Scan LeafArea – A SOFTWARE APPLICATION USED IN THE DETERMINATION OF THE FOLIAR SURFACE OF PLANTS

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Abstract. *The importance of knowing the plant's individual foliar surface and the foliar indexes has led, in time, to the development of a series of methods that help in the determination of the foliar surface. Among these methods, the ones based on imagery are of high interest. The present study reveals the Scan LeafArea application, used in the determination of the foliar surface of plants. The leaves from three species of trees have been studied, Birch (Betula pendulata Roth), walnut (Jugland regia L.) and silver lily (Tilia tomentosa Moench). The leaves were randomly harvested from the tree crowns and were scanned in a 1:1 ratio in the RGB color system. The Scan LeafArea application was developed in Processing Program, with codes written in Java programming language. The foliar surface has been determined by the present application and by a well-known software program, ImageJ that helped in the results comparison. The leaves of the birch tree had a foliar surface that ranged between 13.43 – 44.48 cm^2 with a mean value of 28.55±2.67 cm^2 by using the proposed application, and the ImageJ software has obtained values between 13.25 – 44.71 cm^2 and a mean value of 28.59 cm^2. The mean difference between the two methods was -0.04 cm^2. By using Scan LeafArea application, the leaves of the walnut, had a foliar surface ranging from 21.92-114.30 cm^2 with a mean value of 65.78 cm2. For the same type of leaves, the ImageJ program has registered the following results: values between 21.32 - 114.32 cm^2 with a mean value of 65.47 cm^2 and the mean difference between the two methods is represented by the value 0.31 cm^2. The same process had been held for the linden leaves and with the help of the Scan LeafArea, its foliar surface ranged between 23.89 - 98.11 cm^2 with a mean value of 63.96 cm^2. ImageJ had the following results: foliar surface value: 23.25 - 97.94 cm^2 and mean value: 63.58 cm^2. The mean difference between the program and the software is 0.37 cm^2. The relationship between the foliar surface determined by the application Scan LeafArea and the one revealed by ImageJ software has been described by the first degree mathematical equations in the following statistical condition: $p<0.001$, $R2=0.999$.*

Keywords: *Scan LeafArea, foliar surface, leaves, plants, IT application, Processing Program, Java*

INTRODUCTION

The importance of knowing the plant's individual foliar surface and the foliar indexes has led, in time, to the development of a series of methods that help in the determination of the foliar surface that can be now grouped in destructive and nondestructive methods (SESTAK et al., 1971; JONCKHEERE et al., 2004; KIRK et al., 2009; BEHERA et al., 2010). Although both categories have advantages, the nondestructive methods are preferably used due to their precise, rapid characteristics and most importantly, facilitates repetitive study foliage dynamics and a foliar indexes (CAMPILLO et al., 2010; SOUZA and AMARAL, 2015; KHAN et al., 2016; YESHITILA and TAYE, 2016).

The development of the IT industry has helped in the agricultural and plants research by facilitating different methods and approach protocols, in the recognition and determination of the foliar surface of some representative organs which are important for some species of plants (CRISTOPHEL and BLACKBURN, 1974; PEREZ-HARGUINDEGUY and DIAZ, 2013; VASCO et al., 2014). Applications and models have been created for the determination of the foliar

surface of different flora species, species that present interest for agriculture, horticulture or forestry (SALA et al., 2015a; KUMAR et al., 2017).

Along with the development of the mobile industry, various studies have turned to the process of realizing mobile applications on Android and IOS for smartphones and tablets, for the sole purpose of recognizing various species based on their leaves, buds, shrubs, fruits or bark (DONOSO and CALVI, 2008; ISOPERLA, 2011, 2013; ARAYA, 2013; STAGG and DONKIN, 2016; WOODLAND TRUST, 2016; PLANTNET - project, 2007; TEAMSOA. Inc, 2007).

Different programming languages and editing programs have led to the development of open source and free applications in academic purposes or non-comercial, in the name of research (RASBAND, 1997). The fact that different color properties can be assigned to the images for a clear deceleration of the leaf tongue and that working at a pixel level, it can ensure a degree of high precision in the determination of the foliar surface.

The present study has assessed the possibility of the determination of the foliar surface with the Scan LeafArea application, constructed in Processing program, with Java code line, to three different plant species that have different leaf typologies: birch, walnut and linden.

MATERIAL AND METHOD

The study's main objective is to determinate the foliar surface to specific plant species, based on the images of the limbs of the leaves using an application created in Processing program.

