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Non-destructive Method of Leaf Area Estimation for Oleander (*Nerium oleander* L.) Cultivated in the Iraqi Kurdistan Region

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***Abstract*—This study was conducted in the Iraqi Kurdistan region in January 2014 to determine the individual leaf area of oleander (*Nerium oleander* L.) by easy, accurate, inexpensive, and nondestructive method. Simple, multiple and exponential regression analyses were used by length (L) and width (W) and their combinations as independent variables and with leaf area as dependent variable to determine more accurate models (high coefficient of determination and less MSE). The results showed that the best fitting models that show more accurate estimation of oleander leaf area, compared to other models, were the simple linear regression that depends on length multiple width for Koya and Erbil cities and the total leaves of the two cities plants. On the other hand, the best fitting multiple linear equations were those which depend on square length and square width for Koya city and the total leaves of the two cities plants, whereas for Erbil city the best model was that depends on leaves with square length and width. Multiple linear regressions were the more accurate among the models, followed by simple linear regression, whereas the exponential model had the lowest accuracy. All coefficients of regressions values were found to be significant at the P < 0.0001 level.**

***Index Terms*— Leaf area estimation, *Nerium oleander* L., non-destructive methods, regression equations.**

I. Introduction

Nerium oleander L. (Apocynaceae) is an evergreen shrub, distributed in the Mediterranean region and subtropical Asia. It is an urbanite plant widely used for ornamental purposes in streets, gardens, and hospitals (Rasul, Abbas and Abdul, 1986). Plant Leaf Area (LA) is an essential component to estimate plant growth through its incidence on crop physiology mechanisms (Bhatt and Chanda, 2003), also it is an important determinant of light interception and consequently of transpiration, photosynthesis and plant productivity (Rosatia, Badeck and Dejong, 2001; Blanco and Folegatti, 2005). Leaf area production is essential for energy transference and dry matter accumulation processes in crop canopies. It is also useful in the analysis of canopy architecture (Mohammad, et al., 2011).

Measurement of leaf area divided to destructive and non-destructive methods. Usually destructive methods almost used by means of leaf area meter, this instrument may not available or expensive and very sensitive for calibration, while the non-destructive method is very simple and need to expensive instrument like portable scanning planimeter (Daughtry, 1990), but it is used for plants with a few small leaves (Nyakwende, Paull and Atherton, 1997). The measurement of LA, expressed per tree or as Leaf Area Index (LAI), can be a time consuming process and requires sophisticated electronic instruments, which are expensive especially for developing countries (Bhatt and Chanda, 2003). Moreover, destructive methods may cause inconvenient for some investigations, therefore, alternatives to estimate LA on the field may be provided by practical and non-destructive methods (Gutierrez and Lavín, 2000). For example, a rapid and non-destructive method to estimate LA is the use of equations that needs leaf dimensions (length and width) as inputs. Accurate non-destructive measurements permit repeated sampling of the same plants over time and have the advantage that biological variation can be avoided, especially when using unique plants (Schwarz and Klaring, 2001).

Various combinations of measurements and various models relating length and width to area have been utilized in, for example, grapevine (Gutierrez and Lavín, 2000; Williams and Martinson, 2003), dracaena *Dracaena sanderiana* L. (Srikrishnah, Peiris and Sutharsan, 2012), rose *Rosa hybrida* L. (Fascella and Rouphael, 2013), *Crytorchid monteiroae* (Olosunde, Dauda and Aiyelaagbe, 2010) common bean *Phaseolus vulgaris* L. (Bhatt and Chanda, 2003), pepper *Capsicum annuum* L. (De Swart, et al., 2004), radish

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Raphanus sativus L.(Salerno, et al., 2005), cucumber *Cucumis sativus* L.(Cho, Oh and Son, 2007), cauliflower and cabbage *Brassica oleracea* (Olfati, et al., 2010) and elephant's ears *Bergenia purpuracense* (Zhang and Liu, 2010). Such equations allow growers and researchers to estimate LA in relation to other factors like crop load, drought stress and insect damage (Williams and Martinson, 2003).

