Bangladesh J. Bot. **43**(2): 141-145, 2014 (September)

ROOT DISTRIBUTION OF *ACACIA MANGIUM* WILLD. AND *MACARANGA TANARIUS* L. OF RAINFOREST

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Key words: Root distribution, Fine roots, *Acacia mangium*, *Macaranga tanarius*, Rainforest

Abstract

The number of roots and root area ratio (RAR) decreased with depth in *Acacia mangium* and *Macaranga tanarius* and the maximum value of RAR and root number were observed in the first layer of soil. This process was regular in *Acacia mangium* Willd., but the RAR value showed great variability in *Macaranga tanarius* L. as the RAR decreased with depth until the second layer (20 cm) and increased again. About 35% of all roots in *A. mangium*, and about 50% of all roots in *M. tanarius* are located in the first layer. About 87% of all roots were in the fine root diameter class (d < 2 mm) in *M. tanarius* species. However 90% of all roots were in the fine root diameter class in *A. magnium* species. Fine roots contribution to soil reinforcement due to concentration on upper levels, prevent surface erosion and shallow landslide. These results will be useful for slope stability projects.

Introduction

Root area ratio (RAR) or index of root area is an amount of rotting mass in a soil. (Bischetti *et al.* 2005). Compared to tensile strength, the root area ratio was significantly more important in soil shear resistance. Docker and Hubble (2008) mentioned that there is a correlation between the amount of RAR and increased shear resistance. The root area index is defined by measuring the number of roots in different diameter classes in cross-sectional area of soil exposed on a vertical face of soil (De Baets *et al.* 2008).

Root distribution of three hardwood species in northern of Iran was compared by Abdi *et al.* (2010a). The number of roots and root area ratio (RAR) decreased with depth, but the number of roots showed the regular pattern of decrease with depth compared to RAR. This is because of the presence of large roots, that RAR values are very sensitive to this factor. Also, the results showed that in larger trees, anchorage occur by increasing in the growth of root diameters but not by increasing in the number of roots. Also in other research, the effect of two species on slope stability was investigated by Ji *et al.* (2012). There was a significant difference in mean RAR between the two species and the amount of RAR is higher in *Robinia pseudoacacia*, which were much bigger than *Platycladus orientalis*. For both the species maximum RAR values were located in the first 30 cm layer, and showed a decrease in the RAR values with depth.

The aim of this study is to compare the characteristic of the root system or root distribution in two species of tropical forests which is important for selecting species for erosion control and slope stability.

Material and Methods

The study area is located along east-west highway in Malaysia, which is one of the major roads in the northern part of Malaysia between N 05° 27′ 32.0″ E 101° 07′ 42.3″ and N 5° 42′ 11.15″ E 101° 49′ 54.74″. This highway links Gerik in Perak and Jeli in Kelantan with the length

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of 119 km. The climate is humid and an annual mean precipitation is about 1957.5 mm. The altitude is 283 meters above the sea. The type of soil is sandy, clay and loam and the lithology consist of Schist, phyllite, slate and limestone.

Macaranga tanarius L. is one of the species of Euphorbiaceae which occurs in disturbed rainforest areas. This pioneer species can tolerate in a wide range of soil type including clay, loam and sand. *Macaranga tanarius* is cultivated for ornament and reforestation projects in the tropical regions around the world. It is native to Malaysia and the average annual rainfall between 100 and 200 cm, and the average temperature between 10 and 20 degrees in January to over 20 degrees in July is suitable for its growing.

Acacia mangium Willd. fix nitrogen in the soil, which is useful for other plants, therefore cultivated in mixed cultures and for agroforestry projects (Jeyanny *et al*. 2011). Due to intensive rooting system of *A. mangium*, especially in poor soils (Kadir *et al*. 1998) this species cultivated in disturbed tropical regions.

The root distribution in the soil was analyzed by counting roots directly using a profile trench (Preti and Giadrossich 2009). At first, four trees of each species were selected. Then, under each species sample, one trench with 50 cm of length and depth with a distance about 25 cm from the stem was dug. In consequence, roots were counted in the separate 10 cm of soil layers. The average diameter (breast height) in Macaranga species was about 13 cm and that in *Acacia* species was 27 cm. The soil conditions were the same under the samples, but there was shallow bedrock under *Acacia* trees.

After that, a profile wall of trenches which close to tree stem were marked in every 10 cm thickness, then the number of roots was counted and divided in different root diameter classes i.e., 0 - 1, 1 - 2, 2 -5 , 5 - 10 and >10 mm (as the average root diameter in the root length). According to Ji *et al*. (2012) and Genet *et al*. (2008) roots belong in the first two ranges will classify as fine roots and the other second root diameter ranges consider as thin roots. Then the RAR percentage was calculated in each depth. The occupied area of roots in each layer was calculated by the following equation:

$$\text{Root area} = \sum_{i=1}^{n} \frac{\pi}{4} di^2$$

D_i, is the diameter of roots in each layer and root area is the area that occupied by roots in soil. Then the root area ratio (RAR) was calculated by the following equation:

$$\text{RAR} = \sum_{i=1}^{n} \frac{Ari}{A}$$

In this equation A_{ri} is the area that occupied by roots in each layer and A is the area of soil in each layer (Comino and Marengo 2010).

