Physiological and root profile studies of four legume tree species

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Abstract: It is a great challenge for researchers to select plant species in terms of their physiological and root properties for vegetation on slope. Therefore, this study was aimed to investigate the physiology and root profile of four selected tropical plants namely *Leucaena leucocephala* (LL), *Adenanthera pavonina* (AP), *Peltophorum pterocarpum* (PP) and *Pterocarpus indicus* (PI). The species studied were grown in three different types of soil; slope, clay and sandy, under greenhouse conditions. Outstanding physiological performance, as measured by chlorophyll fluorescence, the photosynthetic rate, the biomass production and growth rate were observed to be the highest in LL, followed by PP, AP and PI. In terms of the root profiles, LL exhibited a higher root length (450%), volume (500%), and root biomass (600%) than PI. The root biomass values of the species studied was highly correlated with the soil moisture content (R^2=0.83). Overall results suggested that *L. leucocephala* exhibited outstanding physiological performance and root profiles and can be a potential plant for soil reinforcement.

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1. Introduction

Vegetation has been widely used as a tool to improve slope stability and protect riverbanks. The relationship between vegetation and soil reinforcement are complex and involve such factors as the combination of soil type, plant coverage and soil moisture content (Normaniza *et al.*, 2008; Nordin *et al.*, 2011). In addition, each species has its own physiological mechanism, including root-soil interaction, for the capacity to survive under different conditions and level of soil nutrients (Stokes *et al.*, 2009). Each plant can perform many functional roles and contribute to slope but certain types of plants are better than others depending on the desired functions including soil reinforcement, water uptake and surface protection (Normaniza *et al.*, 2008). Accordingly, native species are often better adapted to weather conditions within their native range than exotics species (Schnitzlera *et al.*, 2007; Normaniza and Barakabah, 2011). Therefore, the screening of native plant species in observing their potential characteristics as a slope plant e.g., higher growth rate and highly branched root systems for soil reinforcement is crucial.

Several researchers have formulated a set of criteria which are more related to plant physiology and root biomass production for the selection of best plant species (Stokes *et al.*, 2009). For example, based on previous species selection, slope plants should possess a high growth rate, photosynthetic rate, leaf area index (LAI) value, fine roots length and an extensive root system, which leads to enhanced water uptake, reinforced soil, and increased shear strength by binding soil particles (Stokes *et al.*, 2009; Normaniza *et al.*, 2008; Normaniza and Barakabah, 2011). Mafian *et al.* (2009) showed that the reinforcement of soil by vegetation is a highly promising solution and that this approach would be more beneficial if the species displayed the appropriate mechanical (through the reinforcement of the soils by plant roots), hydrological (through the reduction in runoff and by keeping the slope relatively dry) and environmental properties through the increase in carbon sequestration to reduce the rising carbon dioxide levels in the atmosphere (Syed and Iqbal, 2007). Eschenbach *et al.* (1998) and Marron *et al.* (2007) explained that the leaf chlorophyll, nitrogen, and carbon contents were the vital parameters in evaluating high-yielding species. Poorter and Bongers (2006) compared the leaf traits and plant performance of 53 co-occurring tree species in a semi-evergreen tropical moist forest community and demonstrated that leaf traits are good indicators of plant physiological performance. However, other parameters (leaf chlorophyll fluorescence, leaf potassium content, root length, root volume, and root tensile strength) and factors (correlation among root biomass, soil moisture content and leaf area index) have to be considered to understand the actual function of the plant as slope colonizer (Jiang *et al.*, 2006), as plant physiological and root behaviors are interrelated. In relation to this, the development of shoots and roots can also be considered to be influenced by the soil type. It is also reported that the soil density, hydraulic conductivity and soil water relation affect the growth of roots (Laboski *et al.*, 1998). Thus, the root profiles and soil water relation are referred as vital parameters to predict the slope stability and soil erosion rate (Normaniza and Barakabah, 2006). It is well documented that when a plant experiences stress conditions (e.g., water stress and light stress), the performance can be either increased or decreased (Niinemets, 2010; Araus *et al.*, 2002). Hence, a higher physiological performance with root profiles of the plant can indicate a healthy species (an individual) and help to select a potential species.

Therefore, this study was performed to assess the plant physiological and root properties of four selected species in different soil types, to deduce some correlations among the parameters studied and to determine the two best potential species.

