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# Determination of Specific Leaf Area and Leaf Area-leaf Mass Relationship in Oil Palm Plantation

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**Abstract:** Specific leaf area (SLA), the ratio of leaf area to leaf mass is the most important determinant of oil palm growth, which is used in growth monitoring of oil palm and many crop simulation models to estimate total leaf area. Leaf dry weight and leaf area were determined by destructive methods in oil palm plantation. The objective of this study was to obtain suitable linear model for estimation of leaf area and calculation SLA of oil palm plantation with less error of estimation. The SLA was plotted on frond number and found that SLA was decrease systematically with time as the frond mature. In this study we found that the Leaf dry weight was strongly correlated ($R^2$=0.96-0.98) with leaf area in both linear and non-linear regression. The leaf mass were regressed on leaf area using both linear and non-linear model and found following relationship: Leaf Mass=Leaf Area/99 ($R^2$=0.96) Leaf mass were calculated from rectangular leaf area by above linear equation. Leaf Mass=0.0087 (Leaf Area)$^{1.027}$ ($R^2$=0.98) Leaf mass were calculated from rectangular leaf area by above non-linear equation. Actual leaf area (individual or whole of the oil palm plantation) were calculated from leaf dry weight by following linear and non-linear regression equation: Actual Leaf Area=78.89 x Leaf Mass ($R^2$=0.97) Actual Leaf Area=80.926 (Leaf Mass)$^{0.977}$ ($R^2$=0.98) Its also found that the calculated leaf area and measured leaf area was strong linear relationship ($R^2$=0.98).

**Key words:** Specific leaf area, leaf area, leaf mass, oil palm

## INTRODUCTION

Leaf area and leaf mass relationships can be expressed by the Specific leaf area (SLA) ($cm^2\,g^{-1}$ or $m^2\,Kg^{-1}$), which is the ratio leaf area to leaf dry weight. According to Barden[1] SLA has been related to leaf structure, growth and net photosynthesis. Also SLA is used in crop simulation models to estimate total leaf area or dry weight[2]. Leaf area and specific leaf area are important parameters in many agronomic and ecological processes, including photosynthesis, transpiration and field energy balance, but can be difficult and expensive to measure[3]. It is used to estimate total leaf area at various stages of growth and many crop model to predict leaf area from leaf dry weight or vice versa. SLA also can be used in conjunction with leaf area to estimate leaf mass for nutrient balance calculations and growth estimates. In most crops leaf area is defined by the leaf area index LAI. This term expresses the area of the aboveground plant components such as leaves, branches and fruit per unit area of ground in $m^2\,m^{-2}$ [4].

In oil palm, it is difficult and time consumes to measure total leaf area in various stages. But it can be easily estimated by SLA. From SLA model, any oil palm plantation manager could be estimate total leaf area of the plantation. Many crop models calculate either leaf area or leaf dry weight and use SLA to determine the value of the other variable. Some scientists have assumed a constant SLA for leaves after full expansion[5,6].

The intrinsic photosynthetic capacity of palms depend on the leaf structural characteristics, such as leaf thickness, size and arrangement of mesophyll cells that determine the amount of photosynthetic tissue per unit leaf area. Also SLA indicates leaf thickness of the leaflet. Therefore, parameters such as specific leaf area (SLA), specific leaf dry weight (SLDW, dry weight per unit leaf area) or the total content of chlorophyll per unit area of leaf (SPAD) are considered good indicators of the strength of the photosynthetic tissue[7]. However, These parameters are important for forest and agricultural research as well for crop management practices.

The inverse of SLA, specific leaf mass or specific leaf dry weight, has been positively correlated with leaf water

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use efficiency among alfalfa (*Medicago sativa* L.) cultivars by Gutschick[8] who reasoned that leaves with high specific leaf mass are cooler under a given radiation load due to higher stomatal conductance and lower water vapor pressure deficit. Leaf area and leaf mass are closely related to light interception, photosynthesis, transpiration, growth rate and furthermore to yield[9] and Charles-Edwards[10] has also shown a positive correlation between SLA and light use efficiency for several species. Thus SLA is an important crop parameter to estimate.

The objectives of this study were: to determine the SLA from destructive sampling and direct measurements of leaf area and mass in oil palm and determine total leaf mass of oil palm from leaf area measurements. Also to test a statistical model that calculates SLA of individual leaves from their dry mass.

## MATERIALS AND METHODS

Experiments were conducted in experimental plot at MPOB during 2003 to estimate the leaf area, leaf mass and specific leaf area. The first experiment was conducted during May 2003. The second experiment was performed at same plot during October 2003.

