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Determining the leaf area of fig trees by non-destructive methods

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Abstract
The determination of the leaf area on fig leaves by non-destructive methods, based on the size of the leaves and the correction coefficient, was the objective of the present study. Fig leaves were taken randomly, in different categories and sizes. Leaf samples were herborized to ensure leaf integrity. The leaves were measured to determine length (L), and width (W) dimensions. From the analysis of the scanned images of the leaves, the scanned leaf area (SLA) vas determined. Through the comparative analysis of the measured leaf area (MLA) with SLA, the value of the correction coefficient (CC) was determined. Under CC = 0.58 conditions, the minimum ME error value between MLA and SLA was recorded. The RMSEP = 18.0450 calculated value confirmed the optimal value for the correction coefficient. The regression analysis described the fit between MLA and SLA through a linear equation, under conditions of $R^2 = 0.950$, $p<0.001$.

Keywords: correction coefficient, fig tree, leaf area, leaf parameters, model

Introduction

The number of leaves and the size of the leaves are important indicators in physiological studies of plants in relation to environmental factors and growing conditions [11]. The dimensions of plant leaves have an important eco-physiological relevance for the characterization of plant species, as well as in relation to plant growth conditions [15]. Leaf area is an important indicator that expresses plant growth and development [3].

Non-destructive methods for determining the folial surface are important for determinations in the field on large series of samples, for the acceleration and efficiency of the determinations [17]. Through studies on vine leaf samples (fifteen vine species, over 5500 leaves), the authors reported high precision in determining the leaf surface based on leaf parameters (L, W) and a correction coefficient (c).

Foliar parameters are important in studies for the characterization of the leaf lamina and plant phenotyping [18]. Recent studies have reported high precision in the determination of leaf area based on leaf parameters (length, width) in different plant species [1], [2], [6]. Determining the leaf surface based on leaf dimensions is a simple, accessible and sufficiently precise method for studies at the foliar level of plants [6]. Based on an extensive study, as number of taxa, and leaf samples, the authors communicated results of leaf area based on leaf dimensions and correction coefficient values [15].

The dimensions of the leaves (length, width) were used for the construction of models (linear or polynomial) in order to determine the leaf area by non-destructive methods [6], [10]. The advantages of using methods to determine the leaf surface based on mathematical models, as a relationship between the parametric dimensions of the leaves, presented advantages in terms of low costs and accessibility of use [7].

The volumetric approach was used to determine the leaf area, by relating the volume of the leaf to the thickness, in conditions of high precision and statistical reliability [4].

Determining the leaf area by means of imaging analysis methods has shown importance in studies of plants in conditions of protected spaces (greenhouse) with the recommendation to be used also for companies and small-scale cultivators [11]. Imaging analysis, associated with a leaf flattening technique, was used to determine the leaf area under conditions of high precision [8]. The author communicated high precision in the analysis of the results by the approach method, compared with the results by scanning the leaves ($R^2 > 0.98$). Different applications have been developed, as useful tools in determining the leaf surface in certain species, but with extended possibility of adaptation and use [16].

To determine the leaf area, different methods can be used, with variable precision, based on observations, direct measurements, imaging analysis, portable or fixed scanners, with variable costs [3]. The authors proposed a system for determining the leaf surface by using a photovoltaic type panel, and the recorded precision was at the level of $R^2 = 0.99$, according to the authors.

The present study analyzed samples of fig leaves to find out the value of the correction coefficient for use in determining the leaf area of figs by non-destructive methods.

Material and Method

In relation to the purpose of the study, fig leaves of variable size were randomly sampled. The leaves were herborized to preserve the unaltered shape of the leaves, figure 1.

Figure 1. Fig leaf, example from the sample series (original figure, by Florin Sala)

Each leaf was measured to obtain dimensional parameters, length (L), and width (W). The extreme points of the leaves were measured to obtain dimensional parameters.

The leaves were scanned and analyzed to obtain the scanned leaf area (SLA) values. Imaging analysis methods were used to parametrically determine SLA [12].