2. Material and Methods

Experimental site, soil and plant materials: Three types of soil (clay, sand and slope soil) and four native legume tree species, LL, AP, PP and PI, were selected for this experiment. Seeds were collected from the Forest Research Institute of Malaysia (FRIM) and grown in an open-ended 30 cm PVC pipe. Individually, each type of soil (Table 1) was used to fill the PVC pipe (2356 cm^3), with ten replications; 120 seedlings [3 (three types of soil) ×10 (replication) ×4 (species)] were grown. The experiment was conducted for six months under glasshouse conditions (temperature of 21-32°C, average 12-h photoperiod, maximum PAR of 2100 µE m^{-2} s^{-1} and relative humidity of 60-90%) at the Plant Physiology Garden, University of Malaya. The plants were arranged in a completely randomized design (CRD), with 30 cm row to row distances and 30 cm plant to plant distances. The plants were irrigated once every two days to avoid water stress.

Plant height and biomass: The plant height and stem diameter were measured at six months of growth using a measuring tape and Vernier calipers, respectively. The shoot and root dry biomass (oven-dried at 80°C for 48 hours) were determined using a balance (Model-Mettle PJ3000, Japan) after six months of growth.

Measurements of photosynthesis, transpiration rate, stomatal conductance and chlorophyll content: The photosynthetic rate, transpiration rate and stomatal conductance of the plants were measured using the Portable Photosynthesis System (Model *LI-6400XT*, USA) at six month of growth. The chlorophyll content was measured using a portable chlorophyll meter (SPAD-502, Minolta, Japan).

Table 1: Properties of the soils used in this present study.

Soil properties	Slope soil	Clay soil	Sand soil
Specific gravity	2.62	2.68	2.0
Dry unit weight (kN/m^3)	13.1	13.3	10.5
Soil Field Capacity	20.3 %	32.7 %	29.9 %
pH	4.45	3.94	5.51
Color	6/8/Hue 10 [Bright yellowish brown]	5/3/Hue 2.5 Y [Yellowish brown]	5/4/Hue 7.5 YR [Dull brown]
Type	Size distribution	Size distribution	Size distribution
500 to1.0 mm	12.165 %	0 %	65.36 %
250 to 500 mic	29.45 %	32.12 %	17.02 %
100 to 250 mic	38.58 %	21.4 %	11.42 %
50 to100 mic	13.14 %	27.53 %	4.5 %
<2 to 50 mic	6.64 %	18.93 %	1.67 %

Measurements of chlorophyll fluorescence: The chlorophyll fluorescence was measured at 2-month intervals using a Plant Efficiency Analyser (Model LH36/2R, Hansatech Instrument Ltd., England). A leaf clip was attached to one of the leaves and kept in the dark for 30-45 minutes for dark adaptation; the leaf clip was then oriented with the shutter plate. When light was applied to the leaf, the fluorescence signal was counted for 3 seconds and the quantum yield or photosynthetic yield (temperature = 28ºC, time range = 10 µs^{-3} sec) was measured. The maximal fluorescence (Fm) and minimal fluorescence (Fo) values were obtained. The yield of variable fluorescence (Fv) was calculated as Fm-Fo, and the calculation of chlorophyll fluorescence was determined according to the equation for Fv/Fm.

Leaf area index (LAI) and soil moisture content: The leaf area index and soil moisture content were measured using a leaf area instrument (AccuPAR-LP80, UK) and portable Delta-T soil moisture meter (HH2 Moisture Meter, England), respectively, at 2-month interval.

Potassium estimations: The most recent fully expanded leaves of the same age and relative position were collected from each treatment. One gram of fresh leaf tissue was ground with 5 ml distilled water in a mortar and then centrifuged at

3,500 rpm for 20 min. A sampling paper was placed on the sensor, and 3 to 5 drops of the supernatant liquid were added to the calibrated sensor pad (Cardy Potassium Meter, Model-2400, USA) until the sampling paper was saturated. After stabilizing (30 to 45 seconds), the measurements (ppm) were recorded.

Root profiles: The root lengths of all the different species were determined by scanning and using the WinRHIZO Pro Software after three and six months. This software was also used to assess the nodulation frequency, total root length, fine roots and average volume of the root.

Root tensile strength: The laboratory root tensile test was conducted by using Universal Testing Machine (Instron, Model 5582, United Kingdom) to determine the root tensile strength. The roots were cut into 10 cm in length and two ends of root were clamped with sand paper to avoid slippage during the testing. The roots were pulled up vertically at 500 mm/min in the testing machine. During the test, the result data of Force and Extension at failure had been obtained and automatically generated by the software that connected to the Universal Testing Machine.

Statistical analysis: The data was analysed using SPSS 11.5 statistical software. ANOVA was applied to evaluate significant differences in the studied treatments. The LSD ($p < 0.05$) was calculated using the error mean squares of the analysis of variance. The correlation test among parameters (root biomass, soil moisture content and leaf area index) studied was analyzed using Microsoft Excel.