The objective of this study was to develop an accurate, simple, non-destructive and time saving model for estimation leaf area for oleander shrubs.

II. MATERIALS AND METHODS

A. Sample Collection

The research was conducted in both of Koya (clayey soil with pH 7.45 and EC 9.15, located at 44°39`E, 36°05`N, and 618 m of altitude) and Erbil (sandy clay soil with pH 8.1 and EC 0.5, located at 44°03`E, 36°16`N, and 436 m of altitude) cities, Iraq-Kurdistan. Sampling of leaves of oleander shrubs was conducted at January 2014. Ten shrubs from each location were selected and leaves from 4 branches (one branch for each site of North, South, East and West) per shrub were chosen as samples (leaves number were 210 for each city). Table I shows the temperature, relative humidity and the amount of rain fall during the last 13 months of conducting the study, as it prepared in Agro-Meterological Station in Koya city/ Ministry of Agriculture/ Iraq- Kurdistan Region for Koya city and Directorate of Weather and Earthquakes/ Erbil/ Iraq-Kurdistan Region for Erbil city.

B. Measurement Parameters

The measurements parameters comprise of leaf length (L) from lamina tip to the connected place petiole to lamina and width (W) from tip to tip at the widest of the lamina. The length and maximum width of leaves were measured to the nearest 0.01 cm and the area to the nearest 0.01 cm^2.

C. Leaf Area Estimation

Leaf area is determined by spreading each leaf over a paper, and the outline of the leaf was drawn. By using a scissor, the area of the paper covered by the outline was cut and weighed on an electronic balance. One $cm^2$of the same paper was also cut and weighed. The following equation was used to calculate the leaf area:

$Leaf\ area\ (cm^2) = {}^{x}/_{y}$, where x is the weight of the paper covered by the leaf outline (g) and y is the weight (g), of the cm^2 area of the paper (Pandey and Singh, 2011).

Simple linear, multiple linear and exponential regression equations were utilized by using length (L), width (W) and their products (L+W), (L^2+W), (L+W^2), (L^2+W^2) and (LW) as independent variables. These analyses were performed on each location individually, and also on the two locations together. The best and more accurate predicted equation for the leaf area (LA) was the equation with high coefficient of determination and less mean square of error (MSE).

D. Statistical Analysis

Analyses of the data were done by using SPSS program. ANOVA analysis was carried out to detect the significantly of the different regression models (Reza, 2006).

III. RESULTS AND DISCUSSIONS

A. Simple Linear Regression

Table II show simple linear regression models that used for determine the predicated leaf area regarding to leaf length (L), square length (L^2), width (W), square width (W^2), length plus width (L+W) and length multiple width (LW). The results show that in both Koya and Erbil cities and also about total leaves of the two cities, the equation numbered 16, 17 and 18

TABLE I
MAXIMUM, MINIMUM AND AVERAGE OF TEMPERATURE, AVERAGE RELATIVE HUMIDITY AND THE AMOUNT OF RAIN FALL DURING JANUARY 2013 TO JANUARY 2014

Jan. 2013 to Jan. 2014	Koya					Erbil				
	Temperature (C°)			Average Relative Humidity (%)	Fall mm)	Temperature (C°)			Average Relative Humidity (%)	Fall (mm)
	Min.	Max.	Average			Min	Max.	Average		
Jan.	5.87	10.90	8.21	72	254.5	5.3	12.7	9.0	74	174.4
Feb.	8.21	13.75	10.98	72	95.7	7.7	16.4	12.1	76	55.8
Mar.	10.10	17.52	13.97	66	10.9	10.0	19.9	15.0	62	17.7
Apr.	15.87	23.23	19.55	60	10.6	14.5	26.2	20.4	54	37.4
May	21.48	29.16	25.47	57	16.4	19.4	31.2	25.3	48	40.6
June	27.43	36.87	32.15	42	0.0	24.8	38.0	31.4	31	0.0
July	26.10	33.81	29.97	36	0.0	27.3	41.3	34.3	29	0.0
Aug.	16.71	25.87	21.29	36	0.0	27.1	41.0	34.1	29	0.0
Sep.	20.60	29.40	25.00	30	0.0	22.0	35.6	28.8	38	T.R *
Oct.	18.77	28.32	23.40	30	1.5	17.5	28.9	23.2	39	0.2
Nov.	20.47	17.65	14.20	60	69.5	12.8	21.9	17.4	68	19.1
Dec.	5.81	10.26	8.00	61	117.7	5.6	13.6	9.6	66	86.6
Jan.	6.23	11.97	9.10	65	330.5	1.9	18.0	9.8	66.0	47.8
Average	15.7	22.2	18.6	52.8	69.8	15.1	26.5	20.8	52.3	36.9

