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Accelerating the growth of red meranti (*Shorea leprosula*) wildlings by utilizing better topsoil media from under mother trees and optimum tending duration in a simple greenhouse

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Abstract

Topsoil under mother trees has been being used for substrates or media of growing wildlings in the nursery in the forest, but information about where the positions of the topsoil should be collected from the base of mother trees was not sufficiently studied. The study divided the positions into three parts: the closest, the middle, and the farthest positions from the base of mother trees within the projection of the crown of the mother trees. In addition, wildlings used as seedling stocks usually suffer from stress because of extraction from the original sites and transportation process, so they need tending in a simple greenhouse. The study divided the tending duration into four periods: without tending, two weeks, three weeks, and four weeks. The experimental design used was a factorial 3 × 4 with a randomized complete design. Based on the F-test, the positions of topsoil from mother trees and tending duration in a simple greenhouse separately affected the growth of the wildlings. With the least significant difference level of 5%, the results showed that the topsoil close to the base of mother trees, and tending for 3-4 weeks in the simple greenhouse yielded the best growth for the red meranti (*Shorea leprosula*) wildlings.

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Introduction

Red meranti (*Shorea leprosula*) is one of tree species from Dipterocarpaceae family that ecologically dominating tropical forests in Southeast Asia including Indonesia. The family is economically significant because the Dipterocarps account for 80% of timber exports supporting the revenue of many developing countries (Kettle, 2010). The species has high demand because they supply wood industries and wood construction with raw materials. The need of industries and housing for the red meranti is getting higher from year to year because the forests producing the red meranti species decrease from time to time. As a result, the demand and supply is not balance. Demand is much higher than supply; therefore, cultivation of the tree species is crucial to do.

One problem in cultivating the red meranti is seedling procurement in adequate quantity and in the right time. This is because the red meranti does not bear fruits and seeds regularly. Sometimes they bear fruits every two years or even every ten years (Ashton *et al.*, 1998). In addition, seeds of red meranti are recalcitrant - cannot be stored for long periods (Adjers and Otsamo 1996 in Kettle, 2010). To address the problem, wildlings (wild seedlings) around mother trees can be utilized for planting stocks. Some advantages in utilizing the wildlings for planting stocks are: no problems with seed germination; the wildlings are growing gratis in natural forests so the time needed for seedling procurement is shorter and the price per seedling is cheaper; and the wildlings have been inoculated with mycorrhizae (Smith, 1990). Djers *et al.* (1998) also reported that performance of wildlings in the field was better than that of seedlings with some reasons, i.e. the wildlings collected from natural forests have gone through a natural selection, and the wildlings may have a better developed mycorrhizal association. However, in procurement process of the wildlings; they mostly undergo two problems that make them stressed, i.e. they suffer from root damage when they are extracted from original sites, and they suffer from dryness during transportation from the original places to nurseries around planting positions.

Therefore, the wildlings should be given a specific treatment such as tending them in a simple greenhouse before they are planted in the field. By tending the wildlings in the simple greenhouse, they will grow in high temperature and high humidity. As such conditions the wildlings will grow optimally (Sagala, 1988). In addition, Djers *et al.* (1998) declared that duration of wildlings kept in a greenhouse had a significant effect on the survival of wildlings. The minimum duration in the greenhouse was three weeks and this resulted in acceptable survival.

In addition to wildling tending, positions of topsoil under mother trees within the projection of the crown of a mother tree used as a growth medium of wildlings should also be considered. The problem is where the positions of the topsoil under a mother tree should be used for growth media. In this case, it is presumed that topsoil that has different distance from a mother tree within the projection of a mother tree crown has different conditions in terms of pH and nutrients because of different microclimates. Therefore, the research examined the effects of topsoil from different distance to mother trees and tending duration in a simple greenhouse on the growth of red meranti wildlings (RMWs).

