# Chapter 2

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# Plant Screening : Root Length Density

## 2.1 Introduction

Root are primarily involved in absorption, food storage, conductance and anchorage (Fitter, 1991). It penetrates soil and spreads laterally under the ground and its growth is dependent upon soil moisture, temperature, and soil composition (Klepper, 1987). In addition to root distribution and quantity, it is reported that branching pattern also influenced the strength of anchorage (Coutts, 1983). A study done by Gray (1995) showed that root system assists the mass-stability of the slopes. Hence, for the purpose of vegetation selection on slopes, root profile studies will indeed be essential.

The objective of this experiment is to investigate the root profiles of five species of shrubs mentioned earlier (Table 1.5). Some physiological criteria of the shrubs also will be studied to see the relationship between those parameters and root length density. The four species that exhibit good root profiles and physiological characteristics will be chosen for further studies.

## 2.2 Materials and Methods

### 2.2.1 Plant Materials

All the species of shrubs were grown in polybag for six replicates by stem cutting. The plants were transferred into PVC pipes (200 cm in length; 11 cm in diameter) after four weeks of propagation. Normal water condition was maintained by applying water every morning. The pipes were placed at the Botanical Garden, University Malaya in normal condition. Physiological aspects such as photosynthesis, transpiration rates and stomatal conductance were observed after 12 weeks after being transferred into the PVC pipes. After 16 weeks, the plants were harvested to examine their RLD.

### 2.2.2 Measurements

#### (a) Photosynthesis, Transpiration Rates and Stomatal Conductance

Both photosynthesis and transpiration rates were measured using portable photosynthesis system (ADC, model LCA-4, UK) and a portable porometer (Delta T Devices, model AP4, UK) was used to measure stomatal conductance. Six young expanded leaves of each species were measured randomly. Each measurement was taken diurnally.

#### (b) Root Length Density (RLD)

Root length was measured using leaf area instrument (Image Analyser, Delta-T Devices, UK). The RLD was calculated as: root length / soil volume. The 200 cm PVC pipe was segmented into 20 or 30 cm of soil depth. This resulted in the volume of soil being 2850 $cm^3$.

#### (c) Water Absorption Capacity (WAC)

Water absorption capacity was formulated based on Baker's theory (1984). According to him, 98% of water absorption by roots is being transpired to the atmosphere. This statement leads the formula (Zaidah, unpublished) as,

$$\text{WAR} = \text{Water absorption rate by root/day } (\text{l } H_2O\text{/plant/day}) = \frac{E^{\#}\ 100}{98}$$

$$\text{WAC} = \text{Water absorption capacity by root } (\text{l } H_2O\text{/m root/day}) = \frac{\text{WAR}}{1^{\#\ \#}}$$

WAC' = Water absorption capacity by root = WAR
(l $H_2O$/g root/day) --------
m # # #

where,

# E = Transpiration rate(l $H_2O$/plant/day)

# # l = total root length

# # # m = total root biomass

**(d) Leaf Area and Biomass**

The leaf area were measured using a portable leaf area meter (LICOR, model LI-3000A, USA). The shrubs was separated into three parts as stem, leaf and root to get the biomass. All parts were oven-dried ( 80°C ) to constant weight.

