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The Performance of Water Mobilization and Transpiration in Oil Palm

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ABSTRACT

This study was being elucidated in order to understand the performance of water mobilization and transpiration in oil palm tree at the age of 2, 4, and 22 years old respectively. To gain that, we attempt to collect the data in regard with the large of total leaf surface (meter square), description on transpiration rate in total leaf surface (in ml/second/cm^2), the number of stomata at both top and bottom leaf surface, description of root anatomy and total number of roots, water retention, and transpiration. To measure the large of total leaf surface (meter square), we calculated the large of single leaf in (m^2), multiply with number of leaves per midrib, and total midrib. We quantified transpiration rate in total leaf surface (in ml/second/cm^2) using the method of cobalt chloride, and calculated the numbers of stomata at both top and bottom leaf surface microscopically, and observed and described qualitatively the palm oil root anatomy and total number of roots. We estimated water retention via calculating the percentage of water content in root and stem. Finally, we recorded the environment data such as air humidity, air temperature and light intensity during the observations. The result showed that in average the total leaf surface at one oil palm tree is 88.77 m^2; 102.55 m^2; and 134,91 m^2 at 2, 4, and 22 years old respectively. This larges of leaf are to accomplished the transpiration at the rate of 3.38; 5.69, and 1.24 (ml/second/cm^2) correspondingly. The number of stomata at bottom leaf surface is bigger than the one at top surface so that the bottom surface is mostly for the place of transpiration occurrence. The number of root for water absorption per palm oil shoot is 324 in average. We illustrated that young root anatomy is more compact and as the growth and development occured, the root is more complicated into root branch and root of the root branch. As the maturation occured, the tissue of mature organ of root branch was disrupted and blessingly to become easier and more effective for water absorption. Water retention was estimated on the data of water content at root (71,70% to 73,40%) in shoot (49,45 – 71,27%). In conclusion, the water mobilization in oil palm tree is a complicated, huge and very dynamics, from roots below the soil, absorbed into stem, and finally evaporated mostly into transpiration. The dynamics depend on its environment variables.

Keywords: *Oil palm tree, water mobilization, transpiration.*

1. INTRODUCTION

Oil palm consists of two species, namely *Elaeis guinensis,* and *Elaeis oleifera*). It belongs to a family member of Palmae, sub-family of Cocoidae (including coconut tree), genus *Elaeis* [1]. The height of the plant reached twenty meters or more at its fully developed. The plant stem is upright and sturdy, leaf fronds arranged spirally appears from the main stem, twenty in numbers up to 40 branchs. The root system comprises of primary and secondary root in the topsoil up to 140 centimeter in the soil. The leaves are a bunch, straight, spread or descending, long up to 3 to 5 meters in a developed plant. The leaf stalks are short, widen at the basic. Leave has thorns, fibrous along the margin from the sheath. Leaf sheets is as much as 100 to 160 pairs [2].

Indonesia belongs to a country which have a wide land for oil palm plantations. Most of the plantations products are crude palm oil (CPO), and the palm kernel oil. From both products, the farm oil palm yields a variety of consumable outcome such as cooking oil, margarine, soap, cosmetics, and some other products used in steel industry, wires, radio, leather dan farmacy industry [3]. More over, oil palm is also an important ingredients for non food products such as wax, paraffin, and biodisel fuels [4].

Indonesian oil palm plantations are expanded annually. According to FAO report (2007) [4], there are 43 countries which are the producers for world wide palm oil, and Indonesia occupies the largest producer in the world together with Nigeria. Indonesia and Malaysia alone are the suppliers for the product as big as 85 % worldwide palm oil. This is because of its highest excellence product of palm oil among other plant sources. In the world, there is 5.5 percent of volume of oil palm as one compares with the total of ten other type of other oil farms. The oil palm contributes to vegetable oil and fat as much as 32 % among ten other oil plant production [5].

Besides of economic advantages, the oil palm plantations has also raises a lot of critics about the disadvantage the plantation, one of them is the tendency of the monoculture of the plantation will give raise to the low canopy quality, increase number of pestiside and anorganik fertilizer consumption, low quality of microclimate stability, the need for 'replanting' programme after 25 years of the plantation, the soils experiencing a nutrient fatigue, and as a results there are a decrease in quality of soils, the quality and quantity of soil water. In long term it will give raise to the negative impact on social economics of the farmers [6].

