Root Tensile Strength Variations In Inter and Intra Species in Rainforest

Habibah Lateh, Nazi Avani, and Ghassem Habibi Bibalani

***Abstract*----**The aim of this study is to investigate individual root tensile strength (Tr) and of *Acacia mangium* and *Macaranga tanarius* in rainforest in and among species with regard to position around the tree stem. Excavation method was used for collecting roots around each tree at two distances of 25 cm and 1 meter from tree stem. Analysis of covariance (ANCOVA) was used to assess the inter and intra species variations. The results showed that there is a significant difference between root tensile strength in two species at two distances and Tr was significantly higher for *Acacia mangium* (50.49± 2.31MPa at 25 cm and 43.67 ± 2.44 MPa at 1 meter) than *Macaranga tanarius* (27.64 ± 1.72 MPa at 25 cm and 23.81 ± 0.97 MPa at 1 meter). The results indicated that Tr is significantly higher at 25 cm than 1 meter at both species. Intra species variations showed that there is a significant difference in root tensile strength regarding to tree samples in m.tanarius, but there is not a significant differences in A.mangium tree stem.

***Keywords*-----**RAR, Root tensile strength, Soil cohesion, *Acacia mangium.*

I. Introduction

WHEN shearing the soil, because of shear stresses that develop in the soil, roots mobilize their tensile strength in the soil matrix and then shear stresses are transferred to the tensile resistance of the roots [1]. Averages of the root tensile strength of trees vary by species [2] Laboratory root tensile strength tests has been widely studied [3, 1, 4,5,6,7,8] to analyze the root resistance to failure in different species at different sites.

The greatest important issues governing the soil stabilization are RAR and tensile strength of the roots [9, 4]. By measuring tensile strength and distribution of roots within the soil, the effect of tree roots on slope stability can be recognized. These two structures control the major mechanisms of stability such as soil reinforcement, soil arching and defense and root anchoring [10]. In order to establish root effects on slope stability, determination of the tensile strength of different types of tree roots is necessary .A crucial step to consider root reinforcement is root tensile strength [1]. Root tensile strength is affected as much by species as by differences in size (diameter). In general, there is a relationship between root tensile strength (Tr (d)) and diameter (d) that is a simple power function [11].

$$Tr = \alpha\, d^{-\beta} \qquad (1)$$

Where α is scale factor and β is a strength decay rate (which control the amount of strength decay with diameter) and depending on species [11].

The most important factor to indicate the suitable species for soil reinforcing in slope stability projects is tensile strength of roots [12]. Genetic, environmental and edaphic conditions influence on root characteristics, therefore still we need more data about root system around the world. The objective of this research is to investigate the root tensile strength different positions around the tree stem in and among the species.

II. Material And Method

A. Site details

Roots were sampled along East-West Highway, Malaysia (N 05° 27′ 32.0″ E 101° 07′ 42.3″ to N 5° 42′ 11.15″ E 101° 49′ 54.74″) with an altitude about 283 meters above the sea level, which located between Gerik in Perak and Jeli in Klantan with the length about 119 km, is the major road in the northern part of peninsular Malaysia. The climate in this area is humid with an average annual precipitation of 1957.5mm.

Investigated species are Acacia mangium and Macaranga tanarius. A. mangium is a fast growing species which develop an intensive rooting system especially in a low fertile soil and improve damaged tropical sites [13]. This species generally planted with the other plants due to its nitrogen fixation benefits to other plants. Any plants from Leguminaceae family due to fix nitrogen in the soil act as nurse plants to young native species by improving the organic and nutrient balance of the soil. *Macaranga tanarius* usually occured in disturbed rainforest areas. This is a pioneer species which tolerate a wide range of soil type including clay, loam and sand. *M. tanarius* is cultivated for many purposes such as ornamental and reforestation projects in the tropical regions around the world.

B. Methodology

Eight trees of *A. mangium* and *M. tanarius* were selected randomly along East-West highway, the average diameter at breat hight for A. mangium was 16.87 cm and this value was 16.75 cm for M. tanarius. Then one trench at a distance of 1 meter [4] and one trench at a distance of 25 cm [14] was dug. The dimension of profiles was 50 cm long × 70 cm depth. For each selected tree, roots were randomly collected in every holes in different diameter class and soil depth [9,14], afterwards all roots cut in different root length and keep in a plastic bag with a 15% alcohol solution (ethanol) [15] to

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preserve their moisture content [1] and prevent microbial degredation [11] then send to the laboratory and keep in a refrigerated box at a temperature of 4°C to conserve their refreshment [11].