3. Results

Biomass production: The influence of different soil types on the biomass production was measured at the 6th month (Table 2). The biomass production of LL was observed to be the highest amongst the species evaluated, followed by PP, AP and PI. In the sandy soil, the reductions in the root weights of AP and PP might be attributable to lower shoot growth. PP demonstrated the second highest shoot-root biomass in the slope soil.

Table 2: Shoot dry weight (SDW) and root dry weight (RDW) was measured in 6th months.

Species	SDW			RDW		
	Clay	Sand	Slope	Clay	Sand	Slope
LL	15ay	19ax	17ax	5aby	7ax	5by
AP	10bx	5byz	10cx	4cx	2cz	4cy
PP	10by	4bz	14bx	5ax	3by	6ax
PI	2cy	5bx	3dx	0.9dy	1dx	1dxy

The values of plant height and stem diameter were significantly ($p < 0.05$) higher for LL, followed by PP, AP and PI (Fig. 1 and Fig. 2). A higher plant height (13%) for LL was observed in the sandy soil than those in clay soils, whereas AP and PP species showed lower values in the sandy soil than clay. Thus, the plant growth or shoot biomass was presumably associated with the root growth and biomass production.

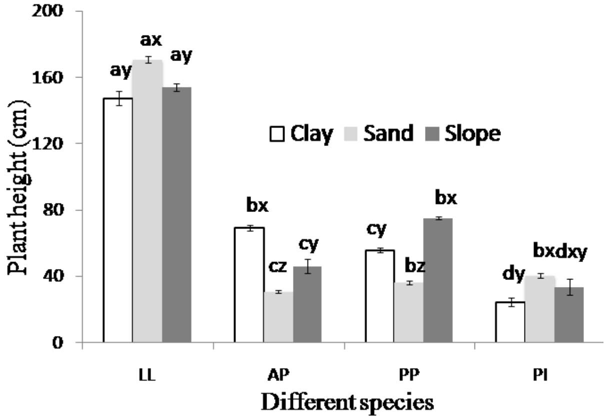

Fig. 1. Plant height of four species was affected by different types of soils. [*Leucaena leucocephala* (LL), *Adenanthera pavonina* (AP), *Peltophorum pterocarpum* (PP), and *Pterocarpus indicus* (PI)]. For the same types of soil with the different species, different letters (a-d) showed significantly different ($p < 0.05$, ANOVA). For the same species with the different soil types, different letters (x-z) showed significantly different ($p < 0.05$, ANOVA).

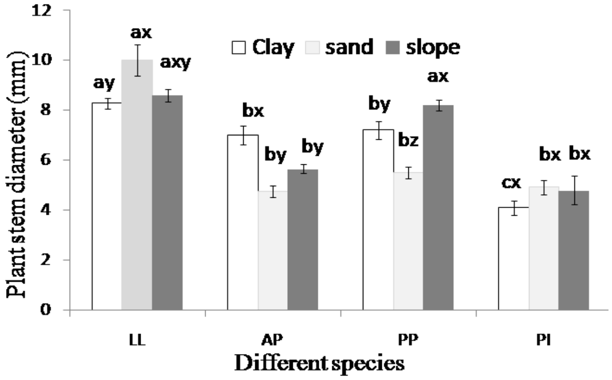

Fig. 2. The effects of different soils on the plant stem diameter. Different letters were significantly different ($p < 0.05$, ANOVA).

Leaf chlorophyll content and chlorophyll fluorescence: The leaf chlorophyll content is one of the most important parameters in determining the photosynthetic rate (Rong-hua *et al.*, 2006). The high chlorophyll content was observed in LL in all soil types and attributed to a enhanced capacity of the plant to utilize the existing soil nutrients (Fig.

3). Low chlorophyll content was observed for AP grown in sandy soil. Consequently, the plant height was the smallest in the sandy soil versus the clay and slope soils. Additionally, in sandy soil, LL showed a higher chlorophyll fluorescence by 19, 17 and 9 % than AP, PP and PI, respectively. This was due to the higher capability of LL to transport electrons through PSII (Fig. 4). In the sandy soil, AP and PP showed lower chlorophyll fluorescence values (0.7 and 0.71, respectively) due to their inability to metabolize normally. Therefore, the plant shoot and root biomass values were also lower in the sandy soil than in the slope and clay soils. Furthermore, the lower chlorophyll fluorescence and smallest plant sizes in the sandy soil indicated that the leaves were less efficient in utilizing light energy, which ultimately led to a decline in the growth of the plants. LL showed an excellent chlorophyll fluorescence (0.83) value in the sandy soil, reflecting its outstanding photosynthesis capability, which could result in a faster growth of this species. Therefore, the chlorophyll fluorescence represents a parameter to recognize better performance species.