In order to understand the water consumtion in the oil palm field we need to study on some aspects of water depletion in the field. One of them is to recognize the water mobilization from soils to the trees for plant metabolism system, and eventually evaporated via the process of transpiration. For the purposes this study will focuse on the performance of water mobilization and transpiration of oil oil palm tree (E*laeis guineensis*).

Specific purpose of this study is to gain the following: overview the surface area of each leaf, midrib and each oil palm tree; overview the amount of water that is moistened through the transpiration process on the surface of the leaves, on each oil palm tree; obtain environmental factors surrounding oil palm at the time of research; asses the number of stomata (i.e. leaf pores that serve to transpiration of water–the end of water mobilization) on the surface of oil palm leaves; get a morphological and anatomical picture of rooting, stems and leaves that enable the mobilization of water from the roots to the surface of the leaves; and get an idea of the function of oil palm stems as a vegetation community. This study was being elucidated in order to understand the performance of water mobilization and transpiration in oil palm tree at the age of 2, 4, and 22 years old respectively.

2. MATERIALS AND METHODS

To measure the large of total leaf surface (meter square), we calculated the large of single leaf in (m^2), multiply with the amount of leaf per midrib, and total midrib. We quantified transpiration rate in total leaf surface (in ml/second/cm^2) using the method of cobalt chloride, and calculated the numbers of stomata at both top and bottom leaf surface microscopically, and observed and described qualitatively the palm oil root anatomy and total number of roots. We estimated water retention via calculating the percentage of water content in root and stem. Finally, we recorded the environment data such as air humidity, air temperature and light intensity during the observations.

The research has been conducted in a period of three months (during June to August 2017) at the bio-nusantara plantation location of Pondok Kelapa District, Bengkulu Tengah Regency. To find data on leaf surface area, the following work is done:

a. Calculate the surface area of each leaf sheet, and calculate the length of each leaf on a leaf midrib (Lm), so that we will get Lm1, Lm2, Lm3, up to Lmn. Calculate the width of the base of the leaves on each leaf on the midrib (L), so that we get the values of L1, L2, L3 up to Ln value. The surface area of each leaf can be estimated by multiplying (Lm1).L2)/2.
b. Next is to calculate the number of leaves per frond and
c. Calculate the number of fronds per tree.

The Data a., b., and c. above is used to calculate the total surface area of the upper and lower leaves on each tree by multiplication of the three data above.

$$\text{Total area} = (a.).(b.).(c). \qquad (1)$$

The data obtained is used to calculate the total transpiration of trees to get an idea of the amount of water that is moistened through the process of transpiration on the surface of the leaves, which is carried out by observations of transpiration using cobalt chloride paper ($CoCl_2$).

At first whatman paper scissors width and paper length = 2 X 8 cm. Dip the Whatman piece of paper in a 10% $CoCl_2$ solution in aquadestilata, then dry in the oven at 70 to 80 degrees.Wait until it is dry red pink. Store this cobalt paper in a waterproof plastic bag. Cobalt paper is brought to oil palm plantations for use in transpiration measurements. In order to perform the transpiration value, we first measure the width of the leaves, pinch the cobalt paper on the upper and lower surfaces of the leaves. Note the size of the paper covering the leaves, and note how long it takes to change the red of cobalt paper to blue.

Convert the data with the amount of water that evaporates the unity of time (seconds) in the breadth of the leaves per cm^2 [7]. The formula is:

$$G = 3600/t \quad (2)$$

Where:

G : the amount of water that evaporates per cm^2.
3600 : transpiration constant
t : the length of time it takes to convert red cobalt paper to blue.

With data on the total area of pertree leaves, it can be obtained the number of transpiration unity total leaf area per tree The data obtained is analyzed descriptively to describe the transpiration ability of plants.

In order to obtain the environmental factors at the time of the study was conducted by recording the folllowing abiotic (variables are air humidity, temperature, light intensity) and biotic factors (number of stomata, morphological and anatomical picture of rooting, stems and leaves.

