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MATHEMATICAL MODEL FOR PREDICTING LEAF AREA OF *OCIMUM GRATISSIMUM* (HAFENDAHL FW) USING LINEAR MEASUREMENTS

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ABSTRACT

An experiment was conducted to develop a mathematical model for predicting leaf area for *Ocimum gratissimum* using linear measurements. A total of 300 leaves, representing five various leaf sizes, were randomly selected from the field over a period of three months. The leaf sizes and number of leaves collected per size were as follow: very small (0.5cm width) and 75 leaves; small (1.2cm width) and 70 leaves; medium (2.6cm width) and 60 leaves; large (4.5cm width) and 50 leaves; very large leaves (6.5cm width) and 50 leaves. The maximum lamina length (L) and lamina width (W) of the leaf samples were measured with a well-graduated meter rule and the selected leaves were also traced on a standard graph paper. The square, sum and product of the L and W were calculated and recorded as the leaf area estimates while the number of squares within which the trace of the leaf fell on the graph paper were counted and also estimated as a leaf area. The best-fit model was selected based on F-test, mean square error (MSE) and coefficient of determination (R^2). The results of statistical analyses showd that correlation coefficient of all the parameters were highly significant at 1% level of significance. Linear regression indicated that L, L^2, W, W^2, L+W, L*W and graph paper were 91 %, 92 %, 89 %, 93 %, 95 %, 98 % and 98 % respectively to the actual leaf area. The regression model of Y= 0.5466(L*W) + 0.7501, such that the actual measurements of L and W are simply inserted into the equation and leaf area computed.

Keywords: *Ocimum gratissimum, leaf area, linear measurements, lamina length, lamina width*

INTRODUCTION

The most important part of most tropical plants is the leaf, since it is associated with photosynthesis and evapotranspiration; hence, leaf area measurement becomes a valuable index and parameter in identifying plant growth and development for most physiological and agronomic studies. It is also considered as the most important single determinant of dry matter accumulation and yield in most plants (Satou *et al.*, 1978, 1988; Jacobs and Chand, 1992; Chan *et al.*, 1995, 1998; Guo and Sun, 2001).

Where the instrument used in measuring leaf area directly is absent due to its sophistication and cost, the other ways of assessing leaf area can be both time consuming, elaborate and labour costing. Even though, many methods have been devised to facilitate the measurement of leaf area, these methods which include tracing, blueprinting, linear measurements, photographing or even the conventional planimeter, involves the excision of leaves from the plants which is destructive (Lu *et al*., 2004). This makes the successive measurements of the same leaves impossible and plant canopy is also destroyed, which might make other measurements or experiments problematic.

Portable scanning planimeters can quickly, accurately and nondestructively measure a leaf area (Daughtry, 1990), but it is suitable only for small plants with few leaves (Nyakwende *et al*., 1997) and it is not readily available in developing countries like Nigeria. Using a digital camera with image measurement and analysis software is also an alternative method of measuring leaf area. The capture of image by digital camera is rapid, but the processing procedure is time consuming and the facilities are generally expensive (Lu *et al*., 2004).

Developing a rather inexpensive, rapid, reliable and non-destructive method for measuring leaf area becomes imperative for agronomists and plant scientists alike. By clarifying the mathematical relationships between leaf area and one or more dimensions of the leaf, a method using just linear measurements to estimate leaf area would be advantageous than many of the aforementioned methods (Villegas *et al*., 1981; Beerling and Fry, 1990). A mathematical model can be obtained by correlating the leaf length (L), width (W) or product of the length and width (L*W) to the actual leaf area (ALA) of a sample of leaves using regression analysis as has been achieved by various workers for various plants like *Vitis vinifera* (Maniviel and Weaver, 1974), *Carthamus tinctorius* (Sepaskhar, 1977), *Fragaria moschata* (Strik and Proctor, 1985), *Cucumis sativus* (Robbins and Pharr, 1987), *Cocos nucifera* seedlings (Mathes *et al*., 1990), *Musa spp* (Potdar and Pawar, 1991), *Cucurbita pepo* (Nesmith, 1992), *Lactuca sativa* (Guo and Sun, 2001), *Phaseolus vulgaris* (Bhatt and Chanda, 2003) and *Treculia africana* (Jayeoba *et al*., 2006).