Nykvist (1996) found that in a 45-month-old plantation of *Acacia,* the total nitrogen, phosphorus, potassium, calcium, magnesium, manganese, and sodium in the humus layer and plant-available or exchangeable nutrients in the top 30 cm of the soil were lower than before planting owing to plant uptake and leaching. In contrast, Youkhana and Idol (2008) found that chemical soil properties such as pH, total soil organic matter and nitrogen, available potassium and phosphorus were all improved under the first year of *Leucaena leucocephala* and *Robinia pseudocasea* plantations. Vijayanathan *et al.* (2011) also found that plots where *Acacia mangium* trees were thinned showed increased levels of N, P, K and Ca because of larger amount of organic debris in these plots after thinning activities. Based on the three studies above, trees can increase or decrease soil pH and nutrients under the trees, but which parts of topsoil from the base of mother trees are good for growth media are not sufficiently studied.

Therefore, the study about effects of topsoil positions from the base of mother trees on growth of red meranti (*Shorea leprosula*) is interesting to do. The present study will support seedling procurement of tropical forest chiefly in a sustainable way without using inorganic fertilizer in the forest.

The aim of the study was to analyze the effects of the growth media under mother trees and the effects of a simple greenhouse on the growth of the RMWs. The study has tested whether or not the growth media with different positions from the base of a mother tree of red meranti had effects on the growth of the RMWs. The study also tested the function of a simple greenhouse in revitalizing the stressed wildlings because of removing from original sites.

Better topsoil in terms of nutrients under mother trees of red meranti in the forest is very important to study. Soil in the tropical forest is very poor so that it is needed to find the topsoil suitable for seedling growth. The present study had proved that the topsoil close to the base of mother trees was better than that in the middle or far locations from the base of the mother trees. In addition, the present study revealed that the simple greenhouse was successful to revitalize the RMWs from stress because of extracting from the original site. This information is very useful for collecting growth media in the tropical forest. This will support the nursery managers to accelerate the wilding growth in the nursery managed naturally and cheaply.

Materials and methods

The research was done in the nursery at working areas of the Sumalindo Forest Company Concessionaire. Geographically, the company is located at 114°54'-115°28' EL and 1°12'-1°31' SL. Materials used were 60 RMWs, and growth media of wildlings (topsoil) from three different positions under mother trees within the projection of the crown of the mother trees. Position 1 (A_1) is the closest topsoil to the base of mother trees, position 2 (A_2) is the middle topsoil, and position 3 (A_3) is the farthest topsoil from the base of the mother trees. Topsoil depth is about 0-15 cm.

The topsoil from the same positions under three mother trees were mixed, and then put into polybags as growth media for wildlings and then labeled. Also soil pH and nutrients of the topsoil at each position (A_1, A_2, and A_3) were analyzed in a laboratory. Furthermore, wildlings collected around the mother trees (within 9 m from the mother trees) were transplanted to the polybags. The wildlings used have around 17-28 cm high and 4-6 leaves. Larger wildlings will be risky because they are difficult to handle (Djers *et al*., 1998). Then the polybags that have been filled with substrate and planted with wildlings were put in the simple greenhouse; while the wildlings as control were put outside the greenhouse.

Equipments used were handy kit for preparing a simple greenhouse. The greenhouse had about 2 m long x 2 m wide x 2 m high and covered with plastic sheets. Other equipments were a hygro-thermometer for measuring temperature and relative humidity inside and outside the simple greenhouse, a ruler for measuring wildling height, a sprayer for watering the wildlings, polybags for wildling containers, a hoe and spade for collecting topsoil and preparing a nursery, tally-sheets and stationery for recording the research data.

Methods

Factors applied were topsoil positions (A) that consisted of the closest topsoil to the base of mother trees (A_1), the middle topsoil position (A_2), and the farthest topsoil from the base of the mother trees (A_3). The second factors were wildling tending duration (B) that encompassed without tending/control (B_0), 2 weeks (B_1), 3 weeks (B_2), and 4 weeks (B_3) of tending duration. The number of treatment interactions was 12 and each interaction consisted of 1 wildling and 5 replications. So, the number of wildlings planted/ tested was 60 wildlings.

