International Journal of Agriculture and Animal Production
Vol: 03, No. 2, July-Dec 2023
ISSN: 2799-0907, DOI: 10.55529/ijaap.35.1.7

Research Paper

A rapid measurement method for cannopy porosity of orchard crops

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Article Info

Article History:
Received: 24 April 2023
Revised: 02 July 2023
Accepted: 10 July 2023
Published: 26 August 2023

Keywords:
Canopy Porosity
Orchard Trees
Pesticides
Spraying
Environment

ABSTRACT

The paper presents a research for rapid measurement of canopy porosity used in the process for optimization of treatment with plant protection products of orchard cultures. Spraying trees and bushes with more porosity canopy without optimizing the amount of pesticide solution can lead to significant wasting of solution on one hand and to significant pollution of the environment on other. Although there are a lot of investigations about canopy porosity, including with the development of smartphone applications for measurement of this value, they have a lot of drawbacks that obstruct their use in the real agronomist practice. The proposed method for measurement of the canopy porosity in the present study is simple, easy to be performed and can be used under any weather conditions.

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1. INTRODUCTION

When using pesticides in agriculture, is essential for the mechanisms by which chemicals are applied to be as efficient as possible in order to be achieving the maximum effect from their application with minimum adverse effect on humans, non-target organisms and the environment. The process for optimization of treatment with plant protection products, means not only correct timing but also the

International Journal of Agriculture and Animal Production (IJAAP)

correct calculation of pesticide solution amount (rates) needed to be sprayed for a given area (crops). Unlike arable cultures, trees and bushes are three-dimensional targets. Hence spray deposition heavily depends on the structure of the target (orchard trees / bushes) - height, width and length of the sprayed canopy but also – very important canopy porosity (density). Spraying trees and bushes with more porosity canopy (less density) without optimizing the amount of pesticide solution in this aspect will lead to significant wasting of solution on one hand and to significant pollution of the environment on other [1], [2], [3]. Canopy porosity is also key factor favor fruit exposure and air circulation, both benefits to fruit quality and health [4], [5], [6], [7]. Although there is a lot of investigations about canopy porosity [4], including with development of Smartphone applications for measurement of this value, like VitiCanopy [8], [9], [10], [11], [12], [13], Easy Leaf Area [14], [15], [16], BioLeaf - Foliar Analysis [17], [18], [19], and others, such methods and applications have several flaws: often they are not universal - are specified for specific culture / cultures, like VitiCanopy which is designed for porosity estimation of grapes but not for orchard trees or Canopeo which can estimate LAI of arable crops but not orchard cultures or grapes, BioLeaf - which can measure the area of single leaves but not LAI or canopy porosity. Very often such kind applications have too much complicated an interface, require high grade cameras, have free version with limited functionality or are available only for Android or only IOS operational system. Due to the fact that image must be taken preliminarily in order to be made calculation or if there are specific field conditions during that time like direct sunshine, additional objects such as other trees, shades, buildings, or structures, values cannot be calculated or calculation can be with significant deviations. The right area / LAI/ Porosity calculation directly depends on the good and precise focus of the taken images.

The purpose of the present paper is to evaluate simple, easy to be performed and rapid method for field calculation of canopy porosity under any conditions

2. METHODOLOGY

The base of the method is a transparent plate created by any suitable materials – sheet of plastic, polycarbonate, polypropylene and est. including waste packages from cheese, candy and other such products. The plate was divided into squares with different dimensions: 0.1 x 0.1 cm; 0.5 x 0.5 cm; 1.0 x 1.0 cm; 1.5 x 1.5 cm; 2.0 x 2.0 cm; 2.5 x 2.5 cm and 3.0 x 3.0 cm with permanent marker or pencil for glass. The graduated plate was positioned at different distances from trees (in the investigation was used different orchard trees, at different growth stages) and human face (eyes). The canopy area was calculated by counting the number of squares "filled" with the canopy. The porosity was calculated as a percent of squares with no or particular canopy:

Percent of porosity = (squares with no or particular canopy * 100) / squares "filled" with canopy. The results were compared with data received from ImageJ software [20], [21], [22].

