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ESTIMATION OF LEAF AREA IN SWEET CHERRY USING A NON-DESTRUCTIVE METHOD

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ABSTRACT

Leaf area measurement can be a time consuming process and requires sophisticated electronic instruments. The objective of this research was to develop a simple, accurate, non-destructive and time saving predictive model for leaf area (LA) estimation in sweet cherry trees. Linear regression equations were fitted and evaluated for three cultivars and two training systems using alternatively the length (L), the width (W) and their product (L*W) as independent variables. Regression using L*W variable fitted the data better (R^2 = 0.994) than L or W (R^2 = 0.863 and 0.787, respectively). The slopes using L*W as the explanatory variable were between 0.6776 and 0.6442 for different combinations of cultivar and training system. Combinations of cultivar – training system showed different slopes (P<0.05), except for «tatura-Bing» and «vase-Lapins». A general equation had a slope of 0.6612 with R^2 = 0.993 (slightly lower than considering all combinations of cultivar and training system). Validation of the general equation using extra data from a «Lapins/ Mahaleb» orchard showed high accuracy (R^2 = 0.9826), but underestimated LA. However, the general equation can be used for predicting LA for practical purposes, such as estimating Leaf Area Index of commercial orchards.

Key words: *leaf area, Prunus avium, non-destructive estimation, leaf length, leaf width.*

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RESUMEN

ESTIMACIÓN DEL ÁREA FOLIAR EN CEREZO, USANDO UN MÉTODO NO DESTRUCTIVO

La medición del área foliar puede ser un proceso lento y requerir instrumentos electrónicos sofisticados. El objetivo de esta investigación fue desarrollar un modelo predictivo simple, preciso, no destructivo y rápido, para estimar área foliar (LA) en cerezo. Ecuaciones de regresión lineal fueron ajustadas y evaluadas para tres cultivares y dos sistemas de conducción usando alternativamente el largo (L), el ancho (W) y su producto (L*W) como variables independientes. En las regresiones, los datos ajustaron mejor usando L*W como variable regresora (R^2 = 0,994) que con L o W (R^2 = 0,863 y 0,787, respectivamente). Las pendientes usando L*W como variable explicativa fueron entre 0,6776 y 0,6442 para las diferentes combinaciones cultivar–sistema de conducción. Las combinaciones de cultivar–sistema de conducción tuvieron diferentes pendientes (P<0,05), excepto «tatura-Bing» y «vaso-Lapins». Una ecuación general tuvo pendiente de 0,6612 con R^2 = 0,993 (sólo levemente inferior considerando todas las combinaciones de cultivar y sistema de conducción). La validación de la ecuación general usando datos extra medidos en un monte de «Lapins/Mahaleb» mostró alto ajuste (R^2 = 0,9826), pero subestimó LA. Sin embargo, la ecuación general puede ser usada para predecir LA con fines prácticos, tales como estimación del Índice de Área Foliar en montes comerciales.

Palabras clave: *área foliar, Prunus avium, estimación no destructiva, largo de hoja, ancho de hoja.*

INTRODUCTION

Leaf area (LA) is an essential component to estimate plant growth through its incidence on crop physiology mechanisms (Ramesch and Singh, 1989; Portela, 1999; Bhatt and Chanda, 2003). It is used as a variable into canopy photosynthesis models, training systems evaluation and pruning practices (Gutierrez and Lavín, 2000).

In sweet cherry (*Prunus avium* L.), like in other crops, the measurement of LA, both expressed per tree or as Leaf Area Index (LAI), can be a time consuming process (Portela, 1999) 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 (Chirinos *et al.*, 1997).

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. These have been used for grapevine (Gutierrez y Lavín, 2000; Williams and Martinson, 2003), taro (Hsiu-Ying *et al*., 2004), common bean (Bhatt and Chanda, 2003), hyacinth bean (Singh, 1990), banana (Potdar and Pawar, 1991) and melon (Chirinos *et al.*, 1997). 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 research was to develop a simple, accurate, non-destructive and time saving predictive model for leaf area estimation in sweet cherry trees.