The variables observed were height growth, leaf number increments, and survival percentage of the RMWs. Height growth was measured from the base of wildlings (1 cm from the soil surface) to the tip of a wildling stem. Leaf number increments were the difference between the number of leaves at the initial and at the end of observation.

Survival percentage was the ratio of the number of wildlings survived to the total wildlings planted multiplied by 100%.

Analysis

The experimental design applied was a factorial 3 × 4 in a randomized complete design using the Statistical Package for the Social Sciences (SPSS) software. Significance effects among treatments on each variable were analyzed with the least significant difference (LSD) test at critical level of 5%.

Results

Height Growth

Based on the F-test or the tests of between-subjects effects (Table 1), the factor of topsoil positions (A) significantly affected the height growth of the RMWs (p-value 0.08 < 0.10).

The factor of wildling tending duration (B) also significantly affected the height growth of the RMWs (p-value 0.00< 0.10). The two factors affected the height growth of the RMWs separately.

Based on the LSD test (Table 2), the treatment of the closest topsoil to mother trees (A_1) resulted in the highest height growth on the RMWs.

The treatment was significantly different from the treatment of the farthest topsoil from the mother trees (A_3), but it was not significantly different from the middle one (A_2).

Table 1. The F-test of effects of topsoil positions and tending duration on height growth of red meranti wildlings.

Tests of Between-Subjects Effects					
Dependent Variable: Height Growth					
Source	Sum of Squares	Degrees of Freedom	Mean Square	F	Sig.
Topsoil Positions	.23	2	.11	2.66	.08
Tending Duration	1.73	3	.58	13.47	.00
Topsoil * Tending	.14	6	.02	.54	.78
Error	2.06	48	.04		
Total	119.50	60			
Corrected Total	4.15	59			

Table 2. The multiple comparison effects among topsoil positions on height growth of red meranti wildlings.

(I) Topsoil Position	(J) Topsoil Position	Mean (cm)	Mean Difference (I-J)	Sig.
Close	Middle	1.41	.04	.49
	Far	1.30	.15*	.03
Middle	Close	1.45	-.04	.49
	Far	1.30	.11	.13
Far	Close	1.45	-.15*	.03
	Middle	1.41	-.11	.13

*.The mean difference is significant at the .05 level based on the LSD test.

In addition, on the basis of the LSD test (Table 3), wildlings tended for 4 weeks (B_3) resulted in the highest height growth of the RMWs. The treatment was significantly different from the wildlings tended for 2 weeks (B_1) and the wildlings tended for 3 weeks (B_2).

This meant that the optimum duration of the wildlings tended in the simple greenhouse for height growth of the RMWs was 4 weeks.

It was surprising that the wildlings without tending in the greenhouse had higher height growth than those were tended in the greenhouse.

Table 3. The multiple comparison effects among tending duration on height growth of red meranti wildlings.

(I) Tending	(J) Tending	Mean (cm)	Mean Difference (I-J)	Sig.
Without Tending	2 Weeks	1.14	.43*	.00
	3 Weeks	1.33	.24*	.00
	4 Weeks	1.51	.06	.40
2 Weeks	Without Tending	1.57	-.43*	.00
	3 Weeks	1.33	-.19*	.02
	4 Weeks	1.51	-.37*	.00
3 Weeks	Without Tending	1.57	-.24*	.00
	2 Weeks	1.14	.19*	.02
	4 Weeks	1.51	-.18*	.02
4 Weeks	Without Tending	1.57	-.06	.40
	2 Weeks	1.14	.37*	.00
	3 Weeks	1.33	.18*	.02

*. The mean difference is significant at the .05 level based on the LSD test.