3. RESULTS AND DISCUSSIONS

The conducted trials with different orchard trees, at different growth stages, reveal that the most suitable plate graduation was by 1.0 * 1.0 centimeters. Squares with fewer dimensions will provide more accurate measurement but they will be more difficult to be counted especially under field conditions and people with worse vision. The calculations made by squares with bigger dimensions will be too inaccurate (Figure 1 and Figure 2).



Figure 1. Canopy Porosity Measurement Via Proposed Method and Verified Via Imagej During Summer

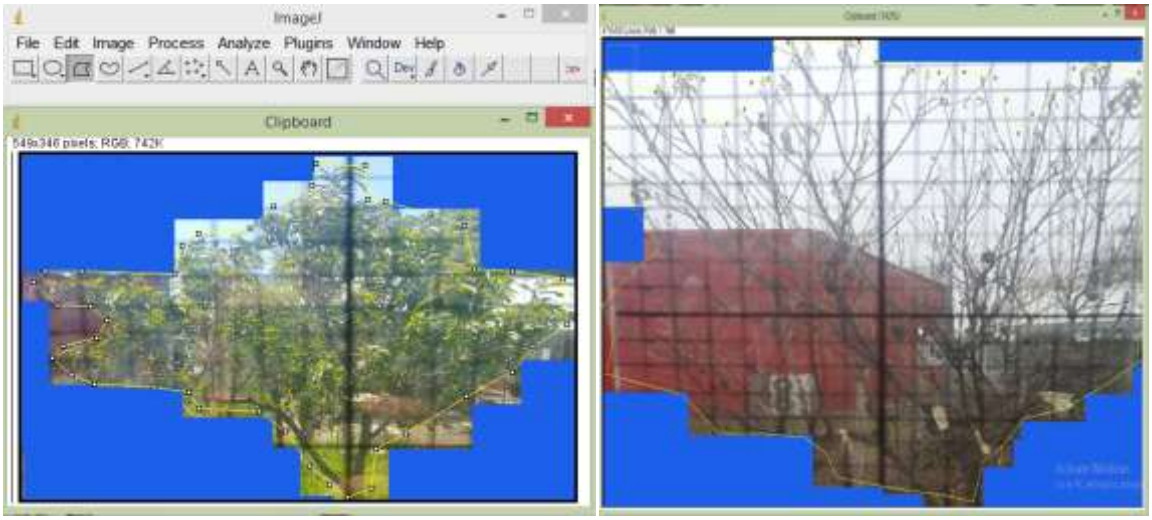


Figure 2. Canopy Porosity Measurement Via Proposed Method and Verified Via Imagej During Spring and Winter

The tests show that the most appropriate distance of the plate from a tree is approximately 2.5 meters. Less distance cannot cover the all canopy of the tree from one side and measurements due to the fact, squares will be "fill" with too much canopy will be too inaccurate. The most appropriate distance of the plate to the face (eyes) is 30 cm. At this distances each squire of the plate with an area 1 square centimeters corresponds to 56.25 square centimeters canopy area (Figure 3) established by color sheets of paper.

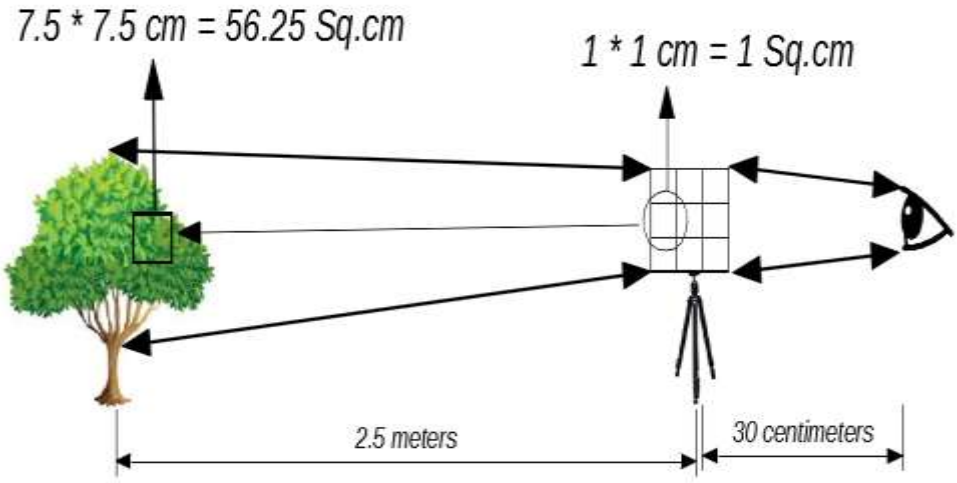


Figure 3. Canopy Porosity Measurement Method

The comparative measurement by ImageJ show deviation = 8.9 %. The measurements of orchard trees canopies made in different growth stages (with different canopy porosity) show deviation between 4.5 and 8.5 % (Figure 1, Figure 2 and Figure 4).