MATERIALS AND METHODS

Leaf samples were taken at fruit harvest from trees of two commercial orchards in the valley of Chubut river (43° 16' S; 65 25' W), Argentinean Patagonia, in December 2003. Both orchards were planted in 1997 with 'Bing', 'Van' and 'Lapins' cultivars on 'Mahaleb' rootstock. One orchard was trained as tatura and the other as vase. Ten trees from each combination of «training system – cultivar» were selected and leaves from 6 spurs randomly chosen per tree were sampled. Leaves without petiole were digitalized with a scanner Hewlett Packard Scan Jet 4C and processed using the «Image Tool 3.0» (UTHSCSA, 2002). The length (without petiole) and maximum width of leaves were measured to the nearest 0.1 cm and the area to the nearest 0.1 cm^2.

Linear regression equations passing through the origin were fitted and evaluated for each combination of cultivar and training system using alternatively the length (L), the width (W) and their product (L*W) as independent variables. The variables to predict LA were chosen based on the capability of the overall models to explain the variance as well as on the analysis of residuals to detect any bias. ANOVA analysis was carried out to detect differences between slopes obtained from these linear regressions.

Furthermore, the variable with the highest explanatory capability was used to develop a general equation without sorting by cultivar or training system. This general equation was tested using extra data from leaves randomly sampled from a 4 year-old «Lapins/Mahaleb» orchard trained as vase in Los Antiguos valley (46° 33' S; 71 37' W).

RESULTS AND DISCUSSION

Equations using leaf length (L), maximum leaf width (W) or their product (L*W) had strong relationships with LA, manifested in high coefficients of determination (R^2) of the equations and low standard error of estimates (SEE) (Tables 1, 2 and 3). 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 (Williams and Martinson, 2003). However, a better fit was achieved using L*W (R^2 = 0.994) than using L or W (R^2 = 0.863 and 0.787, respectively).

Table 1. Slopes for the relationship between Leaf Area (LA) and Leaf Length (L) for the combinations of 'tatura' and 'vase' training systems with 'Van', 'Lapins' and 'Bing' cultivars.

	Van	Lapins	Bing
Tatura	3.877 ab (0.0282)	3.401 c (0.0314)	3.943 a (0.0372)
Vase	3.325 c (0.0361)	3.796 b (0.0281)	3.286 c (0.0314)

Note: The overall model accounted for 86.3% of the variance and the standard error of observations was 6.62. Standard errors of estimates are between brackets. Different letters Indicate significant differences (P<0.05).

Table 2. Slopes for the relationship between Leaf Area (LA) and Leaf Width (W) for the combinations of 'tatura' and 'vase' training systems with 'Van', 'Lapins' and 'Bing' cultivars.

	Van	Lapins	Bing
Tatura	7.793 b (0.0711)	6.935 c (0.0802)	8.299 a (0.0986)
Vase	6.593 d (0.0902)	7.909 b (0.0737)	7.015 c (0.0843)

Note: The overall model accounted for 78.7% of the variance and the standard error of observations was 8.26. Standard errors of estimates are betwe en brackets. Different letters indicate significant differences (P<0.05).

Table 3. Slopes for the relationship between Leaf Area (LA) and the product of Leaf Length and Leaf Width (L*W) for the combinations of 'tatura' and 'vase' training systems with 'Van', 'Lapins' and 'Bing' cultivars.

	Van	Lapins	Bing
Tatura	0.678 a (0.0010)	0.662 c (0.0012)	0.656 d (0.0012)
Vase	0.670 b (0.0014)	0.654 d (0.0010)	0.644 e (0.0012)

Note: The overall model accounted for 99.4% of the variance and the standard error of observations was 1.33. Standard errors of estimates are between brackets. Different letters indicate significant differences (P<0.05).

The slopes using L*W as the explanatory variable were between 0.6776 and 0.6442 for the different combinations of cultivar – training system. Combinations of cultivar – training system showed different slopes (*P*<0.05), except for «tatura-Bing» and «vase-Lapins». These values are close to those presented by Gil-Salaya (1999) who, as a general rule for fruit trees, reported that leaf area could be estimated by multiplying the product of L and W with a coefficient usually between 0.67 and 0.75.

