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PREDICTION OF LEAF AREA BY A NON-DESTRUCTIVE METHOD OF *Platanus orientalis TREE*

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ABSTRACT

***Platanus orientalis* L. is one of the most popular cultivated forest trees in In Kurdistan Region of Iraq. The leaf area is considered as an important parameter in the majority of physiological studies including plant growth. The simplicity of making measurements, quickness, and non-destructivity of the plants are some of the merit uses of the leaf area in such purposes. The aim of the current research was to develop and validate an equation to predict the individual leaf area (LA) of *Platanus orientalis* L. The parameters used in this study included leaf length (*L*) and width (*W*) as well as some combinations of these variables of plane tree leave. The SPSS software package was used to develop seven different regression equations along with many measures of precision for testing the performance of the developed equations in predicting the response variable. At the beginning, a scatter diagram was done using the leaf area as dependent variable and each of the leaf parameters as independent variables. The purpose of such a diagram was to figure out the type of relationship between studied variables in order to determine the most appropriate transformed forms of both response variable and explanatory variables. 20 trees were randomly chosen from Erbil City. Out of seven regression equations developed the equation LA= 20.912199+0.408927*(L*W) was finally selected because of being the most appropriate one among the other different equations.**

KEYWORDS: Leaf area, *Platanus orientalis* l., Predicted leaf area Model validation, Non-destructive methods

1. INTRODUCTION

According to Kew Species Profiles (KSP) *Platanus orientalis* L. plane is a tree with extensively spreading branches, leaves like a maple tree with flaky bark. It is a common ornamental tree in urban areas such as towns and cities. The species recognized owing in part to its capability to cope with water stress, air pollution, and soils with less ability to absorb precipitation (Plants of the World, 2019). Ecologically, Plane has been the main part of Erbil parks, gardens, planted for shade along streets. Generally, Leaf is the main plant organ, and is related with photosynthesis and evapo-transpiration processes. Consequently, in the majority of physiological studies including plant growth that leaf growth measurements are requested (Guo and Sun, 2001). Leaf area LA can be defined as the one-sided projected surface area (Spann and Heerema, 2010). In addition, measuring leaf area LA is an explanatory variable for other physiological studies such as light interception, and other crops for restraining of irrigation and fertilizers (Blanco and Folegatti, 2005). Sinoquet and Andrieu (1993) stated that the two key measurements which can influence the canopy capacity to light interception are the total leaf area and the geometrical composition of the leaves. Another benefit of measuring leaf area is essential to measure leaf area index LAI. Asner *et al.*, (2003) suggested that analyzing the structure of the canopy LAI is one of the mainly essential parameters; owing to the fact that it gives an explanation of plants restraint to the environmental condition of locations.

There are several common direct methods are offered to measure leaf area for a single plant leaf such as scanner methods, laser planimeters, gravimetric methods, with a fixed camera and image analysis software. On the other hand, these methods need leaf removal from the plants. It is for that reason not imaginable to make straight measurements of the same leaf. Plant canopy cover is also destroyed, which may cause problems for other researches (Rouphael *et al.*, 2010). With respect to the above tools using a handy planimeter LA can be measured quickly, precisely, (Daughtry, 1990). However,

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Nyakwende *et al.,* (1997) observed that the tool is only appropriate for small plants with few leaves and it is not practicable for a larger number of leaves. The main restrictions of direct method are being costly and destructive (Eslamdoust *et al.,* 2017). Accurate, indirect methods give a permission frequent sampling of the single leaves over time and eliminate biological variation in destructive measurements (De Swart *et al*., 2004). LA of a plant can be calculated from a linear measurement like leaf length (L) and leaf width (W) of each single leaf. A Linear measurement of leaves can be used as a general relationship A=b ×L×W where b is a coefficient which was documented by (Rouphael *et al*., 2010). As a result, different equations have been examined in order to measure leaf area by nondestructive methods. Furthermore, built up a modeling approach is less expensive, fast, dependable and a nondestructive substitute for accurately measuring leaf area (Lu *et al*., 2004). In addition, these equations may enhance accuracy where leaf sizes of sample are not easy to handle, and could decrease of sampling attempt and cost (Williams and Martinson, 2003).