To estimate the number of stomata (i.e. leaf pores that serve to transpiration of water – the end of the mobilization of water on the surface of oil palm leaves), microscopic observations was accomplished with fresh preparation of palm leaf surface, with the following steps: by using a sharp razor blade, make a wet preparation of the upper and lower surface of leaves, by making a thin incision of a surface of palm leaves, then put the wet preparation on the surface of the glass object. Further such preparations are observed under a microscope. Observe and calculate the number of stomata in each field of view. Record the diameter of each field of view with a micrometer. And repeat those observations five times. The above observations apply to the base leaves, mid leaves and tip leaves.

Data obtained was described qualitatively and to be connected with the transpiration ability of oil palm trees. To get a morphological and anatomical picture of rooting, stems and leaves that enable the mobilization of water from the roots to the surface of the leaves, carried out the following ways of working:

a. The number of roots or rooting on oil palm trees. Oil palm trees are torn down and calculated the number of roots on basalt trunks. Weighted wet and dry mass of stems and roots per unit area. From this data, we calculated percent of water on the stem and roots. The data were analyzed descriptively qualitatively.
b. Root anatomical observations. We take the main root, branch root, and branch root and make microscopic wet preparation, and observed under the microscope. Pictures are taken, and descriptively analyzed to explain the function of water absorption from the soil.

3. RESULT AND DISCUSSION

With a step-by-step calculation as described in the methodology, we summarized total leaf surface of each of the tree, and corresponded with transpiration rate, as it is presented in Table 1.

Table 1. Average total leaf surface of each of the tree, and corresponded with transpiration rate at every single of tree

No	Age (years)	Average total leaf surface (m^2)	Average transpiration rate ($ml/second/cm^2$)	Estimation of daily water evaporation
1	2	88.77	3.38	292.03 liter/day
2	4	102.55	5.69	491.62 liter/day
3	22	134,91	1.24	107.14 liter/day

As we see in the Table 1, the more the age of oil palm tree, the surface of leaf is increase, but the transpiration rate is decrease. Perhaps it is because of the apoptosis stomata function. Although in term of number increase as the development of oil palm tree, the functional stomata are decrease. As we find the average transpiration per second, we could estimate the daily water evaporation by multiplying the average of transpiration number in second with 24 hours (equal to 86.400 second). We obtained the number of evaporation is in the range of 107.14

liter/day to 491.62 liter/day. These are a lot of water that mobilized from root to the surface of leaves.

The number of stomata at bottom leaf surface is bigger than the one at top surface so that the bottom surface is mostly for the place of transpiration occurrence. (See Table 2).

Table 2. Average number of stomata per field of view

No	Part of leaf	Age of plant (years)	Below surface Average number of stomata	Top surface Average number of stomata
1	Base part	2	23,73 ± 3,15	1,13 ± 1,04
		4	30,87 ± 4,37	1,67 ± 1,78
		22	-	-
2	Mid part	2	23,73 ± 3,75	0,13 ± 0,33
		4	25,33 ± 2,47	0,80 ± 0,83
		22	35,60 ± 3,95	1,33 ± 0,60
3	End part	2	19,67 ± 4,09	0,93 ± 1,12
		4	21,13 ± 5,97	0,68 ± 0,60
		22	31,33 ± 2,44	0,53 ± 0,63

It can be seen that the transpiration rate occurs on the leaf surface of oil oil palm trees. Actually, the transpiration data are temporal data (according to the conditions when the data were collected), and spatial microclimate.

The number of stomata is presented in Table 2. It is generally seen that the number of stomata on the lower surface of the leaves is more than the top. Generally, the number of stomata on the lower surface is 20 to 50 times compared to the number of stomata on the upper surface. It seems that there is already a division of duties on the leaf surface. The tops of the leaves are more exposed to sunlight under the canopy of other leaves as well as in direct sunlight. Therefore, the upper surface is more functional for photosynthesis. While the lower surface of the leaves is found with stomata in the number of 20 to 50 times more. This shows that the lower surface has been specialized for transpiration, and the evaporation of the photosynthetic gases mainly oxygen (O^2).

The data in Table 4 also provide other clues. First, the more the plant age, the more stomata the number. This correlates directly with the increased metabolic activity of trees which must be supported by better transpiration capabilities. Better transpiration ability is facilitated by a higher number of stomata.