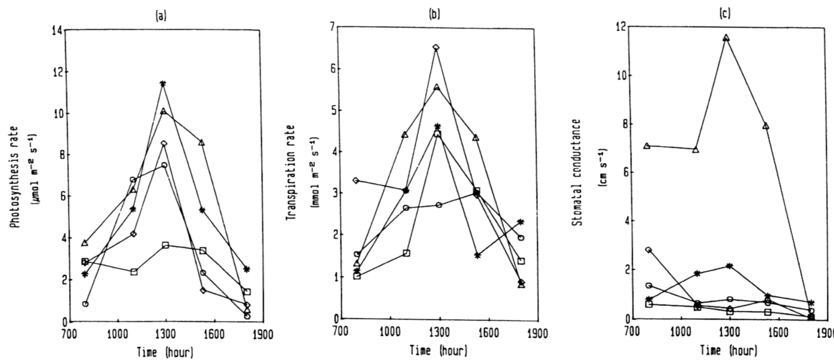
## 2.3 Results and Discussion

### 2.3.1 Photosynthesis, Transpiration Rates and Stomatal Conductance

Photosynthesis rates of all species except *E.bicolor* were low in the morning and late evening but high at midday (Fig. 2.1a). This is a typical diurnal pattern found in the most species studied. *L.camara* had the highest photosynthesis rates among the species which was nearly four times of the lowest rates of *E.bicolor*. The four species studied showed high value of photosynthesis during midday with a range of 7-12 $\mu mol\ m^{-2}\ s^{-1}$. These species with higher photosynthesis rates indicate that they are more efficient in utilizing light for enhancing growth and are more likely to grow faster, a characteristic essential for a slope colonizer. The diurnal pattern of transpiration rates was similar to those of photosynthesis rates. This observation implies that both parameters are related to each other. However, *T.erecta* showed the highest transpiration rate among the species during midday followed by *J.betonica* and *L.camara*. Higher transpiration rates

**Fig. 2.1** : Physiological criteria of 5 species studied in (a) photosynthesis rate, (b) transpiration rate and (c) stomatal conductance. Each point represents the mean of 6 determinations (Δ *J. betonica*, ◊ *T. erecta*, □ *E. bicolor*, ○ *H. mutabilis* and ∗ *L. camara*).

Fig.2.1: Physiological criteria of 5 species in (a) photosynthesis rate, (b) transpiration rate (c) stomatal conductance.



can, arguably, be taken to mean extensive rooting system (Fig. 2.1b).

Unlike the previous physiological characteristics, stomatal conductance of the most species studied did not show a typical diurnal pattern. Only *J.betonica* and *L.camara* showed the highest stomatal conductance during midday. Others exhibited uncertain pattern which might be attributed to unpredictable stomatal closure possibly caused by a negative feedback loop due to high rate of transpiration (Fig. 2.1c).

In all the physiological aspects discussed, results (value during midday) showed the following trend :

(i) Photosynthesis rates (μmol $m^{-2} s^{-1}$)
*L.camara* > *J.betonica* > *T.erecta* > *H.mutabilis* > *E.bicolor*

(ii) Transpiration rates (mmol $m^{-2} s^{-1}$)
*T.erecta* > *J.betonica* > *L.camara* > *E.bicolor* > *H.mutabilis*

(iii) Stomatal conductance (cm $s^{-1}$)
*J.betonica* > *L.camara* > *H.mutabilis* > *T.erecta* > *E.bicolor*

Thus, *L.camara* and *J.betonica* are among the species which are always in higher ranking. These results imply that both species have promising physiological characteristics. These species also showed strong correlation among the three parameters studied (Table 2.1).

### 2.3.2 Root Length Density (RLD)

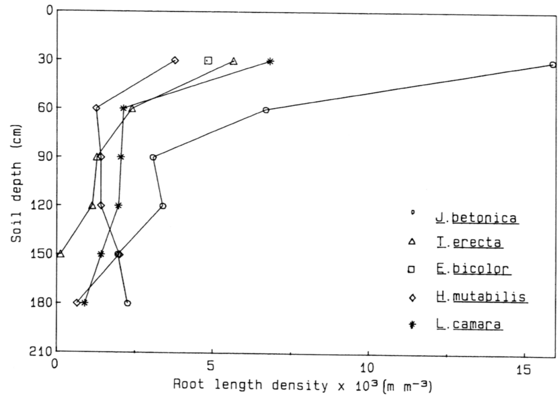
RLD decreased with increasing soil depth (Fig. 2.2). The results indicate that the favourableness of conditions for root growth usually varied at different depths of the soil (Russel, 1977). In this experiment, all species showed the highest percentage of RLD at the first 30 cm of soil depth. The root density was shown to be in a range of 35-53% of