It is an important to provide a reliable modeling approach of leaf area estimation to use in physiological researches to environmental stresses of *P. orientalis* L. leaves separately. Nevertheless, there is no prediction equation for *P. orientalis* L. for estimation of leaf area estimating leaf area index: within Kurdistan Region of Iraq. In order that the aim of present research was to develop an indirect methodology for leaf area estimation for plane tree leaves planted widely in urban areas of Erbil city, based on linear measurement models.

2. MATERIALS AND METHODS

2.1. Study Location

The research was carried out in Erbil city, Kurdistan of Iraq with an elevation of 439 m above sea level (a.s.l) and it is located at latitude 36° 12' 0''N and longitude 44° 12’0” E. The microclimate condition of Erbil is a Mediterranean climate with long, very hot summers and mild winters. A sample of 20 trees of (*P. orientalis* L.) was used to develop a leaf area (LA) prediction model.

2.2. Plant Samples And Leaf Measurements

A total of 430 a fully mature leaves sampled from 20 adult of *P. orientalis* tree on the 1st of June 2020. Immediately after cutting, leaves were placed in plastic bags with a great care and taken to the laboratory. Samples were taken randomly from the south side of the crown at 160–200 cm of the trees. The trees were of a similar age, sun exposure and had uniform height and growth form. The portable Digital Leaf Area Meter were used for measuring the leaf area (LA), leaf length (L) and leaf width (W) of each individual leaf samples; where L and W of each sample were measured at the same time. The LA is expressed in cm^2 whereas both L and W are expressed in cm. Length of leave (L) was measured from the tip of leaf to the intersection point of the lamina while leaf width (W) was measured from the widest lobes of the lamina straight to the midrib (Rouphael *et al.,* 2010) (Figure 1).

Table (1): Statistical summary for leaf characteristics of *P. orientalis.*

Parameters	No.	Range	Minimum	Maximum	Mean
Leaf length	430	12.60	13.30	25.90	19.34
Leaf width	430	10.00	12.00	22.00	16.65
L+W	430	21.80	26.10	47.90	35.99
L*W	430	398.30	170.30	568.60	325.63
L^2	430	496.00	175.80	671.80	379.75
W^2	430	338.00	144.70	482.70	280.80
OLA	430	172.20	88.00	260.20	154.07

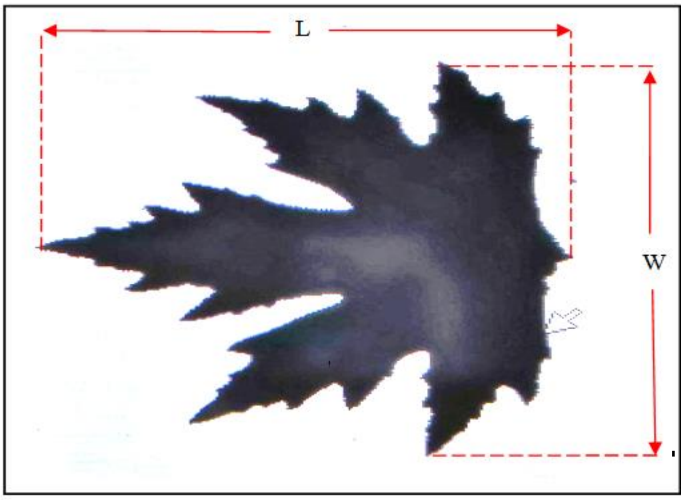

Fig. (1): Showing the position of leaf length (L) and width (W) ***P. orientalis*** L. leaves**.**

