J. Agric. Mach. Bioresour. Eng. 5(1&2), 2009 : 31-36 ISSN 1993-4041

Regression Model for Indirect Estimation of Oil Palm Frond Area

M.A. Awal[1], Mohd. Haniff Harun[2], Wan Ishak[3] and J. Endan[4]

Abstract

The fronds (leaves) play an important role in oil palm's growth and production. In oil palm, frond area is one of the most important aspects in its morphological and physiological studies and also important indicator of oil palm's future production and yield. Precise estimation of frond area is one of the important issues for oil palm growth analysis. Frond area is also important for analysis of canopy structure of the oil palm. Accurate, rapid, non-destructive, simple and reliable approach for determination of frond area in oil palm is essential. Destructive method and portable leaf area meter were used to develop frond area model. In this study, regression models for accurate estimation of leaflet area from simple measured leaflet length and middle width were described and two models for frond area were also developed. The regression models for leaflet were, (I) A = 75.517D – 45.411, with co-relation coefficient r = 0.91 and standard error 1.62. (ii) $A = 28.845\ D^{1.633}$ with co-relation coefficient r = 0.93 and standard error 0.031 and (iii) $A = 0.0286\ L^{2.0142}$, with co-relation coefficient r = 0.93 and standard error 0.26, where A, D and L represent area (cm^2), width (cm) and length (cm) of the leaflets. The developed frond area models were, (a) TFA = 0.58 PLA with co-relation coefficient r = 0.99 and standard error of estimation coefficient .007431 and (b) TFA = 0.467 PRLA with co-relation coefficient r = 0.99 and standard error of estimation coefficient 0.00536 where, TFA, PLA and PRLA represents true frond area, predicted frond area and predicted rectangular frond area in m^2. Statistical analysis indicates a high degree of association ($R^2 = 0.99$) and the low standard errors of estimation were 0.007431 and 0.00536 for model 'a' and 'b' respectively. Model 'b' was more simple and easier in terms of frond area measurement.

Key words : Leaf area, Frond area, Regression model and Oil palm

1. Introduction

In oil palm, frond refers to its leaf. Each frond (leaf) has 50 to 140 leaflets. In plants, the leaves work as an energy producer's organ, which are collectors of energy. Hence, the leaves play an important role in plant's growth and production. In oil palm, leaf area is one of the most important aspects in its morphological and physiological studies. Although leaf area plays a key role in the absorption of radiation, in the deposition of photosynthesis during the diurnal and seasonal cycles, and in the pathways and rates of biogeochemical cycling within the canopy-soil system (Bonan, 1995), The knowledge of leaf area is an important factor in understanding photosynthesis, light interception, water and nutrient use, crop growth, and yield potential (Williams, 1987). Leaf area is also important for analysis of canopy of leaf area and the spatial and geometric organization of individual elements within a defined canopy envelope. The problems associated with quantification generally increase with the size and temporal and spatial heterogeneity of the canopy (Awal *et al.*, 2004). Rapid, non-destructive and precise methods for measuring LA are required to model plant growth, transpiration and photosynthesis (Rhoden and Croy, 1988).

Many methods have been developed (including direct and indirect) to measure leaf area of the plant. Different leaf area meter and photographic methods are used for indirect measurement. However, these equipments are not suitable for all cases and all time to measure the leaf area for oil palm. Leaf area also determined directly for individual leaves using automatic leaf area meters, leaf area-leaf dimensions relations, or leaf area-weight ratios (Norman and Campbell, 1989). But these methods require sample data, are time consuming and involve destructive sampling. An alternative way to measure the leaf area of a plant is the measurement of light attenuation by crops, known as a Gap Fraction Method. This method is based on the fraction of skylight attenuated by the canopy. (Wells, 1990). The use of regression equations to estimate leaf area is a nondestructive, simple, quick, accurate, reliable and non-expensive method (Pinto et al 2004). Therefore, in oil palm, simple and reliable indirect methods to estimate of total leaf area accurately are necessary that will help to growth analysis as well as to use as a yield prediction model. The main aim of this study was to

[1] Associate Professor, Dept. of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh
[2] Research Officer, Biological Division, Malaysian Palm Oil Board, Bangi, Malaysia
[3] Professor, Dept. of Agricultural and Biological Engineering, UPM, Malaysia
[4] Associate Professor, Dept. of Food and Process Engineering, UPM, Malaysia
Corresponding e-mail : mawal69@yahoo.com

develop regression models, which would accurately and reliably predict the leaf area of the oil palm.