After collecting roots from holes and bringing to the laboratory, roots were washed and then cut in a specific length (Figs.1). Some researches [1, 5, 10] mentioned roots with the 0.1 m length, and 0.2m length stated by [6]. The minimum root length of 50 mm mentioned by [16] and roots less than 50 mm was neglected by [7] due to the difficulty in placing in the tensile strength device.

According to [16] there is a significant effect of root length on root tensile strength therefore a range of root length between 5.5 cm and 20 cm considered in this study. Universal testing machine with the load cell of 2KN was used for analyzing the root tensile strength in the laboratory. The average root diameter in three points along the root length was analyzed with the digital caliper before testing. The strain rate of 10 mm/min was used in the recent study according to other authors such as [1, 11, 15, 4, 17, 6] The most critical problem in the laboratory tensile strength tests is that the roots rupture near the clamps due to root structure damage by grips, therefore for ensuring that the rupture is due to tensile force, not root structure or stress due to clamp, only the specimens which broke in the middle of the root length would take into consideration [18]. Root tensile strength was investigated by dividing the applied force at breaking point (N) to root area (mm^2), by the following equation:

$$T_r = \frac{4F}{\pi\, d_i^2} \qquad (2)$$

Where, F is the maximum load at the rupture point (N),

d is the average root diameter at five points with a bark before traction (mm),

T_r is individual root tensile strength (Mpa)

And i indicates the root diameter class.

Figs. 1 (left) *Acacia mangium* root samples and (right) *Macaranga tanarius* root samples.

Analyses of Covariance (ANCOVA) were used to analyze the effect of profile, species and tree stem on root tensile species while root diameter consider as covariate.

III. Results

A. Root tensile strength result in Macaranga tanarius

The results showed that root tensile strength reduced by increasing root diameter according to power low equation at 1 meter distance and 25 cm distance of the tree stem (Figures 3 and 4 respectively). Table 1 gives some information on Tr and root diameter at different distance of the tree stem in *Macaranga tanarius*.

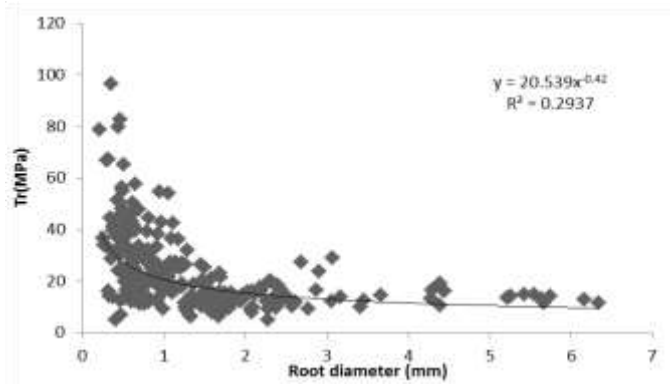

Fig. 2 Relationship between Tr and root diameter at 1 meter distance of the tree stem (*Macaranga tanarius*)

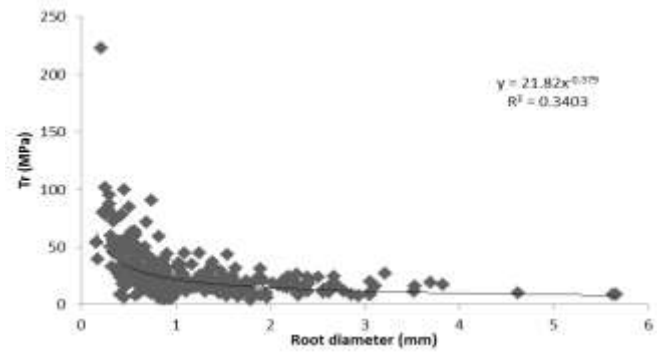

Fig. 3 The relationship between Tr and root diameter at 25 cm distance of the tree stem (*Macaranga tanarius*)

At 1 meter distance of the tree stem the range of root tensile strength for 8 trees varied between 4.95 MPa (d = 2.28 mm) and 96.61 MPa (d = 0.35 mm) with the average root tensile strength of 23.81 (average amount of d = 1.38mm). Totally 420 root samples analyzed and the correct failure, which roots rupture in the middle of root length not near jaws was 56.42%, which 237 of root samples rupture in the middle of root length out of 420 root samples tested. At 25 cm distance of the tree stem, 501 root samples tested and there were 276 correct tests which roots rupture in the middle of the root length. The root tensile strength varied between 4.26 MPa (d = 1.79) and 222. 42 (d = 0.21 mm) with the mean of Tr of 27.64 MPa (average of d = 1.22 mm).