Ocimum gratissimum is generally regarded as a plant of utmost importance in Nigeria and some other parts of African countries as it is used as spice in the preparation of the pepper soup delicacy, which is highly favoured by most people. The plant is usually cultivated for its leaves as it is also regarded as a medicinal plant; hence, a non-destructive method of evaluating leaf area for its agronomic studies is highly desirable. The objective of this study, therefore, was to develop a non-destructive and convenient mathematical model for estimating leaf area of *Ocimum gratissimum* using linear measurements.

MATERIALS AND METHODS

The study was carried out at the Federal College of Forestry, Ibadan (lat. 7^o 26$'$ N; long. 3^o 26$'$ E) Nigeria. A total of 300 leaves, representing five various leaf sizes, were randomly selected from the nursery stock and matured plants over a period of three months. The mean leaf sizes and number of leaves were as follows: very small (0.5cm width: 75 leaves); small (1.2cm width: 70 leaves); medium (2.6cm width: 60 leaves); large (4.5cm width: 50 leaves); very large (6.5cm: 50 leaves).

The actual leaf area (ALA) of the leaves was measured using a LI-COR-3000 area meter. The maximum lamina length (L) and lamina width (W) were measured from the lamina tip to the point of petiole intersection along the lamina midrib and tip to tip at the widest part of the lamina respectively with the aid of a well graduated meter rule. Furthermore, the leaves were also traced on standard graph paper and the numbers of squares within the boundary of the leaf outline were counted and the leaf area estimated thus.

Correlation analysis of the actual leaf area (ALA) and of the independent variables L, W, L^2, W^2, L+W and L*W were calculated. The data generated were fitted to linear and quadratic regressions to establish the best fitted regression model, which represents the relationship between ALA and combinations of L and W. Actual leaf area was taken as the dependent variable (Y) and the combinations of L and W as the independent variable (X) Statistical criteria for model selection were based on F-test, mean square error (MSE) and coefficient of determination (R^2).

RESULTS AND DISCUSSION

The descriptive statistics of the linear measurements is as presented in Table 1. The mean values for the measurements ranged from 12.19 for the ALA, 20.92 for L*W and 13.72 for graph which is closest to ALA while the standard error (s.e) was 0.69, 1.25 and 0.79 for ALA, product of L and W and graph paper respectively. The correlation matrix of the linear leaf measurements with that of the ALA (Table 2) indicates that L*W and graph were highly correlated at 0.98 compared with the other linear measurements. This is followed by L+W at 0.97. All the parameters were also highly significant at 1% level of significance; this indicates that all the linear measurements have good relationship with actual leaf area.

Table 1: Descriptive statistics of Linear Measurements

	ala	l	l^2	W	w^2	lw	l+w	graph
Mean	12.19	5.91	40.36	3.12	11.14	20.92	9.03	13.72
Standard Error	0.69	0.19	2.57	0.10	0.65	1.25	0.28	0.79
Median	8.66	5.45	29.71	2.90	8.41	15.22	8.10	10.12
Mode	9.84	3.80	14.44	2.00	4.00	12.00	6.40	5.11
Standard Deviation	8.50	2.35	31.69	1.18	7.97	15.38	3.45	9.77
Sample Variance	72.30	5.53	1004.57	1.40	63.48	236.59	11.92	95.40
Kurtosis	-0.09	-0.36	1.05	-1.06	-0.39	0.08	-0.71	0.18
Skewness	0.94	0.61	1.27	0.36	0.80	0.97	0.53	0.99
Range	35.73	10.40	147.68	4.90	33.81	70.10	15.00	42.95
Minimum	2.51	1.90	3.61	1.00	1.00	2.47	3.20	2.05
Maximum	38.24	12.30	151.29	5.90	34.81	72.57	18.20	45.00
Sum	1852.33	897.60	6135.16	474.70	1693.23	3180.25	1372.30	2085.42
Confidence Level (95.0%)	1.36	0.38	5.08	0.19	1.28	2.47	0.55	1.57

Table 2: Correlation matrix of actual leaf area and linear leaf measurements

	Actual Leaf area (la)	*Lamina length (l)*	*Lamina width (w)*	*Sq. Lamina Length (l^2)*	*Sq. Lamina width(w^2)*	Length + width (l+w)	Length * width (l*w)	*Graph paper*
Leaf Area	1							
L	0.956	1						
l^2	0.958	0.981	1					
W	0.944	0.900	0.869	1				
W^2	0.963	0.901	0.890	0.988	1			
Lw	0.989	0.969	0.973	0.953	0.970	1		
l+w	0.974	0.989	0.965	0.954	0.951	0.986	1	
Graph	0.989	0.958	0.961	0.939	0.960	0.998	0.974	1