2. Materials and Methods

2.1. Study site

Measurements were conducted at Malaysian Palm Oil Board (MPOB) research plot. MPOB is situated about 30 km north of Kuala-Lumpur at Latitude of 2° 58′ 0.36″ N and Longitude of 101° 44′ 26″ E) at an average altitude of 66.5m from sea level. Seven years old uniform commercial palms (D x P) were used for this study.

2.2 Measurement of leaf area

2.2.1 Measurement of leaf area by manual method

Leaf samples used in this research were selected randomly from ten palms. Three and seven year old palms were selected in this study in 2003 and 2004. Two experiments were conducted. First study was to determine leaflet area from leaflet width or leaflet length. A total of 400 leaflets were selected randomly from frond 1 to 25 from both palm ages. Frond 1, 9, 17, and 25 were cut at the petiole. The fronds were brought to the laboratory as soon as possible to prevent drying and rolling of leaflets. The length of the rachis was measured from C to A and cross-section of the petiole at point C was also measured. The leaflet in both side of rachis was counted. From C to A (rachis length) was divided into equal ten sections. Leaflets were chosen at both side of the rachis. An upper and lower rank leaflet with good edges was taken from the middle of each section. For both side leaflets were numbered 1 to 10 on the underside of the leaflet by using a permanent marker. Total twenty leaflets (each side ten leaflets) were selected from each frond and placed according to numbering on the table. A steel-measuring ruler was used to carefully measure the length (L) and middle width (W) of each leaflet. The areas of each leaflet were calculated by following equation:

Leaflet Area = Leaflet Width x f OR Leaflet Area = Leaflet Length x f

Where, f = Empirical Co-efficient which needs to be determined.

A second experiment was conducted to determine the frond area coefficient. Frond 17 was selected from both palm ages groups. According to Tailliez and Koffi (1992), frond 17 is near the middle of the oil palm crown, which is assumed to be representative of the crown as a whole. This frond is easy to identify and is also traditionally used for leaf mineral nutrition analysis. A total five fronds were selected from both palm ages group. After cutting the frond, total leaflets were counted. Six leaflets were cut from the middle portion of each frond. The leaflets were chosen from both upper and lower rank to minimize area variability. Maximum length and middle width of the leaflet were measured by a steel ruler use to calculate the leaflet area. The same leaflet was used with the leaf-area meter. After leaf area measurement, average leaflet area from six leaflets were determined and multiplied by total leaf number to fined out total leaflets area of the frond.

Again, total one-sided leaflet were cut and leaflet area were measured by leaf-area meter to determine true leaf area. From this one sided leaflet area, total leaflet area of the frond was determined by multiplication of 2. After this results were analyzed by statistical package SPSS-11.5 to find out frond area coefficient.

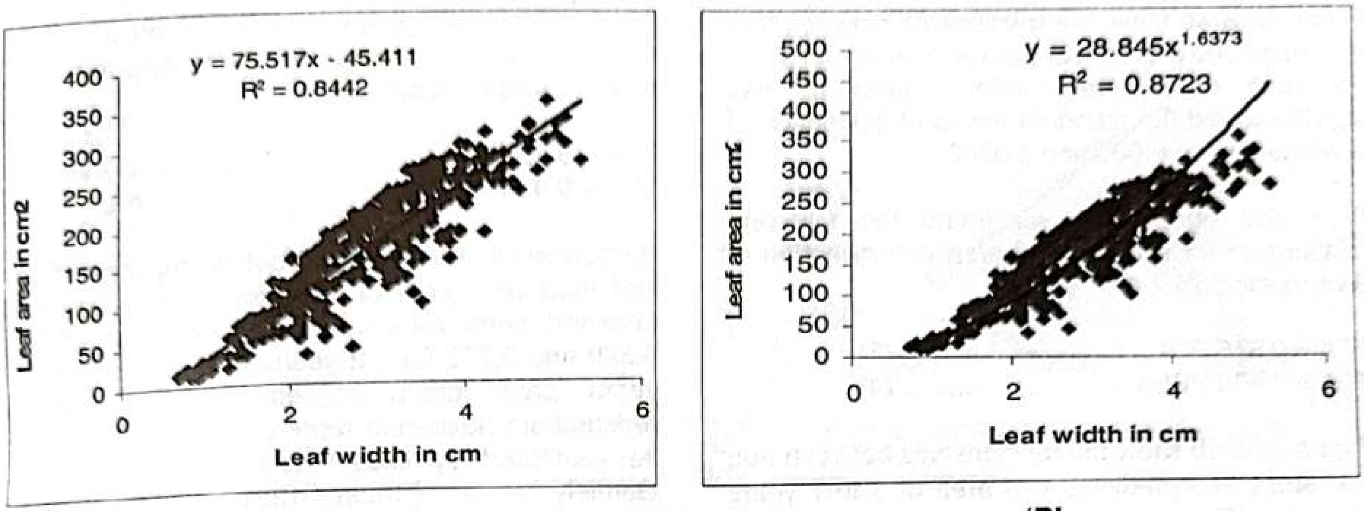
2.2.2 Measurement of leaf area by Leaf Area Meter

