus, nodule frequency was given a weighted value of 3. Root biomass is also an important criterion for root influence on slope stabilisation for example soil anchorage and water suction. Similarly a weighted value of 3 was given. Since leaf and total biomass are fairly important criteria, a weighted value of 2 was given to each parameter. These parameters represent the amount of fixed carbon of the plant and are very useful for estimating carbon sink potential and the ability to convert inert CO$_2$ into organic matter. All parameters were given the ranking category as tabulated (Table 3.2).
Table 3.2: Weighted value of physiological parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photosynthetic rate (A)</td>
<td>4</td>
</tr>
<tr>
<td>Growth rate (GR)</td>
<td>4</td>
</tr>
<tr>
<td>Nodule frequency (NOD)</td>
<td>3</td>
</tr>
<tr>
<td>Root biomass (ROOT)</td>
<td>3</td>
</tr>
<tr>
<td>Shoot biomass (SHOOT)</td>
<td>2</td>
</tr>
<tr>
<td>Total biomass (BIOM)</td>
<td>2</td>
</tr>
<tr>
<td>Chlorophyll (CHL)</td>
<td>1</td>
</tr>
</tbody>
</table>

(Ranking: 4: Best; 3: Good; 2: Fair; 1: Poor)
Cumulative ranking analysis illustrates that sandy-loam is the best soil medium for the growth of *L. leucocephala* (Table 3.3). This is represented by its outstanding value (least value) in almost all parameters studied. Clay shows the second highest and its value is double that of sandy loam. This is followed by peat which also shows a prominent ranking in both root and shoots biomass. Finally, both slope soil and sand show the lowest performance in terms of enhancing growth for *L. leucocephala*.

However, it is worth-noting that *L. leucocephala* in slope soil treatment exhibited good performance in photosynthetic rate and nodulation frequency. These are prominent criteria of the species studied as it continues growing on slope soil despite the adverse conditions of slope soil including low soil fertility.

### 3.4 General Discussion

Slope soil is characterised as acidic, less fertile and with low water holding capacity. Plants exposed to these adverse conditions may survive only after some adaptations in its growth mechanism. The main objective of the thesis is to evaluate the potential slope criteria of *L. leucocephala*. To achieve this, it is imperative to minimize other possible limiting growth factors such as soil properties. Therefore, for this purpose, the best soil type was chosen in this preliminary experiment. This experiment has successfully established the base data for the growth and development of the species studied in a range of different soil types: sandy-loam to slope soil. Overall results indicated that the best growth performance of *L. leucocephala* is in sandy-loam soil, displaying the highest rank in almost all parameters studied (Table 3.3). The greater growth and nodulation performance of the species studied is also observed in clay (Fig. 3.1, 3.2, 3.3 and 3.8; Table 3.3) which may be attributed to soil properties including high pH (Fig. 3.7) and water holding capacity of the soil (ASTM, 1982). Concomitant to this, it is claimed that in well-irrigated
Table 3.3: Cumulative ranking analysis of parameters studied in soil treatments

<table>
<thead>
<tr>
<th>Soil type</th>
<th>A</th>
<th>GR</th>
<th>NOD</th>
<th>ROOT</th>
<th>SHOOT</th>
<th>BIOM</th>
<th>CHL</th>
<th>Sum Total Cumulative Rank</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy loam</td>
<td>4</td>
<td>8</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>25</td>
<td>1</td>
</tr>
<tr>
<td>Sand</td>
<td>16</td>
<td>16</td>
<td>20</td>
<td>12</td>
<td>8</td>
<td>8</td>
<td>4</td>
<td>84</td>
<td>4</td>
</tr>
<tr>
<td>Peat</td>
<td>20</td>
<td>12</td>
<td>16</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>65</td>
<td>3</td>
</tr>
<tr>
<td>Clay</td>
<td>8</td>
<td>4</td>
<td>8</td>
<td>9</td>
<td>6</td>
<td>6</td>
<td>1</td>
<td>42</td>
<td>2</td>
</tr>
<tr>
<td>Slope soil</td>
<td>12</td>
<td>20</td>
<td>12</td>
<td>15</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>84</td>
<td>4</td>
</tr>
</tbody>
</table>

The rank is multiplied by the weightage (Table 3.2) with justification (section 3.3.5).
The sum total of rank for the various parameters are discussed previously (section 3.3.5 and 3.4).
clayey soils, little water is lost by direct evaporation, as most of the water transpired via leaves (Reeve, 1984). Peat also showed some prominent criteria in terms of having high root, shoot and total biomass (second highest, Table 3.3). Although slope soil reveals the lowest rank in this study (Table 3.3), *L. leucocephala* exhibited good performance in photosynthetic rate and nodulation frequency. These prominent criteria enhance the credibility of the species studied as a slope plant. In conclusion, in terms of soil type, the results indicate that sandy-loam is the best condition for *L. leucocephala*.

In subsequent chapters (Chapters 4-8), *L. leucocephala* in terms of its potential criteria as a slope plant is described. Hence, in order to ensure that soil properties are not a limiting factor for the early growth and development of the species studied, sandy-loam was used as the soil medium for *L. leucocephala*.