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A DIGITAL SYSTEM TO MONITOR THE CANOPY IN SOME APPLE AND QUINCE CULTIVARS

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Abstract

Nowadays, we still need to know every link in the production chain to optimize it by reducing costs and allocating resources to develop essential segments. WinSCANOPY is a system that analyses tree canopy through image analysis. This work aims to present the influence of the planting system and the fruit tree species on specific canopy parameters (foliar index, direct, diffuse, and total radiation) by monitoring the canopy projection in an apple and quince orchard. A secondary objective consisted of studying the canopy developing dynamic during a growing season in the analyzed species. The results compare the parameters monitored on the four sides of the trees (North, East, South, and West) in three moments of the day and five series in the vegetable season.

Key words: *non-destructive equipment, foliar index, direct, diffuse, and total radiation*

INTRODUCTION

Modern analysis methods offer new possibilities to understand the interaction of the fruit tree with the environment and its response to orchard management.

The paper aims to present a method to analyze the influence of the planting system on some apple and quince cultivars using several canopy parameters. Foliar index, direct, diffuse, and total radiation were measured. At the same time, the canopy dynamic during a growing season in the analyzed species was monitored.

In modern horticulture, selection, selective crosses, and system planting designed for super-intensive orchards led to yields of more than 80 tonnes per hectare in the apple crop, aided by modern cultivation technologies: controlled fertilization (fertigation), foliar fertilization, phytosanitary protection, and the use of different canopy shapes that promote the obtaining of fruits and the most judicious use of the less and less available labor force for carrying out maintenance and harvesting works (Ghena et al., 2004; Stănică & Peticilă, 2011).

In the last decades, we have gone from natural selection and trees with natural and massive crowns, challenging to harvest, which are still found in nature today, to controlled selection and breeding, with clear objectives and the creation of shape canopies adapted to the demands of society of today, especially maximum production with minimum labor consumption.

From extensive orchards, we have moved to a plantation with more than 3,300 plants per ha, and the first step was the pyramid canopy. It was still a canopy for the vigorous plants. Still, it allowed better harvest management due to the architecture, the skeleton being well defined, strong branches, and the majority of the fruits towards the outside due to the shading effect of the axis. The pyramidal canopy shape was a canopy that delayed fruiting, requiring a long time to achieve it at planting densities (5/4 or 6/5 m). It was a canopy intended for extensive orchards with vigorous cultivars and rootstocks.

The pyramid canopy shape was used and promoted until around the 1950s when the Vase canopy was discovered, which resembled the pyramid's first floor. This was formed by removing the spindle after the branches had consolidated their position. The advantages of the Vase system planting consisted of redistributing the vigor of the pyramid's vertical axis on the three or four arms of the Vase canopy. This fact allowed the fruiting branches to be closer to the ground, simplifying pruning and harvesting and much better penetration of light inside the crown, reducing the pressure of fungal diseases that develop in an environment with increased humidity and light radiation.

From this point, a step forward was the flattened crown forms: Late Flattened Vase, Simple Palmette, Tiered Palmette, Non-tiered Palmette, Free Palmette, etc., which increased the number of trees per hectare and brought the fruit closer to the soil, implicitly facilitating harvesting and maintenance work (pruning, harvesting, phytosanitary protection).

The next step towards orchards with high-yielding planting systems was the discovery, creation, and use of low-vigor rootstocks, which further increased the number of trees per hectare and led to a change in tree crown architecture to simpler, more productive, and more accessible and faster to create.

Obtaining the Thin Spindle required removing only a few pyramid levels and replacing them with semi-skeletal, fruit-bearing branches. A simple crown, in which only a few elements represent the skeleton, was the zig-zag axis, formed by replacing the arrow extension with the competitor or the next branch, provided that a relatively straight and vertical line of growth was kept.

From an evolutionary point of view, the following canopy shapes further simplified the formation and creation of fruit system planting, to be created by a workforce with as little experience and training as possible. Simplicity increased workforce efficiency.

The next canopy shape was the Vertical Axis canopy shape. This was the simpler version of the Slender spindle canopy. The skeleton (the elements that remain in the architecture of the tree throughout its lifetime) was represented only by the trunk and its extension (axis), plus the skeletal branches that were periodically replaced (the fruiting branches) by minimal cuts. This canopy shape speeded up fruiting. For planting trees with early shoots (at least in the case of apples), the first fruits were obtained from the very first year after planting. An economical production could be obtained from the second or third year.

