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REFLECTION OF FRUIT TREES UNDER THE INFLUENCE OF ENVIRONMENTAL STRESSES

[1]Matilda Mema, [2]Kejda Kristo, [3]Emil Xhuvani

*[*1]Polytechnic University of Tirana, Faculty of Mathematical and Physical Engineering, Department of Physics, Tirana, Albania,*

[2]University of Tirana, Faculty of Natural Sciences, Department of Physics, Tirana, Albania,

[3]University of Tirana, Faculty of Natural Sciences, Department of Physics, Tirana, Albania,

Abstract

Direct solar radiation affects the process and development of photosynthetic activity on fruit trees and on green plants in general. The influence of solar radiation on leaves can be analyzed using diffuse reflectance and also observing their color. The measurements were carried out with three types of leaves (sun, partial shade and shade) for Santa Maria (pear) variety in two areas under and above water. The reflectance values provide the possibility to determine the parameters that evaluate the activity of the photosynthetic apparatus in two different areas in the same period. The resulting spectrum values allow the determination of brightness, "dominant" wavelength, and photochemical diffuse reflectance index (PRI).

Keywords: Reflection spectra, R550, PRI, Brightness-Y, Thickness.

1.Introduction

In natural conditions, most leaves are exposed to continually changing of the solar irradiances caused by variable cloud cover or self-shading of leaves in the crown periphery caused from the leaf movement. Light undergoing short-term fluctuations in irradiance accounts for over 70% of the daily illumination in forest understories (Chazdon 1988), and represents the major energy source for understory vegetation and leaves in the inner tree crown (Valladares et al. 1997, Schulte et al. 2003). In trees, sun leaves, i.e., leaves that have developed in high incident irradiances, possess much higher photosynthetic rates than shade leaves (Boardman 1977, Lichtenthaler 1981, Lichtenthaler and Babani 2004), yet most of the leaves in forest canopies, in particular canopies with a high leaf area index, are in deep shade (Urban et al. 2007). Therefore, effective utilization of a dynamic light environment, especially in the lower canopy, may account for the largest proportion of daily carbon gain in forest ecosystems (Pearcy 1990, Urban et al. 2007). Because the carbon gain of shade leaves and shade-acclimated plants is more dependent on continually changing solar irradiance, they are expected to have faster photosynthetic induction kinetics than sun leaves and sun-acclimated plants (Pearcy et al. 1994, Valladares et al. 1997). The purpose of the paper is to evaluate the photosynthetic apparatus in fruit trees (pears) in Tirana region, in the presence of environmental conditions (solar radiation, temperature, humidity) to which they are exposed.

2. Material and methods

2. 1. Plants

Measurements were made with leaves selected in three positions (sun - southern part of the crown, blue shade - northern part and semi-shade/shade - inside a tree crown) for the variety: Santa Maria (pear), part of a group of *Pyrus Communis* L pear species in the rose family. The study of the variety was done in area: under and above water in period July. The areas have a Mediterranean climate with average annual temperatures of around 16°C.

2. 2. Pigment determination

Leaf pigments were extracted with 100% acetone in the one circular piece of 9mm in diameter cut from the leaves using a mortar. The pigment extracts were centrifuged for 5 min at 500 X g in glass tubes to obtain the fully transparent extract. The pigment contents, Chl a, Chl b and total carotenoids, were determined spectrophotometrically from acetone extract using the extinction coefficients and equations re-determined by Lichtenthaler (Lichtenthaler, 1987; Lichtenthaler and Buschmann, 2001). The represented values are the means of six determinations from six leaves.

2. 3. Reflectance spectra

Leaf reflectance (R) was recorded from upper side of the leaf in a spectral range from 400nm to 800nm with a spectral resolution of 2nm with a spectrophotometer equipped with an integrating sphere attachment (Bushman et al., 2012; Gitelson et al., 2003). Leaf reflectance spectra were recorded against barium sulphate as a white reference standard. Leaves were placed on black velvet used as a background which has a reflectance less than 0.5% over the spectral range of measurements. Reflectance (R) was represented as the ratio of the radiation intensities reflected by the leaf sample and the white standard respectively. The leaf spectra were taken in the intercostal fields between the larger leaf veins. These spectra represent an integrated signal over several square centimeters. The measurement of spectral reflectance is a nondestructive and a rapid method (Gamon J.A, Serrano L, Surfus J.S, 1997).