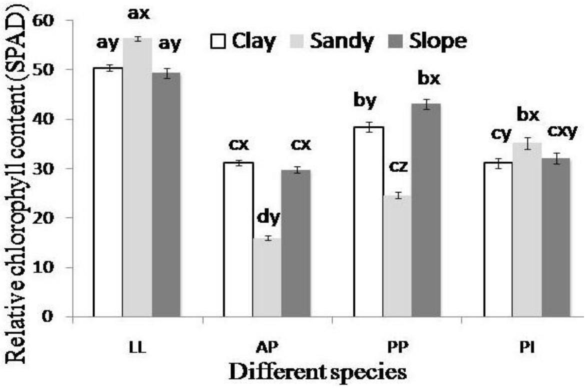

Fig. 3. Relative chlorophyll content (SPAD) was recorded during the 6th month of four different species.

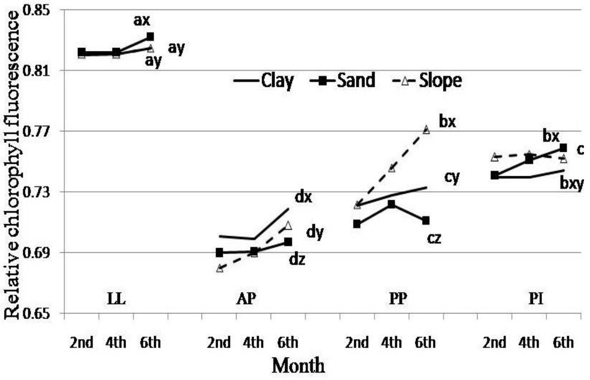

Fig. 4. Relative chlorophyll fluorescence of different species was measured at two-month interval. Different letters were significantly different (p < 0.05, ANOVA).

Photosynthesis, transpiration and stomatal conductance: In the sandy soil, the photosynthetic rate of LL was remarkably high, with a value that was twice those of AP and PP (Fig. 5); LL also grew very well in both clay and slope soils. Although PP grew well, displaying a high physiological performance in the slope soil, it did not grow well in the sandy soil. This finding is due to the lower rate of photosynthesis, which have affected its normal physiological activities, such as plant growth. The total photosynthesis and transpiration rates were significantly ($p < 0.05$) higher for LL in all soil types, whereas photosynthesis and transpiration were significantly lower in the sandy soil for both AP and PP (Fig. 6). This result was due to the highly reduced chlorophyll content of the leaves or species-specific variations in photosynthesis, transpiration and stomatal conductance (Fig. 7).

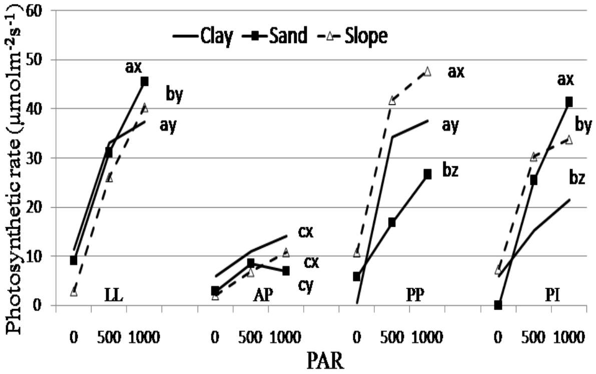

Fig. 5. Photosynthetic rate in different species. Different letters were significantly different ($p < 0.05$, ANOVA).

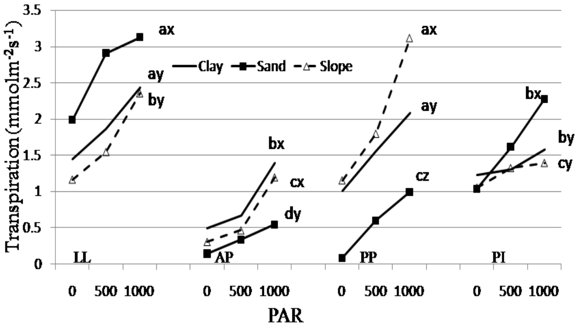

Fig. 6. Transpiration rate of different species. Different letters were significantly different ($p < 0.05$, ANOVA).

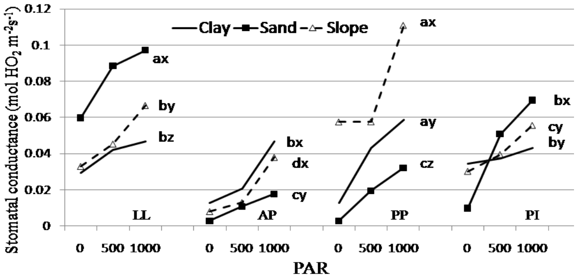

Fig. 7. Stomatal conductance of different species.