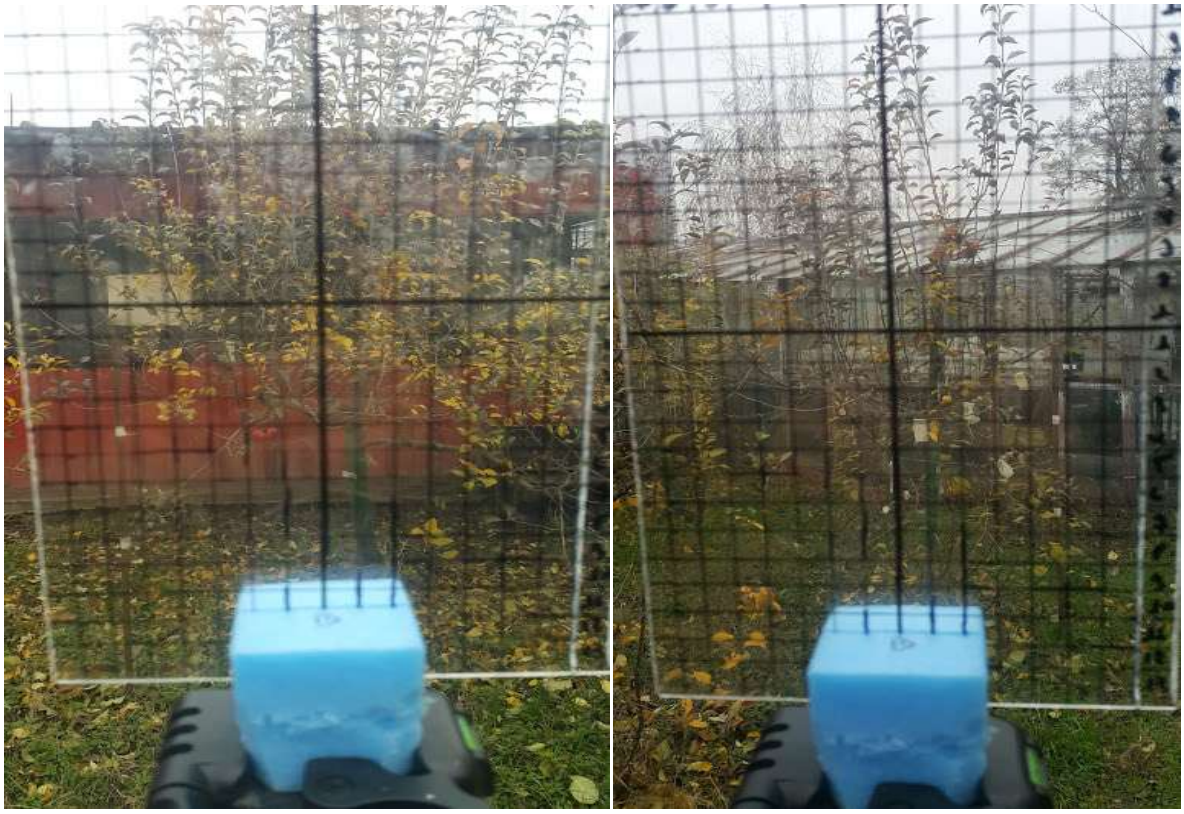


Figure 4. Canopy Porosity Measurement Via Proposed Method During Autumn

The measurements of separate leaves from different cultures with different forms, made by putting the graduated transparent sheets over leaves, show deviation between 0.3 and 8.9 % compared with measurements by ImageJ (Figure 5).