Leaf Number Increments

The F-test (Table 4) showed that the factor of topsoil positions (A) significantly affected the leaf number increment of the RMWs (p-value 0.07 < 0.10). The factor of tending duration (B) also significantly influenced the leaf number increment (p-value 0.02 < 0.10). The two factors affected the the leaf number increment of the RMWs separately.

Table 4. The F-test of effects of topsoil positions and tending duration on leaf number increments of red meranti wildlings.

Tests of Between-Subjects Effects					
Dependent Variable: Leaf Number Increments					
Source	Sum of Squares	Degrees of Freedom	Mean Square	F	Sig.
Topsoil	.41	2	.21	2.82	.07
Tending	.80	3	.27	3.68	.02
Topsoil * Tending	.19	6	.03	.43	.86
Error	3.49	48	.07		
Total	107.98	60			
Corrected Total	4.88	59			

The LSD test (Table 5) indicated that the treatment of the closest topsoil to the mother tree (A_1) significantly affected the increment of leaf numbers of the RMWs. This treatment was significantly different from the treatment of the farthest topsoil from the mother tree (A_3), but it was not. Significantly different from the middle one (A_2). The LSD test (Table 6) showed that the wildlings tended for 3 weeks had the highest leaf number increment. This was significantly different from the wildlings tended for 4 weeks and without tending (control), yet it was not different from the wildlings tended for 2 weeks.

Table 5. The multiple comparison effects among topsoil positions on leaf number increments of red meranti wildlings.

(I) Topsoil Position	(J) Topsoil Position	Mean (sheet)	Mean Difference (I-J)	Sig.
Close	Middle	1.30	.12	.18
	Far	1.22	.20*	.02
Middle	Close	1.42	-.12	.18
	Far	1.22	.08	.33
Far	Close	1.42	-.20*	.02
	Middle	1.30	-.08	.33

*. The mean difference is significant at the .05 level based on the LSD test.

Table 6. The multiple comparison effects among tending duration on leaf number increments of red meranti wildlings

(I) Tending Duration	(J) Tending Duration	Mean (sheet)	Mean Difference (I-J)	Sig.
Without Tending	2 Weeks	1.38	-.18	.08
	3 Weeks	1.47	-.27*	.01
	4 Weeks	1.20	.00	.10
2 Weeks	Without Tending	1.20	.18	.08
	3 Weeks	1.47	-.09	.37
	4 Weeks	1.20	.18	.08
3 Weeks	Without Tending	1.20	.27*	.01
	2 Weeks	1.38	.09	.37
	4 Weeks	1.20	.27*	.01
4 Weeks	Without Tending	1.20	-.00	.10
	2 Weeks	1.38	-.18	.08
	3 Weeks	1.47	-.27*	.01

*. The mean difference is significant at the .05 level based on the LSD test.

Survival Percentage

All wildlings tested survived. That meant that there were no different effects between factors and among treatments on the growth of RMWs in terms of survival percentage.

Discussion

Based on the height growth and leaf number increment variables, the closest topsoil to mother trees had better effect than that of the middle and the farthest topsoil from the base of the mother trees. This might be related to pH and macronutrients contained by the topsoil under mother trees.

On the basis of the topsoil analysis (Table 7), the topsoil close to the mother trees had higher pH, total nitrogen, available phosphorus, potassium, and calcium than those of the middle and farthest positions from the mother trees.

Those natural chemical properties of soil are very important factors supporting the wildling growth. This is because most soils in tropical forests especially at the yellow-red podzolic soil have low nutrients and pH because of high precipitation and leaching. So if there are specific sites that have a slightly higher nutrients and pH, the sites are important to utilize for growth media.

Table 7. Topsoil analysis.