Leaf area index (LAI): LAI is considered to be a value of the leaf area per unit area of land. The results showed that there were significant ($p < 0.05$) differences among the soil types and species. The LAI values for LL and PP were increased by 20% and 15%, respectively, compared to PI (Fig. 8); PI displayed the lowest LAI values in all of the soil types, which was due to the lower growth rate. LL showed a higher (163%) LAI than PI in sandy soil, which is due to the better physiological performance (especially with regard to photosynthesis and chlorophyll fluorescence). PP also showed a high LAI value in the slope soil that was almost similar to that for LL. The higher LAI of PP was possibly attributable to the high photosynthetic activity and growth. AP, PP and PI showed lower LAI values than LL in the sandy soil, a result that was due to their lower growth rates and photosynthetic activities.

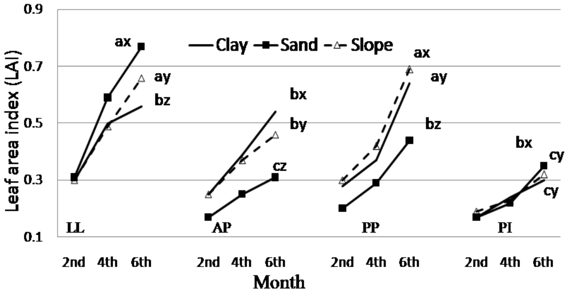

Fig. 8. Evaluation of the leaf area index (LAI) of different species in the 2nd, 4th and 6th months.

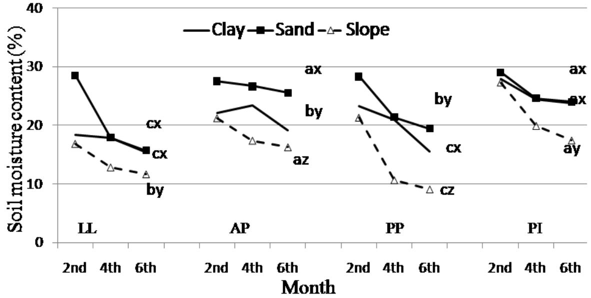

Fig. 9. Measurement of soil moisture content (%) of different species at the 2nd, 4th and 6th months.

Soil moisture content (%): The initial moisture content of three different soils is referred to as the water-holding capacity (Tripathi *et al.*, 2009). With the progression of time, the soil moisture content was more related to the presence of the plant species, plant height and root biomass. The three types of soil showed a similar downward trend for this parameter. A Comparatively lower moisture content (47%) was found for PP than PI in the slope soil (Fig. 9). The sandy soil contained a high moisture, even though it does not have the capacity to hold water like clay does, and this was due to the low plant growth and root-shoot biomass, especially for AP and PI, the conservative water-use strategies by the plants or the regular irrigation.

Potassium contents: The potassium content was higher (75%) in LL than AP in sand soil. For AP and PP, the potassium content was significantly ($p < 0.05$) lower in the sandy soil than the slope and clay soils. The high level of potassium allowed increased photosynthesis. Therefore, the high potassium contents were observed in LL leaves (Table 3).

Table 3: The leaf potassium content (ppm). Different letters were significantly different ($p < 0.05$, ANOVA).

Species	Potassium		
	Clay	Sand	Slope
LL	53.6±0.8ax	56±1.15ax	54.33±3.2ax
AP	44.3±1.8bx	32.66±2.9by	43.66±0.8bx
PP	45.6±1.2bx	34.33±2.6by	48±3abx
PI	45.6±0.88bx	52±2.3ax	47±2.5abx

Potassium deficiency in AP and PP were observed in the sandy soil and resulted in low plant canopy (LAI). Concerning the effect of potassium on the leaf, it has been shown by Maria *et al.* (2008) that potassium stress leads to reduce stomatal opening, which also reduces plant productivity. It is well documented that the key role of potassium is to act as a catalyst for many enzymatic processes and regulate the water use of the plant. A lack of potassium in the leaf can reduce the net CO_2 assimilation rate, increase the leaf respiration and control the photosynthetic rate in many woody ornamental plants and crops (Egilla and Davies, 1995; Basile *et al.*, 2003).

Table 4: Nodule frequency of the studied species in different soils. Different letters were significantly different ($p < 0.05$, ANOVA).

Species	Nodule		
	Clay	Sand	Slope
LL	63±7.8z	182±8.9x	102±9y
AP	No	No	No
PP	No	No	No
PI	7.3±1.8z	82±2.9x	21±2y

Root nodulation: After six months of growth, nodules were found only in LL and PI. The number of nodules of these legume species was the highest in sand soil (Table 4). This was due to the symbiotic relationships between sand soil microbes and these leguminous species.