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2.3 model build-out

The 430 leaf measurements as mentioned above, with the aiming of testing the relation between LA and L, W, (L+W) and LW, L^2 and W^2. Tree Leaf area (LA) was used as a dependent variable, while L, W, (L+W) and LW were used as independent variables in development of the regression models. The data were contoured together to a linear regression equation Y= B_0+$\mathbf{B_1}$X, where Y represent the leaf area and X will be leaf L, W, (L+W) and LW. Using some measures of precision for testing the performance of the developed regression equations in prediction of the response variable, the most appropriate equation is to be selected. An extra 100 sample of leaves of the same measured trees were used to validate the application of the selected regression equation.

2.4. testing the performance of developed equations

Coefficient of Determination(R^2), Root Mean Square Error (RMSE), Coefficient of Residual Mass (CRM) and the Mean Square Error (MSE) for each of the models was performed for testing the performance of the explanatory variables in predicting the response variable by using SPSS as documented by Ghoreishi *et al*. (2012).

3. RESULTS

The LA of *P. orientalis* ranged from 88 to 260.2 cm^2 (average = 174.1 cm^2). The L ranged from 13.3 to 25.9 cm (average = 19.6 cm), the W ranged from 12.0 to 22.0 cm (average = 17 cm) (Table 1). Different mathematical models for a nondestructive estimation of leaf area of different plant species have been documented in many literatures. The findings of this study were in accordance with some of the previous studies. Using SPSS software package, the response variable (LA) was regressed on both leaf length (L), leaf width (W), and some of their transformations. Accordingly seven regression equations were developed with some measures of precision (Table 2).

Table (2): The slope (B1), and Y-intercept (B_0) data of the models used to determine the leaf area of *P. orientalis* L. leaf area (LA) from length (L) and width measurement of single leaves.

Reg. No.	Regression model	R^2	Y-intercept(α)	Coefficients (β)	RMSE	CRM
1	LA= α + B_0 *L	0.820	-87.95	β112.51	13.73	1.001328
2	LA= α + B_0 *W	0.692	-79.90	B1=14.05	17.97	0.000518
3	LA= α B_0 *(L+W)	0.846	-111.35	B1=7.374	12.68	0.000091
4	LA= α + B_0 *LW	0.850	20.91	B1=0.408927	12.56	-0.000008
5	LA= α + B_0 *L^2	0.826	33.04	B1=0.31869	13.48	0.000027
6	LA= α + B_0 *W^2	0.698	36.16	B1=0.419875	17.79	0.000044
7	LA= α + B_0 *(L+W)+ β1LW+ β2*L^2	0.863	72.77	B1=-2.7968,β2=0.405543, β3=0.131423	12.01	-0.000019

This table showed that a strong relationships (P<0.001) was found between (LA) and leaf dimensions such as (L), and leaf width (W), as well as their transformations and interactions, such as the square of length (L^2), the square of width (W^2) the product of length and width (LW) and the sum of length and width (L + W). Furthermore, It is well known that the precision of an equation is directly proportional with the value of $R^{2,}$ which ranges between (0 and 1), and indirectly proportional with RMSE, as well as MAE. Although, the model number 7 showed the highest R^2 and lowest RMSE in relation to the other models (Table 2), it was not selected as the most appropriate model because of having many parameters and hence difficulty in application. On the other hand, the equation number 4 LA= 20.912199+0.408927*(LW) was selected for the purpose of prediction of the leaf area because of having an acceptable values of both coefficient of determination, RMSE and CRM (Table 2) (Figure 2). Pearson correlation showed that there was a perfect positive relationship between actual leaf area and predicted leaf area was significant by (Rs= 0.922^{***}, p<0.001) for model number 4.

3.1. Validation Of The Selected Equation

The selected equation must undergo a test of validation before using it for the purpose of prediction. For such goal a new sample of leaves

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(100 leaves) were taken. Their length, width and leaf area were recorded.