2. 4. Photochemical index (PRI)

The photochemical index of diffuse reflectance serves as a photosynthetic indicator of radiation utilization efficiency (Gamon J. A, Serrano L, Surfus J. S, 1997). The photochemical reflectance index (PRI), calculated from the reflectance at 531 and 570 nm, is sensitive to the photochemical changes induced by the photoprotective xanthophyll cycle, acting upon light saturation of the chlorophyll antenna (Gamon J. A, 1990; Gamon J. A, Surfus J. S, 1999). The values of the photochemical index of diffuse reflectance fluctuate in the range from -1 to 1. The

PRI values are calculated using the reflectance values at 531nm and at 570nm as reference wavelength:

$$PRI = \frac{R531 - R570}{R531 + R570}$$

The photochemical index of diffuse reflectance (PRI) depends on photosynthetic (leaf) pigments, the amount of energy falling from the sun on the surface, the angle of the sun's rays falling on the leaf surface and the water content (Gamon & Berry, 2012).

2. 5. Colorimetry

Evaluation of the visual impression of a leaf sample was assessed by the chromaticity coordinates in the CIE 1931 color space which allow defining quantitative links among wavelengths in the electromagnetic visible spectrum and physiological perceived colors in human color vision. In order to help to assess the visual impression of a sample, the reflectance spectra of the leaf samples were used to define the color as x and y chromaticity coordinates in the CIE 1931 color space, a colorimetric standard widely used in the textile and coating industries, (Malacara D, 2003/2). With the measured values of diffuse reflectance, it is also possible to calculate color parameters on different leaves by means of a special algorithm in the Excel program such as: brightness-Y, "dominant" wavelength.

2.6. Thickness

Measurement of the thickness of the samples (leaves) taken in three positions was accomplished by using a micrometer or Palmer caliper. Micrometers serve to measure the thickness of the object that is clamped between point B of the screw and a stop C attached to the micrometer. The screw is turned by means of a step A that wraps the nut: the step of the screw is 1mm. The number of millimeters with which we have placed the screw on a scale located on the nut and detected by the cap is estimated. We estimate the parts of a millimeter by measuring the parts of a screw lead by a mark removed along a diode conductor and a scale where 30 divisions, we thus estimate the thickness of the leaf placed between two thin glasses, with the proximity of 1/ 20mm.

3. Results

3. 1. Photosynthetic pigments

The highest value of the chlorophyll content Chl (a+b) is presented by the variety Santa Maria (pear) in the area under water compared to the area above water. It is also observed that the content of chlorophylls Chl (a+b) decreases in variety from sun leaves to blue-shade and shade leaves (Tab. 1).

Table 1. *Content of Chl (a+b) and total carotenoids (x+c) per leaf area unit as well as the pigment ratios Chl a/b and chlorophylls (a+b) to carotenoids (a+b)/(x+c) between sun, blue-shade, shade/half-shade leaves of Santa Maria variety of pear trees, period July. Mean values of 6 determinations per leaf-type.*

Leaf-type	**Chl (a+b) (mg dm^{-2})**	**Chl a/b**	**(a+b)/(x+c)**
Santa Maria– Under water			
Sun	8.733 ±0.015	2.37	5.37
Blue-shade	6.100 ±0.027	2.49	5.62
Half-shade/shade	4.567 ±0.034	2.77	6.40
Santa Maria – Above water			
Sun	7.868±0.078	2.45	5.39
Blue-shade	5.630±0.050	2.38	5.56
Half-shade/shade	4.339±0.079	2.21	6.23

The ratios of the photosynthetic pigments, Chl a/b and (a+b)/(x+c), reflecting the light adaptation of the photosynthetic apparatus showed different values in the three leaf types. The mean values of the ratio Chl a/b are higher in sun leaves as compared to blue-shade and shade leaves (Tab. 1). Sun leaves displayed lower values of the ratio (a+b)/(x+c) as compared to two other leaf types (Tab. 1).