Root profiles: LL had a higher root length (450%) and volume (500%) than PI in sand soil (Fig. 10 and Fig. 11). Consequently, LL also had a higher root biomass than PI in sand soil (Table 2). High root lengths and volumes maximize the soil-root interface and water uptake rate. Therefore, LL showed a lower moisture content than PI. Whereas, the root tensile strength of four different tree species were exhibited in Table 5. The results showed that there was a significant difference ($p < 0.05$) of root tensile strength amongst the species studied. The root tensile strength of species studied provide information that LL roots will be able to supply better ductility to the root-soil composite with a higher ability to reinforce soil (Nordin *et al.*, 2011). Stokes *et al.* (2009) documented that high tensile strength of roots will be able to show more resistant in tension during slope failure. Thus, this property of LL roots would ultimately increase in share strength of the root-soil composite in the natural slope condition.

4. Discussion

Relationship of plant biomass and physiological characteristics: The differences in the plant biomass production and nodule formation among the different soil types are shown in Figure 12 and Table 4, respectively. Higher shoot dry weights (SDW) were observed for LL and PP, presumably due to their higher root dry weight (RDW). In contrast, the plant height and root biomass were significantly ($p < 0.05$) lower for PI grown in all types of soil. PP showed low photosynthesis (43%) and chlorophyll florescence (7%) in the sandy soil, which was due to the low shoot biomass that contain low levels of chlorophyll content per unit leaf area for the interception of sunlight for photosynthesis (Jordan and Smith, 1993). Jordan and Smith (1993) also reported that low canopy may less effectively capture CO_2 molecules. Moreover, AP had also low photosynthetic rates and LAI values, despite growing in a high soil moisture (Fig. 9) in the sandy soil, a result that could be due to low root biomass. It was found that LL and PI contain more roots and produce more nitrogen-fixing nodules in the sandy soil than the clay and slope soils, which is due to more internal metabolism.

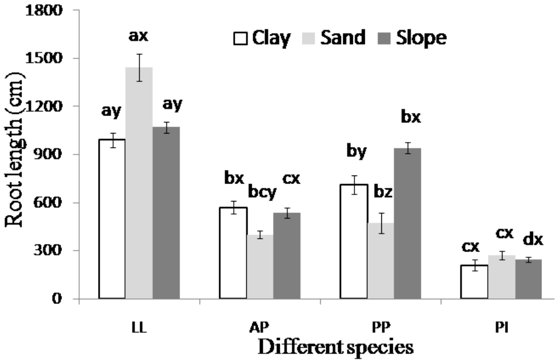

Fig. 10. Effect of different soils on the total root length of different species.

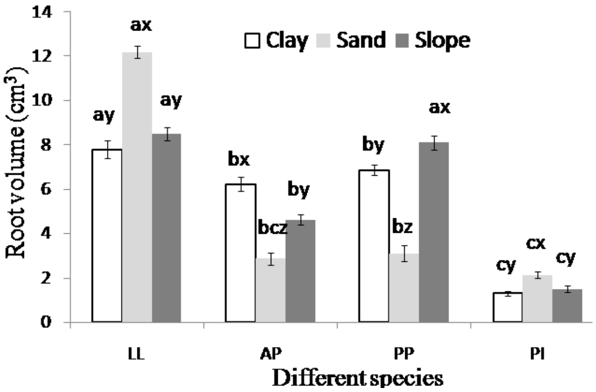

Fig. 11. Total root volume of different species was affected by different soil type. Different letters were significantly different ($p < 0.05$, ANOVA).

The production of nodules resulted in more nitrogen fixation, leading to better physiological performance (Antolin *et al.*, 2010). Nitrogen-related symbiosis with plants generally function effectively in the presence of nodules and fine roots, with microorganisms fixing atmospheric nitrogen. However, McKey (1994) reported that nitrogen fixation developed in legumes to maintain their internal nitrogen demand and not because of a low nitrogen content in the soil. Therefore, nodulation formation increased with the increasing of plant age and biomass to support metabolism (Table 4). It can be assumed LL and PI had strong symbiotic relationships that allowed these species to produce more nodules as the plant grew. A higher number of nodules were observed for LL and PI growing in the sandy soil. Consequently, higher shoot and root biomass values were observed in the sandy soil than in the clay and slope soils. We suggest that nodulation also supported the higher photosynthetic rates of LL and PI in the sandy soil, whereas the sandy soil was less beneficial for AP and PP. Therefore, this finding provided a well idea of root-shoot relationship. It seemed that root growth promoted the shoot growth or LAI (Fig. 8). Therefore, the presence of more root biomass for LL was arguably associated with a higher water uptake and concomitantly high rates of photosynthesis and transpiration. Additionally, Kumar et al. (2010) described that high values of root length and biomass are the most promising characteristics for better physiological performance. Whereas, Tognetti et al. (2009) described that a high root biomass would be beneficial for water absorption and to increase water movement from the soil to plant tissue. Root biomass is also an important criterion for root influence on soil reinforcement for example soil anchorage. In the presence of a large plant size and LAI, the effects will be more beneficial in reducing the soil moisture content via transpiration. Similar results were reported by Cairns *et al.* (1997) who described that a reduction of the soil moisture content was due to the presence of more root and shoot biomass. Shaozhong *et al.* (2002) also showed that more root biomass most likely leads to a higher water uptake by roots.