**Table 2.1** : Correlation coefficient between (a) photosynthesis rates and stomatal conductance and (b) transpiration rates and stomatal conductance of 5 species of the shrubs studied

| **Species** | **Correlation coefficient (r)** | |
|---|---|---|
| | (a) **photosynthesis & stomatal cond.** | **(b) transpiration & stomatal cond.** |
| ***J.betonica*** | 0.920 | 0.850 |
| ***T.erecta*** | -0.110 | 0.000 |
| ***E.bicolor*** | 0.350 | 0.000 |
| ***H.mutabilis*** | -0.083 | 0.000 |
| ***L.camara*** | 0.870 | 0.910 |

**Fig. 2.2** : Root profile of 5 species of shrubs. Each point represents the mean of 6 determinations (Δ *J. betonica*, ◊ *T. erecta*, □ *E. bicolor*, O *H. mutabilis* and ∗ *L. camara*).

Fig.2.2: Root profile of 5 species of shrubs



the total RLD (according species indicated) at the first 30 cm depth. In fact, 100% of *E.bicolor* root was found at the first 30 cm. The RLD of the species at the first 30 cm in descending order is as follows;

*J.betonica* > *L.camara* > *T.erecta* > *E.bicolor* > *H.mutabilis*

Results show that *J.betonica* had the highest total root length (Table 2.4) and RLD (Table 2.2). It had twice RLD than *L.camara*. RLD of *T.erecta* and *H.mutabilis* were about the same. Overall results showed a trend and which could be summarized as follows;

(i) Total root length (m)

*J.betonica* > *L.camara* > *T.erecta* > *H.mutabilis* > *E.bicolor*
(94.8) (43.5) (30.3) (30.0) (13.8)

(ii) Total root length density (km $m^{-3}$)

*J.betonica* > *L.camara* > *T.erecta* > *H.mutabilis* > *E.bicolor*
(33.3) (15.3) (10.6) (10.5) (4.9)

### 2.3.3 Water Absorption Capacity (WAC)

From the formula derived, the total water absorption by 1m or 1g of root per plant in day could be determined. *L.camara* had the highest transpiration rate and water absorption rate (Table 2.3). Such a big loss through transpiration would demand large amount of water absorption by the root to get a flow in the soil-plant-atmosphere continuum. However, in terms of WAC and WAC', *L.camara* was the second highest among the species. In contrast, *E.bicolor* had the lowest transpiration rates and WAR but the highest WAC and WAC'. The results imply that not all the species have the positive relationship between transpiration rates and WAC and WAC'. It may due to

**Table 2.2** : Root length density of the 5 species studied

| **Species** | *Justicia betonica* | | *Thunbergia erecta* | | *Exoecaria bicolor* | | *Hibiscus mutabilis* | | *Lantana camara* | |
|---|---|---|---|---|---|---|---|---|---|---|
| soil depth (cm) | $m\ m^{-3}$ | % | $m\ m^{-3}$ | % | $m\ m^{-3}$ | % | $m\ m^{-3}$ | % | $m\ m^{-3}$ | % |
| **0 - 30** | 15888 | 47.77 | 5675 | 53.44 | 4857 | 100 | 3780 | 35.94 | 6839 | 44.77 |
| **30 - 60** | 6690 | 20.12 | 2401 | 22.61 | 0 | 0 | 1256 | 11.94 | 2119 | 13.87 |
| **60 - 90** | 3069 | 9.23 | 1279 | 12.05 | 0 | 0 | 1416 | 13.46 | 2042 | 13.37 |
| **90 - 120** | 3388 | 10.19 | 1136 | 10.70 | 0 | 0 | 1412 | 13.43 | 1968 | 12.89 |
| **120 - 150** | 1954 | 5.88 | 127 | 1.20 | 0 | 0 | 2011 | 19.12 | 1413 | 9.25 |
| **150 - 180** | 2266 | 6.81 | 0 | 0 | 0 | 0 | 642 | 6.11 | 894 | 5.85 |
| **180 - 200** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total** | **33255** | | **10618** | | **4857** | | **10517** | | **15275** | |

**Table 2.3** : Water absorption capacity of root in the 5 species of shrubs studied.

| Species | E | WAR | WAC | WAC’ |
|---|---|---|---|---|
| *J.betonica* | 1.76 | 1.80 | 0.019 | 0.58 |
| *T.erecta* | 1.01 | 1.03 | 0.034 | 0.25 |
| *E.bicolor* | 0.93 | 0.95 | 0.069 | 1.61 |
| *H.mutabilis* | 1.29 | 1.32 | 0.044 | 0.29 |
| *L.camara* | 2.27 | 2.32 | 0.053 | 0.71 |

several factors such as stomatal behaviour (Fig. 2.1.c), total leaf area and RLD of the species (Table 2.2).