The canopy, which, instead of one axis, had two parallel axes of identical force at the same distance from the trunk, with the same branching angle between them, was called Bi-Baum® (in German, "two trees"). This canopy type could theoretically reduce the cost of planting material by 50%. Practically, these expenses were increased by the longer formation time of this canopy in the nursery or the newly established plantation.

In addition to the disadvantage of a more extended formation and fruiting time, the Bi-Baum® crown had the advantage of a longer lifespan compared to the Vertical Axis and the minor need for trees to establish a plantation.

The Trident canopy was formed similarly to the Bi-Baum®, with the difference that it had three instead of two central arms. So, this planting system had the advantage of reducing the need for planting material to a third of the Vertical Axis. (Hoza, 2000; Grădinariu, 2002; Hoza, 2003; Ghena & Braniște, 2003; Iordănescu, 2008; Stănică & Braniște, 2011; Asănică & Hoza, 2013; Sumedrea et al., 2014; Cimpoieș, 2018).

At the farm level, there is a need to thoroughly know every link in the production chain to optimize it by reducing costs and allocating resources to develop essential segments. Growing fruit trees, although a storied activity, still has aspects we do not fully understand or have yet to measure.

WinSCANOPY system analyses tree canopies through indirect methods and image analysis.

Modern analysis methods offer new possibilities to understand the interaction of the tree's canopy with the environment and their response to the applied culture technology. These observations lead to the efficiency of culture technology and the creation of more efficient canopy shapes that require as little input as possible for formation and maintenance and give a qualitative and quantitatively efficient production with a reduced labor requirement.

The main objective of the research was to determine the influence of the crown shape and the tree species on specific parameters (foliar index, direct, diffuse, and total radiation, etc.) by using the WinSCANOPY system for monitoring the canopy projection in some tree species.

A secondary objective was monitoring how the analyzed species' canopy shapes developed during a growing season.

MATERIALS AND METHODS

The experiment was conducted in the Didactic Experimental Field of the Faculty of Horticulture, located north of the city, in the University of Agronomic Sciences and Veterinary Medicine of Bucharest. The representative profile has the geographical coordinates 44°28'10" N and 26°04'00" N.

Four canopy shapes were analyzed for the biological material: Vertical Axis, Bi-Baum®, Trident at apple, and Vase at quince.

WinSCANOPY system for monitoring the crown projection was used (WinSCANOPY, 2014). The system includes image acquisition hardware, a fisheye lens camera, and computer programs for hemispheric and covers image analysis and data visualization.

During these analyses, it was possible to observe:

• Offset fractions per sky region, altitude ring, and direction. Opening on the lifting ring.

• The level of direct and indirect (diffuse) solar radiation above and below the crown and total radiation throughout the day.

• The angle of the leaves in the crown.

• Distribution and duration of sunny areas at crown level.

• Crowding index according to zenith angle and sky region.

• The leaf projection coefficient depends on the zenith angle.

• Distribution of measured and theoretical shaded areas at crown level.

The method consisted of taking several photographs and then analyzing them with the WinSCANOPY software. The pictures were taken in the phenophase of intensive shoot growth in 5 series with repetition at ten-day intervals. The device has a series of rings that allow it to balance perfectly horizontally, with the objective towards the zenith, or perfectly downwards if a series of weights are placed on it with which it is provided.

During the same day, three series of photos were taken in the morning, around 9 o'clock, at noon, when the sun was at its zenith, around 2 o'clock, and in the evening at 6 o'clock. The trees were also photographed (from bottom to top) from each cardinal point, resulting in a total of 60 pictures for each tree (4 cardinal points x 3 moments of the day x 5 series) (Figures 1 and 2).

