Applying a digital method for measuring leaf area index of tomato plants

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***Abstract*— Non-destructive methods of measuring leaf area are suitable for scientific experiments, and allow the measurement of the same plant several times during the growing period. The method was used to estimate the Leaf Area Index (LAI) of tomato plant in different growth stages. LAI was estimated by measuring the length and width of the leaves representing the mean leaf area of the plants. The LAI estimations presented high precision and accuracy when the proposed methodology was used resulting in time and effort savings and being useful. It is cheap and may existing computer and digital camera; thus, it doesn't need extra hardware. Projected technique is going to be valuable in achieving correct area calculation.**

Keywords*— *leaf Area Index, digital method, tomato, measurement.

I. INTRODUCTION

Leaves are the most important organ for photosynthesis process which was studied by Kozlowski and Pallardy [12] in which light energy is apprehended by green plants (mainly by the chlorophyll in leaves) and used to produced carbon compounds from carbon dioxide and water. Therefore, leaf area capacities are required in most physiological and agronomic studies concerning plant growth [11]. The leaf area index (LAI) is an important parameter in crop growth. It reflects the leafiness of the crop. The leafiness in one way reflects the photosynthetic capability of the crop. The development of the fruit size depends on a number of factors such as the leaf-fruit ratio, leaf area index, genetic and climatic factors, position in the plant and the branch, tree age, number of seeds and water and nutrient supply [7]. Measurement of Leaf Area is an important factor in agricultural studies, and is associated with photosynthesis and evapotranspiration; therefore, leaf area measurements are required in most physiological and agronomic studies involving plant growth [10]. Many methods of leaf area measurements have been developed.

Many methods for measuring leaf area have been developed. Direct methods for determining the area of a sheet are limited to using an automatic area counter. Tracking, plotting shadows or using a planimeter to measure the area of leaves attached to shoots is time consuming and tedious, in some experiments, there is not enough time to carry out such measurements [13].

There are two main categories of procedures to estimate LAI: direct and indirect methods [9]. The former group consists of methods measuring leaf area in a direct way, while the second group consists of methods where LAI is derived from more easily (in terms of time, workload and technology) measurable parameters [8, 9].

Direct methods for determining leaf area are restricted to the use of an automatic area-integrating meter. Tracing, shadow graphing or the use of a planimeter to measure the leaf area of leaves attached to shoots is time consuming and tedious; also, in some experiments time is insufficient to make such measurements [13]. Also, measuring instruments are very expensive and are often not available in developing countries [5, 6]. Alternative indirect methods such as image analysis could be used to measure leaf area as they play an important role in the measurement of leaf dimensions [3] and in the detection of cotton pests and diseases [11]. In image analysis, digital cameras are used to acquire images that are then analyzed with appropriate software, either commercial or freeware. Digital scanners and cameras in combination with digital image processing software have replaced older leaf area measuring techniques [2].

The objective of this study was to develop a rapid and simple computer vision-based method for measuring tomato leaf area. In the developed method, images of tomato leaves collected using an off-the-shelf digital camera was analyzed using "ImageJ" program.

II. METHODS

This experiment was a part of dissertation work to study the effect of plant growth regulators on some tomatoes cultivars and hybrids under delta Volga conditions (2016-2018). Three tomatoes varieties (Mariana, Superjol and Revisor) and two hybrids (Metro F1 and Kendras F1) were applied by four different types of synthetic growth regulators (Crezacin, Chitosan, Scircon and Energene) additional to Control treatment. Leaf Area Index measured by IMAGEJ program at different ages of tomato plants (30, 60 and 90 DAP).

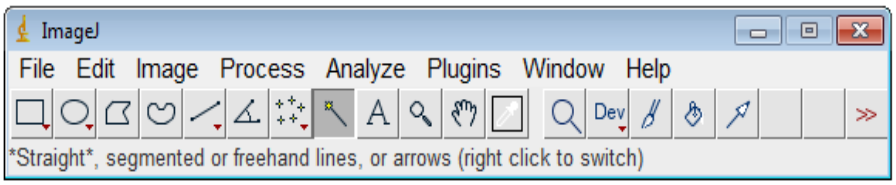

Fig. 1. Main menu of the ImageJ software

ImageJ Software is a powerful program that was developed at the National Institutes of Health, USA [1]. It is in the public domain, runs on a variety of operating systems, and is updated frequently. It can be downloaded for free [4]. The various buttons on the tool bar enable analysis of images. The window of the main menu of the ImageJ software is shown in Fig. 1.