Another interesting clue in this study is that there are more stomata at the base, and the lower the number of stomata is at the tip of the leaf. Perhaps this is related to the stage of growth and the development of the base, which is certainly older than the end, so that it is relatively in tune with increasing age the more the number of stomata increases.

The rate of transpiration depends on the photosynthesis activity, internal metabolism in the cells of the tree, and influenced by many

Table 3. Environment factors when measurement was being obtained for the tree at age of 4 years)

Transpiration time	Abiotic Factors		
	temperature	Humidity	Light Intensity
Morning	30◦C	65%	15160 lx
Late Morning	28,9◦C	67%	1948 lx
Noon	33,2◦C	65%	25165 lx
Afternoon	28◦C	56%	22340 lx

Table 4. Environment factors when measurement was being obtained for the tree at age of 22 years

Transpiration time	Abiotic Factors		
	temperature	Humidity	Light Intensity
Morning	28◦C	72%	1470 Ix
Late Morning	31,5◦C	64%	1840 Ix
Noon	29,9◦C	65%	1034 Ix

environmental variables, namely temperature, humidity and sunlight intensity. This environmental variable also does not work at single factor independently, but is a collaborative influence and reciprocal influence.The abiotic environmental factor variables are listed in Table 3 and 4 belows.

We calculated that the number of root for water absorption per palm oil shoot is 324 liter/day in average. This amount is able to absorb nutrients and water from the soil into the stem. The passage of water into the epidermis of the root surface goes apoplast (extra cellular along the space between the cortical tissue cells), and simplest (intracellularly through the holes in the cell wall or lamellae and cytoplasm of the cortical tissue cells) to the endodermis tissue at the outer boundary of the stele . Furthermore, the water travels to the silem transport network to the upper network.