After selection the leaflets, cutting, numbering and placing on the table was performed same way as manual measurement. After placing on the table, each leaflet area was measured by portable Leaf Area Meter (LI-3100A, LiCor, USA). For more information, we record leaf area, maximum width, average width and maximum length. Recorded maximum length was compared with manually measured length and then the length of the Leaf Area Meter was adjusted. Finally, more accurate results were recorded in the data sheet.

3. Results and Discussion

3.1 Relation between leaf length and leaf width vs. leaf area

Figure 1 shows the relationship between leaf areas with leaf width. Results shows that leaf area varied with leaf width both linearly and non-linearly. Non-linear regression fit very well than linear regression. The linear regression equation for oil palm leaf was $y = 75.517x - 45.411$, with co-relation coefficient $r = 0.91$ and standard error 1.62. On the other hand, the equation of the non-linear regression was $y = 28.845x^{1.633}$ with relation coefficient $r = 0.93$ and standard error 0.031. Note that we did not consider maximum width of the leaf. We considered width at the middle portion of the leaflet. Since it is difficult to identify maximum width but easy to measure middle width of the leaflet.



'A' 'B'

Fig. 1. Oil palm leaf width vs. leaf area measured by leaf area meter. Points are plotted actual leaf area and corresponding leaf width. 'A' for the linear model and standard error of the estimation is 32.15. 'B' for non-linear model and std. Error of the estimation is 0.26

Fig. 2. Shows the relationship between leaf areas with leaf length. Results shows that leaf area varied with leaf length non-linearly. The non-linear regression equation was $y = 0.0286 x^{2.0142}$, with co-relation coefficient r = 0.93 and standard error = 0.26.

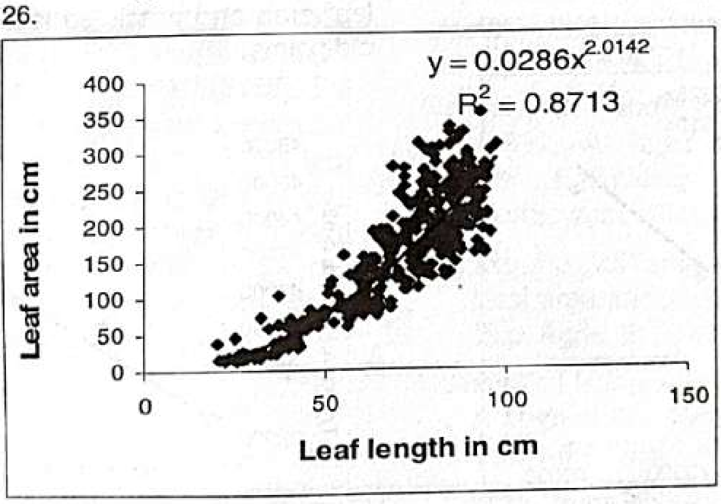


Fig. 2. Oil palm leaf length vs. leaf area measured by leaf area meter. Points are plotted actual leaf area and corresponding leaf length. For the non-linear model standard error of the estimation is 0.26.