3. 2. Reflection spectra

Reflection spectra of the three types of leaves exhibited a higher reflectance in the green-to-orange range of the spectrum at wavelengths 500nm to 650nm and mainly in the near infrared from 680nm to 740nm on both pear varieties. In addition, reflection spectra exhibited a low reflectance from 400nm to 500nm in blue part of visible spectra and near 680nm in red part of visible spectra (Fig. 1). The observed variations correspond to the absorption region of the in-vivo chlorophyll bands. The reflection spectra exhibit the highest values in the green-orange range of the spectrum of shade leaves compared to two other leaf types for variety. Santa Maria (pears) in the two area under study for three types of analyzed leaves are related to the chlorophyll content being lower in shade leaves and higher in sun leaves (Tab. 1). In the underwater area, the Santa Maria variety presents the highest value in the shade position and the lowest in the sun position.

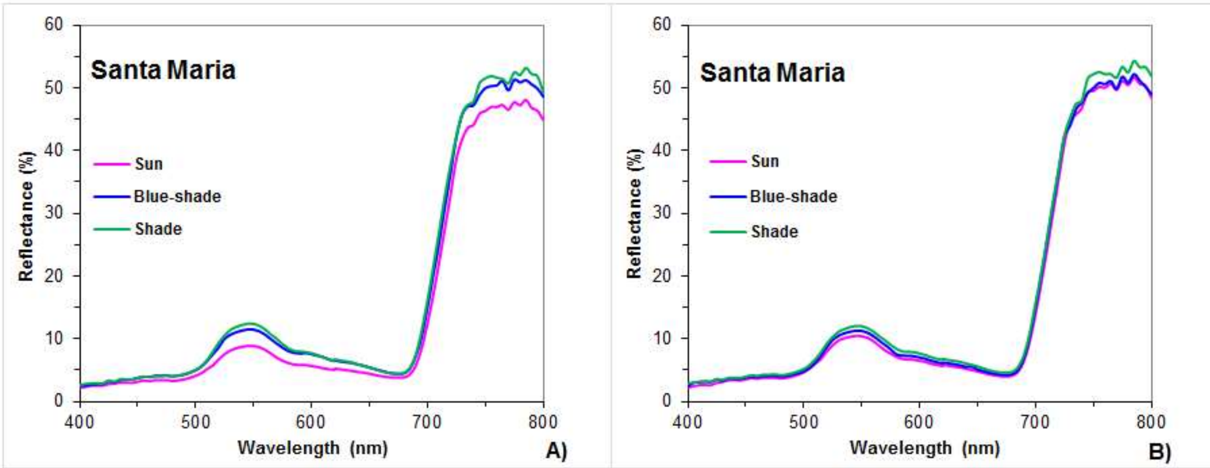

Figure 1. Reflectance spectra of the sun (south part), blue-shade (north part) and shade/half shade leaves of Santa Maria pear variety; A) Area under water, B) Area above water.

The reflection spectra exhibit the highest values in the green-orange range of the spectrum of shade leaves compared to two other leaf types of both varieties. Santa Maria (pears) in the two area under study for three types of analyzed leaves are related to the chlorophyll content being lower in shade leaves and higher in sun leaves (Tab. 1). It is observed that the highest values R550 of variety are presented in the shade position compared to the other two positions (Tab 2). The values of R700, R750 and R800, for variety Santa Maria are presented in the shaded position. The high values of reflection in the wavelengths 700nm, 750nm and 800nm are explained by the low absorption in the shadow position, in the area above the water.

Table 2*. Reflectance on sun, blue-shade, shade/half-shade leaves of Santa Maria variety of pear trees. Mean values of 6 determinations per leaf-type.*

Leaf-type	**R550**	**R700**	**R750**	**R800**
Santa Maria– Under water				
Sun	8.83 ±0.54	12.3	46.3	44.9
Blue-shade	11.4 ±0.42	14.8	49.9	48.6
Half-shade/shade	12.4 ±0.83	15.9	51.5	49.4
Santa Maria– Above water				
Sun	10.4 ±0.11	13.8	49.5	48.4
Blue-shade	11.2 ±0.54	14.8	50.9	49.0
Half-shade/shade	11.9 ±0.83	15.5	52.1	51.9

In the two area under study, higher values of R550 are observed in the sun position (Fig 2). In the shade position, the R550 value is higher and the chlorophyll concentration value is lower (Fig 3).