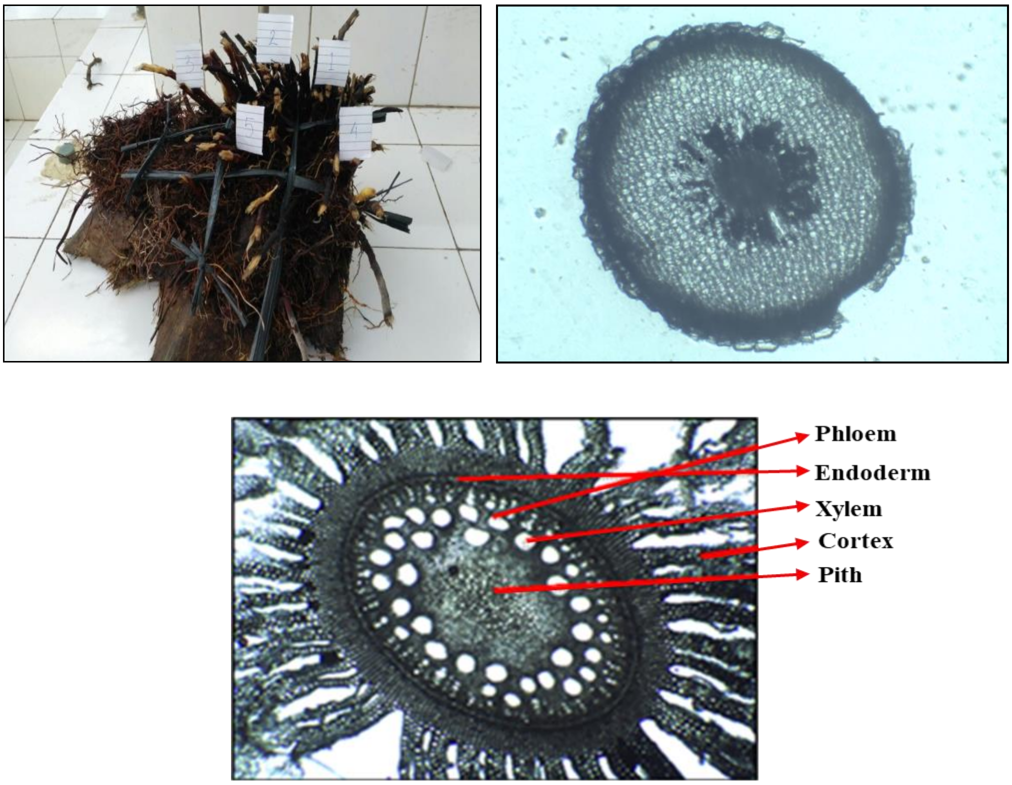

Figure 1. a. Basal shoot that contains hundreds of root number to support the water absorption; b. Anatomy of root (at 400x magnification), showing the structure of epidermal layer, cortex, endoderm, and stele; and c. As the maturation occured, the tissue of mature organ of root branch was disrupted and blessingly to become easier and more effective for water absorption.

We illustrated that young root anatomy is more compact and as the growth and development occurred, the root is more complicated into root branch and root of the root branch. As the maturation occurred, the tissue of mature organ of root branch was disrupted and blessingly to become easier and more effective for water absorption.

The morphology and anatomy of roots, stems and leaves that are capable of mobilizing water from the roots to the leaf surface. The young root organs (Figure 1b) are still compact. Parts of the root organ tissue are still complete successively from the outside into the epidermis, cortex tissue with parenchyma cells, endodermal tissue, and stele which contains phloem and xylem transport bundles, the deepest part is the pith.

As the root get older, root tissue grows and develops from the main roots branching and bearing branches. Mature root branches appear to have damaged tissue in the cortex. This is to accommodate the development of expanded roots. In fact, the cortical tissue is mature tissue that does not divide anymore so that it compensates for the passive expansion of the root width and tears in the cortex. However, the function of this tear of the cortex still functions to absorb water, plus the physical function of maintaining moisture in the root environment, thereby ensuring a supply of water from the roots. Using the data of root weight and shoot weight (both at moist condition, and dried condition after drying in the oven), we find that water retention was estimated on the data of water content in the root (71.70% to 73.40%) and in shoot (49.45–71.27%). It shows that there are a lot of water absorbed by root and mobilized into shoot via transport file xylem, and eventually evaporated into the surface of leaves.

Water retention in the roots and stems is indicated by the amount of water content in these two organs. The water content in the roots ranged from 71.70% to 73.40%. The water content in the stems ranged from 49.45% to 71.27%, and the mean water content of the stems was 61.89%. The water retention in the roots is more than the stem. But when compared to the volume of the trunk area which is much greater than the volume of the roots, the addition of other organs to the leaves causes a large amount of water mobilization but does not damage the tree organization system because it is able to maintain a constant amount of water content in the roots (an average of 72%) and stems (average 61.89%). The way to maintain the amount of water is by means of equilibrium between the absorption of water from the roots with a constant transpiration rate on the leaf surface.

4. CONCLUSION

In conclusion, the water mobilization in oil palm tree is a complicated, huge and very dynamics, from roots below the soil, absorbed into stem, and finally evaporated mostly into transpiration. The dynamics depend on its environment variables. The average total leaf surface area of a tree is 109.55 square meters (4 years old). This leaf surface area has the lowest range of 27.82 m^2 to 220.04 m^2.At the age of 22, the average leaf surface area is 134.91 m^2, with the lowest range of 27.90m^2 to the highest 314.99 m^2). Transpiration is very influenced by many variables, namely temperature, humidity when measuring transpiration and sunlight intensity. Abiotic environmental factors, temperature, humidity and sunlight intensity influence the transpiration fluctuation

The number of stomata on the lower surface of the leaf is more than the top. Generally, the number of stomata on the lower surface is 20 to 50 times compared to the number of stomata on the upper surface. The older the plant, the more stomata number. Likewise, there are more stomata at the base, and the lower the number of stomata at the end of the leaf. The total number of roots that can absorb water from the roots to the trunk of the tree at the base of the stem is 324. Young root organs are still compact, along with the growth and development of the main roots branching off and bearing branches. The roots of the mature branches appear to have damaged tissue in the cortex to accommodate the expansion of roots. Water retention in the roots and stems was indicated by the amount of root water content ranging from 71.70% to 73.40%, while the water content in the stems ranged from 49.45% to 71.27%, and the mean value of stem water content. as much as 61.89%.

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