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Original Article

THE EFFECT OF ROOT AND LITTER ON SOIL MACROPOROSITY OF *Terminalia microcarpa* AND *Dillenia philippinensis* IN PURWODADI BOTANICAL GARDEN

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ABSTRACT

D. philippinensis or Sempur (Java) and *T. microcarpa* are dominated most of vegetation in Purwodadi Botanical Garden area that will be muddy after rain. This condition can be suspected as the effect of low soil macroporosity. This study aim was to observe the effect of root quantity and litter quality surround *Terminalia* and *Dillenia* trees. Root quantity parameters which observed were Lrv (Root Length Density) dan Drv (Dry Root Mass). Sample was taken using drilling method and roots were measured using line interception method. Soil macroporosity was measured using methylene blue staining. Litter decomposed in forest floor, it weight then measures on 12 weeks after taken. Soil macroporosity higher in soil surround *Dillenia* than *Terminalia*. Soil macroporosity surround *Terminalia* and *Dillenia* are not significantly correlated to Lrv (Root Length Density) dan Drv (Dry Root Mass). While, decomposition rate of litter has correlated to macroporosity, especially on *Terminalia*.

Keywords: *Root, litter, macroporosity.*

INTRODUCTION

Soil hidrology is one of main factor which affected on soil living organism, plant and human are included. Soil hidrological condition is determined by water infiltration into soil. There are some factors which determine infiltration. One of the factors is soil macroporosity. Soil macroporosity as general soil physical quality indicator influences water infiltration into soil (Droogers et al. 1998; Laio et al. 2001; Razafindrabe et al., 2006; Rivenshield & Bassuk, 2007; Farahani et al. 2009).

Plant has important role in soil macroporosity condition. Root and leaf litter affect on soil biological activities. Root growth will suppress and loosen soil aggregates which close together. Root water arbsorption on plants which live in forest influence soil condition surround them, such as soil dehydration, soil shrinkage, and small fractures formation. These root activities induce bigger pores (macroporosity) formation. Forest rooting condition allows rain water easily infiltrates into deeper soil layers then flow laterally under soil surface (Susswein et al., 2001). The spread root in soil layers increases soil organic matter contents and loosen soil pore, it then increaseas water volume which infiltrated into soil (Asdak, 1995).

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Hairiah et al. (2006) stated that macroporosity has positive correlation to water infiltration; higher macroporosity will cause higher constant infiltration.

Rotten organic matter is highy able water absorbent. Litter on soil surface keep soil friability and improve soil structure. Protection of litter will keep macroporosity from damage by direct stroke of rain water. It also provides nutrition for soil organism, such as worm as soil digger Hairiah et al. (2006).

Macroporosity can be affected by various factors such as formed gap by soil matrix condensity, root activity, soil animal, soil swell, soil cracking, and soil shrinkage (Hornberger et al., 1990; Francis & Fraser, 1998; Rivenshield & Bassuk, 2007). Plant rooting can be consisted of active roots or died roots. Both of died roots and active roots form empty space which will be filled by infiltrated water (Schoonderbeek & Schoute, 1993). Big macropore space cause higher water infiltration rate.

D. philippinensis or Sempur (Java) and *T. microcarpa* are dominated most of vegetation in Purwodadi Botanical Garden area that will be muddy after rain. Hidrological imbalance caused by domination of these vegetations prevents optimal rain water infiltration. The effect of vegetation factor on soil hidrological condition especially macroporosity is observed in this study. Some parameters are observed such as secondary root length, mass, and litter quality. This study aim to investigate the relationship between root quantity and litter quality of certain trees also observe its effect on soil macroporosity surround the trees. So that will give information about the hydrological phenomena that occur surrounding *Dillenia* and *Terminalia*.