**Study site:** Measurements were made in Malaysian Palm Oil Board (MPOB) ENOVECY research plot. MPOB is situated about 30 km north from Kuala-Lumpur, Latitude 2° 58′ 0.36″ N, Longitude 101° 44′ 26″ E) at an average altitude of 66.5 m from sea level. Agronomy division at MPOB in 1998 planted the plantations. We Considered 5-6 years old uniform palm Tenera (D x P) for this study.

For leaf area measurement, two methods were used in this study

- Manually measurement
- Measurement by Portable Leaf Area Meter (Li-3000A Leaf Area Meter)

**LI-3000A leaf area meter:** The LI-3000A combines an easy to use, microprocessor controlled readout console with the proven scanning technology of the LI-COR LI-3000 sensor head to provide a powerful system for portable non-destructive leaf area measurements. The LI-3000A utilizes an electronic method of rectangular approximation to provide one mm$^2$ resolution. The readout console logs leaf area, leaf length, average width and maximum width as the scanning head is drawn over a leaf. Files can be viewed on the display or output through the RS-232C interface to a computer or printer. For large numbers of detached leaves, the LI-3000A can be used with the LI-3050A Transparent Belt Conveyor Accessory for greater measurement efficiency.

**Measurement of leaf area:** For measurement of leaf area, two types of procedure were chosen. The first one was for selected palm and other was for randomly selected palms.

**Measurement of leaf area by manually in selected palm:** Five palms were chosen randomly in the plantation site and frond 1, 9, 17 and 25 were chosen from each palm. The chosen leafs (frond 1, 9, 17 and 25) ware cut at the petiole level. After cutting the frond, that was brought in cool room as soon as possible for prevent of shrinkage. The length of the rachis was measured and cross-section of the petiole at appropriate point was also measured at same time. Count the leaflet in both side of rachis. Rachis length was divided in to equal ten sections. Leaflets were chosen both side of the rachis. An upper and lower leaflet with good edges was taken from the middle of each section. For both side leaflets numbered 1 to 10 on the underside of the leaflet by using permanent marker. Total twenty leaflets (each side ten leaflets) were placed according to numbering on the table. For measurement, a steel measuring scale was taken and carefully measured length (L) and middle width (W) in cm of each leaflet.

The area of each leaflet was measured by following equation:

$$Ar = L \times W \qquad (1)$$

Here, Ar represents the rectangular leaf area.

This rectangular leaf area used many experiment as well as growth monitoring of the oil palm. Where as, actual leaf area needs for many ecological modeling and LAI. So for actual leaf area calculation we used following relationships;

$$\text{Actual Leaf Area} = L \times W \times f \qquad (2)$$

Where, f = Empirical coefficient

But in this case, for leaf area measurement, leaf length and middle width were measured. That means the yield leaf area was rectangular leaf area and that was slightly higher than actual leaf area.

**Measurement of leaf area by manually in random palms:** In this case, several palms were chosen for investigate. Under this investigate, different size of leaflet were chosen from different fronds. Total 50 leaflets were cut for this purposes including small leaflet and large leaflet from whole of the plantation. After cutting the leaflet, it was put in plastic bag and brought in cool room as soon as possible for prevent of shrinkage. Measurement was performed by stainless steel scale according to above procedure.

**Measurement of leaf area by leaf area meter:** After chosen the leaflets, the leaflets were dissected from petiole, numbering and placing of the leaflet on the table as same way as manual measurement. After placing on the table, each leaflet area was measured by portable Leaf Area Meter. For more information, we record leaf area, maximum width, average width and maximum length. Recorded maximum length was compared by manually measured length and then adjusts the length of the Leaf Area Meter. Finally, more perfect results were records in the data sheet. Before measurement, Leaf Area Meter was calibrated to correct the leaf area of each sample.

**Determination of leaf dry weight:** All marking leaflet of experiment one and two were put carefully in the special paper bag and again mark on the bags. All bags with leaflets were oven dried at 70°C for 72h to obtain the dry mass. After drying, a precision weighing balance was used to weight of the leaflets and records the results on data sheet. A statistical analysis was done to find out a relationship between leaf areas and leaf mass by quadrant and for SLA model.

## RESULTS AND DISCUSSION

**Relationship between specific leaf area and frond ages:** A good linear relationship was found between the frond ages and specific leaf area. Figure 1 shows that SLA was decreased with the frond ages.

The SLA was comparatively higher at younger frond respect to mature frond. Maximum SLA 88.19 cm$^2$ g$^{-1}$ found in frond 1, palm 1 and minimum SLA 76.39 cm$^2$ g$^{-1}$ in frond 25, palm 3. SLA decreases systematically with time as the leaves mature, but increase systematically with depth in the canopy as the light available for leaf development and light interception decreases. There is also evidence that for a given light environment, species with leaves of higher SLA will have a higher relative growth rate.

