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Rapid leaf Area Estimation of *Crytorchid monteiroae*

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Abstract Leaf area measurement of *Cyrtorchis monteiroae* was carried out at the University of Agriculture, Abeokuta, Nigeria in 2008. The objective of this study was to assess rapid leaf area estimation from both destructive and nondestructive sampling methods for *Cyrtorchis monteiroae*. Leaf samples were randomly selected from lower, middle and upper parts of the plant. Leaf length, leaf width, product of leaf length and width, leaf dry weight and leaf area from the graphical method were determined. The results showed that leaf width has the minimum variance (2.083) while leaf length × leaf width had the maximum variance (428.497). Also, all the considered growth indices were directly and significantly correlated. Of the entire investigated model, cubic model of the relationships between leaf area and the leaf length × leaf width gave the best result in term of minimum residual variance and highest coefficient of determination.

Key words

exponential model, cubic model, residual variance, monopodial

Cyrtorchis monteiroae (Rchb.f.) Schltr. is a member of the family Orchidaceae. It is one of the two members of the genus with fifteen species that are indigenous to Africa, including Nigeria and, found occasionally in cultivation for decorative, food, and medicinal purpose (Arditti, 1992; Cullen, 1992). It is a monopodial epiphyte with long stem and leaves are in two ranks, thick, fleshy and leathery, oblong with unequal two lobes at their apices and usually folded when young (Cullen, 1992).

Leaf area is important in the study of physiological process of plants as well as in assessment of plant growth and development. Leaves normally represent a plant's assimilating area and affect its photosynthetic and dry matter production. Several methods used to determine leaf area of plants include using a planimeter (Nautiyal, *et al*,, 1990), tracing out on graph sheet (graph method), measuring of weight of leaves, length of midrib or width, and multiplying by width (Wahua, 1985; Aiyelaagbe and Fawusi, 1988; Aiyelagbe, 1990; Monterro *et al* 2000). Based on the relationship between the actual leaf area (Graph method) and the corresponding length of midrib, width of leaf, and product of length and width, formulae for rapid determination of leaf had been suggested for Okra [*Abelmoschus esculentus* (L) Moench] (Asif, 1977); watermelon (Oseni and Fawusi, 1984); pawpaw (Aiyelaagbe and Fawusi, 1988); Guava [*Psidium guajava*] (Aiyelaagbe, 1990); Pumpkin [*Cucurbita maxima*] (Salau and Olasantan, 2004), and Queen of the Philippines [*Mussaenda philippica* A. Rich] (Olosunde, 2007).

Orchids are grown primarily as ornamentals and as cut flowers. They are multibillion dollar worth industries in many countries of the world (Wang, 2004), unlike in Nigeria. Exporters of potted orchids include Taiwan, Thailand, Japan, The Netherlands, Germany, China, India, Costa Rica and the United States (Griesbach, 2000; Laws, 2004. Majority of cultivable orchids exist in the wild in Nigeria (Vang and Cribb, 1983) and little work were known to popularize its cultivation and production for local and foreign markets which could enhance Nigeria's economy . The development of an appropriate and accurate measurement of leaf area for *Cyrtorchis monteiroae* is a useful tool in agronomical and physiological studies for its domestication and establishment for commercial production for export and domestic uses.

This study was undertaken to assess rapid leaf area estimation of *Cyrtorchis monteiroae* using both destructive and nondestructive sampling methods.

Materials and Methods

The study was conducted in the 2008, at the University of Agriculture, Abeokuta (7 15' N, 3 25'E) Ogun State, Nigeria, employing both nondestructive and destructive methods to estimate leaf area. For leaf area measurements, 200 mature and fully expanded leaves were randomly selected from the lower, middle and upper parts of the (plant) shoot. In the non – destructive method, the length and the width of midrib were collected when the leaves were still intact on the plant, and the product of length and width of each of the leaves were recorded. While for the destructive method, dry weight of 200 leaves were obtained by oven drying at 70°C for 36 hrs and cooled before the leaf dry weight were determined. Actual leaf areas of the leaves were obtained by graph paper tracing.