3.1.1 Procedure Of Validation

1) At the beginning the measured values of leaf parameters, (L, and W) were taken leaf length, Min=.14.45, Max=24.40, Mean=20.4 and range= 9.95) and leaf width (Min=.13.88, Max=21.47, Mean=17.9656 and range= 7.59)

2) These values were substituted in the selected equation and the predicted values of the LA for each leaf was obtained.

3) These predicted values of LA was regressed in a simple linear equation as follow:

$\widehat{LA} = B_0 + B_1$*LA the values of (B_0 = 7.88 and B_1=0.946)

If the value of $B_0 + B_1$ is close to zero and one respectively, and if it has an acceptable value of R^2 it will give an indication that the selected equation is reliable and can be used for other data, and vice versa. When we divided B_0 by the mean predicted leaf area (8.11 /170= 0.047) which mean the result will be very much close to zero and $B_1$was close to zero as well. Although, the calculated value of the R^2 was (0.65), RMSE was (1.81) and is less than the original value of R^2 for the selected equation (0.85), it can be accepted in such concepts as shown in figure (3) the relationship between the observed leaf area and predicted leaf area. A visual inspection of their normal Q-Q plots indicated that the data of leaf area were approximately normally distributed for both observed leaf area by leaf area meter and predicted leaf area with a skewness of 0.673(SE= .118) and a kurtosis of 0.180 (SE= .235) for observed leaf areas and a skewness of 0.583 (SE= .118) and a kurtosis of .039 (SE= .235) for predicted leaf areas (Figure 4).

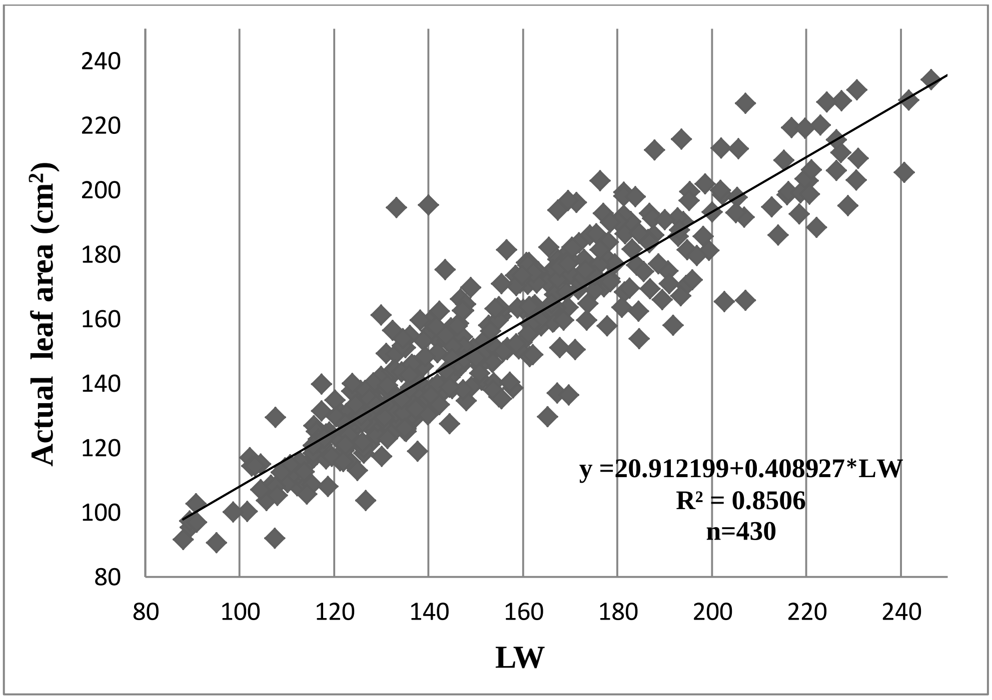

Fig. (2): A regression model to determine the leaf area of P. orientalis. from the product of length and width L W (cm) RMSE = 12.56, CRM= -0.000008 (n=430).