The non-destructive methods of determining the leaf area, based on the dimensions of the leaves (L, W), assume a correction factor or correction coefficient for high precision. In order to obtain the correction coefficient for fig leaves, the value of the correction coefficient was determined based on the model proposed by Sala et al. [13]. For this purpose, the measured leaf area (MLA) was determined based on the dimensions of the leaves (L, W) and a series of values of the correction coefficient (CC).

$$\mathrm{MLA} = \mathrm{L} \times \mathrm{W} \times \mathrm{CC} \qquad (1)$$

where:
MLA – measured leaf area (cm^2)
L – leaf length (cm)
W – leaf width (cm)
CC – correction coefficient, where CC belongs to the range (0, 1)

To find out the optimal value of CC, comparative analyzes were made of SLA (as a reference) with MLA (on the range of variation of CC) and the value of the average error (ME) was determined for each leaf in the sample series, equation (2).

$$\mathrm{ME} = \mathrm{MLA} - \mathrm{SLA} = (\mathrm{L} \times \mathrm{W} \times \mathrm{CC}) - \mathrm{SLA} \qquad (2)$$

CC = optimal when ME = 0, or has the lowest value

To validate the results, the RMSEP parameter was calculated for the data series related to the CC values used (11 calculation values), according to relation (3).

$$\mathrm{RMSEP} = \sqrt{\frac{1}{\mathrm{n}}\sum_{j=1}^{\mathrm{n}}\left(\mathrm{y}_{\mathrm{j}} - \hat{y}_{j}\right)^{2}} \qquad (3)$$

The recorded data were analyzed by appropriate statistical methods. Appropriate mathematical calculation tools were used in EXCEL and dedicated applications [5].

Results and Discussion

The data series for the dimensional parameters of fig leaves (L and W) showed a normal distribution, figure 2. Anova Test (Alpha = 0.001) confirmed the reliability of the experimental data and the presence of variance in the data set, table 1. The series were analyzed of data for parameters L, W, SLA, and the data series for the correction coefficient (CC), the calculated mean error (ME) and the measured leaf area (MLA) related to the values of the correction coefficient (CC) in the considered interval.

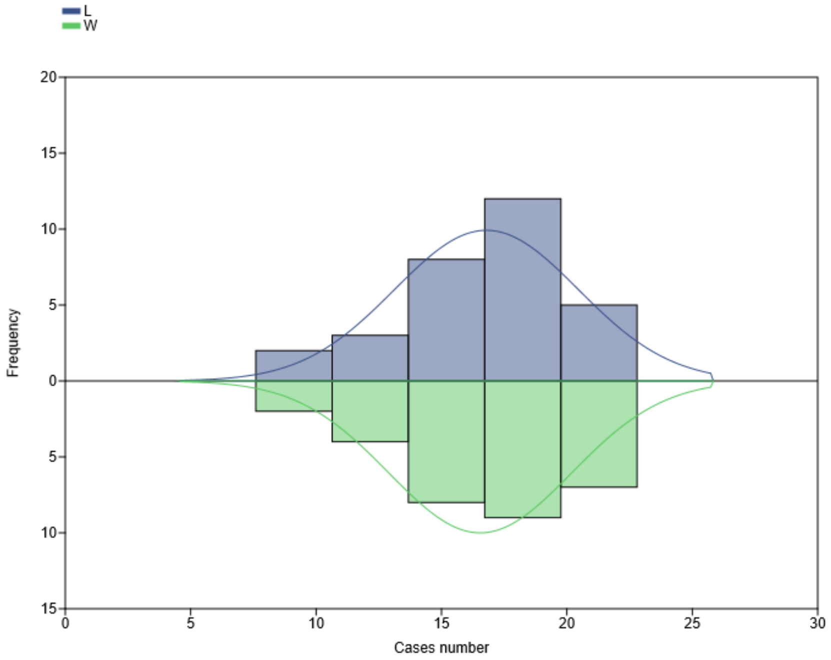

Figure 2. Distribution diagram of L and W values, fig leaves

The determination of the leaf surface by non-destructive methods, based on leaf parameters, is of interest in recent studies [1], [2], [6], [10]. The determination of the correction coefficient (CC) was made based on the model proposed by Sala et al. (2015) [13].