3.2 Frond area coefficient

Multiple regression analysis was used for determination of the frond area coefficient. Points are plotted between true leaf area and predicted leaf area measured by leaf area meter for 7 years old palm (Fig. 3a). Results show that the relation between true leaf area and predicted leaf area is linear. The coefficient of determination (R^2) is 0.919 and Standard error of estimation of coefficient is lower (0.007431). The following relationship for simple frond area determination for 7 years old palm is developed:

TFA = 0.582 PLA .... (1)

Where, TFA is a true frond area in m^2 and PLA is the predicted leaf area in m^2. Note that leaf area measured by leaf-area meter.

Figure 3b shows the relationship between true frond areas and predicts rectangular leaf area. Results shows that the relation between true leaf area and predict leaf area was linear with coefficient of determination of 0.934 and Standard error of estimation of coefficient was lower (0.00536). From this observation we found the following relationship for simple frond area determination of 7 years old palm:

TFA = 0.467 PRLA .... (2)

Where, TFA = true frond area in m^2 and PLA = predict rectangular leaf area in m^2.

Figure 4a & 4b show the relationship between true leaf areas and predict leaf area of 3 years old palm. For both cases, the model adjustment was significant and the standard errors of estimation of coefficient were 0.006 and 0.0088.

From this observation we found the following relationship for simple frond area determination of 3 years old palm :

TFA = 0.575 PLA .... (3)
TFA = 0.460 PRLA .... (4)

Figure 5a & 5b show the relationships between true leaf areas and predicted leaf area of 3 to 7 years old palm. The coefficient of determination (R^2) is 0.99, when leaf area was measured by leaf area meter and R^2 =0.99 for predicted rectangular leaf area. For both cases the model adjustments were significant and standard error of estimation of coefficient was lower 0.003 and 0.005.

From this final observation we proposed the following simple model for frond area determination of 3 to 7 years old palm :

TFA = 0.58 PLA .... (5)
TFA = 0.46 PRLA .... (6)

Hardon *et al* (1969) carried out an experiment on leaf area and yield of oil palm in Malaysia and obtained frond area coefficient values of 0.512, 0.529 and 0.573 for 1-2 years, 4-6 years and 8-11 years palm group respectively. Many other researchers have also reported that leaf area can be estimated by linear measurements such as Gamiely *et al.* (Onion, 1991), Mathes *et al.* (Coconut, 1990), Potdar *et al.* (Banana, 1991), Robbins *et al* (Cucumber, 1987) and Whithworth *et al.* (Pecan, 1992). All these researchers found the close relationships between leaf area, leaf length and leaf width from their study. In this study, we also found very close relationship between true leaf area and predicted leaf area for 3 to 7 years old palms.