Topsoil A_1 (close position to mother tree)		
pH/Nutrient	Unit	Value
pH (H2O)	-	4.09
N total	%	0.34
Available P	ppm	4.02
K (Kalium) or Potassium	ml/100 g	0.79
Ca (Calcium)	ml/100 g	18.06
Topsoil A_2 (middle position from mother tree)		
pH/Nutrient	Unit	Value
pH (H2O)	-	4.01
N total	%	0.31
Available P	ppm	3.89
K (Kalium) or Potassium	ml/100 g	0.61
Ca (Calcium)	ml/100 g	15.02
Topsoil A_3 (far position from mother tree)		
pH/Nutrient	Unit	Value
pH (H2O)	-	3.96
N total	%	0.26
Available P	ppm	3.65
K (Kalium) or Potassium	ml/100 g	0.34
Ca (Calcium)	ml/100 g	14.06

Source: Research Institute for Swamp Plants, 2012.

It is unsure that by supplying inorganic nutrients to media or substrates through fertilizer, they will be useful for the wildling growth. Kannan & Paliwal (2008) had studied about the effects of nitrogen, phosphorus, and potash fertilizers on *Cassia siamea* seedlings under nursery conditions. Kannan & Paliwal (2008) concluded that the effects of nitrogen increased seedling growth, whereas phosphorus or potash fertilizers, either separately or in combination, did not improve seedling growth. It was concluded that natural chemical properties of soil are very important factors supporting the wildling growth, and therefore findings in the present research showing that the topsoil located close to the base of mother trees is very useful in cultivating trees, especially when utilizing topsoil from the forests as growth media.

In addition to nutrients, soil pH is also very important for supporting the growth of trees, particularly in the acid soils like in tropical forest in Borneo. Baillie (1996) in Baillie *et al*. (2006) stated that many tropical forests grow in poor soils because of lack available nutrients, and availability of nutrients is highly determined by soil pH level. Khadka *et al*. (2016) stated that availability of macronutrients is highly dependent on the soil pH. Therefore maintenance of optimum soil pH (neither acidic nor alkali) is imperative for reducing the unavailability of macronutrient problems. According to Fuji (2014), in tropical forests, soil fertility is low (low soil pH) because of soil acidification and nutrient loss. The soil acidification and nutrient loss are a result of large amounts of precipitation that exceeds evaporation. Furthermore, low pH and nutrient deficiency will limit plant production. This statement supported the topsoil taken under mother trees especially the one close to the base of mother trees. The topsoil close to the mother trees had higher pH and nutrients (Table 7).

This is probably because the topsoil located under mother trees did not get severe leaching as the impact of high precipitation. Gindaba *et al*. (2005) found that trees on farms could keep soil fertile through protection from leaching, and organic matter decomposition on the soil surface under their canopies.

In addition to nutrients and soil pH, the topsoil under mother trees was presumed to contain more mycorrhizae. Smits (1988) stated that inoculation techniques using topsoil from under mother trees have advantages because the topsoil often contains various fungi and probably some of them can form ectomycorrhizae with the seedling inoculated. Likewise, Sabirin (1991) stated that at forest floors, many kinds of fungi grow to form my corrhizae, particularly at leaf litter and humid sites that are deficient of sunlight. Additionally, Smith (1988) affirmed that the topsoil used for inoculating mycorrhizae should be collected from as close as possible sites to mother trees.

The reason for this might be because the topsoil close to the mother trees is moister than that in the middle and far locations from the mother trees. Kramer and Kozlowski (1979) explained that when several species of fungi invade a single host, they often show variable sensitivity to soil moisture. A white fungus for example, the major my corrhiza former is dominant when soil moisture is high, but is absent under drought conditions. According to Fuji (2014), in adapting to the soil phosphorus deficiency, the roots of specific trees and rhizophore of fungi can release organic acids and enzymes for nutrient acquirement. The organic acids can support the solubility of phosphorus bonded to aluminum and iron oxides from poor phosphorus soils. So, it was presumed that the topsoil close to mother trees besides contained higher pH and nutrients; it also contained more mycorrhizae that supported the red meranti wildling growth. Shib'li *et al*. (2013) concluded that abundance of arbuscular mycorrhizal fungi (AMF) can be used to estimate soil fertility because AMF has correlation with chemical, biological, and physical aspects of soil. Because in the present research, the mycorrhizae contained in the topsoil were not investigated, so it was suggested to study the mycorrhiza existence regarding to topsoil positions under mother trees in the future research.