The data were subjected to descriptive statistics (like mean, variance and sums) and correlation analysis. Relationship between actual leaf area and leaf length, leaf width, leaf length × breadth and dry weight was determined using the following regression models;

$$Y = f(x_i),$$

$$Y = f\ln(x_i)$$

$$Y = f(x_i, x_i^2)$$

$$Y = f(x_i, x_i^2, x_i^3)$$

$$Y = f(\ell^{x_i})$$

where Y = leaf area (*LA)* and x_i = 1, 2 and 3. That is leaf length, leaf width and leaf length × width. The models were further subjected to analysis of variance to test for existence of significance difference in the means of the dependent and independent variables. Also, the coefficients of determination (R^2) as well as the variance of the residuals were computed. Lastly, the distribution of both observed and the predicted values were computed using Beta ($f(x) = \frac{1}{B(\alpha_1, \alpha_2)} \frac{(x-a)^{\alpha_1 - 1}(b-x)^{\alpha_2 - 1}}{(b-a)^{\alpha_1 + \alpha_2 - 1}}$), chi square ($f(x) = (x-\gamma)^{\nu/2 - 1} \exp(-(x-\gamma)/2) \Big/ 2^{\nu/2}\Gamma(\frac{\nu}{2})$) exponential ($f(x) = \lambda \exp(-\lambda(x-\gamma))$) gamma ($f(x) = \frac{(x-\gamma)^{\alpha-1}}{\beta^{\alpha}\Gamma(\alpha)} \exp(-(x-\gamma)/\beta)$) Laplace ($f(x) = \frac{\lambda}{2}\exp(-\lambda$), Normal ($f(x) = \frac{\exp(-\frac{1}{2}(\frac{x-\mu}{\sigma})^2}{\sigma\sqrt{2\pi}}$) Pareto ($f(x) = \frac{\alpha\beta^{\alpha}}{x^{\alpha+1}}$) and Power function ($f(x) = \frac{\alpha(x-a)^{\alpha-1}}{(b-a)^{\alpha}}$).

Results and Discussions

The descriptive statistics showed that mean leaf length, leaf width and length ***x*** width (*l x w)* were, respectively, 12.744cm, 2.124cm, and 37.651cm. The variance ranges between 2.083 for width and 428.497 for leaf length *x* leaf width. It was observed that leaf width have minimum variance. The implication of this is that the variance is a function of the magnitude of the data. The correlation analysis returned correlation coefficient ranging between 0.14 (correlation between length and width) and 0.963 (correlation between width and interaction of length width). All the correlation coefficient were significant at 0.05 level of significance. Similarly, narrowing down to leaf area, leaf length returned the highest correlation coefficient (0.867) with the leaf area while the least was the correlation between leaf area and leaf width (0.193). Neither negative nor zero coefficients was obtained (Table 2). The implication of this result is that all the growth indices are directly related though the relationship might be low in some cases.

Table 1

Descriptive statistics of the growth Indicies

Parameter	Mean	Variance	Minimum	Maximum	Sum
Leaf Length	12.744	4.034	6.8	16.1	2548.8
Leaf width	2.924	2.083	1.9	22.5	584.7
Length x width	37.651	428.497	13.6	299.25	7530.24

Table 2

Correlation table for the growth indices.

	Dry weight	***Leaf Length***	***Leaf width***	***Length x width***	***Leaf area***
Dry weight	-	0.541**	0.160*	0.292**	0.778**
Leaf Length		-	0.137*	0.396**	0.867**
Leaf width			-	0.963**	0.193**
Lenght x width				-	0.414**
Leaf area					-

The different models produced different sets of coefficient of determination (R^2) as well as of varying pattern. For the models and for all plant indices, the cubic model (1) gave the highest coefficient of determination (R^2). The implication is that the cubic model in each gives the highest predictive capacity. Each of the investigated models has different components and which are uniform across the different growth indices used in the models. The only exception is the cubic model which is not uniform across the growth indices (Table 3).