* T. R means that rain fall was less than 1 mm

TABLE II
INTERCEPT (a) AND REGRESSION COEFFICIENT (b) FOR SIMPLE LINEAR REGRESSION USED FOR ESTIMATING *Nerium oleander* L. LEAF AREA FROM LENGTH (L), WIDTH (W) AND SOME COMPATIBLES

Location	Treatment No.	Equation type	Intercept (a)	Coefficient (b)	Coefficient of Determination (R^2)	Coefficient of Correlation (R)	MSE	Significant (P<0.0001)
Koya	1	$LA = a + bL$	-21.464	3.336	0.841	0.917	14.368	**
Erbil	2		-7.149	1.771	0.772	0.879	4.433	**
Total	3		-19.162	3.042	0.817	0.904	15.940	**
Koya	4	$LA = a + b\,L^2$	-0.160	0.126	0.857	0.926	12.852	**
Erbil	5		1.073	0.090	0.827	0.909	3.363	**
Total	6		-2.191	0.129	0.870	0.933	11.310	**
Koya	7	$LA = a + bW$	-12.223	15.194	0.889	0.940	10.516	**
Erbil	8		-4.492	11.229	0.837	0.915	3.176	**
Total	9		-8.606	13.532	0.914	0.956	7.526	**
Koya	10	$LA = a + bw^2$	5.287	3.102	0.882	0.939	10.703	**
Erbil	11		3.538	3.698	0.825	0.908	3.435	**
Total	12		4.678	3.198	0.919	0.959	7.046	**
Koya	13	$LA = a + b\,(L + W)$	-21.853	2.866	0.889	0.943	10.027	**
Erbil	14		-8.163	1.643	0.839	0.916	3.131	**
Total	15		-18.785	2.611	0.778	0.937	10.652	**
Koya	16	$LA = a + b(LW)$	1.037	0.681	0.951	0.975	4.432	**
Erbil	17		1.222	0.659	0.956	0.978	0.865	**
Total	18		.915	0.683	0.970	0.985	2.574	**

that using leaf length multiple width (LW) had the strongest relationship (p<0.0001) with LA, manifested in high coefficients of determination (R^2) of the equations and low mean square of error (MSE), whereas, regarding the equations that used only one leaf dimension, the equation using leaf width (W) had the strongest relationship (p<0.0001) with LA, compare to equations depend on leaf length (L), square length (L^2) and square width (W^2).

Kumar and Sharma (2010) found that linear model ($LA = -3.44 + 0.729\,LW$) which depending length multiple width (LW) as independent variable gave more accurate estimation for saffron (*Salvia sclarea* L.) leaf area compared to other models. Many other researchers also reported that leaf area can be estimated by linear measurement such as leaf width and leaf length in plants, such as Cristofori, et al. (2007), Mendoza-de Gyves, et al. (2007), Peksen (2007) and Rivera, et al. (2007) for developing simple and non-destructive models for estimating plant leaf area by using simple linear regression measurement. Also each of Lakshmanan and Pugazhendi found that the best fitting equations for oleander was $LA = -22.562 + 21.209W$ and $LA = -22.226 + 2.978L$ with $R^2 = 0.847$ and 0.893 respectively. The results in Table II show high significant correlation relationship (P<0.0001) between independent variables used in the study with the leaf area which consider as dependent variable.