From the *Juglandaceae* Family the walnut leaves (*Juglans regia* L.) have been analyzed. These are composite leaves that consist of large lamina with a pinnate venation, numerous secondary veins and a smooth margin. Actually, leafs lamina has been analyzed. Silver linden (*Tilia tomentosa* Moench), from the *Tiliaceae* Family, is a tall growing tree, with green leaves, toothed margin, asymmetrical, white tomentose on the inferior side with pinnate venation and second and third degree prominent veins. The birch (*Betula pendula* Roth, *Betulaceae* Family) is a medium sized tree, easy to recognize due to its white bark and flexible - pedunculate branches. Its leaf lamina is relatively small (after our assessment, the average length is 8.27 cm and the width is 6.32 cm) with a triangular and slightly rhombic form, pinnate venation, long petiole (2.7-3.1 cm) and irregular margins. As to what the walnut is concerned, its leaves and foliole have variable sizes and were randomly collected from the tree and scanned in a 1:1 ratio in the RGB color system. Subsequently, the images were analyzed for the determination of the foliar surface, figure 1.

(a) birch leaf (b) walnut foliole (c) linden leaf

Fig. 1. Birch leaves (a), walnut foliole (b) and linden leaves (c) were used in the determination of the foliar surface with the Scan LeafArea application.

The recognition and determination of the foliar surface application was constructed in Processing Program. The code lines were written in Java language. As a working process in the recognition and determination of the foliar surface, the program has red pixel to pixel and counted every green colored pixel in relation to the white pixels in the background (figure 2).

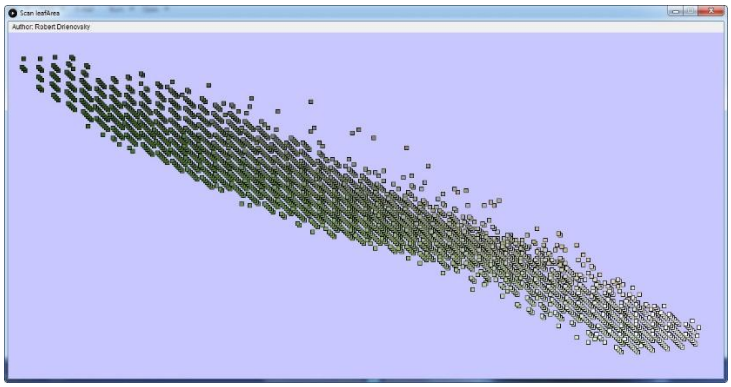

Fig 2. 3D portrait in the Scan LeafArea application for the recognition and determination of the leave's foliar surface

The experimental data has been analyzed by using the ANOVA test to assess the variance through statistical correlation and the analysis of the variance coefficient. The statistical module from the ECXEL application, Office 2007 pack and PAST software have been used (HAMMER et al., 2001).

RESULTS AND DISCUSSION

The logic scheme from figure 3 presented the foliar surface determination process made by the Scan LeafArea application which was constructed in the Processing Program, with code lines written in Java language. For the process of comparison of the leave's foliar surfaces presented in this study, the ImagJ software (RASBAND, 1997) has been used. From the imaging analysis of the birch, linden leaves and the walnut foliage, made with the help of the two applications, the results presented in table 1 were obtained.

In the case of the foliar surface determined with the Scan LeafArea application, the foliar surface of the birch leaves varied between 13.43 – 44.48 cm^2, with a mean value of 8.55±2.67 cm^2. For the same leaves, with the ImageJ application, the foliar surface values ranged between 13.25 – 44.71 cm^2, with a mean value of 28.59±2.71 cm^2. The mean difference between the two methods was -0.04 cm^2.

As to what the walnut foliole is concerned, by using the Scan LeafArea application, the foliar surface values varied between 21.92 – 114.30 cm^2, with a mean value of 65.78±10.02 cm^2. For the same leaves, with the ImageJ application, the foliar surface values ranged between 21.32 – 114.32 cm^2, with a mean value of 65.47 cm^2. The mean difference between the two methods was 0.31 cm^2.

In the case of the linden leaves, using the Scan LeafArea application, the foliar surface values varied between 23.89 – 98.11 cm^2, with an average value of 63.96±8.06 cm^2. For the same leaves, with the ImageJ application, the foliar surface values ranged between 23.25 – 97.94 cm^2, with a mean value of 63.58±8.11 cm^2. The mean difference between the two methods was 0.37 cm^2.

Analysis of the variance through the ANOVA test facilitated the highlighting of the safety of the experimental data in the three species studied, p<<0.001, F > Fcrit, table 2. The graphical distribution of the values for the foliar surface determined in the three species was of the normal type, according to the histograms of Figures 4-6.