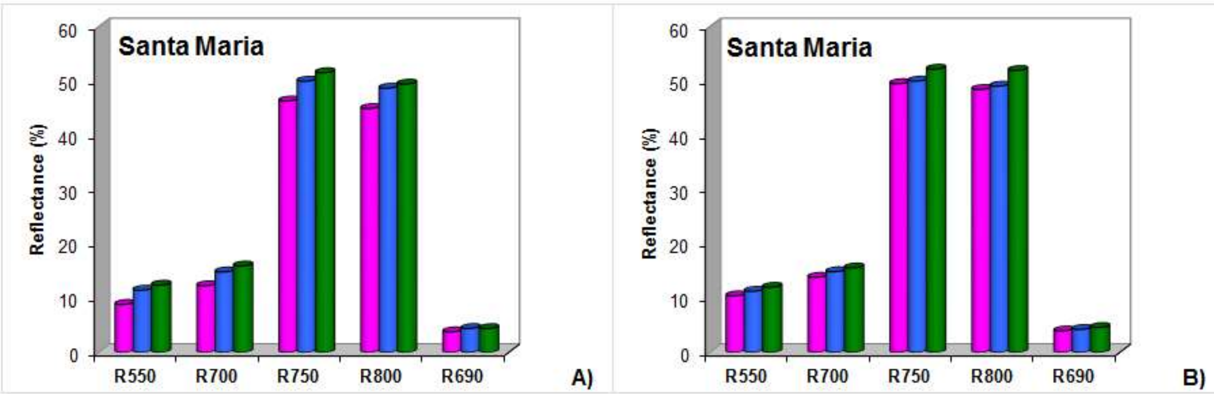

Figure 2. Values reflectance of the sun (south part), blue-shade (north part) and shade/half shade leaves of Abbas pear variety; A) Area under water, B) Area above water.

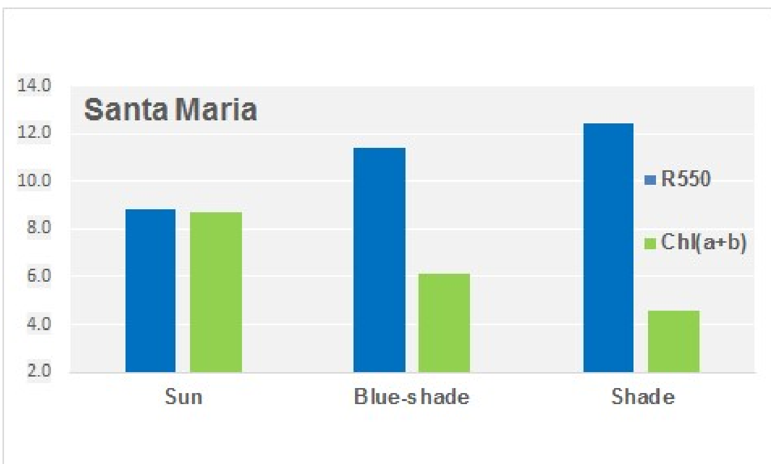

Figure 3. Values reflectance R550 and content of Chl (a+b) of the sun (south part), blue-shade (north part) and shade/half shade leaves of Santa Maria (pear) variety, area under water.

In the shadow position, the concentration value of Chl (a+b) is low, while the value of R550 is high (Fig.3).

The leaves of fruit trees in the shade absorb less solar energy and reflect more. Conclusions apply to the area above the water (Fig. 4).