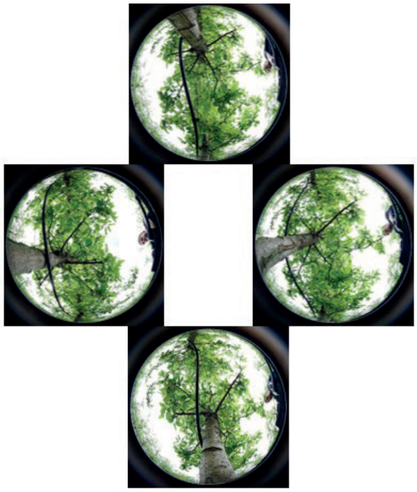

Figure 1. Apple - Vertical Axis canopy shape, series 1, morning (source: own data)

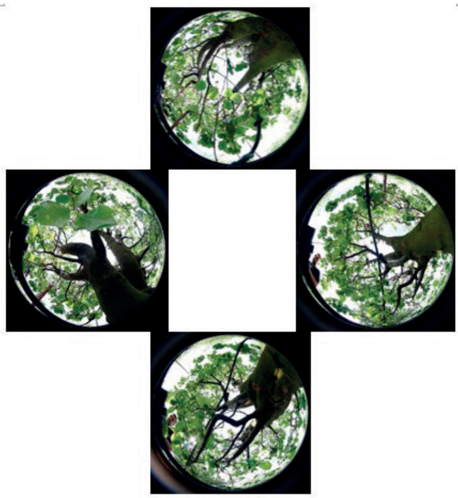

Figure 2. Quince - Vase canopy shape, series 1, morning (source: own data)

For the descriptive statistics of the data, XLScanopy software, Microsoft Excel 2016, and IBM SPSS v. 28.0.1.1 were used for a significance level of $p = 0.05$.

RESULTS AND DISCUSSIONS

The results quantified the canopy projection on the ground for all experimental variants.

Influence of species and planting system on crown projection

Gap fractions (% Cer_1) and crown openness (% Cer_2) were rendered dynamically for the two species and canopy shapes analyzed (Figures 3-6).

In the quince, in the Vase planting system (Figure 3), the East, North, and South showed similar values, decreasing as the crown developed, varying between 27.09% - 13.46%.

The analyzed data showed how the western part of the canopy was more developed, the parameters varying between 15.79%-6.45% in the morning, 19.3%-8.29% at noon, and 10.99-6.82% in the evening.

The values determined in the measurements taken at noon were the highest, followed by those in the morning and evening.

In the apple species, in the Vertical Axis system planting, the values were between (1) 28.72-12.74% (East), 32.62-14.28% (North), 33.68-15.43 % (South), and 37.36-15.33% (West) as well as (2) 38.75-13.03% (East), 39.02-15.15% (North), 38.98-14.43% (South), and 43.43-16.02% (West) (Figure 4).

The Bi-Baum® system resulted in the following values: 36.29%-15.48% (East), 36.76%-14.44% (North), 41.99-15.6% (South), and 35.66-13.55% (West) (Figure 5).

In the Trident canopy shape, the values were between 30.16-9.83% (East), 22.28-8.02% (North), 32.26-9.91% (South), and 29.08-9.69% (West) (Figure 6).

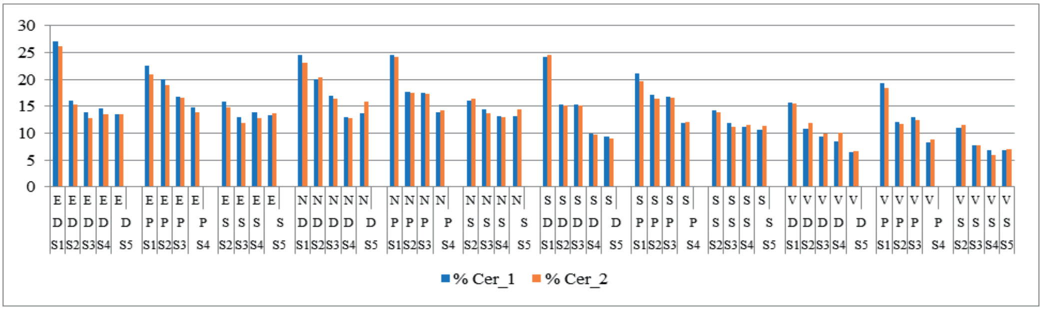

Figure 3. Vase Canopy projection to quince (%) (source: own data)