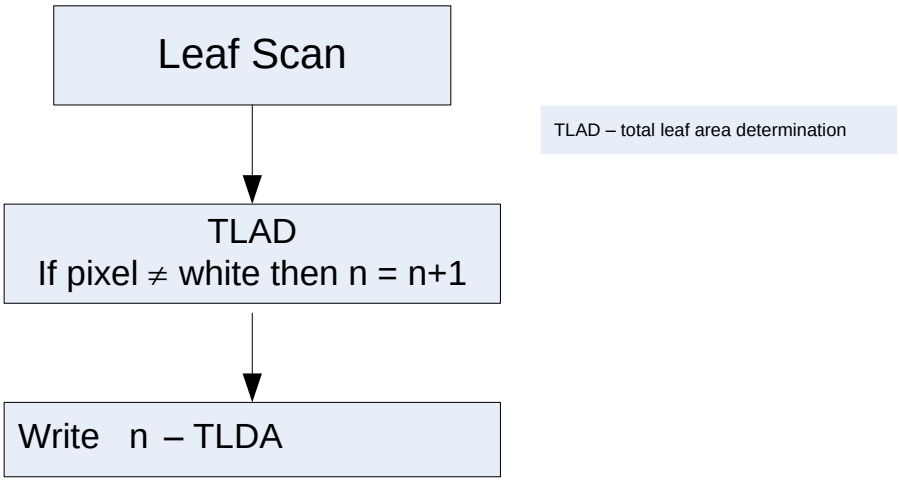

Fig 3. Logical scheme for the determination of foliar surfaces with Scan LeafArea

Table 1.

Data on the birch's foliar surface, walnut and linden determined by imaging methods

Case study number	Birch			Walnut			Linden		
	Scan LeafArea	ImageJ	Dif	Scan LeafArea	ImageJ	Dif	Scan LeafArea	ImageJ	Dif
1	31.99	32.16	-0.16	44.41	44.08	0.33	70.59	70.66	-0.07
2	44.48	44.71	-0.23	75.90	75.85	0.06	30.85	30.32	0.53
3	36.68	36.87	-0.20	98.55	98.62	-0.07	23.89	23.25	0.64
4	13.43	13.25	0.18	21.92	21.32	0.60	49.97	49.48	0.49
5	22.42	22.33	0.09	59.89	59.57	0.32	83.07	82.92	0.16
6	25.52	25.54	-0.02	66.11	65.51	0.60	98.11	97.94	0.17
7	28.61	28.65	-0.04	24.89	24.14	0.75	73.89	73.63	0.26
8	30.39	30.46	-0.06	51.35	50.86	0.48	45.68	45.04	0.64
9	22.81	22.74	0.07	114.30	114.32	-0.02	69.41	68.88	0.53
10	29.19	29.24	-0.05	100.44	100.39	0.05	94.09	93.72	0.37
Means	**28.55**	**28.59**	**-0.04**	**65.78**	**65.47**	**0.31**	**63.96**	**63.58**	**0.37**

Table 2.

ANOVA test, single factor

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	72433.25	8	9054.157	23.45146	3.69E-18	3.69908
Within Groups	31272.54	81	386.0808			
Total	103705.8	89				

Alpha = 0.001

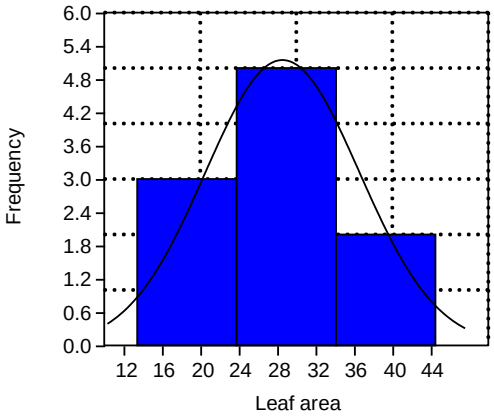

Fig. 4. Distribution of experimental values for the birch foliar surface, determined with the Scan LeafArea application

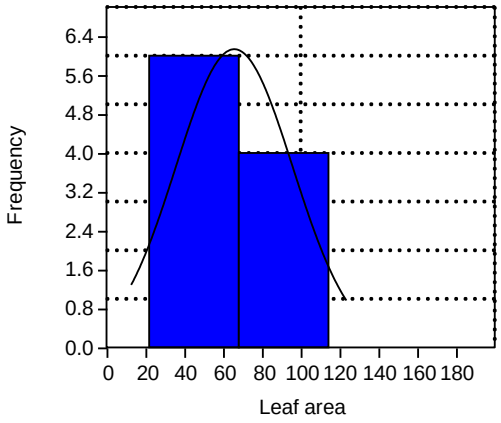

Fig. 5. Distribution of experimental values for the walnut foliar surface, determined with the Scan LeafArea application

