# LEAF AREA EVALUATION IN *Solanum nigrum* L. BASED ON FOLIAR PARAMETERS

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***Abstract.*** *The study investigated the leaf area of Solanum nigrum L. by non-destructive method. Determining the leaf area based on leaf parameters and a correction factor is accessible, sufficiently accurate, and with minimal costs. To find out the correction factor, and to make the working model, the leaves were taken at random from different plants, the species Solanum nigrum L. The leaves were scanned (1:1 ratio). Images of the leaves were analyzed imagistically and scanned leaf area (SLA) values were obtained. The foliar SLA index registered values between 11.481 – 32.878 ± 0.967 cm$^2$. The length and width of the leaves were measured for each leaf (L and w). The parameter L had values between 5.40 - 9.90 ± 0.206 cm, and the parameter w had values between 3.25 - 6.45 ± 0.151 cm. To determine the leaf area based on foliar parameters (Measured Leaf Area - MLA), a relation of type MLA = L · w · CF was used, where CF represented the correction factor for the studied specie. To find the CF, the scanned leaf area (SLA) was compared to the measured leaf area (MLA). The CF value at which the average of the errors had the minimum value (MEM) was considered optimal in the case of the analyzed samples. In the case of the studied samples, MEM = -0.036 cm$^2$, corresponding to CF = 0.52. In the narrow range of calculations, the MEM values varied between -1.884 cm$^2$ and 1.813 cm$^2$, corresponding to the variable values of CF. The RMSEP parameter confirmed the optimal value found for CF (RMSEP = 3.86015, according to CF = 0.52). The MLA values obtained, at CF = 0.52, showed a normal distribution. The experimental data set presented statistical certainty, according to ANOVA test (F> Fcrit, p <0.001). The variation of MLA as a function of leaf length (L) was described by a polynomial equation of degree 2, in statistical safety conditions, according to $R^2$ = 0.875, p <0.001. The variation of MLA as a function of leaf width (w) was described by a linear equation, in statistical safety conditions, according to $R^2$ = 0.942, p <0.001.*

***Keywords****: leaf parameters, measured leaf area, model, Solanum nigrum*

## INTRODUCTION

*Solanum nigrum* L. is a species that belongs to the *Solanaceae* Family. It is widespread throughout the world, on all continents, from tropical areas to temperate zones (SÄRKINEN et al., 2018; CAMPISI et al., 2019).

The leaves and fruits of *Solanum nigrum* have been studied in relation to the active principles they contain, of pharmaceutical, medicinal, and functional food interest (JAGATHEESWARI, 2013; PATEL et al., 2014; WANG et al., 2015; CAMPISI et al., 2019).

*Solanum nigrum* has been studied in relation to the response of plants to environmental conditions, as a model of ecological expression (genomic and phenotypic) of plants (SCHMIDT et al., 2004).

The germination of *Solanum nigrum* seeds has been studied in relation to various influencing factors, such as temperature, seed density, seed depth in the soil, etc. (LATI et al., 2012; DONG et al., 2020).

*Solanum nigrum* L. is included in the category of weeds for agricultural crops, the plant species being present in different agricultural crops in over 70 countries (DEFELICE, 2003; TAAB and ANDERSSON, 2009; LATI et al., 2012).

As a weed in crops, *Solanum nigrum* has been studied in relation to the biology of the species, vegetation requirements, relationship with soil, ability to compete, ability to multiply, control methods, compatible herbicides and efficiency, integrated management methods, etc. (COLEMAN et al., 2020).

Physiological indices and biometric parameters have been studied in *Solanum nigrum*, as growth indicators, in relation to soil water content (MCGIFFEN et al., 1992), in relation to mineral and organic fertilizers (BVENURA and AFOLAYAN, 2014), in relation with the plant preferences to soil (COLEMAN et al., 2020).

The present study evaluated the leaf area of *Solanum nigrum* L. based on the biometric parameters of the leaves and a correction factor.

## MATERIAL AND METHODS

The study analyzed a set of leaf samples from the species *Solanum nigrum* L. in order to determine the leaf area by the non-destructive method.

Leaves from the species *Solanum nigrum* L. were randomly collected from the agricultural area adjacent to Timișoara, figure 1.