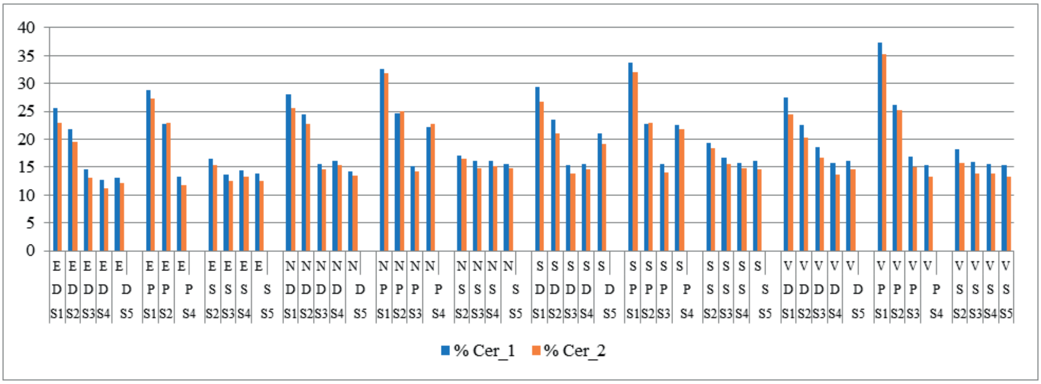

Figure 4. Canopy projection Vertical Axis (1) to apple (%) (source: own data)

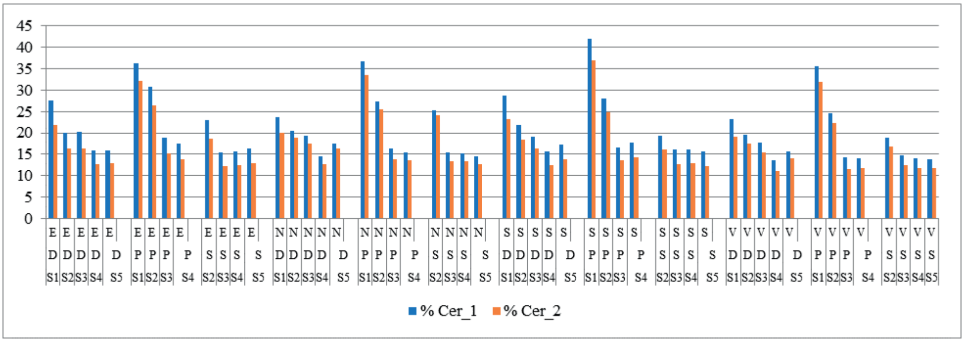

Figure 5. Projection of Bi-Baum® canopy shape at apple (%) (source: own data)

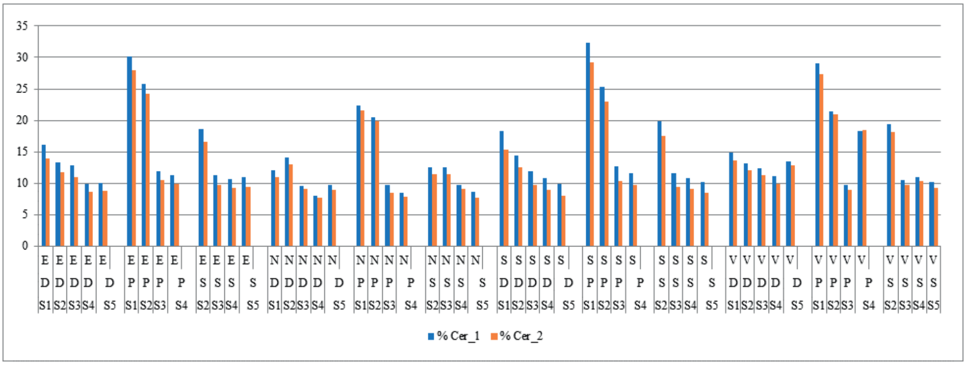

Figure 6. Projection of Trident canopy shape at apple (%) (source: own data)

The influence of species and canopy shape on the evolution of the Foliar Index

The foliar index varied depending on the cultivar and planting system/canopy. From Figure 7, for quinces, Vase canopy shape, significant differences in the index could be observed between the four cardinal points. The growth tendency was present, natural to crown development. Values ranged from 1.34-2.11 (East), 1.17-1.91 (North), 1.08-2.53 (South), and 1.78-3.69 (West).

In apple, at the Vertical Axis canopy shape the following values for the Foliar index (1) 1.09-2.03 (East), 0.76-1.53 (North), 0.78-1.5 (South), and 0.76-1.76 (West), respectively (2) 0.64-1.74 (East), 0.74-1.72 (North), 0.59-1.45 (South), and 0.67-1.73 (West) were presented (Figure 8).

In the Bi-Baum® canopy shape, the Foliar Index showed values between 0.94-1.83 (East), 0.63-1.6 (North), 0.9-2.56 (South), and 0.94-1.98 (West) (Figure 9).