B. Root tensile strength results in Acacia mangium

The results showed that the root tensile strength decrease by increasing root diameter according to power law correlation. Figure 5 shows the relationship between Tr and root diameter at 25 cm distance of the tree stem in *Acacia mangium.*

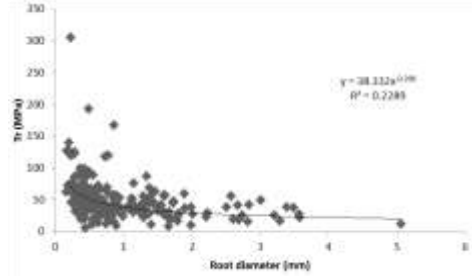

Fig. 4 The relationship between Tr and root diameter at 25 cm distance of stem (*Acacia mangium*).

At 1 meter distance of the tree stem, the amount of Tr decreased with increasing root diameter. Figure 6 shows the relationship between Tr and root diameter according to power law correlation 1 meter distance of the tree stem.

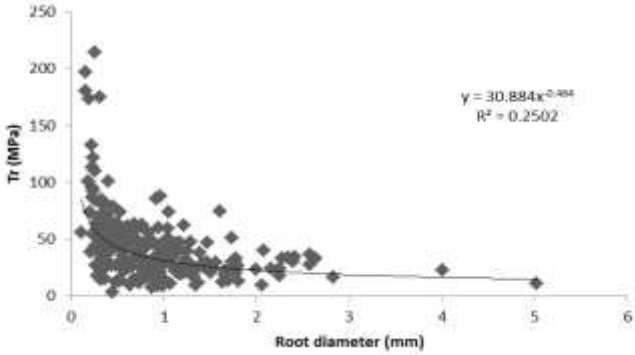

Fig. 5 The relationship between Tr and root diameter at 1 meter distance of stem (*Acacia mangium*).

At 25 cm distance of the tree stem, Tr value ranges between 5.85 MPa (d = 0.44mm) and 304.88 MPa (d= 0.22mm) with the average of Tr 50. 49 MPa (average value of root diameter is 1.01 mm). 196 root samples out of 327 roots which tested rupture in the middle of the root length, therefore 59.93% of roots consider as correct test. At 1 meter distance of the tree stem, 238 roots rupture in the middle of the root length out of 375 root samples, which 63.64% of all roots rupture in the middle of the root length and consider as correct test. Tr values change between 3.14 MPa (d = 0.45 mm) and 214 MPa (d = 0.25) with the average value of Tr 43.66 (Average d = 0.9 mm).

C. Root tensile strength at 25 cm distance of the tree stem

TABLE I showed some information on the minimum, maximum, mean and Std. error of root tensile strength in two species at 25 cm distance of the tree stem.

TABLE I
TR INFORMATION AT 25 CM DISTANCE OF THE TREE STEM FOR BOTH SPECIES

Species	Minimum	Maximum	Mean	S.D.
Acacia mangium	5.85	304.88	50.49	2.44
Macaranga tanarius	4.26	222.42	27.64	1.72

ANCOVA analysis showed that there is a significant difference between Tr at 25 cm distance in *Acacia mangium* and *Macaranga tanarius* while controling by root diameter ($P < 0.01$). Therefore the average root tensile strength at 25 cm distance of the tree stem is significantly higher in *Acacia mangium* than *Macaranga tanarius*.

D. Root tensile strength at 1 meter distance of the tree stem

TABLE II
TR INFORMATION AT 1 METER DISTANCE OF THE TREE STEM FOR BOTH SPECIES

Species	Minimum	Maximum	Mean	S.D.
Acacia mangium	3.14	214.35	43.67	2.002
Macaranga tanarius	4.95	96.60	23.81	0.97

ANCOVA analysis showed that there is a significant difference between Tr at 1 meter distance between two species (root diameter as covariate) ($P < 0.01$). Therefore the average value of Tr at 1 meter distance of the tree stem is significantly higher in *Acacia mangium* than *Macaranga tanarius.*

E. Root tensile strength in species regarding to profiles

TABLE III
TR INFORMATION AT 25 CM AND 1 METER DISTANCE OF THE TREE STEM IN *ACACIA MANGIUM*

Acacia mangium	Minimum	Maximum	Mean	S.D.
25 cm	5.85	304.78	50.49	2.31
1 meter	3.14	214.35	43.67	2.44

ANCOVA analysis showed that there is a significant difference between root tensile strength at 25 cm and 1 meter distance of the tree stem in *Acacia mangium* (root diameter as covariate) ($P < 0.05$). Therefore the average value of Tr is significantly higher at 25 cm that 1 meter distance of the tree stem (TABLE III).

