Estimations of hazelnut leaf area with bivariable linear measurements

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ABSTRACT

Accurate and nondestructive methods to determine individual leaf areas of plants are useful tools in physiological researches. Determining the individual leaf area (LA) of hazelnuts (*Corylusavelana*) involves measurements of leaf parameters including: length (*L*) and width (*W*), or some combinations of these parameters. This research was carried out during 2008 on eleven hazelnut genotypes under open field conditions, to evaluate whether an equation could be developed to estimate leaf area of hazelnut genotypes. Analysis of regression LA *vs*. *L* and *W* revealed several equations that could be used for estimating the area of individual hazelnut leaves. Bivariable linear equations have *W* and *L* as the independent variable provided the most accurate estimation of hazelnut LA. The equation (LA =70.8562+4.21497L +10.98479W, AdjR-Sq=0.8002, RMSE=12.38587) exhibited a high correlation in estimating hazelnut LA.

***Keywords*:** Bivariable linear regression, Correlation,*Corylus avelana*, Leaf length, Leaf width, Planimeter.

INTRODUCTION

Plant leaf area is an important determinant of light interception and consequently of transpiration, photosynthesis and plant productivity (Goudriaan and Van Laar, 1994). Plant physiologists and have demonstrated the importance of this parameter in estimating crop growth, development rate, yield potential and radiation use efficiency as well as water and nutrient use (Bhatt and Chanda, 2003; Olivera and Santos, 1995; Williams, 1987; Williams and Martison, 2003).

Leaf area can be measured by destructive or nondestructive measurements. Many methods have been devised to facilitate the measurement of leaf area. However, these methods, including those of tracing, blueprinting, photographing, or using a conventional planimeter, require the excision of leaves from the plants. It is therefore not possible to make successive measurements of the same leaf. Plant canopy is also damaged, which might cause problems to other measurements or experiments. Leaf area can be measured quickly, accurately, and nondestructively using a portable scanning planimeter (Daughtry, 1990), but it is suitable only for small plants with a few leaves (Nyakwende*et al.*, 1997). An alternative method for leaf area measurement is image area calculation followed by computerized analysis. Although the image capture by digital camera is rapid and the analysis using proper software is accurate (Bignami and Rossini, 1996), but the processing is time consuming, and the facilities are generally expensive. Therefore, an inexpensive, rapid, reliable, and nondestructive method for measuring leaf area is indispensable for the physilogists. If the mathematical relationships between leaf area and one or more dimensions of the leaf (length and width) could be clarified, a method using just linear measurements to estimate leaf area would be more advantageous than a series of the methods mentioned above (Beerling and Fry, 1990; Villegas *et al.*, 1981).

Various combinations of measurements and various equations concerning with length and width to area have been developed for several horticultural crops such as cucumber (Cho *et al.*, 2007; Robbins and Pharr, 1987), pepper (De Swart et al., 2004), grape (Montero *et al.*, 2000; Williams and Martinson, 2003), kiwifruit (Mendoza de Gyves*et al.*, 2007), rabbiteye blueberry (NeSmith, 1991), muskmelon (Panta and NeSmith, 1995), faba bean (Peksen, 2007), zucchini squash (Rouphael*et al.*, 2006), and tomato (Schwarz and Kläring, 2001), while information on the estimation of hazelnut leaf areas is still lacking. Although, hazelnut is one of the most important nuts in northern part of Iran, gaining about 90% of the country production, but there is no published date on the physiological aspects of this species including leaf area. Therefore, the aim of this study was to develop an equation for leaf area better prediction from linear measurements of leaf length and width in hazelnut.

MATERIAL AND METHOD

The experiment was conducted at the University of Guilan, Rasht, Iran, in 2016. The hazelnut varieties that used in this research are regarded from research garden of Karaj seed and plant improvement institute.