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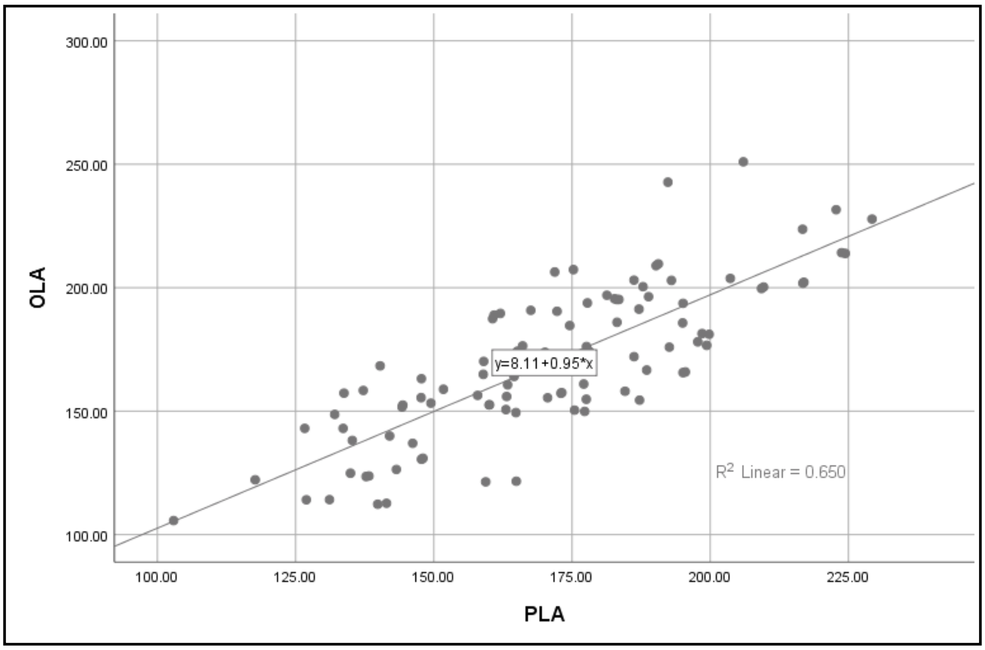

Fig. (3): Predicted leaf area (PLA =23.12+ 0.8511 LW) plotted against the actual leaf area for *P. orientalis* (n=100).