TABLE IV
TR INFORMATION AT 25 CM AND 1 METER DISTANCE OF THE TREE STEM IN *MACARANGA TANARIUS*

Macaranga tanarius	Minimum	Maximum	Mean	S.D.
25 cm	4.26	222.42	27.64	1.72
1 meter	4.95	96.60	23.81	0.97

ANCOVA analysis showed that there is no a significant difference in root tensile strength at 25 cm and 1 meter distance of the tree stem in M.tanarius ($P > 0.05$).

F. Root tensile strength variations intra species

The ANCOVA result showed the significant difference in root tensile strength in sample trees in M. tanarius (root diameter as covariate) ($P=0.00$; $P<0.01$). the results of ANCOVA showed that there is no significant differences in root tensile strength due to tree samples in A. mangium ($P= 0.207$; $P>0.05$).

IV. DISCUSSION

Root tensile strength decreased with increasing root diameter according to power law equation. Many authors concluded this relationship in their research [11, 4, 19]. The significant differences were found between two species in root tensile strength, tensile strength of *Acacia mangium* was significantly higher than that of *Macaranga tanarius*, this result is according to Reference [14] which found significant difference between two studied species in tensile strength in the same environment. Reference [20] mentioned that the difference in cellulose content can result the difference tensile strength between species. Many authors around the world analyzed root tensile strength of species and found different results. The diameter of root in A. mangium at 25 cm distance of the tree stem varied between 0.16 and 5.06, and this amount was between 0.11 and 5.02 at 1 meter distance of the tree stem. The root diameter of M. tanarius was 0.16-5.66 at 25 cm and 0.21-6.34 at 1 meter distance of the tree stem.

Reference [15] also stressed the significant difference between studied species in Italian Alps. In the study which

conducted by [1] on some Mediterranean species, they found that the maximum root tensile strength belonged to *Nerium oleander* (shrub) with 303 Mpa (D= 0.09 mm) followed by *Tamarix canariensis* with 267 MPa (D= 0.1 mm). This result is comparable to the recent paper, which the maximum tensile strength for Acacia mangium at 25 cm was 304.88 MPa (D= 0.22) and the maximum tensile strength for *Macaranga tanarius* at 25 cm was 222.42 MPa (D= 0.21). Burylo et al., (2011) found the significant difference in tensile strength of different species in the Southern Alps, France. Root tensile strength of *spartium junceum* was analysed by [21] and they found the mean of root tensile strength of 31.7 MPa and the amount of maximum and minimum of 65MPa and 9.7 MPa. Although the maximum of root tensile strength in M. tanaris was much higher (222.42 MPa) at 25 cm of the tree stem than *spartium junceum* (65 MPa), but the mean root tensile strength of *spartium junceum* (31.7 MPa) is comparable to the mean of *Macaranga tanarius* at 25 cm (27.64 MPa). Significant differences were found in root tensile strength at 25 cm and 1 meter distance of the tree stem in the same species and that was significantly higher at 25 cm of the tree stem. It means that roots near the stem had more mechanical resistance in tension rather than roots far from the stem.

Root tensile strength among tree samples in M. tanarius showed significant difference, but this result was not significant among tree samples in A. mangium. Reference [20] stated that root cellulous influenced on root chemical content and also root chemical content is influenced by root morphology and in consequence by local environment, therefore more studies are necessary to analyze the root tensile strength variations in and among species in the same site.

The positive effect of vegetation roots to prevent erosion is through the mechanical effect of roots in tension. With distance from the tree the effect of roots to resist to soil failure decrease. This result is in agreement by the research conducted by [22], which soil near the tree stem is stronger. The same finding was concluded by [23], which the roots effect on soil strength to failure is much higher close to the tree stem and this value can be negligible more than 1 meter distance far from the tree stem. This differences/similarity in root tensile strength of different species may interpret by the differences in environmental situation and root characteristic system in different environment. These differences might be qualified to differences in root architecture and root age between species, soil type, and climate between environments. Therefore, interdisciplinary approach is needed to investigate the different factors on species to analyze root tensile strength at different environment.

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