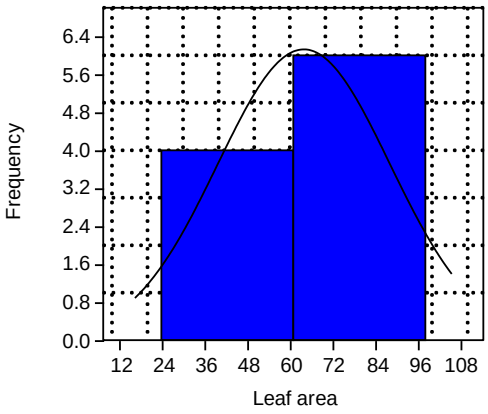

Fig. 6. Distribution of experimental values for the linden foliar surface, determined with the Scan LeafArea application

The relationship between the foliar surface determined by the Scan LeafArea application and that determined by the ImageJ software was described by first degree mathematical relations under statistical safety conditions, as follows: for the birch, the relationship (1), p<<0.001, R^2 = 0.999; for walnut, relationship (2), p<<0.001, R^2 = 0.999; for linden, relationship (3), p<<0.001, R^2 = 0.999. The graphical distribution of the particular values for the foliar surface determined by the Scan LeafArea and ImageJ application for the three species is shown in Figures 7 – 9.

$$SLA_b = 1.015x - 0.385 \quad (1)$$

$$SLA_w = 1.008x - 0.8454 \quad (2)$$

$$SLA_l = 1.006x - 0.7749 \quad (3)$$

where: x – the foliar surface determined with the Scan LeafArea application.

Spontaneous or cultivated plants are a complex subject of research. Modern, expeditious and non-invasive methods of work can be used in flora and vegetation studies, in research on rare, endemic or protected species, in the study of invasive species, in differentiating ecotypes from habitats, respectively specific environmental conditions (IMBREA and NICOLIN, 2007; NICOLIN and IMBREA, 2007; MOUNTFORD et al., 2008), with environmental factors of influence and stress (CRAMER et al., 2011; PEREIRA, 2016), with the

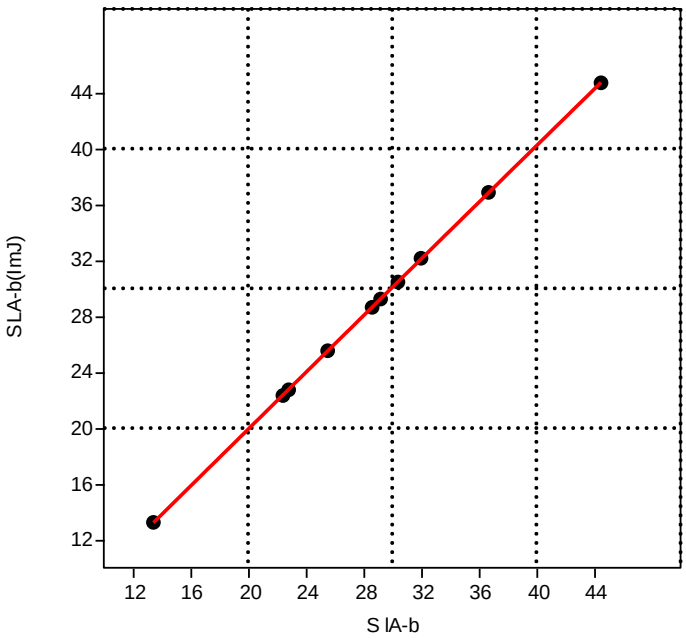

Fig. 7. Distribution of experimental values for the birch foliar surface, determined with the Scan LeafArea & ImageJ application; S lA – b: leaf area values obtained with proposed application; SLA – b (ImJ): leaf area values obtained with ImageJ software.