Fig. 1. *Solanum nigrum* L. - sample from the set of leaves studied

The leaves were measured to obtain the dimensions of the leaf parameters, length (L) and width (w). The leaves were scanned, 1:1 ratio. The obtained images were analyzed (RASBAND, 1997), and data on the leaf area (SLA - scanned leaf area) were obtained.

To determine the leaf area by measurement (MLA), directly in the field, without involving a related digital technique, the values of leaf dimensions, leaf length (L), leaf width (w) and a correction factor (CF), relation (1), are required. The correction factor adjusts the calculation of the leaf area with very high precision. In order to find out the optimal value of CF, in the case of the studied leaf samples, in the *Solanum nigrum* L. specie, the model proposed by SALA et al. (2015) was used.

$$MLA_{Sn} = L \cdot w \cdot CF \quad (1)$$

where: $MLA_{Sn}$ – Measured Leaf Area for *Solanum nigrum* L.; L – leaf length; w – leaf width; CF – correction factor

The processing and statistical analysis of experimental data (HAMMER et al., 2001) was done in conditions of high statistical safety (ANOVA test, correlation analysis, regression analysis; safety coefficients $R^2$, r, p, RMSEP).

**RESULTS AND DISCUSSIONS**

The experimental data set resulting from the measurements and digital analysis of the scanned leaves included values for leaf length (L), leaf width (w), scanned leaf area (SLA), with the graphical distribution in figure 2. The parameter L had values between 5.40 - 9.90 ± 0.206 cm, the parameter w had values between 3.25 - 6.45 ± 0.151 cm, and the SLA had values between 11.481-32.878 ± 0.967 $cm^2$.

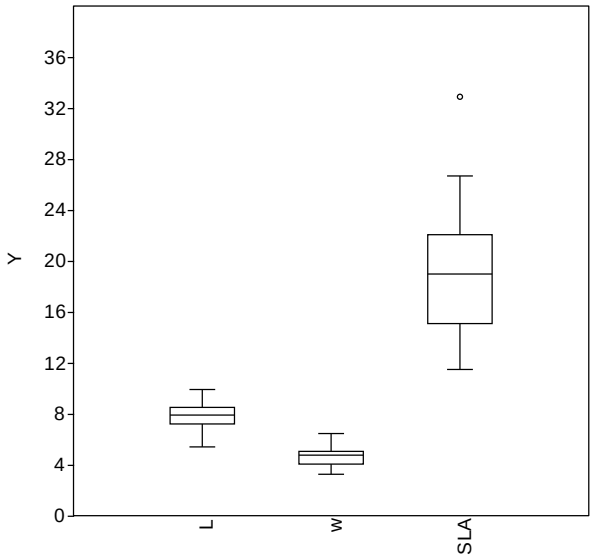


Fig. 2. Graphic distribution, box plot, of the values of the studied parameters and indices at *Solanum nigrum* L. leaves

In order to find out the optimal value of CF, the model proposed by SALA et al. (2015) was used. From the comparative analysis of the SLA values (considered as reference) with the MLA values, obtained by calculation at different CF values, different values of errors resulted, table 1.

In conditions that the minimum errors mean (MEM) recorded the lowest value, table 1, figure3, was considered optimal for CF. This was recorded at the value CF = 0.52, and this value was considered optimal for finding the MLA in the conditions of the studied leaf

samples, in the species *Solanum nigrum* L. The safety parameter RMSEP, relation (2), table 1, confirmed the optimal value for CF.

$$RMSEP = \sqrt{\frac{1}{n}\sum_{j=1}^{n}\left(y_j - \hat{y}_j\right)^2} \quad (2)$$

The experimental data set presented statistical certainty, according to ANOVA test (F> Fcrit, p <0.001), for Alpha=0.001, table 2.