METHODS

This study was conducted from February – June 2012 at Purwodadi Botanical Garden, Pasuruan, East Java. Based on climate observations in 2005 – 2009, it was recorded an average rainfall 2018 mm/ year; relative humidity 70-80%; monthly relative air humidity varied between 67.41 to 89.89% (Solikin, 2009). Plants which observed in this study were *T. microcarpa and D. philippinensis*. These plants are collection for reforestation of Purwodadi Botanical Garden. Plants which observed were aged 20 years and have good root condition (not influenced by another plant). Root samples were taken from 3 differents soil depth (0-10cm, 10-20 cm, 20-30 cm from soil surface) with 3 repetitions. Root length density (Lrv) and root dry mass (Drv) were measured on 2 meters distance from the trees by taking soil sample with drilling method. Root mass and length were measured each soil unit volume. Litter samples were taken from each tree with 6 repetitions. Litter then naturally decomposed in forest floor, it weight then measures on 12 weeks after taken.

Lrv Measurement

Secondary root mass was measured using drilling method. Soil was taken out from 10, 20, and 30 cm of depth. Soil sample weight was measured into 500 gram then mixed with water and filtered to get plant roots in various sizes. Root length can be estimated using grid method (Tennant in Smit, 2000). Root length total (Lrv, cm cm-3) can be calculated using this formula:

$$Lrv = \frac{\pi\{(H+V)D\}/4}{soil\ volume}$$

D = grid size (cm) H = crossed horizontal box V = crossed vertical box (Tennant in Smit, 2000)

Drv Measurement

Drv measured roots were collected, squeezed, and pressed until formed root balls. These root balls the put into paper envelope and dried in the oven on 80o C of temperature for 48 hours. Dried root mass then measured (Drv, g cm-3) (Tennant in Smith, 2000).

Soil Macroporosity

Soil macroporosity was measured using mapping method. Soil was filled with blue solution (methylene blue) and allowed for overnight until the solution was infiltrated to soil pore. Blue solution would leave blue track on its passed soil pores. Blue tracks which appear on soil were identified as soil macroporosity. Distributed blue colors were drawed in clear plastique (Bouma, 1981; van Stiphout et al. 1987; Hatano, 1992). Blue color distribution on each plot was analyzed using Adobe Photoshop.

Macroporosity percentage was measured for each 50x50 cm^2 square. They were identified as soil macro pores. Surface-connected soil macroporosity was measured based on the infiltration pattern of methylene blue dye (Suprayogo et al., 2004).

Soil Physical and Chemical Properties

Macroporosity dependent variables were also measured such as soil physical and chemical properties. They were Bulk Density (BD), Gravity (BJ), porosity, soil texture and structure, soil organic content, and porosity of the land; they were measured in of Soil Physical and Chemistry Laboratory at Brawijaya University , Malang. Dry bulk density (BD) was measured by taking samples of soil using metal cylinders of approximately 100 cm3 volume (5.02 cm diameter and 5.05 cm length) with with six replicas of samples taken from each plot. The samples were collected from the 0–15 cm soil layer. The core samples were collected there in October 2011 and 2012. The samples were weighed and dried (at 105 °C) until they reached a constant weight. Total porosity (TP) was calculated on the basis of results of particle density (PD) and bulk density (BD). The PD was determined using pycnometric method. Analysis of soil texture (% sand, silt, and clay) using the pipette method, pH (1 N KCl), pH (H2O), Corg (Wakley and Black method; Anderson and Ingram, 1993), and N tot (Kjeldahl method; Anderson and Ingram, 1993).

Litter Quality Assessment

Leaf litter was taken a few grams than weighed and analyzed to determine the content of some nutrient elements. To measure the decomposition rates, the litter were put into the litter bag polyvinyl bags with a mesh size of 5 mm (Tian, 1992; Anderson, et al., 1993), put back in the soil surround the plant. During the 12-week weight reduction measured and considered as a mass decomposed litter. The mass of litter which live in litterbag were identified as residual of litter.