*** significant at ($p<0.001$)

Results of the linear regression analysis (Table 3) for the determination of the best-fit models for the leaf area estimation of *Ocimum gratissimum* indicate that L*W and graph explained variation of the leaf area value significantly and better at $P<0.001$ and 98 % (Table 3) while the mean square error (MSE) was 1.62 and 1.56 respectively. The sum of L and W explained the variation by 95 %. The coefficient of determination (R^2) of L^2, L, W^2 and W were 0.92 (Fig. 5), 0.91 (Fig. 2), 0.93 (Fig. 3) and 0.89 (Fig. 1) respectively. The MSE of both L*W and graph best describe a close relationship between the two parameters and the ALA than the other parameters.

Previous work done by other scientists shows that leaf area measurements can be estimated using rapid, simple and rather inexpensive linear measurements.

Other scientists have also reported very close relationships between actual leaf area values and linear measurements such as summer squash at R^2= 0.976 to 0.983 (Elsner and Jubb (Jr), 1988; Ramkhelan and Braithwaite, 1992), cucumber at R^2= 0.76 to 0.99 (Robbins and Pharr, 1987), rabbiteye blueberries at R^2= 0.95 (NeSmith, 1992), grapes at R^2= 0.9841 to 0.9884 (Elsner and Jubb (Jr), 1988; Yin, 1990; Pedro Junior *et al*., 1989), oranges at R^2= 0.89 to 0.93 (Ramkhelawan and Braithwaite, 1992; Arias *et al*., 1989), French bean at R^2= 0.99 (Rai *et al*., 1990), coconut at R^2= 0.95 to 0.98 (Mathes *et al*., 1990) and *Treculia africana* at R^2= 0.93 (Jayeoba *et al*., 2006).

Flavio and Marcos (2003) further showed that equations that leaf area could be conveniently estimated using either L or W for cucumber and tomato suggesting that just one dimension could be showed in leaf area prediction for these plants.

CONCLUSION AND RECOMMENDATION

Mathematical model for predicting leaf area of *Ocimum gratissimmum* was developed using linear measurements of lamina length and width of the leaves. The product of L and W (L*W) and graph provided a more accurate estimation of *Ocimum* *gratissimmum* leaf area than other linear measurement combinations. However, the product of L and W is desirable due to its cost and labour effectiveness compared to the graph measurements. The equation Y= 0.5466(L*W) + 0.7501 is therefore recommended as leaf area prediction model for *Ocimum gratissimum* and this may also be used for other plants of similar leaf design. The equation from the present study could be utilized by inserting it into a cell in EXCEL 5.0, 6.0, 7.0 or LOTUS 3.0, 4.0, 5.0 to calculate the predicted leaf areas of similar plant species.

Table 3: Regression models of relationships between actual leaf area and linear leaf measurements (length and width), square of length and width (l^2 & w^2), product of length and width (l*w), sum of length and width (l+w) and graph paper measurements

Parameters	Regression Model	Mean Square Error (MSE)	Fprob.	R2
Lamina Length (l)	Y = 3.4569x - 8.2275	6.29	<0.001***	0.91
Sq. Lamina Length (l2)	Y = 0.257x + 1.8142	6.00	<0.001***	0.92
Lamina width(w)	Y = 6.7925x - 9.0268	7.96	<0.001***	0.89
Sq. Lamina width(w2)	Y= 1.0281x + 0.7341	5.25	<0.001***	0.93
Length + width (l+w)	Y= 2.3989x - 9.4715	4.91	<0.001***	0.95
Length * width (l*w)	Y= 0.5466x + 0.7501	1.62	<0.001***	0.98
Graph paper	Y = 0.8612x + 0.3711	1.56	<0.001***	0.98