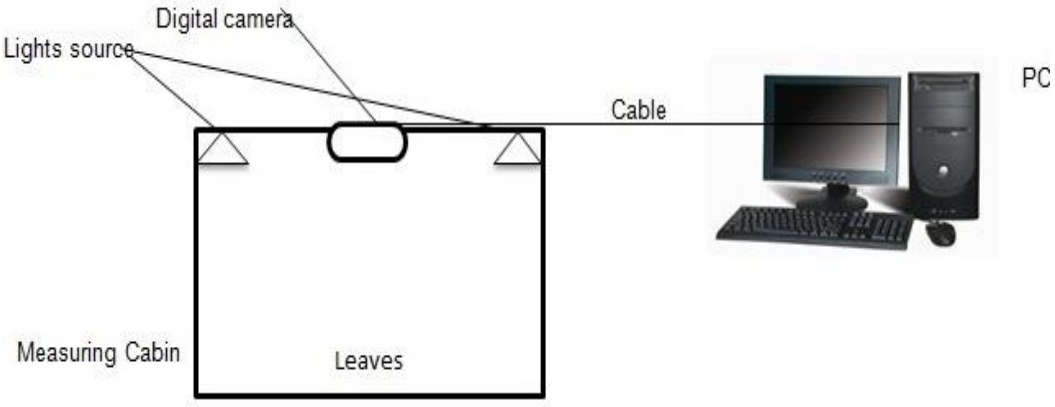

Fig. 2. Image acquisition system

The image acquisition system is depicted in Fig.2. In the center of the upper face, a white plastic box was drilled (lighting room) and the camera was placed in the hole. Sheet placed under the camera and lit with two lamps as a source of light. No shadow was observed.

A color digital camera was positioned vertically above the sample sheet. Samples of images were taken on a white background. Images have been saved in jpeg format. The camera was connected to a computer with an image management software acquisition and acquired digital images directly from the camera.

To evaluate the performance of the proposed measurement system, leaves were collected from different positions on tomato plants, leaves were placed with a standard ruler against a white background and the image captured with the digital camera.

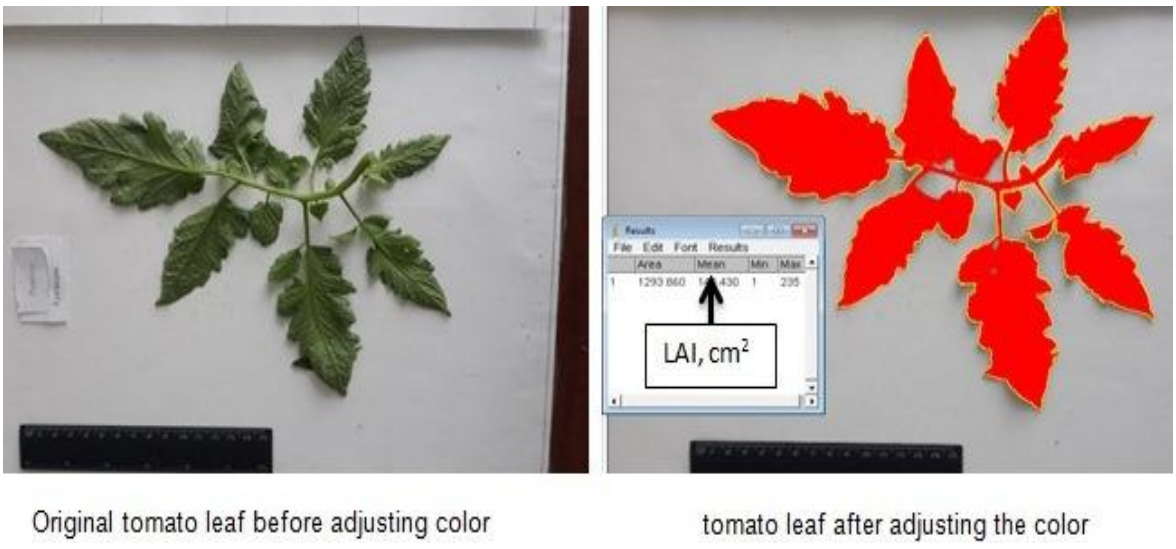

Fig. 3. Selecting the green region of the leaf and adjusting to red color for measurement (cm^2) by program IMAGEJ

The images were transferred to analysis device (computer) for complete measurement process through ImageJ (Fig.3) by following these steps [Open the image, measure the scale using the functional line, then go to "Image"> "Adjust"> "Color Threshold" and make changes to "Hue and Saturation" to get a white background with a red leaf; select the leaf and read the measurement].