Leaves with different size used as samples for leaf area estimation obtained randomly from different levels of the canopy. Leaves from different hazelnut varieties were used for leaf area (LA), length (*L*) and width (*W*) measurement. Leaves were immediately placed in plastic bags after cutting and were transported to the laboratory. Leaf lengthwas measured from lamina tip to the intersection point of the lamina and the petiole, along the midrib of the lamina, while leaf widthwas measured from end-to-end between the widest lobes of the lamina perpendicular to the lamina mid-rib. Values of *L* and *W*were recorded to the nearest 0.01 mm. The area of each leaf (LA) was measured using a planimeter (A. OTT Kempten, Germany, Bayern). The dependent variable (LA) was regressed with different independent variables, including *L*, *W*, L^2, W^2, and the product $L \times W$. Furthermore bivariate equation estimated for leaf area from length and width leaf. The values of the coefficients (*b*), constants (*a*), R square (R^2) and Root of mean square error (RMSE) were also reported (Figures1-5).

RESULTS AND DISCUSSION

Correlation analysis demonstrated strong relationships ($P < 0.001$) between leaf area (LA) and maximum leaf width (*W*), the square of width (W^2) and product of length and width (*LW*) for hazelnut measured leaves (Tables 1). A positive correlation ($P < 0.01$) was obtained between leaf area (LA) and maximum leaf width (*W*) and the square of width (*W2*). This is in accordance with previous studies (Mendoza de Gyves*et al.*, 2007; Peksen, 2007; Rivera *et al.*, 2007; Rouphael*et al.*, 2006; 2007) on nondestructive equation development for predicting leaf area using simple linear measurements. In this study demonstrated that equations with a single measurement of *W* were more acceptable for estimating leaf area for hazelnut. The linear equation having *W* and *W*2 as independent variable exhibited a high accuracy and precision in estimating individual leaf areas. But, We also find a bivariable equation (LA =70.8562+4.21497L +10.98479W) between leaf area as dependent variable and both width and length leaf as independent variable. The correlation between measured and calculated leaf area obtained from above equation had higher correlation coefficient (R=0.8965) than other ones. We insert our data into the equation suggested by Crisofori*et al.*,(2007) (LA=2.59+0.74LW) for estimating our leaf area of hazelnut, then, we calculated the correlation between measured and calculated leaf area. Correlation coefficient (R=0.89073) obtained from above equation was less than bivariable equation. Since the form of hazelnut leaves is nearly oval, we calculated them with the oval area equation (A= [πLW]/4) and then we obtain the correlation coefficient between calculated leaf area from foregone equation and actual measured leaf area. Finally, we found that the correlation coefficient (R=0.89073) obtained according to the oval area equation was exactly equal to the results of Crisofori`s equation. Correlation coefficient, Crisofori and oval area equation, were less than the bivariable equation which we used. According to the above results, the bivariable equation was better than other ones, but, we preferred to apply this equation (*LA=-48.129+13.786W*) due to its simplicity and convenience, as it only involves one variable. As stated by Robbins and Pharr (1987), equation selection requires a balance between predictive qualities of the equation and the economy of including the least number of variables necessary to predict leaf area.

With results of equation LA=70.8562+4.21497L+10.98479W can accurately estimate the leaf area of hazelnut in many experimental comparisons without using any expensive instruments, e.g., a leaf area planimeter or digital camera with image measurement software. This equation could exactly estimate the leaf area in this study. Also, the correlation between measured and calculated leaf area of output equations showed a strong relationship between measured leaf area and calculated leaf area of bivariable equation (Table 2).

Table1. Correlation between hazelnut LA and measured parameters

	L	W	L^2	W^2	LW
LA	0.77***	0.88***	0.76***	0.87***	0.75***

***: significant at $P \leq 0.001$.

Table2. Correlation coefficient between measured leaf area and calculated leaf area of equations

	Calculated leaf area via below equations		
	LA=-68.191+13.679L	LA=-48.129+13.786W	LA=29.805+0.5353LW
Measured Leaf area	0.77***	0.88***	0.75***

***: significant at $P \leq 0.001$.

Table 3.Calculated leaf area with equations

	$LA=18.789+0.053L^2$	$LA=29.044+0.6011W^2$	$LA=2.59+0.74LW$
Measured leaf area	0.76***	0.87***	0.89073***