Fig. 12. Plant profiles after six months of growth. Slope Soil=a, Sand Soil=b, and Clay Soil=c

Root profiles and correlation between root biomass and soil moisture: In terms of root profiles, LL exhibited the highest (176%) root tensile strength. This study suggested that LL has added value as a good potential plant for soil reinforcement works as it exhibited outstanding root mechanical (tensile strength) properties. Root tensile strength also contributes to tree anchorage. It is well documented that high root tensile strength possessed tree showed more resistance to overturning (Stokes *et al.*, 2009; Nordin *et al.*, 2011). This property of roots would eventually increase soil shear strength by producing a composite material, soil and roots. Thus, root tensile strength gives an idea to predict the species contribution to soil reinforcement. Therefore, root tensile strength is a useful tool in selecting potential tree species. In the present study, LL and PP possessed a higher quantity of fine roots in the range of 0.5-1.5 mm (Fig. 13). It is well documented that fine roots increased the efficiency of soil binding between the soil particles and improved cohesion (Stokes *et al.*, 2009; Nordin *et al.*, 2011). It is also suggested that fine roots increased the hydrological properties via their capability to absorb sufficient water, thus lowering the risk of landslides and erosion (Shaozhong *et al.*, 2002).

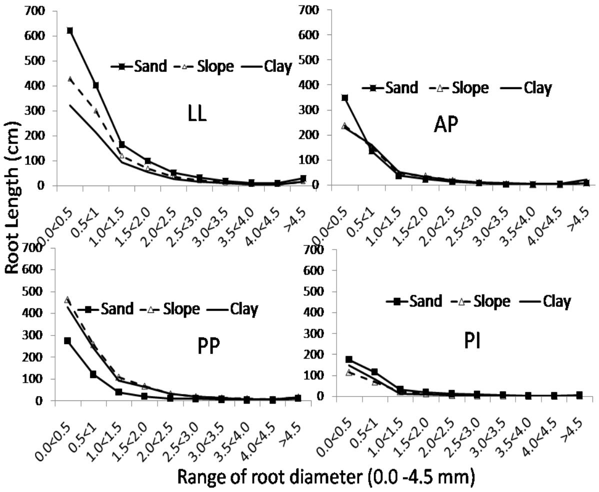

Fig. 13. The effect of different soils on the total fine root length of different species and fine root length according to various diameter classes; fine roots (>0.0–2.0 mm) and thin roots (>2.0–10.0 mm).

Table 5: Root tensile strength (RTS) of four tree species (Different letters showed significantly different at $p < 0.05$, ANOVA).

Species	RTS (MPa) Slope soil
LL	92.6±7a
AP	44.5±8c
PP	63.3±7b
PI	35.5±2d

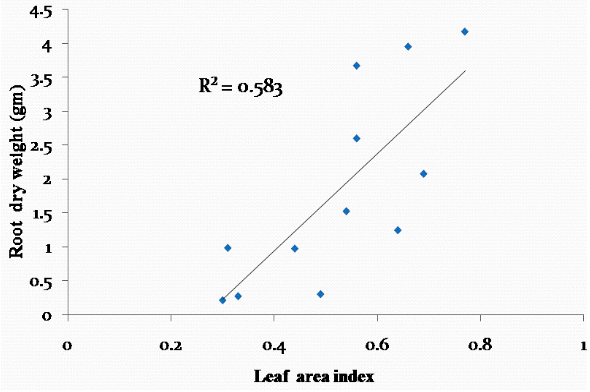

Fig. 14. Positive correlation between leaf area index and root dry weight.

There is a positive correlation (R^2=0.58) between the plant LAI and root biomass (Fig. 14), implying that the belowground biomass would be higher if the aboveground biomass was higher. Conversely, the soil moisture content (%) and root biomass are negatively correlated (Clay: R^2=0.89; Sandy: R^2=0.45; Slope: R^2=0.83) (Fig. 15), implying that a higher belowground biomass is associated with a lower soil moisture content (%). Therefore, increased root biomass, e.g., fine roots (0 to 2 mm), is greatly beneficial in absorbing excess soil water and moving water to the atmosphere via transpiration (Rosado *et al.*, 2011). The removal of excessive water would lead to drying of the soil and a greater stability of the soil.