Table 1. *Dillenia* and *Terminalia* Macroporosity Percentage

Height Phase	Macroporosity (%)	
	Dillenia	*Terminalia*
0-10 cm	15.908	8.85
10-20 cm	6.055	4.60
20-30 cm	2.744	0.64

Table 2. Lrv and Drv values of roots surround *Dillenia* and *Terminalia* trees

Vegetation	Lrv (cm/cm^3)	Drv (g/cm^3)	Macroporosity (%)
Dillenia			
0-10 cm	0.1135	0.000506879	15.908
10-20 cm	0.2695	0.000289646	6.055
20-30 cm	0.103	0.000226285	2.744
Terminalia			
0-10 cm	0.0815	0.000778422	8.85
10-20 cm	0.117	0.001240044	4.60
20-30 cm	0.0925	0.000398262	0.64

Table 3. Decomposed litter and macroporosity on *Dillenia* and *Terminalia*

Vegetation	*Macroporosity (%)*	*Residual of Litter (%)*
Dillenia	8.75	45.164
Terminalia	5.88	14.377

RESULTS

Macroporosity of each plant were different (Table 1). Bigger macroporosity was found in soil surround Sempur (*Dillenia*). Higher macroporosity which found in soil will allow faster water movement below soil surface (Hillel, 1982; Hatano et al. 1992).

Rooting and Macroporosity Relationship

Roots which obtained from drilling method were calculated. The interception line of the roots on a millimeter graphic paper raised value of Lrv (Root Length Density) and ovened the mass raised value of Drv (Root Dry Mass). Lrv and Drv value of each plant are shown on Table 2. Roots were found least at 0-10 cm of soil depth, then found in higher amount at 10-20 cm of depth, and decreased at 20-30 cm of depth. Drv value decreased when roots were taken from deeper soil depth.

Dillenia and *Terminalia* Lrv and Drv values were not correlated to macroporosity which shown with statistical analysis results above 1. Lrv and macroporosity relationship of soil surround *Dillenia* plant was negative which means the longer secondary root, the smaller its macroporosity. Both of Lrv and Drv were not significant affected on macroporosity (p value > 0.05). It means that these factor were probably correlated but with more than 30% of error level.

Litter Quality and Macroporosity Relationship

Litter quality is one of vegetation factor which determine macroporosity. Litter which observed in this study was decomposed and its nutrients were measured. Mass of decomposed litter will decreased day by day. The results of measurements of weight reduction of *Terminalia* and *Dillenia* litter are presented in Table 3. *Dillenia* has greater macroporosity value n residual of litter than *Terminalia*.

Negative correlation between litter residu and macroporosity on *Terminalia* (R= -0.830) is higher than on *Dillenia* (R= - 0.679). Decomposed litter amount was not significantly affected on macroporosity of soil surround *Dillenia* tree (Figure 3). While, it was significantly affected on macroporosity of soil surround *Terminalia* tree (p value < 0.05).