*** significant at (p<0.001)

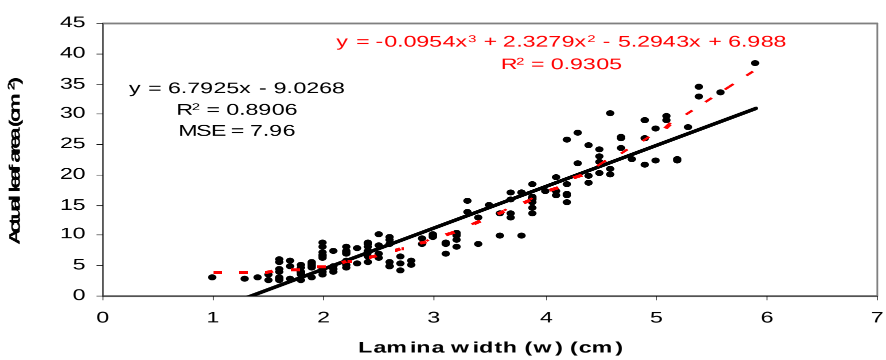

Fig. 1 Relationship between actual leaf area and lamina leaf width of *Ocimum gratissimum*

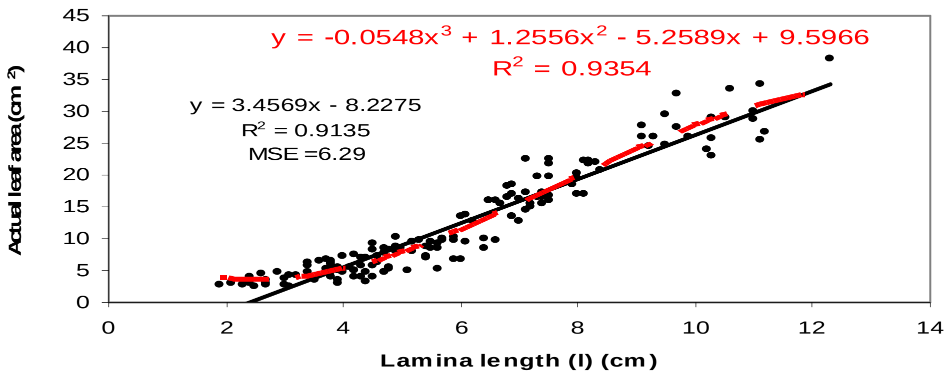

Fig. 2 Relationship between actual leaf area and lamina leaf length of *Ocimum gratissimum*

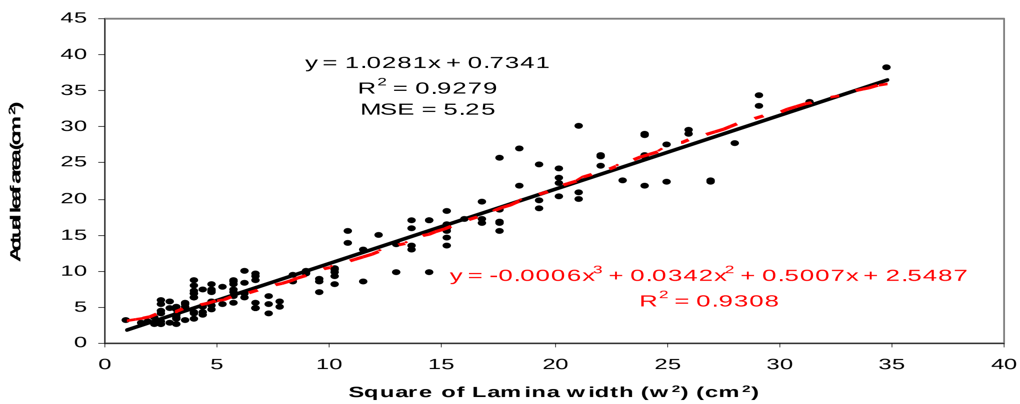

Fig. 3 Relationship between actual leaf area and square lamina leaf width of *Ocimum gratissimum*

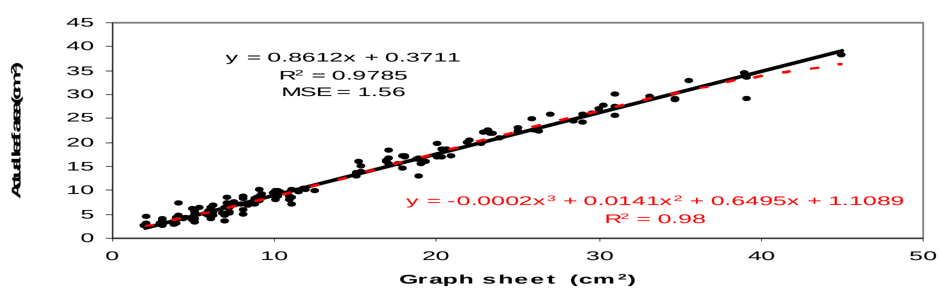

Fig. 4: Relationship between actual leaf area and graph measurement of *Ocimum gratissimum*