Screening the potential species using their physiological and root properties: Chlorophyll fluorescence is the light that can be re-emitted after being absorbed by the chlorophyll molecules of leaves. Light energy, which is absorbed by photosystem II (PSII), can be converted to chemical energy to drive photosynthesis. The chlorophyll fluorescence might reflect whether the plant has suffered stress, such as extreme temperature, light and water availability or lack of nutrients. Stress conditions can reduce the ability of a plant to metabolize normally and, consequently, reduce the chlorophyll fluorescence value. Therefore, the assessment of plant physiology by measuring the chlorophyll fluorescence is well documented. Moreover, the chlorophyll fluorescence can also indicate an imbalance between the assimilation of light energy by the leaves and the use of energy during photosynthesis (Rong-hua *et al.*, 2006).

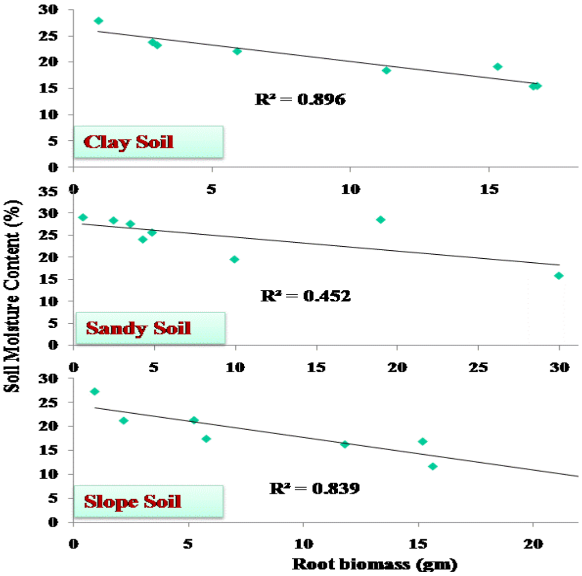

Fig. 15. Negative correlation between soil moisture content and root biomass.

In many plant species, an optimal chlorophyll fluorescence value is approximately 0.8, and this value indicates healthy plants (Calatayud *et al.*, 2002). Values of approximately 0.81-0.83 for LL in each soil type suggested that this species had a better photosynthetic or light reaction ability than the other species. High photosynthesis implies that the plant is more efficient in utilizing light for enhancing growth. Therefore, the plant is also more likely to grow faster. This is essential for slope soil colonizer (Normaniza and Barakabah, 2006). Additionally, root biomass, length volume, and tensile strength are also an important criterion for soil reinforcement for example root-soil interaction. In addition, the LAI, chlorophyll content, and growth rate were the most important parameters for assimilation (Normaniza *et al.*, 2009). The leaf potassium content is related to the ability of the plant to fix carbon, the carbon sink potential and the conversion of CO_2 into photosynthate. Furthermore, the shoot biomass and LAI of the plant influenced the level of chlorophyll pigments. A high chlorophyll content resulted in high photosynthesis and plant biomass production. Fast-growing species, such as LL, had high potassium contents in their leaves (Table 3), resulting in better physiological activities. Hence, overall higher value (studied physiological and root parameters) of a species can indicate a comparatively healthy species among the present plants. According to the observations, LL showed the highest performance in the sandy soil, and PP showed the second highest performance in the slope soil. The higher plant growth and root profiles of LL and PP demonstrated remarkable characteristics that are essential for soil reinforcing plants.

5. Conclusion

The species studied were evaluated on their physiological characteristics such as the photosynthetic rate, transpiration rate, chlorophyll florescence, chlorophyll content and growth rate and root profiles, such as root tensile strength, fine roots, root biomass, root volume and root length. This screening process will assist to select a plant species which showed comparatively better physiological and root profiles or reinforcement (root length, volume and tensile strength) characteristics. A higher physiological performance such as plant growth, photosynthetic rate and chlorophyll florescence and root profiles such as number of fine roots, root length, and root tensile strength were observed in LL which leaded to this species in selecting as potential plants. In conclusion, based on our screenings, *L. leucocephala* grown in sandy soil exhibited the best performance, followed by *P. pterocarpum* in the slope soil. The root biomass is negatively correlated with the soil moisture content and positively correlated to the LAI. However, more stringent screening will be conducted using *L. leucocephala*, and *P. pterocarpum* in microenvironmental slope conditions to examine further their potential as soil reinforcing plants.

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