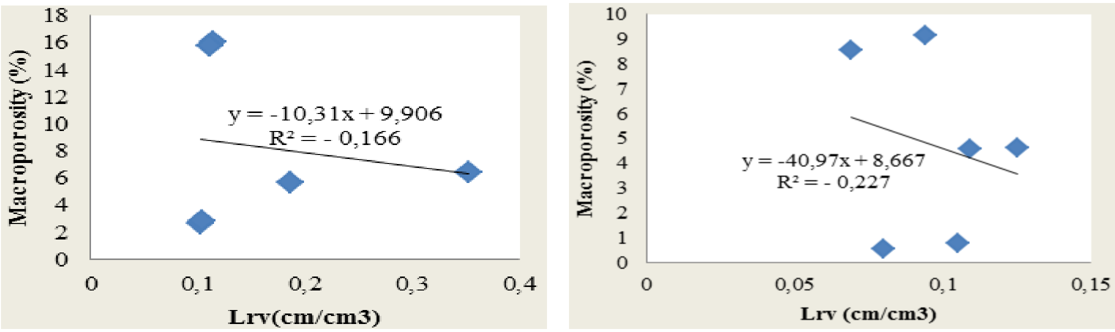

Figure 1. Lrv relationship with macroporosity on a) *Dillenia* b) *Terminalia*

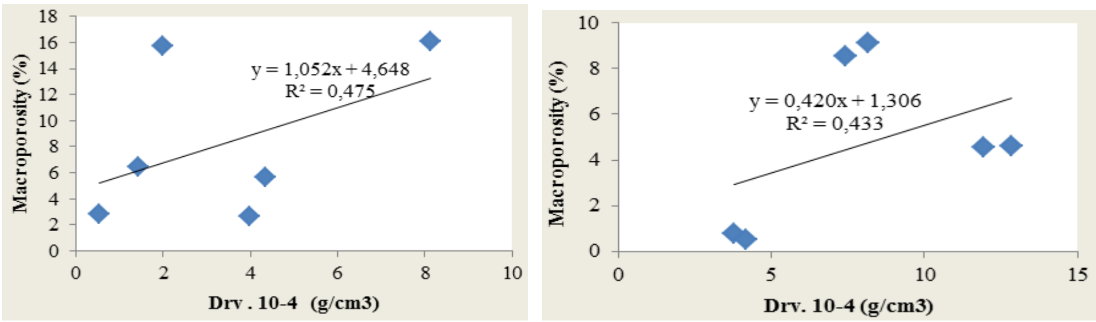

Figure 2. Drv relationship with macroporosity on a) *Dillenia* b) *Terminalia*

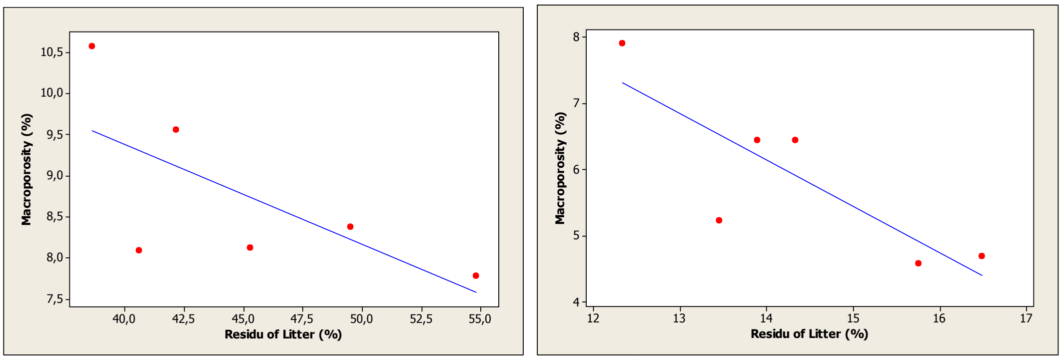

Figure 3. Relationship between litter mass with macroporosity of soil surround a) *Dillenia* (b) *Terminalia*

DISCUSSION

Rooting - Macroporosity Relationship

Macroporosity is normally formed by high root activities on soil. Root branches are found in small amount in 0-10 cm of soil depth and will be more branches are found in 10-20 cm of soil depth. Lrv and macroporosity is not significantly correlated, but the higher Lrv tend to correlated with lower macroporosity. The correlation coefficient of Lrv and macroporosity shows that Lrv is not significantly affect on macroporosity. It can be suspected that macroporosity of soil surround *Dillenia* and *Terminalia* are probably determined by other factors.

Pore amount and size determine the water infiltration process on soil. Big soil pores mainly determine water infiltration ability of soil. More big pores on soil will allow more water to infiltrate into it. Drv is one of factor that determines macroporosity. Higher Drv correlated to higher mcroporosity (Figure 2). Statistical analysis shown there is no correlation between Drv and macroporosity. These conditions can be suspected that there is correlation between soil physical and chemical properties with macroporosity. Table 6 is the result of the measurement and analysis which describes the average number of physical and chemical properties of soil in Purwodadi botanical Garden, especially in plots where samples were taken.