The Foliar index in the Trident system planting had values between 1.31-2.74 (East), 1.03-2.14 (North), 1-2.87 (South), and 0.93-2.04 (west) (Figure 10).

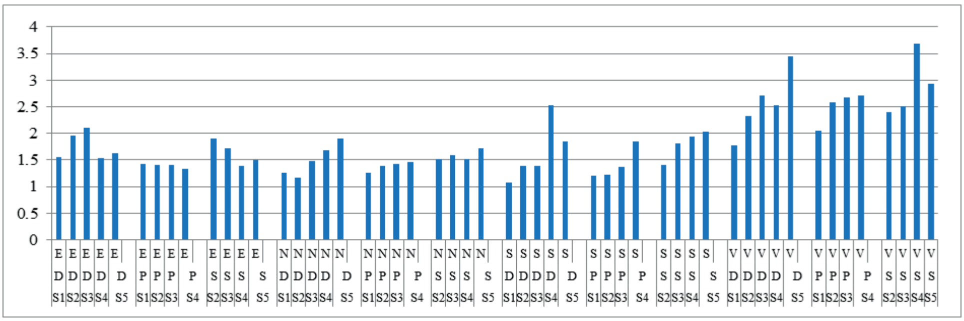

Figure 7. The evolution of the foliar index in quince to the shape of the Vase canopy shape (source: own data)

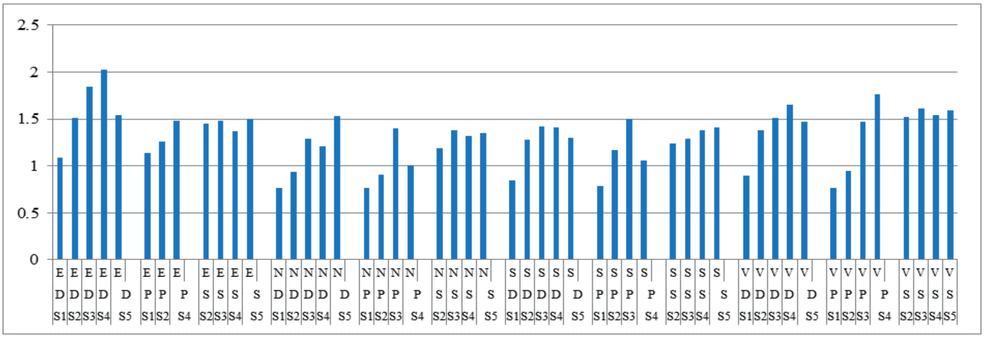

Figure 8. The evolution of the leaf index in apple, Vertical Axis 1 (source: own data)

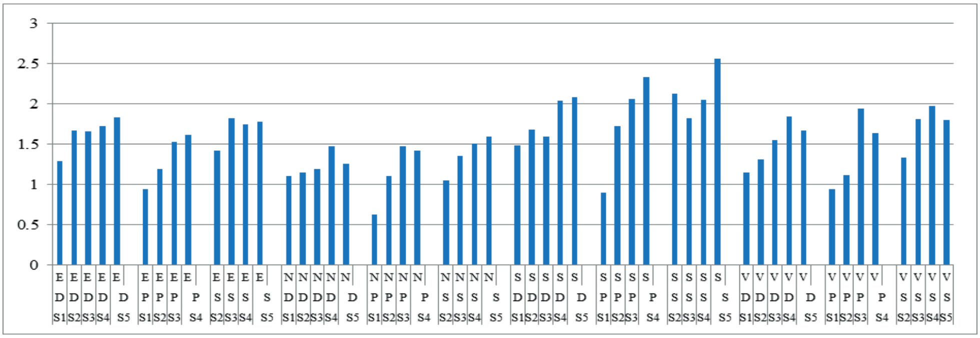

Figure 9. The evolution of the leaf index in apple, Bi-Baum (source: own data)