In this cubic model, the coefficient of any of the components apart from the dependent and the constant were found to be zero for some indices (Table 3).

The F statistics for the different models of the growth indices ranged from 7.650 (for the linear relationship between leaf area and leaf width) to 855.624 (for the quadratic models of the relationships between leaf area and leaf length by leaf width). All these F statistics were significant at 0.05 level of significant because they were all greater than their threshold levels (Table 3). Similarly, the variance of the residuals ranged between 4.913 for the cubic model of the relationship between leaf area and leaf length by width and the 60.784 for the exponential models of the same relationship. The implication of this is that the cubic model of the relationship between leaf area and leaf length by width have the residuals with minimum variance. This model (cubic models of the relationship between leaf area and leaf length by width) in addition gave the highest coefficient of determination as well as a relatively high and significant F statistics. Based on these facts therefore, it is wise to choose the cubic model (1) to predict the leaf area of *Cyrtorchis monteiroae.*

$$Y = -1.773 + 0.984x - 0.004x^2 + 0.00000239x^3 \quad .1$$

The plot of the predicted values against the observed showed that the trend is random and non stationary. This showed that the error term would be random and thus plausibility of the model is implied. Model simulation for the chosen model (cubic model) showed that the validity range of this model is $1 < x = \infty$ (Figure 1B). At x = 1, the leaf area becomes negative and it is absurd. Also, the test of the distribution of both the observed and predicted values gave the same power function as the best distribution functions using χ^2 statistics (Table 4). The graph of the power distribution function revealed a higher distribution values for the predicted values when compared with the observed values (Figure 2). The increase in the power function is a desirable feature of an efficient estimator (Krishnamoorthy, 2006) hence the cubic model could be adjuged as an efficient estimator of the leaf area. This model falls in line with Tsialtas and Maslaris (2008)'s quadratic model for estimating the leaf area of sugar beet. The model explored the relationship between the leaf length and leaf width to estimate the leaf area using quadratic model while this study uses cubic model for the same relationship. The difference in the model type could be related to:

(i) difference in the plant species used and

(ii) No report of attempt to investigate the cubic model was read in Tsialtas and Maslaris (2008).

Similarly, Kathirvelan and Kaliselvan (2007) have explored the interaction between leaf length and width in the allometric relation between leaf area and linear measurement (length x width) of groundnut leaf. Similarly, it is noteworthy that the cubic component of this stochastic model contributed a significantly lower value (0.00000239) to the model. Thus the shape of the model could be similar to that of quadratic model.

From these facts, the importances of linear measurement (leaf length x leaf width) in leaf area estimation have been stressed. Also, the choice of the cubic model for the estimation of the leaf area for *Cyrtorchis monteiroae* is justified.

Conclusions

1. This model (cubic regression model-1) developed in this study is adoptable for rapid and sufficient (that is with minimal residual's variance) estimation of leaf area otherwise known as adaxial leaf area.
2. This model provides a better estimation over the quadratic form that are widely in use for other plants because of its minimum variance as well as higher coefficient of variations (R^2).
3. Non destructive determination of the leaf area through this model assures sustainable experimental monitoring and research.
4. The model provides a good substitute where graphing method's materials as well as expertise are unavailable in addition to its been simple.
5. through this stochastic model prompt determination of leaf area is assured.

It is thus recommended that spatial and temporal dependence of the model be investigate in future research to determine its reliability across time and space.

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Table 3

Summary of the different models, their coefficient of determination and their residuals' variances