Table 4. Physical and chemical properties on soil surround *Dillenia* and *Terminalia* trees

Properties	*Dillenia*	*Terminalia*
BD (g/cm3)	1.06	1.03
SG (g/cm3)	2.32	2.3
Porosity (%)	54.22	55.2
Sand (%)	9	15
Dust (%)	66	51
Clay (%)	25	34
Texture Class	Dusty clay loam	Dusty clay loam
C Organic (%)	3.48	2.865
Organic Matter (%)	6.01	3.94

Soil macroporosity is probably affected by origin soil condition because narrow secondary root is not significantly affects on macroporosity of soil surround it. Organic matter level has an important role in macroporosity. Soil bulk density represents soil density. Higher soil bulk density level lead less macroporosity. Soil bulk density increases according to soil depth. The more soil depth will be less soil organic matter, rooting activities, biotic, and peat content will be found (Lal dan Greenland, 1979). Soil bulk density becomes less on deeper soil depth surround *Dillenia* and *Terminalia* (Table 2). Organic matter content on soil is correlated with microorganism and decomposer activities. The activity of soil microorganism and decomposer form more space between soil particles that increases soil macroporosity. Small amount of organic C on dusty peat soil texture inhibit the water infiltration into soil. This condition leads to watery area formation in observation area.

Tree architectural factor also probably affect on soil hidrological condition. *Terminalia* architecture form aubreville model with craggy tree branches and > 45^{o} plagiotropical branching angle. Leaves are mosltly found in the end of branch with formula 2/5 and divergence angle 144°. These characteristics caused more pores formed between leaves canopy that allow rain water easily through leaves and become surface water (Solikin and Darmayanti, 2013). Fallen surface water disrupts soil pores and reduces macroporosity. It can be suspected as the reason of *Terminalia* macroporosity is smaller than *Dillenia* which has denser canopy.

Litter – Macroporosity Relationship

Terminalia leaf is thinner than *Dillenia* leaf that causes *Terminalia* leaf is easier to be decomposed. Leaf litter of *Terminalia* is faster reduced tha *Dillenia* litter when it leaves on soil surface for 12 weeks (Table 3). Litter decomposition rate is determined by the quality of leaf composition such as C:N ratio, lignin, and polyphenols (Kaushal and Verma, 2003; Hoorens et al., 2010). High quality litter has C:N ratio < 25, lignin <15%, and polyphenol <3% (Hairiah et al., 2006).

Both of *Dillenia* and *Terminalia* litters have high C:N ratio, polyphenol, and lignin that caused their litter decomposition rate are slow, although based on statistical analysis no significant effect caused by *Dillenia* litter on the soil macroporosity. Soil carbon dynamic observation on 4 land cover types show that 45-55% of litter will be decomposed and form metabolic substances such as lignin and polyphenol with N structure (Parton et al., 1987). Low quality of litter can protects soil from rain water pressure which can disrupt soil macroporosity which supported by Hairiah, et al (2006) that low quality of litter will give more benefit to soil conservation compare to high quality litter from Leguminoceae. High quality litter will sustain good humidity and soil temperature in suitable ecosystem condition.

Table 5. Chemical component of *Dillenia* and *Terminalia* litter

Vegetation	C/N	Organic Matter	Polyphenol (%)	Lignin (%)
Dillenia	34	59.04	13.32	28.24
Terminalia	29	65.4	26.37	35.87

Higher decomposition rate will sustain higher soil macroporosity (Figure 4). Fallen leaf which forms litter will provide nutrition to soil organism, such as worm and other small invertebrates. Soil organism activities take an important role in macroporosity formation. Some of it will leave underground holes which can be passed by infiltrated water (Hairiah et al., 2004). The quality of litter input may affect the abundance and diversity of earthworms from the ecosystem engineer groupwhich modify soil structure (Lavelle, et al., 1994; Wardle, et al., 1997). Research has shown that Pontoscolex species produce granular casts that destroy the soil structure as large aggregates are broken down into smaller pieces, reducing soil macroporosity and increasing soil micropores (Lavelle, et al., 2001). But different from what happened in the research of Van Lauwe et al., 1997 which states that decomposed litter with high polyphenol and lignin ratio reported has no significant effect on microbial C growth (i.e., implying that microbial activity would not be diminished). That can be the reason why there was little or no significant effect of *Terminalia* and *Dillenia* decomposed litter on soil macroporosity (based on nutrient content of the litter in Table 5).

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