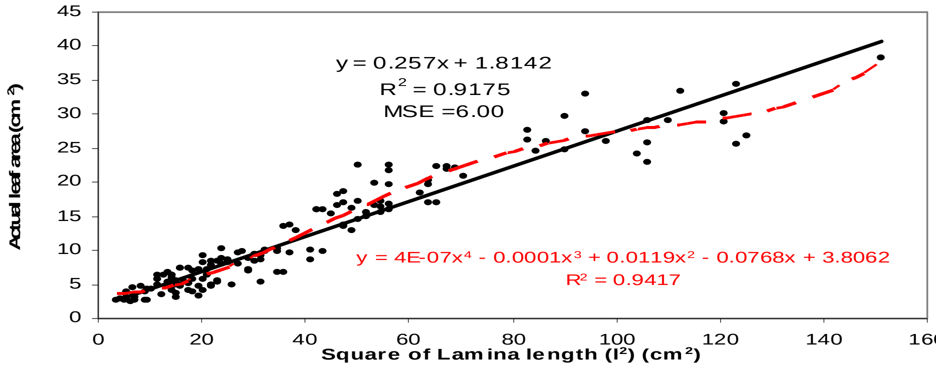

Fig. 5: Relationship between actual leaf area and square lamina leaf length of *Ocimum gratissimum*

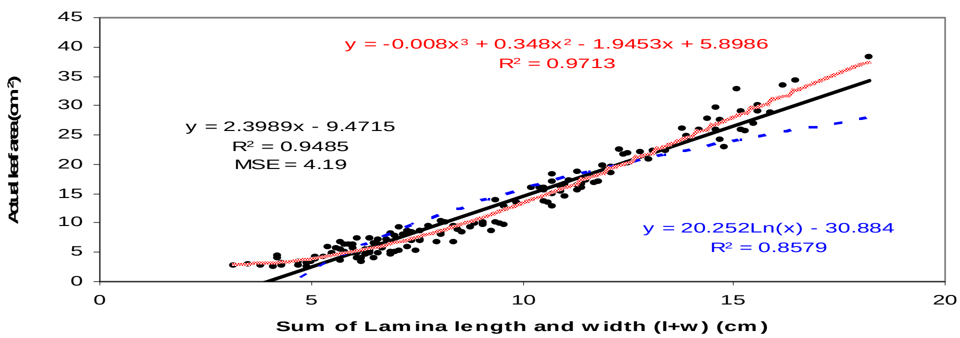

Fig. 6: Relationship between actual leaf area and sum lamina leaf length and width of *Ocimum gratissimum*

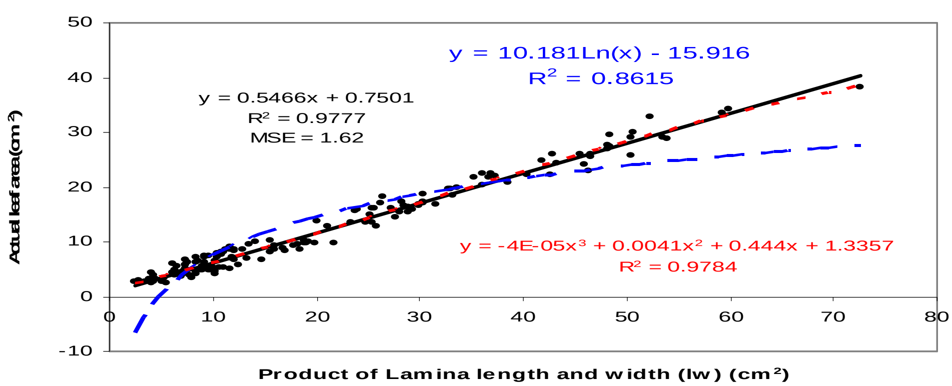

Fig. 7: Relationship between actual leaf area and the product of lamina leaf length and width of *Ocimum gratissimum*

REFERENCES

Arias E., Fernandez M, Telleria T. 1989. Modified method for determining foliar area in leaf samples of Valencia orange, *Hort. Abst.*, 59(11): 9508.

Beerling D.J., Fry J.C. 1990. A comparison of the accuracy, variability and speed of five different methods for estimating leaf area. Ann. Bot. 65:483-588.