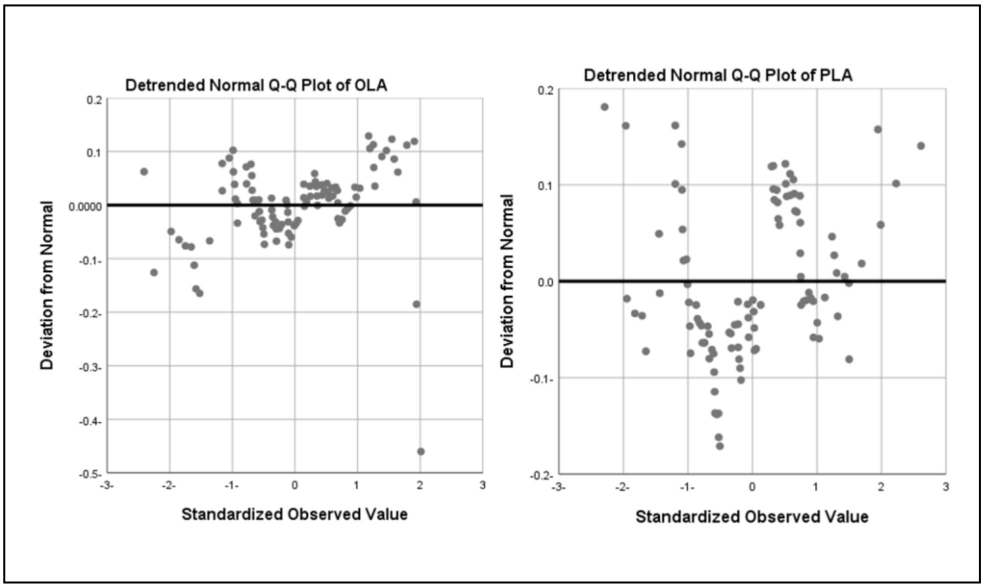

Fig. (4): Differences between measured leaf area (OLA) and predicted leaf area (PLA) of *P. orientalis* (n=100).

4. DISCUSSION

In screening the appropriate regression equation for each study, one must take two important points on consideration which are precision and simplicity of the selected study. Taking equation 4 and 7 it can be seen that equation 4 contains only one variable (combined variable) or it includes one parameter (b LW), on the other hand the 7th equation contains three parameters such as (L+W), LW and L^2 which means that it is more difficult in application. It is shown that the precision of 7th equation it is better for equation 4 by only (0.86-0.84) equal 0.014 that is 1.4% for all these reasons the equation 4th was finally selected, which is required to be the selective standard suggested by as Cristofori *et al.*, (2007). Many studies have been documented and recommend non-destructive equations to determine the leaf area in many various crops. On the other hand, there is no any equation with in Kurdistan region like the one suggested in the present study, especially for plane tree and accordingly, researches need to be implemented in a way that leaves must be excised. Olfati *et al.*, (2010) stated for that reason, when you are not using a non destructive method, it is not likely to make an accurate measurements on the same leaf. Another reason is that it will not allow providing an accurate observation of leaf area by using different plant samples, however the same plant samples. In addition, the present paper is an able to accurately measure the leaf area of *P. orientalis* by using the LA = 20.91+ 0.408927 * LW equation.

Based on the above discussion, both leaf length and leaf width determination were required accurately to estimate *P. orientalis* L. leaf area. The data reported in the present study were in accordance with preceding researches on the other species such as the hazelnut tree a model validation having a combination of measured leaf length and width revealed that a high correlation was found between observed and predicted leaf areas (Cristofori *et al.*, 2007), where the leaf area estimation models were developed using the multiplicative equation (length × width). A study by Souza and Habermann (2014) was found an equation for two an evergreen tree species of Styrax (*Styrax Pholii and Styrax ferrugineus* that a combined variable can provide more practical for measuring of LA. In addition, another leaf area prediction study focused on leaf length and width measurements on Cabernet-Sauvignon grapevine leaves (Tsialtas *et al.*, 2008). A study by Potdar and Pawar, (1990) on two banana cultivars that found a strong correlation between leaf area and a combination of length and width. Under different environmental conditions a research by Serdar and Demirsoy (2006) for 18 cultivars of chestnuts was conducted showed leaf length and leaf width can develop an accurate leaf area measurement. For rose *Rosa hybrida* L. a model tested (LA = a + bL×W) indicated a high correlation was found between observed and predicted leaf area (Rouphael *et al.*, 2010). Karimi *et al.,* (2009) documented that for estimation of leaf area *Pistacia vera* L. seedlings having) the product of length and width of leaves can supply efficient estimation.

5. CONCLUSION

In the current study a simple accurate and nondestructive equation to predict the leaf area for plane tree was developed. This equation was chosen for its simplicity, providing results with the same level of accuracy like other a complex estimation methods or expensive instruments, such as. a leaf area planimeter or digital camera. Results found from the present study showed that *P. orientalis* leaf area could be predicted using simple linear measurements. Dimensions of the leaves can be easily measured in the pot experiments, greenhouse and field. Use of this equation would provide researchers to be enable to make non-destructive on the same leaves. With this developed model, researchers can estimate accurately and in large quantities the leaf area in physiological and quantitative studies.

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