Table 1. Anova Test results

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5551289	29	191423.80	130.1782	4.8E-293	2.046717
Within Groups	1279313	870	1470.475			
Total	6830602	899				

The results are the values presented in table 2, with the optimal value of the correction factor CC = 0.58. At this value of the correction coefficient, the minimum value for the mean error was recorded (ME = -0.056 cm^2). The RMSE parameter confirmed the respective value of the correction factor (RMSE = 18.0450). The distribution of ME values in relation to a series of eleven values of the correction coefficient (CC) in the interval (0.54, 0.62) is presented in figure 3.

Table 2. MLA values and safety parameters for fig leaves

CC	Statistical parameters		
	MLA	ME	RMSEP
0.54	156.253	-11.630	20.9998
0.55	159.146	-8.737	19.5965
0.56	162.040	-5.843	18.6054
0.57	164.933	-2.950	18.0945
0.58	167.827	-0.056	18.0450
0.59	170.720	2.838	18.1065
0.60	173.614	5.731	18.6345
0.61	176.508	8.625	19.6425
0.62	179.401	11.518	21.0600

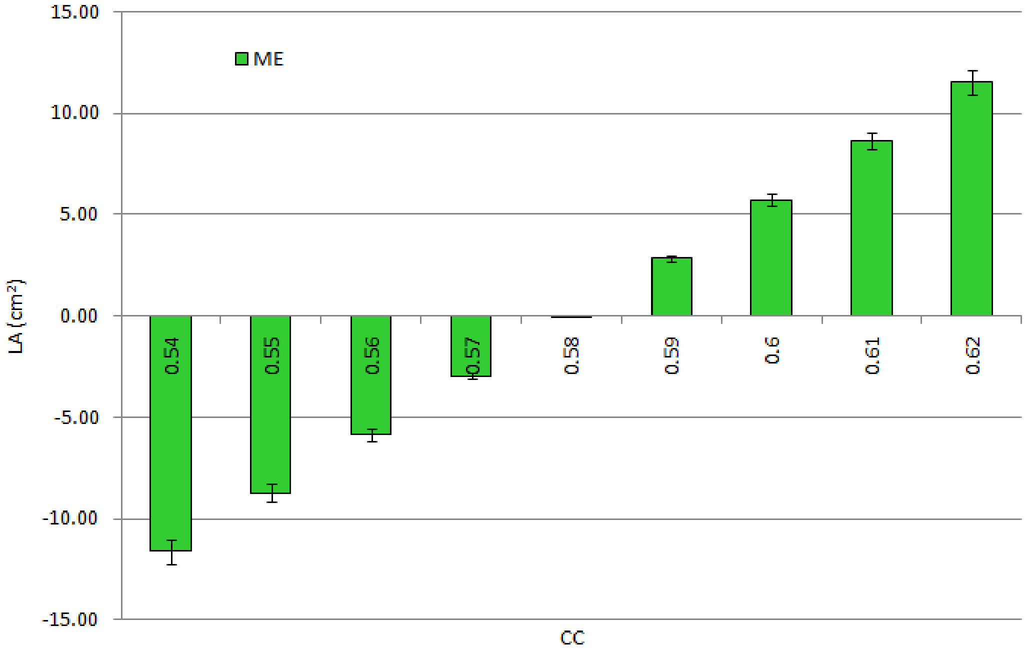

Figure 3. Distribution of the average error when calculating MLA in relation to CC, fig leaves

The calculated RMSEP values confirmed the ME values resulting as the difference between MLA and SLA on the series of CC values in the range (0.54, 0.62). In the case of CC = 0.58 which ensured the value ME = -0.056 cm^2.