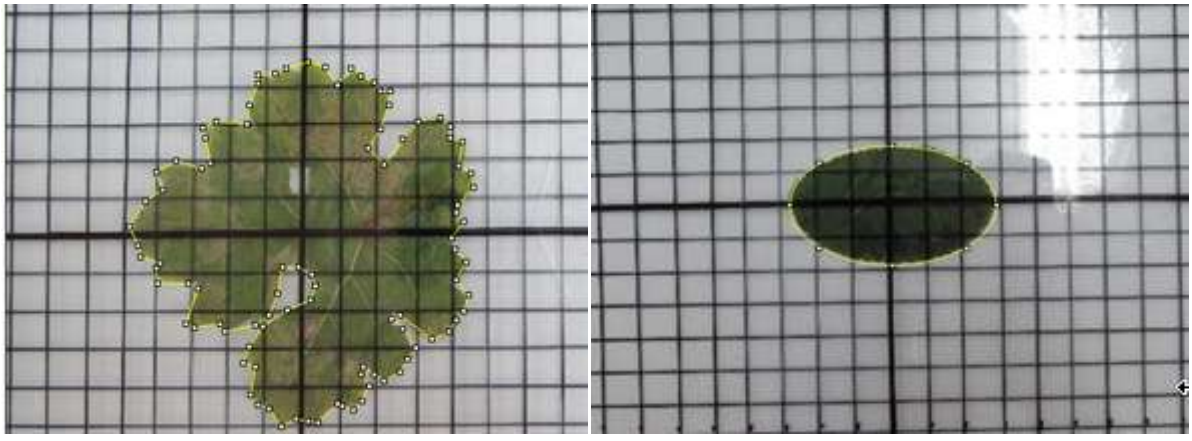


Figure 5. Measurement of Separate Leaves Area Via Proposed Method and Verified Via Image

The conducted trials reveal that in most cases the canopy porosity of the orchard trees in the summer is between 10 % and 20 % (25 % in some cases) (Figure 1 and Figure 2). In the spring – autumn the porosity increased to 30-35 %, while in the winter (no leaves on the branches) – are reach 45-50 % even in some cases – 70-75 %. (Figure 2 and Figure 4) Hence if one orchard plantation must be treated with

600 l pesticide solution /ha for winter (non-vegetation spraying with pesticides) and the trees have canopy porosity of 50 %, the reduction of pesticide solution per dka can be (60*50)/100 = 300 l/ha. In the summer if canopy porosity is for example 20 %, and pesticide solution rate needed for 1 ha area is 1000 l the reduction will be: (1000*20)/100 = 200 liters or 800 l/ha pesticide solution rate.

4. CONCLUSIONS

The present investigation clearly shows that although proposed in this paper method for measurement of the canopy area and respectively porosity with transparent graduated sheets is too simple and primitive compared with available digital instruments (software applications) it is pretty accurate and workable. Creation of such transparent sheets costs nothing and can be done for 10-15 minutes. Unlike software applications, using the sheets does not require anything special, and measurements can be taken under any conditions – quickly and with simple minimal calculations. The proposed method is universal – can be used for any culture, including for measurement of the separate leaves area. The conducted trials reveal that the difference between the measurement taken by transparent graduated sheets and ImageJ in the worst case is approximately 8-9 %, which is completely acceptable for the field conditions. Using the canopy porosity for reduction of the pesticide solution rates per area can increase the effectiveness of the pesticide treatments from one side and can reduce the harmful impact of pesticides on the environment on the other

Acknowledgments

The authors have no specific acknowledgments to make for this research.

Funding Information

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Donyo Ganchev	✓	✓	✓	✓		✓		✓	✓	✓	✓		✓	✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

Conflict of Interest Statement

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Informed Consent

All participants were informed about the purpose of the study, and their voluntary consent was obtained prior to data collection.

Ethical Approval

The study was conducted in compliance with the ethical principles outlined in the Declaration of Helsinki and approved by the relevant institutional authorities.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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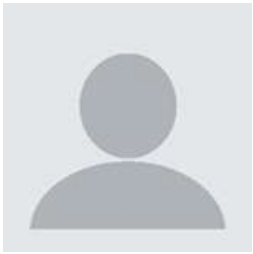
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How to Cite: Donyo Ganchev. (2023). A rapid measurement method for cannopy porosity of orchard crops. International Journal of Agriculture and Animal Production (IJAAP), 3(2), 54–60. https://doi.org/10.55529/ijaap.35.1.7

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