eaf area against	**Model**	**Constant**	X	X^2	X^3	**In** X	ℓ^x	R^2	**F**	σ^2
Dry weight	Linear	5.846	65.323	-	-	-	-	0.606	304.457	18.770
	Logarithmic	53.453	-	-	-	22.973	-	0.616	317.269	18.303
	Quadratic	- 7.449	141.882	- 104.557	-	-	-	0.620	160.524	18.113
	Cubic	34.468	- 217.040	877.504	- 861.902	-	-	0.631	111.501	17.598
	Exponential	12.448	-	-	-	-	2.304	0.596	291.635	20.281
Leaf length	linear	- 8.989	2.978	-	-	-	-	0.751	597.847	11.850
	Log	- 57.753	-	-	-	34.257	-	0.712	488.380	13.7403
	Quard	24.241	- 2.624	0.229	-	-	-	0.778	345.095	10.577
	Cubic	15.185	0	- 0.013	0.007	-	-	0.779	347.789	10.513
	Exp	7.126	-	-	-	-	0.108	0.777	690.055 9	10.702
Leaf width	Linear	26.270	0.922	-	-	-	-	0.037	7.650	45.860
	Log	11.459	-	-	-	16.839	-	0.240	62.520	36.201
	Quad	- 13.677	17.031	- 0.673	-	-	-	0.534	112.795	22.205
	Cubic	- 9.384	13.776	-	-0.024	-	-	0.535	113.483	22.1327
	Exp	25.517	-	-	-	-	0.033	0.038	7.927	47.556
Length X width	Linear	23.767	0.138	-	-	-	-	0.172	41.011	39.459
	Log	- 37.557	-	-	-	18.628	-	0.652	371.603	16.557
	Quad	- 0.833	0.927	- 0.003	-	-	-	0.897	855.624	4.917
	Cubic	-1.773	0.984	-0.004	0.00000239	-	-	0.897	568.094	4.913
	Exp	23.347	-	-	-	-	0.005	0.174	41.822	60.784

NB: **-** implies not applicable for such model while "0" implied zero coefficient for such component.

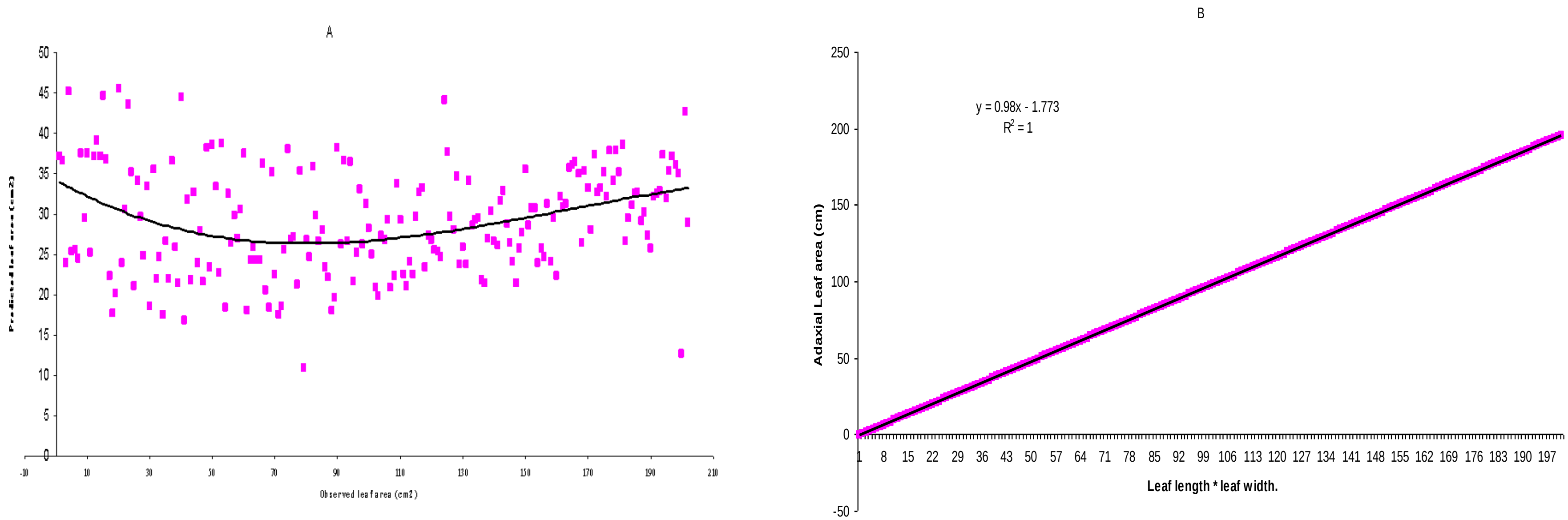

Fig. 1. Predicted leave area against the observed leaf area (A) and Model Simulation for the cubic Model (B).