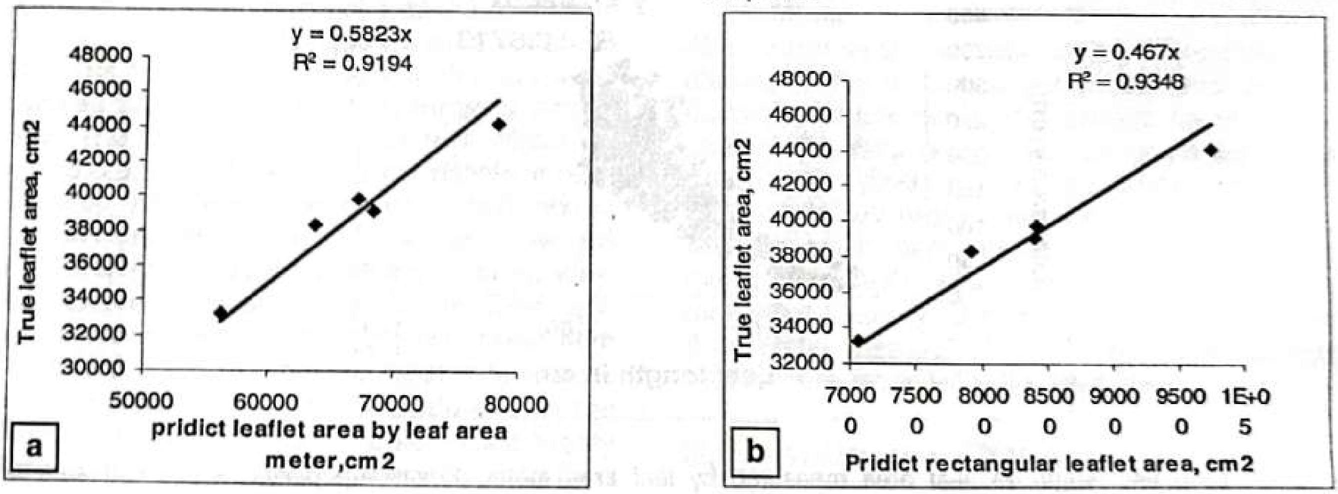


Fig. 3a & 3b. Relation between true leaf areas and predicted leaf area

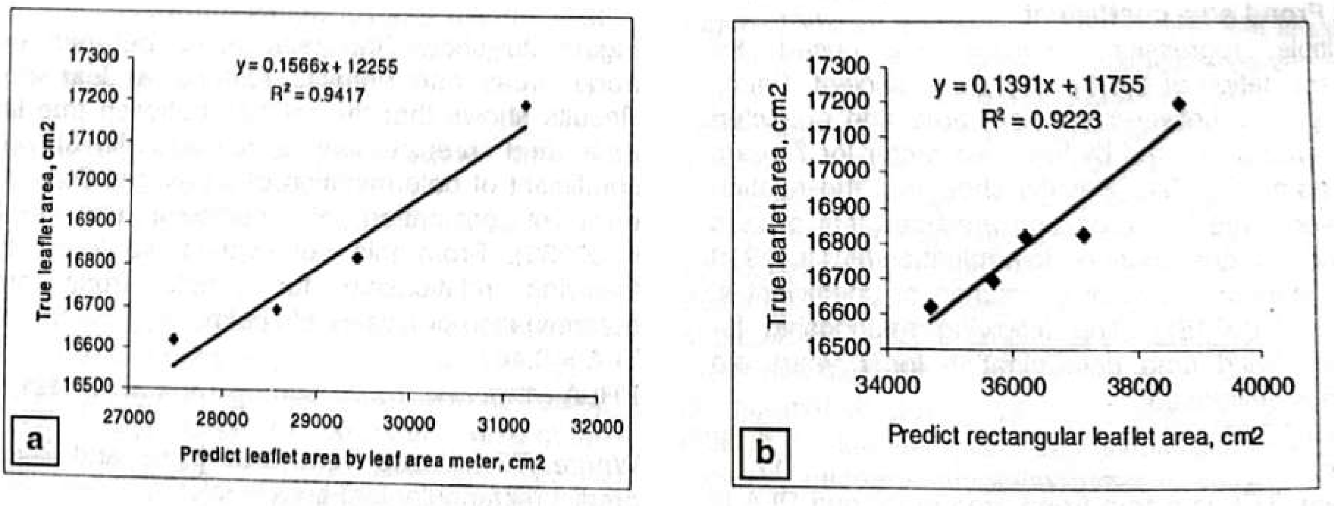


Fig. 4a & 4b. Relation between true leaf areas and predicted leaf area measured.