Overall results indicate that high RLD did not necessarily influence water absorption capacity of the species studied. For example, despite having the lowest RLD, *T.erecta* showed the highest WAC and WAC'. This value may also be affected by the shape of the PVC pipe if the root extension in this species is more on horizontal axis, i.e., laterally rather than on vertical axis meaning their root growth might be slowed by mechanical resistance existing in the pipe (Barley *et al.*, 1965).

### 2.3.4 Dry Weight Partitioning and Biomass

Partitioning of the dry weight into root was high compared to the leaf in all species except *L.camara* and *E.bicolor* (Fig. 2.3). This may be due to the experimental design which allowed the roots to grow vertically but not laterally. Total biomass varied among the species, with *L.camara* the highest and *E.bicolor* the lowest (Table 2.4). *L.camara* also had the highest leaf area among the species studied. This, coupled with the highest transpiration rate it had (Table 2.3) meant that the rate of water loss was highest in this species. *E.bicolor* had the lowest root biomass and root length among the species. This resulted *E.bicolor* to have the lowest root/shoot ratio (Table 2.5).

### 2.3.5 Root/shoot Ratio

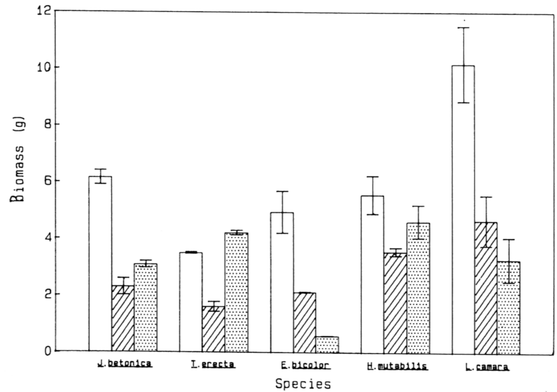
The root/shoot relationship may help to ascertain how environmental and chemical factors affect and modify the growth of the root and shoot. In this experiment, the ratio is important to assess whether one plant has sufficient root surface to absorb water or sufficient leaf surface for transpiration. The overall results show that the root growth of *T.erecta*, *J.betonica* and *H.mutabilis* were favoured over shoot growth (Table 2.5). This is because, for a particular species, the ratio may vary with chronological age,

**Table 2.4**: Biomass of stem, leaf, and root, total root length and total leaf area of 5 species of shrubs (each value represents a mean of 6 determinations except total root length)

| Species | Biomass (g) | | | Total biomass (g) | Leaf area $(m^2)(x10^{-2})$ | Root length (m) |
|---|---|---|---|---|---|---|
| | Stem | Leaf | Root | | | |
| ***J.betonica*** | 6.16±0.26 | 2.31±0.30 | 3.09±0.13 | 11.56 | 5.20±0.52 | 94.76 |
| ***T.erecta*** | 3.50±0.04 | 1.61±0.18 | 4.21±0.09 | 9.32 | 3.80±0.42 | 30.25 |
| ***E.bicolor*** | 4.94±0.75 | 2.12±0.02 | 0.59±0.01 | 7.65 | 4.00±0.75 | 13.84 |
| ***H.mutabilis*** | 5.56±0.68 | 3.55±0.15 | 4.61±0.59 | 13.72 | 6.30±0.04 | 29.96 |
| ***L.camara*** | 10.18±1.33 | 4.65±0.90 | 3.28±0.78 | 31.83 | 9.50±1.65 | 43.54 |

**Fig. 2.3** : Dry weight partitioning of the shrubs studied (□ stems, ▨ leaf and ▣ root). Each value represents the mean of 6 replications. Vertical line on the bar represents standard deviation.