Regression analysis was used to find out the match between SLA and MLA (MLA in CC = 0.58 conditions). The result was the linear equation (4) that described the fit between SLA and MLA under conditions of $R^2 = 0.950$, $p<0.001$, $F = 509$. The graphic representation is presented in figure 4.

$$\mathrm{MLA} = 0.9736 \times \mathrm{SLA} + 2.156 \tag{4}$$

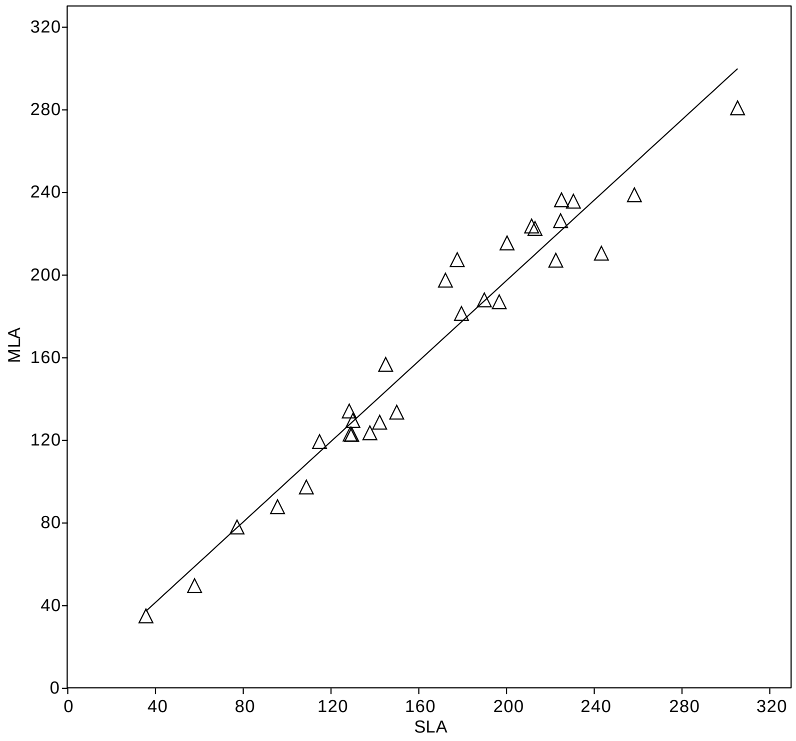

Figure 4. Fiting line between SLA and MSLA in fig leaves

The estimation of the leaf surface based on the dimensions of the leaves was recorded with high statistical confidence ($R^2 = 0.96$ to $R^2 = 0.99$) in horticultural vegetable species [7]. High accuracy was recorded in the determination of the leaf surface based on leaf parameters in grape leaves [14], [17].

The value found for the correction coefficient (CC = 0.58) facilitated the determination of the leaf surface of fig leaves in conditions of high precision and statistical safety. The value of the correction coefficient fell within the range of 0.39 - 0.79 communicated by Schrader et al. [15], with the value 0.39 in the case of very dissected leaves, and the value 0.79 in the case of oblate leaves.

Conclusions

From the study and analysis of fig leaves, the value of the correction coefficient, CC = 0.58, was obtained, useful for determining the leaf area based on the dimensions of the leaves, length and width.

The value of the leaf area determined based on the dimensions of the leaves, and the correction coefficient, was MLA = 167.827 cm^2, with an mean error ME = -0.056 cm^2 in relation to the leaf surface determined by scanning. The RMSEP parameter confirmed the result, through the calculated value RMSEP = 18.0450.

The degree of fitting between MLA and SLA values was described by a linear equation, under conditions of $R^2 = 0.950$, $p<0.001$. The concordance between the results, confirmed by the statistical safety parameters, confirmed the value of the correction coefficient obtained, and the usefulness of the method in the analysis of the fig leaf area, under the study conditions. The method can be developed for other plant species, useful for studies of leaf dynamics, as well as for horticultural practice.

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