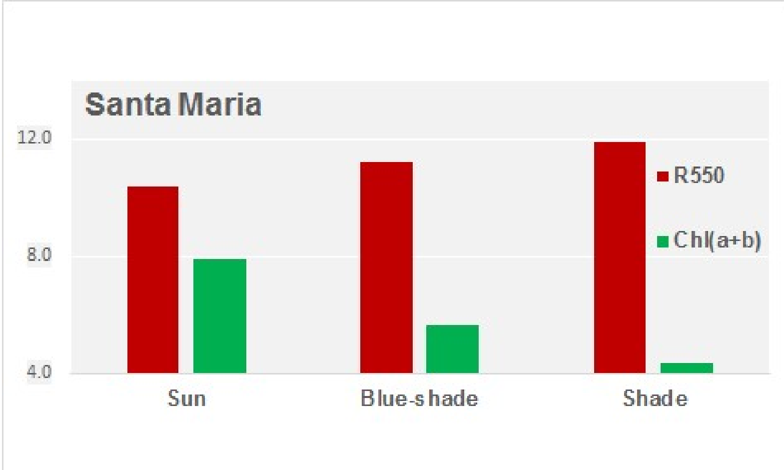

Figure 4. Values reflectance R550 and content of Chl (a+b) of the sun (south part), blue-shade (north part) and shade/half shade leaves of Santa Maria (pear) variety, area above water.

3. 3. Photochemical index (PRI)

The highest value of the photochemical index (PRI) presented in the area under water for Santa Maria (pear), (Tab 3). The photochemical reflectance index (PRI) depends on the amount of energy falling from the sun on the leaf surfaces. The greater the intensity of solar radiation, the higher the PRI value.

Table 3. *PRI values for Santa Maria (Pear) variety, period July*

Leaf-type	**PRI**
Santa Maria–Under water	
Sun	0.092
Blue-shade	0.077
Half-shade/shade	0.070
Santa Maria–Above water	
Sun	0.091
Blue-shade	0.079
Half-shade/shade	0.069

Santa Maria (pear) variety presents the highest values of the photochemical index (PRI) in the sun position, in the two area under study (Fig.5). The highest value of PRI appears in the sun position, in the area in the presence of water. The value decreases in the shade position, in the absence of water.

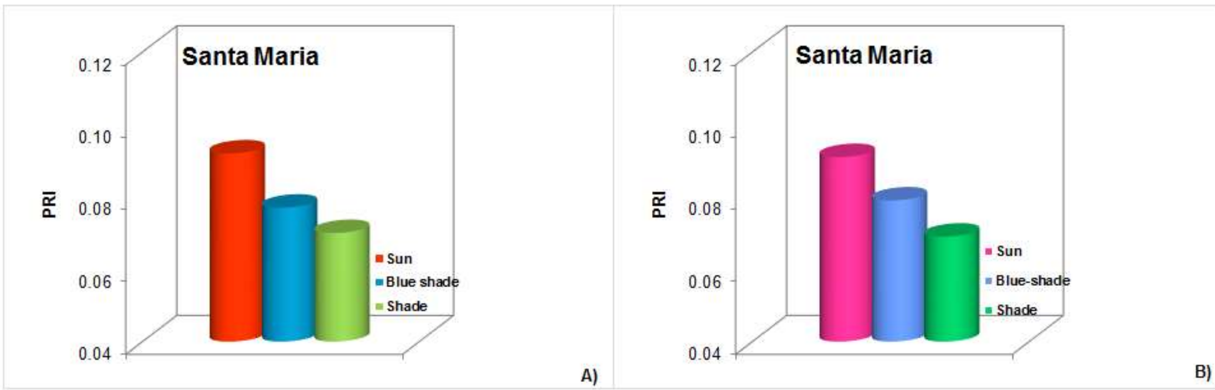

Figure 5. Photochemical index (PRI) values of the leaves of the sun, blue-shade and shade type leaves; of Santa Maria (pear) variety; A) Area under water, B) Area above water.

From the experimental data it is observed that: the concentration of Chl (a+b) chlorophylls from the sun-shade position decreases and the values of the PRI photochemical index decrease (Fig. 6).