Fig.2.3: Dry weight partitioning of the shrubs studied (stems, leaf and root)



stage of morphological development and environmental growing conditions (Aung, 1974; Klepper, 1991).

In this study, *T.erecta* showed the highest ratio of root/shoot in terms of biomass and leaf area; 2.61 and 111.0, respectively (Table 2.5). In contrast, root biomass/shoot biomass ratio of *E.bicolor* and *L.camara* were lesser than 1 due to lower root biomass. Regardless of the mode of calculation of root/shoot ratio, both species showed lower values compared to the other two species. The overall ranking is as follows;

**(i) Root biomass : shoot biomass**

*T.erecta* > *J.betonica* > *H.mutabilis* > *L.camara* > *E.bicolor*

**(ii) Root biomass : leaf area**

*T.erecta* > *H.mutabilis* > *J.betonica* > *L.camara* > *E.bicolor*

### 2.3.6 Correlation between RLD and Physiological Parameters

The results indicate that RLD of five species studied only had strong relationship with stomatal conductance and photosynthesis rates and do not have much impact on WAC and other physiological aspects (Table 2.6).

Transpiration was expected to have a relationship with RLD since water loss must be replaced by absorption of water by roots. However, the results showed vice versa. These results are not in consistent with the theory of Huck and Hillel (1983) which stated that water uptake was among the factors which affected RLD. Previous studies have shown that transpiration rate is controlled in the vapour phase and the root can affect it only indirectly, through changes of leaf water status and hence stomatal aperture. Therefore, a simple relationship between WAC and transpiration rate would not be expected (Newman, 1979).

**Table 2.5**: Root/Shoot ratio of the species studied (2 ways). Each value represents 6 determinations.

| **Species** | **Biomass root : shoot** | **Root Leaf biomass : area ($x10^1$)** |
|---|---|---|
| ***J.betonica*** | 1.34 | 5.90 |
| ***T.erecta*** | 2.61 | 11.10 |
| ***E.bicolor*** | 0.28 | 1.48 |
| ***H.mutabilis*** | 1.30 | 7.32 |
| ***L.camara*** | 0.71 | 3.45 |

**Table 2.6** : Correlation coefficients of other physiological parameters and RLD (n=6)

| X | Y | r | Regression equation |
|---|---|---|---|
| **Photosynthesis rate** | **RLD** | 0.65 | $y = 2.4x - 4.5$ |
| **Transpiration rate** | **RLD** | 0.32 | $y = 2.7x + 2.0$ |
| **Stomatal conduc.** | **RLD** | 0.97 | $y = 2.4x + 6.2$ |
| **Total biomass** | **RLD** | 0.24 | $y = 0.63x + 7.3$ |
| **WAC** | **RLD** | -0.81 | $y = -4.6x + 3.5$ |

Total biomass and WAC did not show any relationship with RLD. These results may be related to several factors. The rate of absorption is influenced by supply of photosynthate plus a favourable soil environmental factors such as temperature, aeration, and concentration of nutrients in the solution around the roots (Drew, 1979). Furthermore, according to Baker (1984), transpiration rates may vary between the species due to different leaf structures. Besides, many factors would influence root growth such as moisture status, soil temperature or aeration especially when the experiment was designed in a pipe (Klepper, 1987).

## 2.4 General Discussion

Four out of five species studied exhibit extensive and dense rooting with the RLD value reaching more than 10,000 m $m^{-3}$ (10 km $m^{-3}$). These results are very outstanding and encouraging in considering that these species could provide surface erosion control and soil reinforcement of the slope. Results also confirm that RLD of the five species studied do not have much impact on WAC and other physiological parameters, except stomatal conductance and photosynthesis rates. However, these species, except *E.bicolor*, have shown promising characteristics including photosynthesis, transpiration and stomatal conductance. Due to favourable RLD and other physiological criteria, *J.betonica*, *L.camara*, *T.erecta* and *H.mutabilis* have been selected for a second screening in the following chapter.