*Table 1*

MLA, MEM and RMSEP values in relation to CF in *Solanum nigrum* L. leaves

| CF | SLA | MLA | MEM | RMSEP |
|---|---|---|---|---|
| 0.47 | | 17.374 | -1.884 | 4.28527 |
| 0.48 | | 17.744 | -1.514 | 4.13352 |
| 0.49 | | 18.114 | -1.145 | 4.01260 |
| 0.5 | | 18.483 | -0.775 | 3.92535 |
| 0.51 | | 18.853 | -0.405 | 3.87406 |
| 0.52 | 19.258 | 19.223 | -0.036 | 3.86015 |
| 0.53 | | 19.592 | 0.334 | 3.88404 |
| 0.54 | | 19.962 | 0.704 | 3.94503 |
| 0.55 | | 20.332 | 1.073 | 4.04144 |
| 0.56 | | 20.701 | 1.443 | 4.17082 |
| 0.57 | | 21.071 | 1.813 | 4.33021 |

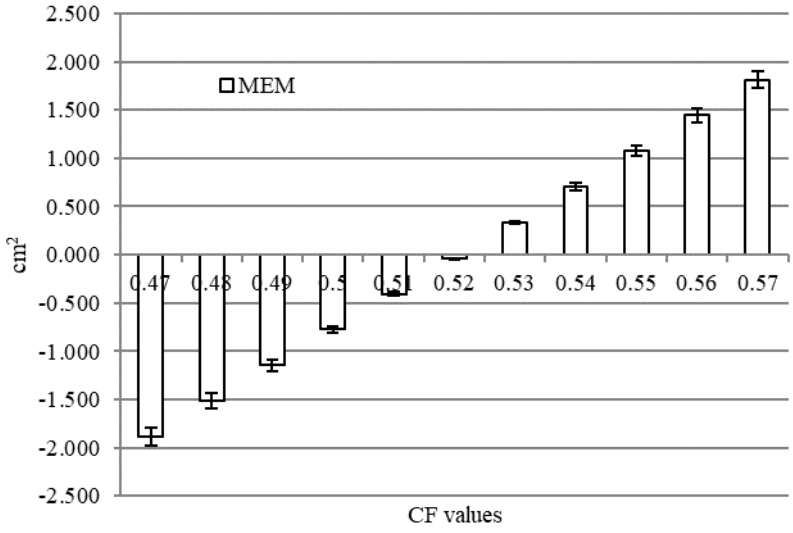


Fig. 3. Graphic distribution of MEM values, depending on CF in leaf samples, *Solanum nigrum* L. specie

*Table 2*

ANOVA single factor

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Groups | 8590.399 | 15 | 572.6933 | 25.70154 | 5.3E-49 | 2.595069 |
| Within Groups | 8556.46 | 384 | 22.28245 | | | |
| Total | 17146.86 | 399 | | | | |

Alpha=0.001

The values for measured leaf area (MLA), in the case study of the leaf samples, *Solanum nigrum* L. specie, were within a normal distribution, figure 4.

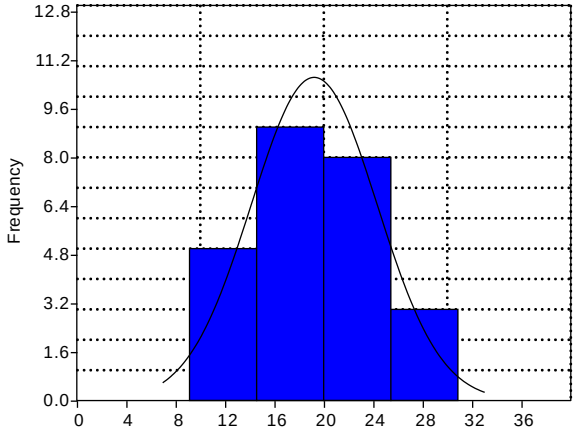


Fig. 4. Normal distribution of values obtained for MLA, corresponding to CF = 0.52 at *Solanum nigrum* L. leaves

The variation of MLA, depending on the length of the leaves (L) was described by a polynomial equation of degree 2, equation (3), in conditions of statistical safety, according to $R^2 = 0.875$, $p < 0.001$. The graphical distribution of MLA values according to L are shown in figure 5.

$$MLA = 0.1676\, x^2 + 2.183\, x - 8.268 \quad (3)$$

where: x – leaf length (L)