**Relation between leaf mass, leaf area and SLA:** Figure 2 shows that leaf mass and leaf area relation was linear. In this study leaf area was measured directly by apply model (1). Maximum leaf area and corresponding leaf mass was 379.96 cm$^2$ and 3.76 g. Whereas minimum leaf area and corresponding leaf mass 24.88 cm$^2$ and 0.26 g. Maximum and minimum SLA was 123.54 cm$^2$ g$^{-1}$ and 81.69 cm$^2$ g$^{-1}$. From this observation we proposed a mathematical linear model for calculating leaf mass from leaf area as follows;

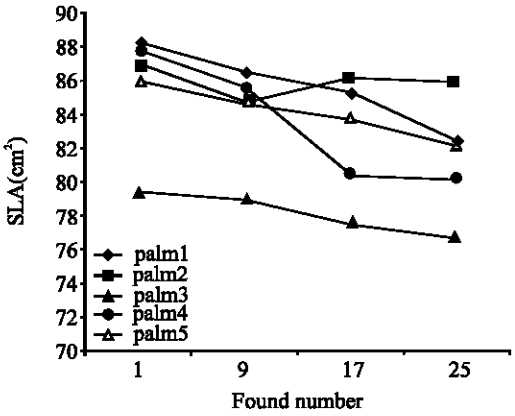

Fig. 1: Relationship between specific leaf area and frond ages. Frond number 1 represents more young where as frond number 25 was more mature

$$L_m=L_a / 99 \tag{3}$$

Where,
$L_m$ is the mass of leaflet and
$L_a$ is the rectangular leaf area of the leaflet

Data indicated a high degree of association ($R^2$=0.96) and the low standard error of estimate of coefficient (0.00028) suggested that the relation accurately estimates oil palm leaf mass, which was used for SLA estimation. From non-linear relation, we found a non-linear model for calculating leaf mass from leaf area.

$$L_m=0.0087 (L_a)^{1.027} \tag{4}$$

Data indicate a high degree of association ($R^2$=0.98) and the low standard error of estimate of coefficient (0.0009). In this case, determination leaf mass depends on accurate measurement of leaf length and leaf middle width.

From Fig. 3 shows that leaf mass and leaf area relation was linear. From this experiment, maximum leaf area and mass was 296.26 cm$^2$ and 3.76 g. Minimum leaf area and mass was 20.6 cm$^2$ and 0.26 g. From this observation we proposed a mathematical linear model for calculating actual leaf area from leaf mass as follows:

$$L_{ac}=78.89 \text{ x } L_m \tag{5}$$

Where,
$L_m$ is the mass of leaflet and
$L_{ac}$ is the actual leaf area of the leaflet

Data indicate a high degree of association ($R^2$=0.97) and the low standard error of estimation were 0.169. The standard error of estimate of coefficient was (0.00029). In

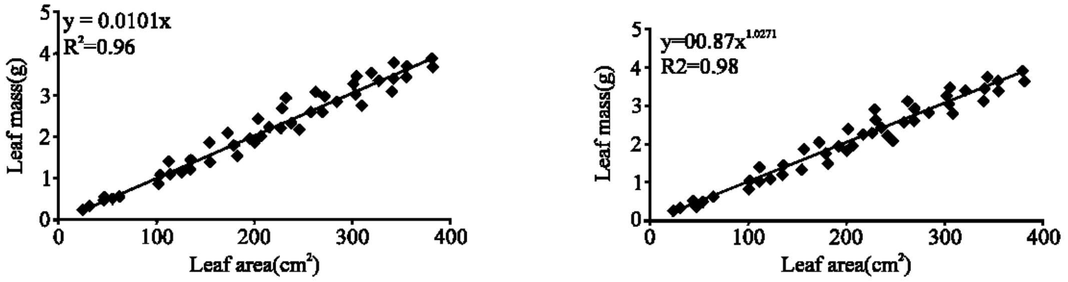

Fig. 2: Oil palm leaf mass vs. leaf area. Points are plotted rectangular leaf area and corresponding leaf mass. For the linear model, $R^2$ is 0.96 and the std. Error of the estimation is 0.200 and std. Error of coefficient is 0.00028. For non-linear model $R^2$ is 0.98 the std. Error of the estimation is 0.097, std. Error of coefficient is 0.0009 and std. error of the power is 0.02