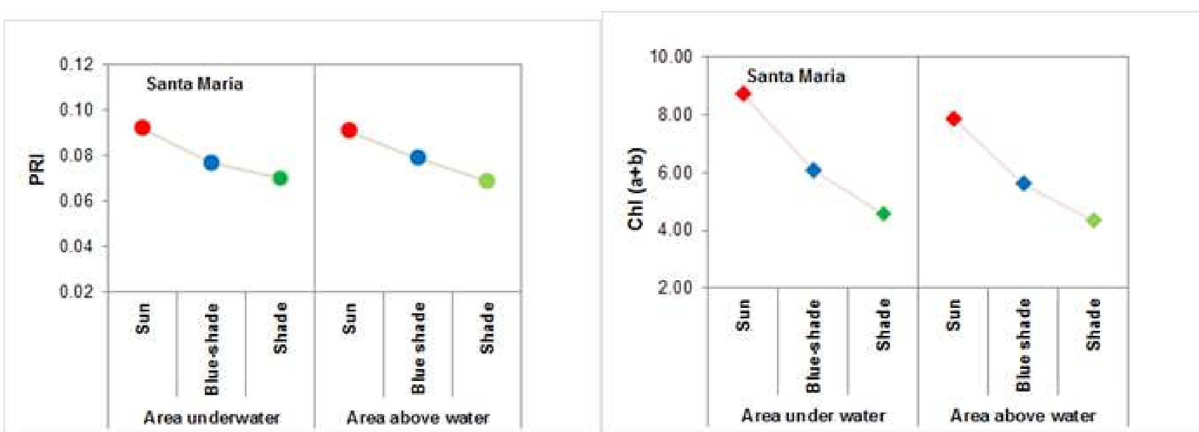

Figure 6. Values PRI and content of Chl (a+b) of the sun (south part), blue-shade (north part) and shade/half shade leaves of Santa Maria (pear) variety, area above water.

3. 4. Colorimetric parameters

In the study, from the diffuse reflectance values, in the three positions, some chromatic parameters can be determined which are: "dominant" wavelength, brightness-Y, luminosity based on the algorithm of the CIE 1931 system, for variety Santa Maria (pear), area under and above water.

Table 4. Colorimetric determination according CIE 1931 for the leaf samples: sun, blue-shade, shade/half-shade leaves of Santa Maria variety trees, in period July. Mean values of 6 determinations per leaf-type.

Leaf-type	Brightness -Y	Dominant wavelength (nm)	Luminosity (%)
Santa Maria–Under water			
Sun	7.29	551.5	27.7
Blue-shade	8.65	555.1	33.6
Half-shade/shade	9.13	556.5	35.1
Santa Maria–Above water			
Sun	7.76	552.0	30.9
Blue-shade	8.36	552.7	33.4
Half-shade/shade	8.99	555.0	34.9

The highest values of the "dominant" wavelength are presented for the leaves in the shade position, compared to the leaves in the other two positions, for the area under-above water in the period July. In the two areas under study, the highest values are presented in under water, position shade.

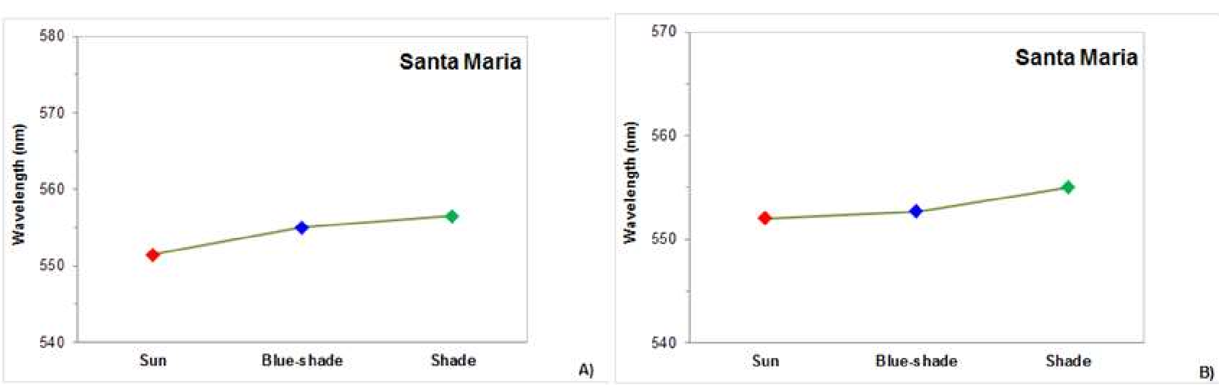

Figure 7. Values of the "dominant" wavelength, of the sun, blue-shade and shade type leaves; of Santa Maria (pear) variety; A) Area under water, B) Area above water.