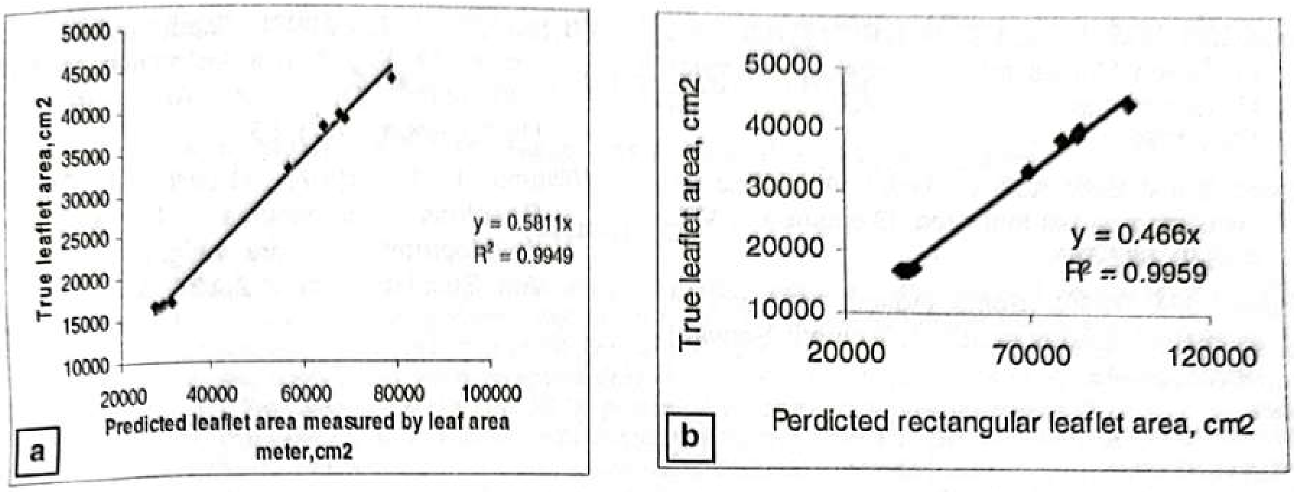


Fig. 5a & 5b. Relation between true leaf areas and predict leaf area measured by leaf area meter and measuring ruler of 3 to 7 years palm.

4. Conclusion

The nature of the variation in area between fronds within individual palms suggested that a good estimate of the total area of palm fronds or mean frond areas can be obtained by sampling only one frond from each palm. Under Malaysian condition it appears that, for many types of work, mean leaf area per palm, based on measuring one or two fronds would give an acceptable estimate of actual mean leaf area (Hardon *et al* 1969). From the present study, we suggested that leaf area measurement model from leaflet width or leaflet length might be easiest and simple tool for true leaf area measurements. For true frond area measurement, model 6 was more suitable for its simplicity. This regression model will be accurate for estimating total leaf area by non-destructive means for oil palm. The model from the present study will enable researchers to model growth and development of oil palm. In oil palm, there appears to be a systematic changes in frond area with ages (until they reach stability maturity), because both leaflet number, size and shape increased with age. Thus mean the relation between leaflet areas with frond area remains constant. So, this final frond area coefficient model (model 5 & 6) can be useful for all age's oil palm.

References

Awal M A, Wan Ishak, Endan J and Mohd Haniff (2004). Regression Model for Computing Leaf Area and Assessment of Total Leaf Area Variation with Frond Ages in Oil Palm. Asian Journal of Plant Sciences, 3 (5), 642-646.

Bonan G B (1995). Land-atmospheric interactions for climate system models: Coupling biophysical, biogeochemical and ecosystem dynamical processes. *Remote Sensing of Environment*, 51, 57-73.

Gamiely S, Randle W M, Mills H A, Smittle D A (1991). A Rapid and Nondestructive Method For Estimating Leaf Area Of Onions, HortScience, 26(2): 206.

Hardon J J, Williams C N and Watson I (1969). Leaf area and yield in the oil palm in Malaysia. Exp. Agric. 5, 25-32.

Mathes D, Liyanage L V K and Randeni G (1990). A Method For Determining Leaf Area Of One, Two And Three Year Old Coconut Seedlings (Var. CRIC 60), Hort. Abst., 60(11), 9366.

Norman J M and Campbell G S (1989). Canopy structure. In: *Plant Physiological Ecology: Field Methods and Instrumentation* (eds R.W. Pearcy, J. Ehleringer, H.A. Mooney and P.W. Rundel), pp. 301–325. Chapman and Hall, London and New York.

Potdar M Y and Pawar K R (1991). Non-destructive Leaf Area Estimation in Banana, *Scientia Horticulturae*, 45(3-4): 251-254.

Pinto A C R, Rodrigues T J D, Barbosa J C and Leite I C (2004). Leaf area prediction models for *Zinnia elegans* Jacq., *Zinnia haageana* regel and 'profusion cherry' .Sci. agric. (Piracicaba Braz.), vol.61 no.1.

Rhoden E G and Croy L I (1988). Relationship between leaf area and dry matter in southernpeas. HortScience, 23, 726-728.

Robbins N S and Pharr D M (1987). Leaf Area Prediction Models for Cucumber from Linear Measurements, HortScience, 22(6), 1264-1266.

Tailliez B and Ballo Koffi C (1992). A method for measuring oil pal leaf area. Oleagineux , Vol. 47(8-9), 537-545.

Welles J.M (1990). Some indirect methods of estimating canopy structure. Remote Sensing Rev. 5, 31–43.

Whithworth J L (1992). Mauromoustakos, A., Smith, M. W., A Nondestructive Method for Estimation Of Leaf Area In Pecan, HortScience, 27(7), 85.

Williams L E (1987). Growth of 'Thompson Seedless' grapevines. I. Leaf area development and dry weight distribution. J. Am. Soc. Hort. Sci. 112, 325–330.