A general equation had a slope of 0.6612, with R^2 = 0.993. This coefficient of determination was only slightly lower than considering particular equations between cultivar and training system. Residual analysis of this equation showed a slight LA overestimation in the range of 0 to 35 cm^2 of L*W (Figure 1).

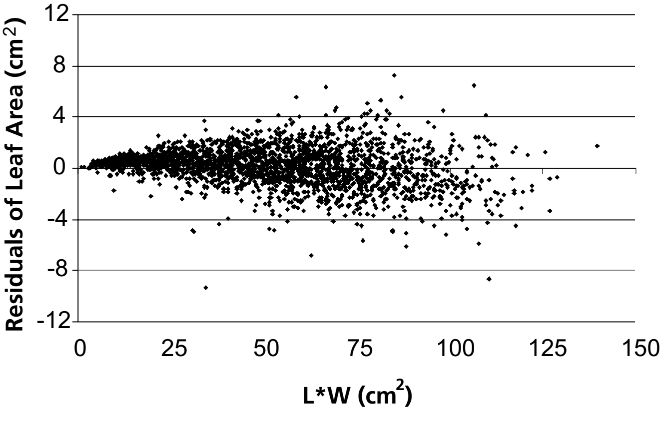

Figure 1. Residuals of Leaf Area (LA) versus L*W. A slight overestimation is observed in the range of 0 cm^2 to 35 cm^2 of L*W.

Comparisons between observed LA from a «Lapins/Mahaleb» orchard grown at Los Antiguos and predicted LA using the general equation had a good fit (R^2 = 0.9826) (Figure 2) with a slope of 1.0464 which differed from the 1:1 relationship (*P*<0.05). However, this deviation between observed and predicted values could be acceptable for predicting leaf area for practical purposes, such as estimating LAI of commercial orchards.

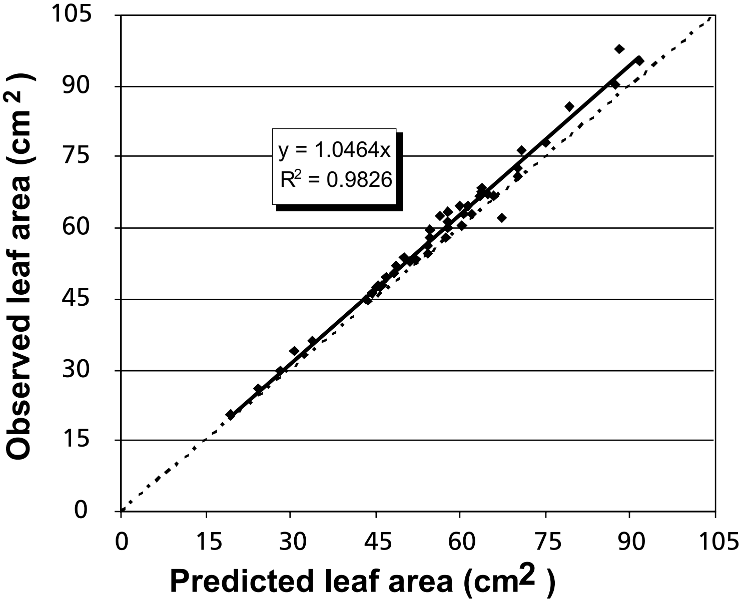

Figure 2. Observed vs. predicted area of leaves from a 'Lapins/Mahaleb' orchard of Los Antiguos valley using a general equation (without considering neither cultivar nor training system) with LW as independent variable (LA = LW * 0.6612). Data values above the 1:1 line (dashed line), which was statistically different (*P*<0.05) from the regression line (solid line), indicate under predictions.

CONCLUSIONS

Using the product of leaf length and leaf width as the explanatory variable was more accurate to predict LA than using either length or width.

A general equation fitted in the present work predicted LA with relatively high accuracy. It provide a simple, accurate, non-destructive and time saving tool to optimize training systems and pruning practices in sweet cherry trees.

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