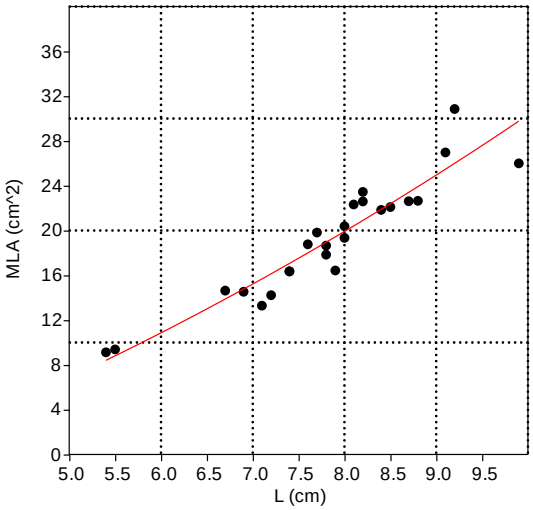


Fig. 5. Graphic distribution of the variation of MLA in relation to L parameter, *Solanum nigrum* L.

The variation of MLA, depending on the width of the leaves (w) was described by a linear equation, equation (4), in statistical safety conditions, according to $R^2 = 0.942$, $p < 0.001$. The graphical distribution of MLA values in relation to w is shown in Figure 6.

$$MLA = 6.677\,x - 11.8 \quad (4)$$

where: x – leaf width (w)

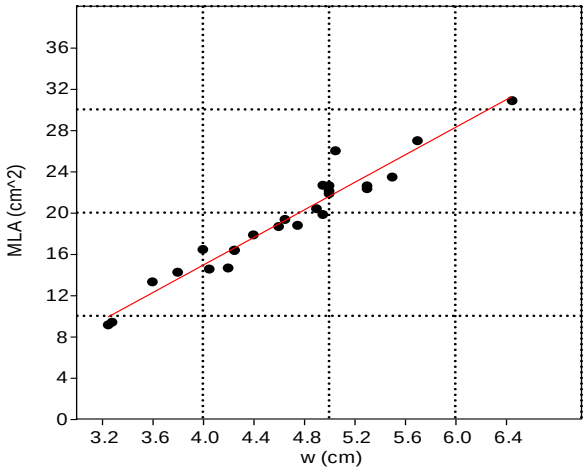


Fig. 6. Graphic distribution of the variation of MLA in relation to w parameter, *Solanum nigrum* L.

Rapid methods for determining the leaf area are useful in studies of vegetation dynamics, photosynthetic efficiency, for calculating foliar indices, for estimating plant health, the study of indicator species in natural or anthropogenic ecosystems, production estimation etc. (GIUFFRIDA et al., 2011; DRIENOVSKY et al., 2017a,b; DATCU et al., 2017; CARVALHO et al., 2018; CÂNDEA-CRĂCIUN et al., 2018).

*Solanum nigrum* is a specie found in various agricultural crops, competing with crops for space, light, water and nutrients (COLEMAN et al., 2020).

The leaf area in plant species, such as the one studied, *Solanum nigrum* L., considered in the category of "weeds" in agricultural crops (from the perspective of agricultural technologies and maintenance works), is important in relation to the degree of land cover, habitus of the plants, with the estimation of plant vigor and propagation potential (seed production), estimation of economic damage in crops generated by weeds, reception of biocidal substances (herbicides) (ZAHED et al., 2011; DADASHI et al., 2014; GUZZO et al. , 2014; SINGH et al., 2017).

From the analysis of the variation of MLA in relation to L and w, it was found that the width of the leaves facilitates a much more accurate description of MLA, and in general of the geometry of the leaves, compared to L, a fact recorded and comunicated in other studies (SALA et al., 2015, 2017; CÂNDEA-CRĂCIUN et al., 2018).

## CONCLUSIONS

For the set of leaf samples, the species *Solanum nigrum* L., the correction factor CF=0.52 was found, which facilitated the determination with high precision of the measured leaf area (MLA) based on the leaf parameters L, and w.

Polynomial and linear models described the interdependence relationship between MLA and L, respectively w, in statistical safety conditions.

The foliar parameter w (leaf width) facilitated a much more accurate description of MLA and leaf geometry in general, compared to L, the species *Solanum nigrum* L.

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