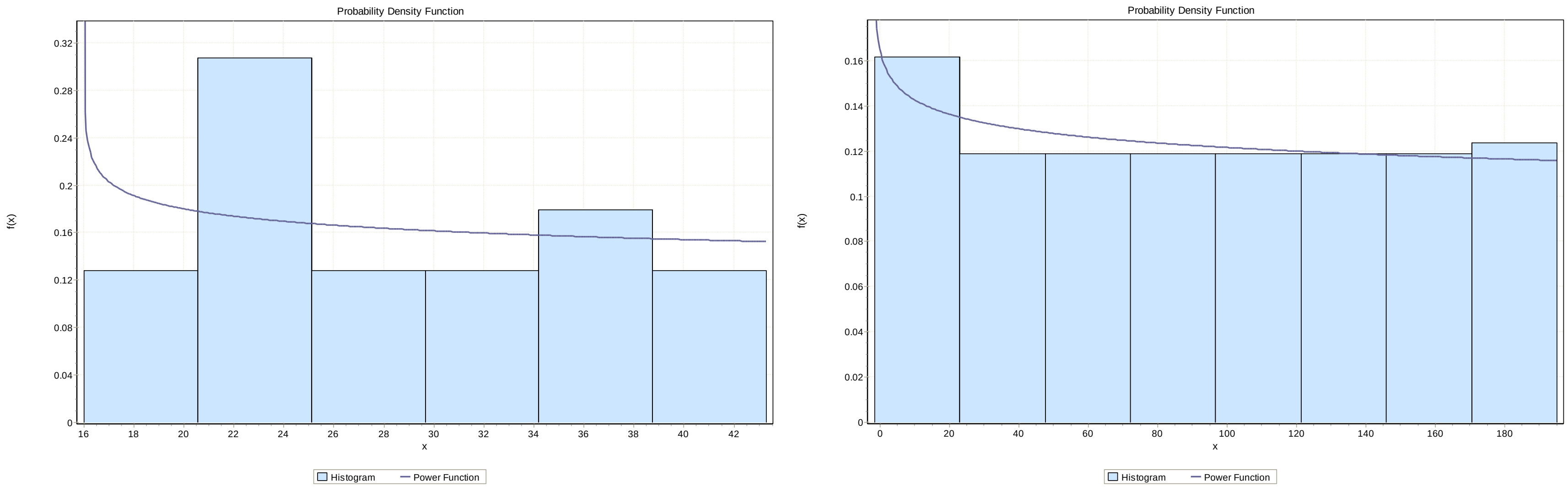

Fig. 2. Distribution (power Distribution) of the observed (A) and predicted (B) value.

Table 4

Summary of the Distribution of the observed and predicted Leaf area

Functions	**Observes**		**Predicted**	
	Parameters	**Rank**	**Parameters**	**Rank**
Beta	α_1=0.92085 α_2=1.0086 a=16.0 b=43.3	**4**	α_1=0.84489 α_2=0.94959 a=-1.675 b=195.21	**6**
Chi square	ν=30 γ=-1.0121	**3**	ν=1746 γ=-1653.8	**5**
Pareto	k=-0.70982 σ=21.349 μ=16.543	**2**	k=-0.97971 σ=202.21 μ=-9.1559	**2**
Normal	σ=7.9669 μ=29.029	**6**	σ=59.24 μ=92.986	**3**
Laplace	λ=0.17751 μ=29.029	**5**	λ=0.02387 μ=92.986	**4**
Power	α=0.91299 a=16.0 b=43.3	**1**	α=0.92604 a=-1.675 b=195.21	**1**
Gamma	α=3.2831 β=4.6755 γ=13.679	**7**	α=22.956 β=12.461 γ=-193.67	**7**