Bhatt M., Chanda S.V. 2003. Prediction of leaf area in *Phaseolus vulgaris* by non-destructive method *Bulg. J. Plant Physiol*. 29(1–2): 96–100

Chan L.F., H.Y. Lu, C.T. Lu, C.H. Lai 1995. Relationship between leaf area and dry biomass production in wetland taro. *J. Agric. Res. China* 44:59–71

Chan, L.F., C.T. Lu, H.Y. Lu 1998. Growth analysis of wetland taro [*Colocasia esculenta* (L.) Schott] under various crop seasons. *J. Agric. Res. China* 47:220–241

Daughtry, C. 1990. Direct measurements of canopy structure. *Remote Sens. Rev*. 5:45–60

Elsner E.A., Jubb G.L.1988. Leaf area estimation of Concord grape leaves from simple linear measurements, *Amer. J. Enol. And Vitic*. 39(1): 95-97.

Flavio F.B, Marcos B. F. 2003. Anew method for estimating the leaf area index of cucumber and tomato plants. *Hortic Bras* 21: 4

Guo, D.P., Sun, Y.Z. 2001. Estimation of leaf area of stem lettuce (*Lactuca sativa* var angustana) from linear measurements. *Indian Journal of Agricultural Sciences*, 71 (7): 483-486.

Jacobs, B.C., Chand V. 1992. Large headsetts and improved cultivar enhance growth and development of taro [*Colocasia esculenta* (L.) Schott] during establishment. *J. Agron. Crop Sci*. 168:119–127.

Jayeoba O.J, Oluwasemire K O, Abiola I.O, Uzokwe.N.E, Ogunbanjo O. R. 2006.Leaf Area Prediction Models for *T reculia africana* (African Breadfruit Tree "AFON") Using Linear measurements. *Savanna Journal of Agriculture* 1(1):27-31

Lu, H. Y., Lu, C. T., Wei, M L., Chan, L F. 2004. Comparison of Different Models for Non-destructive leaf Areas Estimation in Taro. *Agron J* 448 –453

Manivel, L., Weaver, R.J. 1974. Biometric correlations between leaf area and length measurements of 'Grenache' grape leaves. HortScience, 9 (1): 27-28.

Mathes D., Liyanage Randeni, L.V.K. 1990. A method for determining leaf area of one, two and three year old coconut seedlings (Var. CRIC 60), *Hort. Abst.,* 60 (11): 9366.

NeSmith D.S. 1992. Estimating summer squash leaf area nondestructively, *HortScience* 27(1): 77.

Nyakwende E., Paul C.J., Atherton J.G. 1997. Non-destructive determination of leaf area in tomato plants using image processing. *J. Hortic. Sci*. 72:255–262.

Pedro Junior M.J., Ribeiro I.J.A., Martins F.P. 1989. Determination of leaf area in the grapevine cultivar *Niagara Rosada*, *Hort. Abst*., 59(1): 207, 1989

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

Rai A., Alipit P.V., Toledo M.B. 1990. Estimation of leaf area of French bean (*Phaseolus vulgaris*) Using Linear Measurements, *Hort. Abst.*, 60(5): 3405.

Ramkhelawan, E., Brathwaite, R.A.I. 1992. Leaf area estimation by non-destructive methods in sour orange (*Citrus aurantium* L.), *Hort. Abst*., 62(3): 2557.

Robbins, N.S., Pharr, D.M 1987. Leaf area prediction models for cucumber from linear measurements. *HortScience*, 22 (6) 1264-1266.

Satou T., Kawai M., Fukuyama T.1978. Studies on matter production of taro plant (*Colocasia esculenta* Schott). *J. Crop Sci*. 47:425–430.

Satou T., Miyauchi E., Sugimoto H. 1988. Studies on matter production of taro plant (*Colocasia esculenta* Schott). *J. Crop Sci*. 57:305–310

Sepaskhah, A.R. 1977. Estimation of individual and total leaf areas of safflowers. *Agronomy Journal*, 69,(5) 783-785

Strik, B.C., Proctor, J.T.A. 1985. Estimating the area of trifoliolate and unequally imparipinnate leaves of strawberry. *HortScience,* 20 (6) 1072-1074

Villegas, C.D., Bautista, A.T., Cotejo F.R 1981. Accurate and rapid techniques for leaf area measurement in cassava and sweet potato. *Radix* 3:10.

Yin, K. 1990. A study on the correlation between leaf form and leaf area in Kyoho grape (*Vitis vinifera L. X Vitis labrusca L. Cv. Red Fuji*), *Hort. Abst*., 60(11): 9366