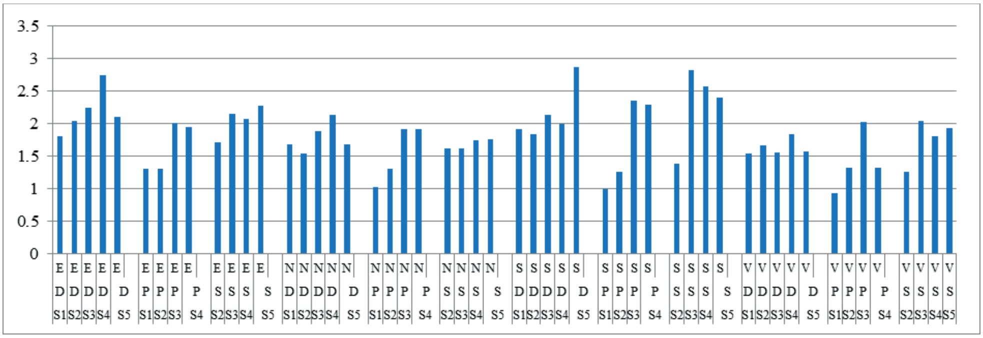

Figure 10. The evolution of the leaf index in apple, Trident (source: own data)

The influence of species and canopy shape on the level of direct and diffuse solar radiation at the tree level

Depending on the tree's growing stage, a decrease in direct and diffuse radiation values was observed under the tree's canopy, a direct cause being the increase in vegetative mass (Figure 11). Species and canopy shape had essential influences on the variation in these factors, briefly outlined below.

In quince, Vase canopy shape, total radiation decreased between the initial and final time of the experiment as follows: (East) 10.66-3.14 MjorMol/m^2/day with an average of 81% direct radiation and 19% diffuse radiation (North) 12.43-1.63 MjorMol/m^2/day with an average of 76% direct radiation and 24% diffuse radiation, (South) 9.72-2.46 MjorMol/m^2/day with an average of 82% direct radiation and 18 % diffuse radiation, (West) 8.25-0.64 MjorMol/m^2/day with average of 71% direct radiation and 29% diffuse radiation (Figure 11).

The apple, on the canopy shapes analyzed, presented the values summarized in Table 1.

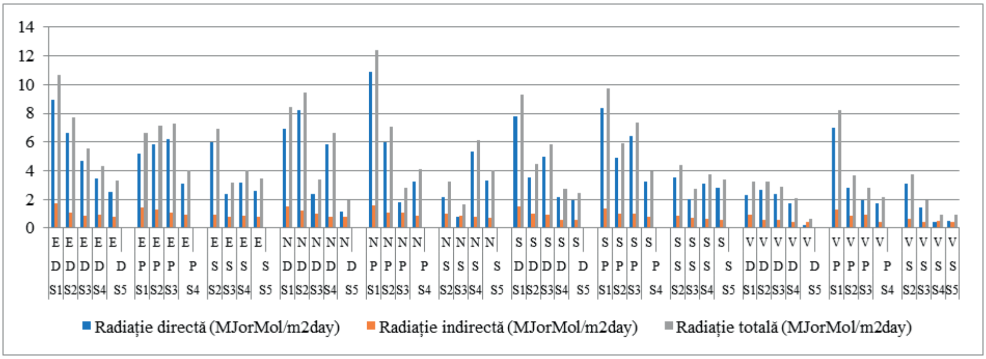

Figure 11. The level of solar radiation under the Vase canopy at quince (source: own data)

Table 1. The influence of the canopy shape and the orientation to the cardinal points on the solar radiation in apple

Cardinal point	Vertical axis 1 Total radiation (MjorMol/m^{2}day)		Vertical axis 2 Total radiation (MjorMol/m^{2}day)		Bi-Baum Total radiation (MjorMol/m^{2}day)		Trident Total radiation (MjorMol/m^{2}day)	
	max direct%	min diffuse%	max direct%	min diffuse%	max direct%	min diffuse%	max direct%	min diffuse%
	14.81	4.31	17.45	4.48	16.82	7.58	13.44	4.2
East	85	15	84	16	87	13	86	14
	16.47	7.03	23.58	6.32	18.63	6.54	10.23	3.74
North	89	11	87	13	88	12	87	13
	20.14	7.82	18.46	6.5	19.3	6.77	15.65	2.13
South	90	10	87	13	87	13	81	19
	15.84	6.84	18.03	5.03	19.75	4.19	19.37	1.96
West	87	13	85	15	83	17	76	24

CONCLUSIONS

Following the research, we recommend the WinSCANOPY system as an extremely useful tool for monitoring crown parameters in fruit growing.
The method can be applied and extended to more species. The results were significant for optimizing technical decisions regarding pruning and other tree management actions and for deeper analysis of the tree physiology.

ACKNOWLEDGEMENTS

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