III. RESEARCH RESULTS

Data on leaf area is presented in Table 1. Analysis of variance (ANOVA) showed that (at 30 days after sowing) the area of a leaf of tomato significantly depends on the variety and hybrid. The largest average leaf area (4.53 dm2) was noted for the interaction between Superjol and Chitosan. The smallest area of the sheet (3.44 dm2) was noted in the variant "Revisor × control".

As can be seen from the data presented in Table 1, the growth dynamics of the LAI (dm2/plant) was largely dependent on type of variety and hybrid. The largest leaf area was obtained from the "Superjol" variety, which was treated with chitosan (36.8 and 69.7 dm2), while the minimum result was obtained from interaction between "Revizor and Crezacin" (21.3 dm2, 60 DAP), and the minimum (49.5 dm2, 90 DAP) was observed when chitosan was applied on variety "Revizor".

Studying each variety at the age of 60 days, as mentioned above, founded that, using of growth regulators had no significant effect on the leaf area of tomato plants: "Mariana" - 33.5–34.1, in Control - 34.9 dm2/plant; "Superjol" - 36.1–36.8, in control - 36.3 dm2/plant; "Revisor" - 21.3–23.1, in Control - 21.9 dm2/plant; "Metro F1" - 28.0–29.8, in Control - 29.6 dm2/plant; "Kendras F1" - 32.5–35.1, in Control - 35.6 dm2/plant. At the age of 90 DAP, Using of different varieties and hybrid have significant influence on the leaf area of tomato: "Mariana" - 65.5–66.6, in Control - 65.0 dm2/plant; "Superjol" - 68.1–69.7, in Control - 68.9 dm2/plant; "Revisor" - 49.5–51.8, in Control - 50.8 dm2/plant; "Metro F1" - 52.0–54.8, in Control - 53.8 dm^2/plant; "Kendras F1" - 65.2–66.9, in Control - 66.1 dm^2.

TABLE I. LEAF AREA INDEX (DM^2/PLANT) OF TOMATO PLANTS MEASURED BY IMAGEJ

Variety /hybrid	LAI, dm^2			
	Plant growth regulator	***30 DAP***	***60 DAP***	***90 DAP***
Mariana	Control	4.04	34.9	65.0
	Crezacin	4.05	33.8	66.6
	Chitosan	3.96	34.1	65.9
	Sircon	4.14	33.5	66.0
	Energene	4.12	33.9	65.5
Superjol	Control	4.10	36.3	68.9
	Crezacin	4.51	36.2	68.1
	Chitosan	4.53	36.8	69.7
	Sircon	4.14	36.1	69.5
	Energene	4.29	36.6	69.6
Revisor	Control	3.44	21.9	50.9
	Crezacin	3.47	21.8	50.2
	Chitosan	3.50	22.2	49.5
	Sircon	3.58	21.3	51.5
	Energene	3.60	23.1	51.8
Metro F1	Control	3.58	29.6	53.8
	Crezacin	3.43	28.8	54.8
	Chitosan	3.58	28.0	52.0
	Sircon	3.58	29.8	53.3
	Energene	3.73	29.7	53.8
Kendras F1	Control	4.08	35.6	66.1
	Crezacin	4.06	32.5	66.9
	Chitosan	4.02	34.8	65.6
	Sircon	4.24	34.6	66.8
	Energene	4.35	35.1	65.2
$LSD_{0.05}$ (AB)		0.3	1.7	3.1

Using IMAGEJ to measure LAI was studied by [1] who reported that, the coefficient of determination for leaf area measurement by the graphical versus the image analysis-based system was 0.9. As studies on plant growth and development continue to increase analysis-based system method will be a very useful tool for estimating the leaf area for cotton plants without requiring additive expensive devices. Patil and Bodhe [14] compared the simple image analysis technique with the graphical for sugarcane leaf area and located that the simple image analysis technique was accurate with a small relative error (2.9%). The results show that, there is a sensible agreement between the values recorded by the projected system and that of the graphical technique.

IV. CONCLUSION

This experiment was carried out using 25 treatments with three replicates. As studies on plant growth and development continue to enhance, a digital method to calculate tomato Leaf Area will be a very helpful tool, which saves the time and money, without requiring additional expensive devices and without losing time. An existing PC and camera; therefore, it doesn't require additional hardware. This method will be valuable in determining accurate and fast area calculation of tomato leaves.

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