***: significant at $P\leq0.001$.

Table 4. Calculated leaf area with equations

	$LA=70.8562+4.21497L+10.98479W$	$A= [\pi LW]/4$
Measured leaf area	0.8965***	0.89073***

***: significant at $P\leq0.001$.

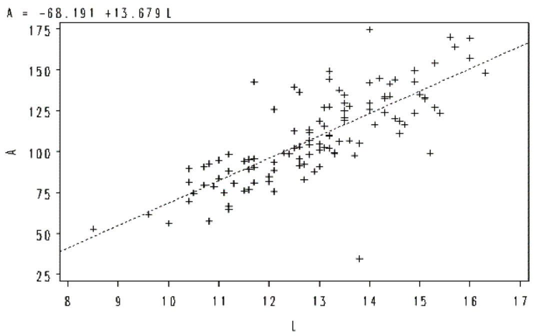

Figure 1. LA and W regression graph for hazel nut. (R^2=0.7762, RMSE= 13.142)

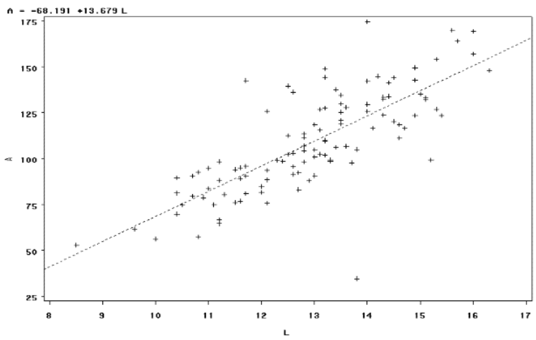

Figure 2. LA and L regression graph for hazelnut. (R^2=0.5941, RMSE= 17.697)

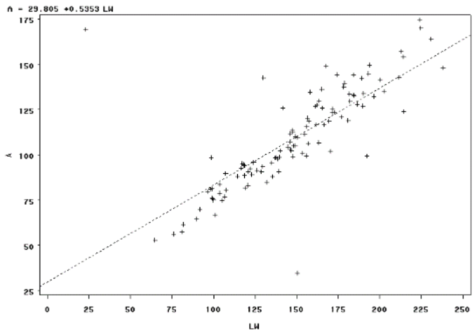

Figure 3. LA and LW regression graph for hazelnut. (R^2=0.5734, RMSE= 18.144)

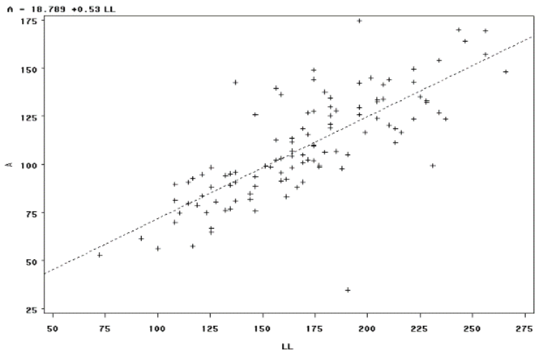

Figure 4. LA and L^2 regression graph for hazelnut. (R^2=0.5920, RMSE= 17.744)

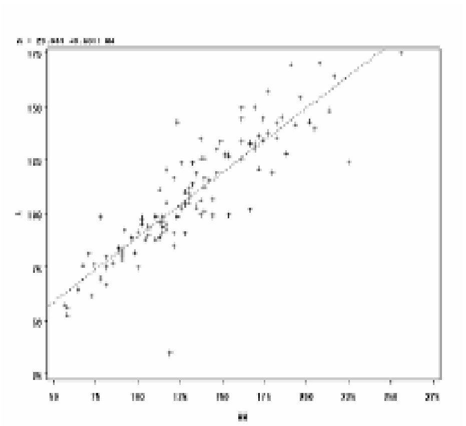

Figure 5. LA and W^2 regression graph for hazelnut. (R^2=0.7715, RMSE= 13.278)

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