Wildling tending duration that yielded the highest height growth was the tending duration for 4 weeks.

By tending the wildlings for 4 weeks in the simple greenhouse, the wildlings were growing in higher temperature and humidity. The simple greenhouse successfully accelerated the height growth and the leaf number increment of the wildlings because it was able to increase temperature from 25.7°C to 28.1°C and increase relative humidity from 76% to 86.3% on average. The higher temperature was caused by the greenhouse effect, whereas higher humidity was caused by the water spraying the wildlings in the simple green house every day during the observation. Jia *et al.* (2015) found that daylight temperature of 25-30°C and night temperature of 20-25°C were effective to support the growth of *Gerbera jamesonii.* On the other hand, if plants suffer from water deficiency, they will grow abnormally. Ozenç (2008) found that water deficiency negatively affected seedling growth and transpiration rates. When water deficit increased, total dry matter content of seedlings, plant height, and transpiration decreased. Sánchez - Blanco *et al.* (2004) also stated that water deficiency caused plant tissue dehydrated and ineffectiveness of stomata activities. With higher temperature and humidity, the wildlings underwent high transpiration resulted in high nutrient uptake. Kramer and Kozlowski (1960) reported that transpiration process can increase absorption and translocation of minerals. Likewise, the other physiological process like photosynthesis also proceeds optimally because water needed for the photosynthesis process was in favorable conditions.

After tending for 4 weeks in a simple greenhouse the wildling growth mostly decreased. This might occurred because mycorrhizae cannot acclimatize to the high temperature for more than 4 weeks. Leppe & Smith (1988) stated that seedlings should be maintained in a greenhouse about 3 or 4 weeks and temperature does not exceed 28°C because it can hamper the mycorrhiza growth. In addition, Kramer and Kozlowski (1960) explained that direct effects of high temperature often causes seedling injury, while indirect effects of high temperature often causes reduced growth. The latter occurred due to photosynthesis begins to reduce rapidly after a critical high temperature is reached. This is because respiration usually continues to rise above that temperature while actual photosynthesis does not.

For the wildlings without tending in the greenhouse (control) that have higher height growth than those were tended in the greenhouse, they might be caused by shade. The wildlings without tending in the greenhouse were placed under shading nets, while the greenhouse was placed at an open place. Jensen *et al.* (1998) stated that the important external factor influencing the growth and development of plants is the light, and auxin is one of the major hormones regulating the plant growth and development. Neff *et al.* (2006) explained that hypocotyl cells exposed to light at the soil/air interface stopped elongating whereas the apical meristems and cotyledons expanded, became photosynthetic and developed as juvenile plants competing for optimal light conditions. In addition, according to Harjadi (1983), the height growth of plants is highly determined by sunlight. Plants with less sunlight will grow faster vertically, but if they receive full sunlight, they tend to grow laterally. This is related to auxin activities. Kramer and Kozlowski (1960) added that if seedlings receive full sunlight, auxin at apical meristems will active and come down to the stem and will trigger lateral growth.

Conclusions and recommendations

Topsoil positions within the projection of the crown of mother trees had significant effects on acceleration of the growth of RMWs. The closest topsoil to mother trees had the best effects on growth of RMWs. Tending RMWs in a simple greenhouse had also significant effects on acceleration of the red meranti growth. Tending the wildlings for 3-4 weeks was the best treatment for red meranti wildling growth. Since there was no interactive effect between topsoil positions and wildling tending duration, the two factors can be applied separately. It is recommended to utilize the topsoil close to the base of mother trees for growth media of RMWs, and or tending the RMWs for 3-4 weeks in the simple greenhouse. The mycorrhizae under mother trees that were presumed to support the red meranti wildling growth should be studied in detail in the future research because they were not studied in the present research.

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