Statistical software of SPSS 20 was used to analyze data. RAR values from the two species were compared using paired-samples T tests. For assessing the best model between RAR and soil depth, various functions were tested, and the function that show not only the highest R^2 but also the lowest standard error was chosen as the best model. Spearman correlation was used to correlate the relation between RAR and soil depth.

Results and Discussion

The number of roots at each depth class showed a more systemic trend when compared with RAR values (Tables 1-4). The function between the number of roots and depth showed that number of roots decreased with depth following a power law for *M. tanarius* (R^2 = 0.818, SE of estimate = 0.361), and following exponential for *A. mangium* (R^2 = 0.378, SE of estimate = 0.592). The amount of RAR values declined with depth following exponential for *A. mangium* (R^2 = 0.536, SE of estimate = 0.975), and for *M. tanarius* following by S (R^2 =0.138, SE of estimate = 1.141).

T tests result showed that there is not a significant difference in the percentage of RAR ($F = 0.283$, $p > 0.05$) and root numbers ($F = 0.040$, $p > 0.05$) between two species.

Table 1. Distribution of number of roots at different soil depth in *Macaranga tanarius.*

Soil depth (cm)	Number of roots at different root diameter classes				
	0-1 (mm)	1-2 (mm)	2-5 (mm)	5-10 (mm)	>10 (mm)
10	185	64	10	6	3
20	81	24	4	1	0
30	39	19	15	0	0
40	26	9	11	1	0
50	14	9	6	7	0

Table 2. Distribution number of roots in soil depth in *Acacia mangium.*

Soil depth (cm)	Number of roots at different root diameter classes				
	0-1 (mm)	1-2 (mm)	2-5 (mm)	5-10 (mm)	>10 (mm)
10	145	57	29	3	3
20	95	44	9	1	1
30	85	25	7	0	0
40	71	17	1	0	0
50	57	11	5	0	0

Table 3 shows the percentage of RAR in each diameter class in two species. As recognized with the table about 72% of all roots in *A. mangium* are located in the diameter root classes with less than 10 mm and this amount is about 85% for *M. tanarius*.

Table 3. Percentage of different root classes to RAR values.

Species	% of RAR at different root diameter				
	0-1 mm	1-2 mm	2-5 mm	5-10 mm	>10 mm
A. mangium	6.32	18.24	34.91	12.57	27.94
M. tanarius	4.05	13.19	26.44	42.23	14.08

By comparing RAR values in fine roots ($d < 2$ mm) and thin roots ($2 < d < 10$ mm), in *A. mangium*, fine roots and thin roots decline with depth regularly, but there is an exception in the root diameter classes of 2 - 5 mm in the 50 cm soil depth (Table 4).

The highest RAR value was in the 2 - 5 mm root diameter class and the lowest RAR value were in the first layer in *A. mangium* (34.91, 6.32%, respectively) (Table 3).

There was a wide variety in the RAR distribution in the root diameter classes of 2 - 5 and 5 - 10 mm in *M. tanarius*. As in the diameter class of 2 - 5 mm, the amount of RAR decreased until the second layer, then increased again until the last layer. This process repeated in the root diameter classes of 5 - 10 mm, at the first the amount of RAR decreased until 30 cm soil depth and then again increased. The largest value of RAR was in the 5 - 10 mm root diameter classes and the lowest was in the first layer (42.23, 4.05 respectively) (Tables 5 and 3).

Table 4. Contribution RAR values in per cent in different size classes at each depth (n = 4 replications) in *A. mangium*.

Soil depth (cm)	Root diameter (mm)				
	0-1 (mm)	1-2 (mm)	2-5 (mm)	5-10 (mm)	>10 (mm)
	% RAR values				
10	2.02	7.16	19.85	9.43	16.76
20	1.32	5.53	6.16	3.14	11.17
30	1.18	3.14	4.79	0	0
40	0.99	1.57	0.68	0	0
50	0.79	0.82	3.42	0	0

Table 5. Contribution RAR values in per cent in different size classes at each depth (n = 4 replications) in *M. tanneries*,

Soil depth (cm)	Root diameter				
	0-1 (mm)	1-2 (mm)	2-5 (mm)	5-10 (mm)	>10 (mm)
	% RAR Values				
10	2.17	6.75	5.75	15.84	14.08
20	0.95	2.53	2.30	2.64	0
30	0.45	2.01	8.62	0	0
40	0.31	0.95	6.32	5.28	0
50	0.16	0.95	3.45	18.48	0

The results indicated that more than 75% of all roots are smaller than 10 mm in diameter. Also Abdi *et al.* (2010b) mentioned that about 60% of the roots are smaller than 10 mm of root diameter. Some authors (De Baets *et al.* 2008, Abdi *et al.* 2010a, Chiaradia *et al.* 2012) considered these roots in soil reinforcement, but the other authors such as Styczen and Morgan (1995) indicated that roots 1 - 20 mm in diameter have the most important role in soil reinforcement.

The root area ratio is an important key for understanding about soil reinforcement by roots as an important factor in soil bioengineering. Therefore, for upgrading the knowledge about the effect of vegetation on slope stability, root area ratio data are useful for this kind of studies.

Acknowledgement

The authors thank Universiti Sains, Malaysia for the financial support through PRGS research grant 1001/PJJAUH/846090 and MOHE grant 203/PJJAUH/6711279.

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(Manuscript received on 18 June, 2013; revised on 27 February, 2014)