B. *Multiple Linear Regression*

The advantage of multiple regressions over simple regression analysis is in its enhancing our ability to use more available information in estimating the dependant variable (Reza, 2006). When the models change from simple to multiple linear regression by using length and width and some combinations as independent variables as it shown in Table III, the leaf area estimation became more accurate through increasing coefficient of determination and decreasing mean square experimental error (MSE). The results of this Table show that the equation numbered 22 that using leaf square length and square width (L^2 and W^2) had the strongest relationship (p<0.0001) with LA in Koya city, manifested in high coefficients of determination (R^2) of the equations and low mean square of error (MSE). In Erbil city the equation numbered 26 that depends square length and the width (L^2 and W) had the strongest relationship (p<0.0001) with LA. About total leaves of the two cities, the equation No. 24 had the strongest relationship with LA, which were (L^2 and W^2) respectively.

This results agree with Cirak, et al. (2005) who found that multiple regression analysis used for determination of the best fitting equation for estimation of leaf area in seven medicinal plants (*Calamintha nepeta*, *Datura stromonium*, *Melissa officinalis*, *Mentha piperita*, *Nerium oleander*, *Origanum onites* and *Urtica dioica*) showed that most of the variation in leaf area values was explained by the basic parameters (length and width) and reached to 91%. The more accurate fitting in multiple linear regression is due to multiple linear regression model can be set more beside leaves length or width, when other variables that not measured in simple linear regression are responsible for the variation in the leaf area (Clewer and Scarisbrick, 2001).

C. *Exponential Regression*

Table IV show exponential regression models that used for determine the predicated leaf area regarding to leaf length (L), square length (L^2), width (W), square width (W^2), length plus width (L+W) and length multiple width (LW). The results show that equations 43 and 45 which use leaf length plus width (L+W) had the strongest relationship (p<0.0001) with LA, manifested in high coefficients of determination (R^2) of the equations and low mean square of error (MSE) for Koya city and total leaves of Koya and Erbil cities. For leaves of Erbil city plants the equation number 47 that depends on leaf

TABLE III
INTERCEPT (a) AND REGRESSION CCOEFFICIENTS (b1 AND b2) FOR MULTIPLE LINEAR REGRESSION WITH TWO INDEPENDENT VARIABLES USED FOR ESTIMATING *Nerium oleander* L. LEAF AREA FROM LENGTH (L) , WIDTH (W) AND SOME COMPATIBLES.

Location	Treatment No.	Equation type	Intercept (a)	Coefficient (b_1)	Coefficient (b_2)	Coefficient of Determination (R^2)	Coefficient of Correlation (R)	MSE	Significant (P<0.0001)
Koya	19	$LA = a + b_1 L + b_2 W$	-19.359	1.551	9.435	0.934	0.987	5.959	**
Erbil	20		-8.536	0.926	7.195	0.940	0.970	1.170	**
Total	21		-13.98	1.291	8.052	0.939	0.969	4.701	**
Koya	22	$LA = a + b_1 L^2 + b_2 W^2$	0.784	0.064	1.808	0.953	0.976	4.261	**
Erbil	23		0.831	0.052	2.131	0.955	0.977	0.871	**
Total	24		0.523	0.058	1.991	0.971	0.985	2.573	**
Koya	25	$LA = a + b_1 L^2 + b_2 W$	-9.209	0.062	8.896	0.945	0.972	4.961	**
Erbil	26		-3.770	0.050	6.562	0.957	0.978	0.846	**
Total	27		-7.244	0.058	8.348	0.961	0.980	3.398	**
Koya	28	$LA = a + b_1 L + b_2 W^2$	-9.667	1.641	1.884	0.949	0.974	4.609	**
Erbil	29		-3.729	0.964	2.343	0.943	0.971	1.114	**
Total	30		-6.186	1.234	2.203	0.965	0.982	3.085	**

TABLE IV
INTERCEPT (a) AND REGRESSION COEFFICIENT (b) FOR EXPONENTIAL REGRESSION USED FOR ESTIMATING *Nerium oleander* L. LEAF AREA FROM LENGTH (L), WIDTH (W) AND SOME COMPATIBLES.