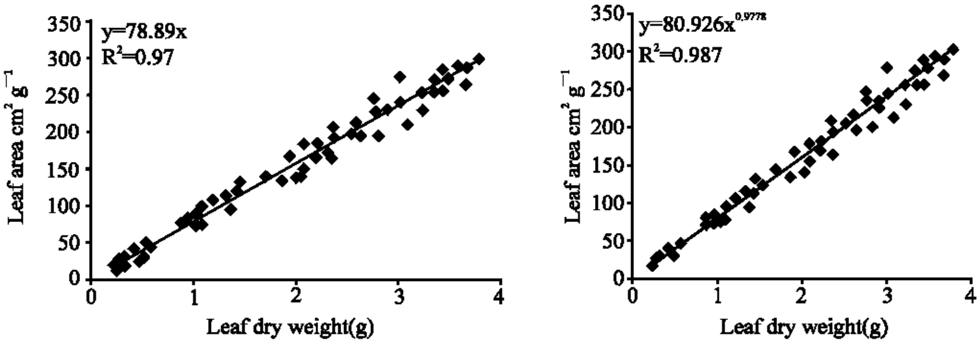

Fig. 3: Oil palm leaf area vs. leaf mass. Points are plotted actual leaf area and corresponding leaf mass. For the linear model, $R^2$ is 0.97 and the std. Error of the estimation is 0.169 and std. Error of coefficient is 0.00029. For non-linear model $R^2$ is 0.98 the std. Error of the estimation is 0.076, std. Error of coefficient is 0.016 and std. error of the power is 0.0009

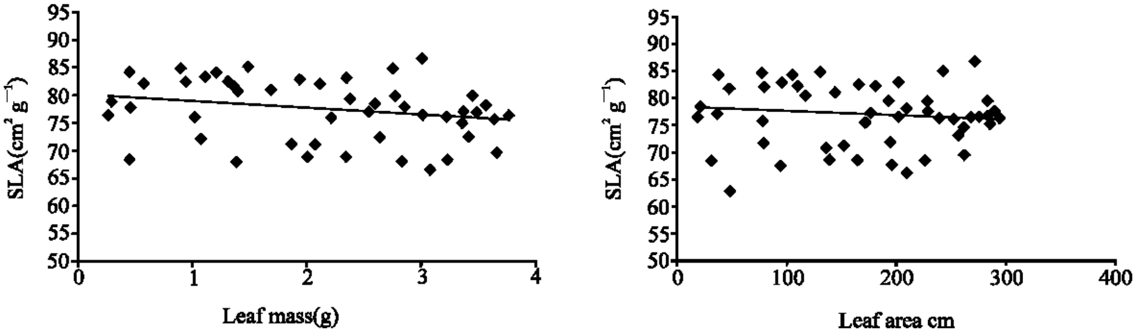

Fig. 4:Relationship between SLA and leaf area (right), SLA and leaf mass (left)

this case, determination actual leaf area depends on accurate measurement of leaf dry weight. From non-linear relation, we found a non-linear model for calculating actual leaf area from leaf dry weight.

$$L_{ac}=80.926\ (L_m)^{0.977} \qquad (6)$$

Data indicate a high degree of association ($R^2$=0.98) and the low standard error of estimate of coefficient (0.0009). It is important noting that in oil palm, the relation between leaf area and leaf mass hardly changes and SLA also remain constant with growth of tree. This does not agree with Payne *et al.*[3] finding that the SLA gradually increase with decreased of leaf mass. However the data present here support the conclusions of Aase[11] for the fifth stage of growth of winter heat and results of Ramose *et al.*[12] for all cultivars of winter barley.

The plot of SLA vs. leaf area and leaf mass (Fig. 4) was more scattered and non-linear relationship. Figure 4 shows that the SLA varied with leaf area or leaf mass.

Large leaf area represents more SLA and also more leaf dry weight represents more SLA. Because of that from Fig. 2 and 3 we found that leaf area and Leaf mass relationship was linear. It means large leaf area represents more leaf mass and specific leaf area (SLA) remains constant during the plants development and there is no significant variation with time. Because of that the leaf area increased means increased its length, width and also thickness. So that increased its mass. According to Blackman[13] the environmental factor, such as light and temperature were modifying the SLA. Acock[14]. Found that SLA differed accordingly to the position of the leaf area on the plant. The distal or youngest leaf sampled had the highest SLA, suggesting that leaf area of a developing leaf stabilizes before its dry weight. This study results strongly support these experimental results.

From the present study it can be concluded that leaf dry weight for oil palm plantation gives good estimate of the actual leaf area, where light and temperature were not much changes. As the same way, Leaf mass can be calculated from simply measured rectangular leaf area.

SLA appears to be constant with increasing leaf area or leaf dry weight. SLA varied with environmental factors like light and temperature. From Fig. 1 it was clear that SLA varied with frond maturity as well as frond position. Younger frond (frond-1) situated at the upper portion of the tree and hence received more light. But in lower frond (frond-25) received comparatively low light intensity. Because light intensity decreased rapidly with increased the depth of canopy. Probably low light intensity was responsible for less SLA in lower frond. For measurement of SLA in oil palm plantation, it was important to accurate calculation of leaf area and leaf mass rather then used crop model.

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