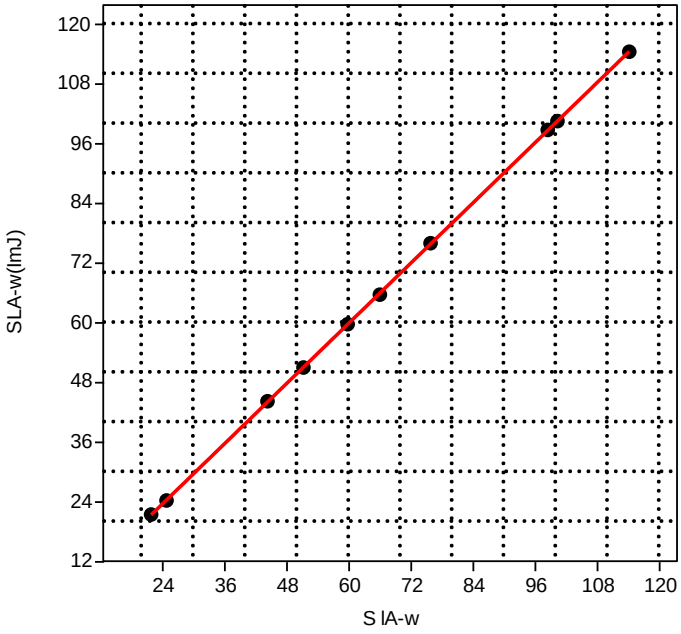

Fig. 8. Distribution of experimental values for the walnut foliar surface, determined with the Scan LeafArea & ImageJ application; S lA – w: leaf area values obtained with proposed application; SLA – w (ImJ): leaf area values obtained with ImageJ software

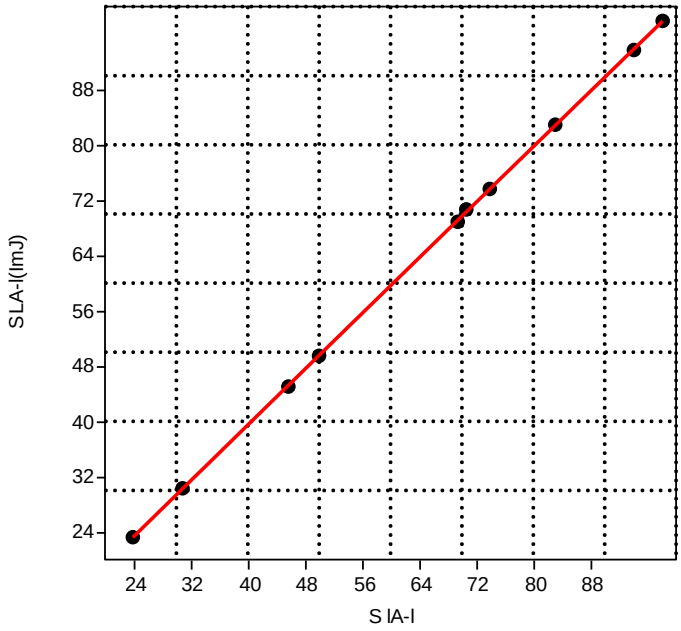

Fig. 9. Distribution of experimental values for the linden foliar surface, determined with the Scan LeafArea & ImageJ application; S lA – l: leaf area values obtained with proposed application; SLA – l (ImJ): leaf area values obtained with ImageJ software

typology of agricultural systems (MEIJER et al., 2015, RAWASHDEH and SALA, 2016), with the investigation techniques used (HERBEI et al., 2015; HERBEI and SALA, 2015), with technical and economic productivity (BOLDEA and SALA, 2010; SALA et al., 2015b, 2016).

ImageJ is software commonly used to analyze and determine macro- and microscopic images of different plant species. As a result, plug-in have been developed for these approaches. Thus, ImageJ is a widely used application in biology, to various imaging studies in plants such as plant phenotyping (HARTMANN et al., 2011), fractal analysis (SALA and BOLDEA, 2014, SALA et al., 2017), foliar surface analysis and leaf dimensional elements (EASLO and BLOOM, 2014; SALA et al., 2015a), particle analysis in the cell study (MALOOF et al., 2013), plant protection for the study of leaves attacked by different pests (STAWARCZYK and STAWARCZYK, 2015) and other studies as appropriate.

Over time, various applications and tools have been developed to study the leaves and their dimensional elements (BARK, 2005; IGATHINATHANE et al., 2006; BYLESJÖ et al., 2008; WEIGHT et al., 2008; KUMAR et al., 2017). This shows that there is an increased interest in the study of plant leaves for their determination and characterization or in relation to different factors of influence. Applications that have appeared over time have sought to be as precise as possible in simple, fast, and minimal operating conditions.

This application fits into these trends in order to provide simple, practical and accurate solutions to the study of plant leaves.

CONCLUSIONS

The proposed Scan LeafArea application for plant foliar determination has made it possible to precisely determine the surface of the three studied species, walnut and linden birch, at a level comparable to established applications (ImageJ).

The relation between the surface area determined by the Scan LeafArea application and that determined by the ImageJ software was described by first degree mathematical relations in statistically uncertain conditions, $p<<0.001$, $R^2 = 0.999$.

The obtained results recommend further development of the application and research based on it in the study of the plant leaves in different spontaneous flora species, cultivated or ornamental plants.

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