Location	Treatment No.	Equation type	Intercept (a)	Coefficient (b)	Coefficient of Determination (R^2)	Coefficient of Correlation (R)	MSE	Significant (P<0.0001)
Koya	31	$LA = ae^{bL}$	2.569	0.157	0.881	0.938	0.022	**
Erbil	32		1.888	0.164	0.810	0.900	0.030	**
Total	33		1.707	0.181	0.873	0.934	0.036	**
Koya	34	$LA = ae^{bL2}$	7.318	0.005	0.835	0.914	0.031	**
Erbil	35		4.172	0.008	0.816	0.903	0.029	**
Total	36		4.955	0.007	0.847	0.920	0.044	**
Koya	37	$LA = ae^{bw}$	4.210	0.693	0.864	0.929	0.026	**
Erbil	38		2.566	1.000	0.808	0.899	0.030	**
Total	39		3.557	0.769	0.886	0.941	0.032	**
Koya	40	$LA = ae^{bw2}$	9.695	0.135	0.791	0.889	0.040	**
Erbil	41		5.361	0.319	0.751	0.866	0.039	**
Total	42		7.631	0.171	0.796	0.892	0.059	**
Koya	43	$LA = ae^{b(L+W)}$	2.556	0.134	0.919	0.950	0.015	**
Erbil	44		1.737	0.151	0.870	0.932	0.020	**
Total	45		1.770	0.154	0.921	0.959	0.022	**
Koya	46	$LA = ae^{b(LW)}$	7.962	0.030	0.886	0.941	0.021	**
Erbil	47		4.326	0.057	0.897	0.947	0.016	**
Total	48		6.092	0.037	0.885	0.941	0.033	**

length multiple widths (LW) had the strongest relationship with LA. Whereas, regarding the equations that used only one leaf dimension, the equation using leaf length (L), square leaf length (L^2) and leaf width (W) had the strongest relationship with LA in each of Koya city, Erbil city and total leaves of Koya and Erbil cities respectively. These results agree with Kumar (2009) whom found that exponential model that depending length as independent variable gave more accurate estimation for saffron (*Crocus sativus* L.) leaf area compared to other models as a result of higher value of R^2.

From the results shows in Tables II, III and IV the equations using leaf length (L), maximum leaf width (W) or their products had strong relationships with LA, manifested in high coefficients of determination (R^2) of the equations and low mean square error (MSE). Single variable equations would be preferred because they avoid problems of co-linearity between L and W, and require measurement of only one leaf dimension.

However, the best fitting simple linear equations for oleander was $LA = 1.037 + 0.681(LW)$ for Koya city, $LA = 1.222 + 0.659(LW)$ for Erbil city and $LA = 0.915 + 0.683(LW)$ for the leaves of the two cities, while, the best fitting multiple linear equations was $LA = 0.784 + 0.064L^2 + 1.808W^2$ for Koya city, $LA = -3.77 + 0.05L^2 + 6.562W$ for Erbil city and $LA = 0.523 + 0.058L + 1.991W$ for the leaves of the two cities. The variation between independent variables included in simple linear, multiple linear and exponential regressions between Koya and Erbil cities may due to the differences between the environmental conditions, and its effects on leaves growth, where the climactic condition in Erbil city is characterizes by more temperature degrees and low relative humidity and rain fall (Table I), in addition to the differences between the soil texture (clayey in Koya city and sandy clay in Erbil city) which has a role in determining the leaf growth and area, this result agree with Al-Barzinji, Khudhur and Abdulrahman (2015) whom found significant differences in *Dalbergia sissoo* (Roxb.) leaf area for plants grow in clayey and sandy clayey soils.

IV. Conclusions

In this study the models for predicting leaf area for the oleander plants were developed, and the multiple linear regression models were more accurate than simple linear regression models. Also simple linear regression model was more accurate than exponential regression model. We can estimate oleander leaf area on the plant without destroying them anywhere in a field or pot and continue with taking data for long time. The highest regression correlation between L and W and actual leaf area belonged to $LA = 0.784 + 0.064L^2 + 1.808W^2$ for Koya city, $LA = -3.77 + 0.05L^2 + 6.562W$ for Erbil city and $LA = 0.523 + 0.058L^2 + 1.991W^2$ for the leaves of the two cities

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