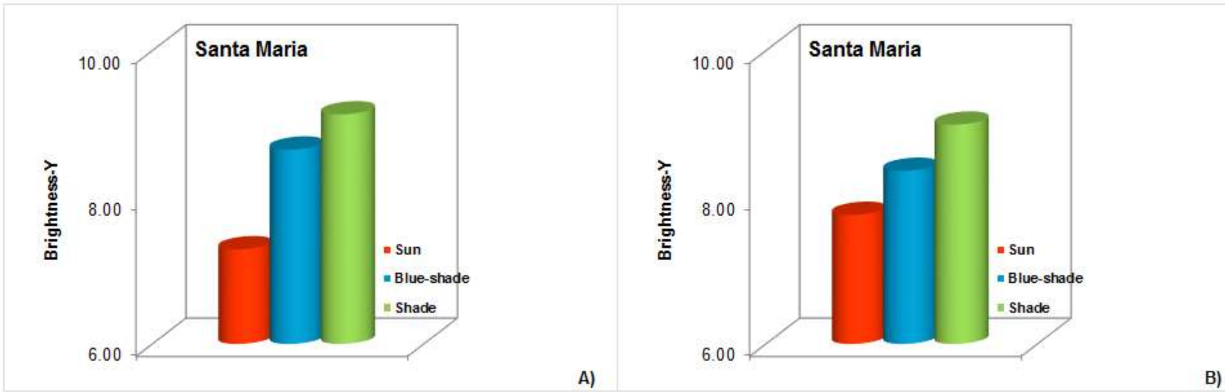

Figure 8. Brightness-Y values of the leaves of the sun, blue-shade and shade type leaves; of Santa Maria (pear) variety; A) Area under water, B) Area above water.

The "dominant" wavelength depends on the concentration of chlorophylls. In the two areas under study, the luminance and brightness values are higher in the shadow position (Fig. 8), (Fig. 9).

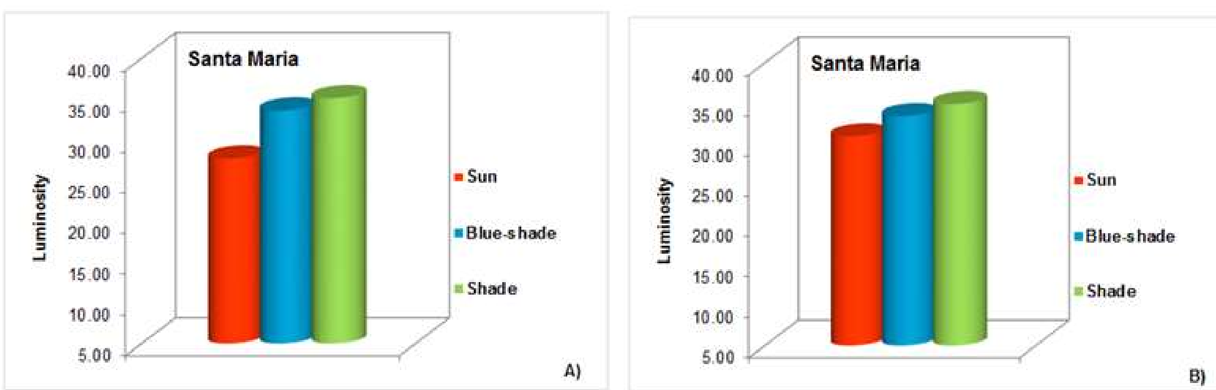

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Figure 9. Luminosity values of the leaves of the sun, blue-shade and shade type leaves; of Santa Maria (pear) variety; A) Area under water, B) Area above water.

3. 5. Thickness

Thickness of the leaves for the variety Santa Maria presents higher values in the area above water, compared to the area under water (Tab 5). Leaves in the sun position in the two area present higher values (Fig. 10).

Table 5. *Thickness values for Santa Maria (pear) variety, period July*

Leaf-type	**Thickness (mm)**
Santa Maria – Under water	
Sun	0.268 ± 0.016
Blue-shade	0.226 ± 0.018
Half-shade/shade	0.199 ± 0.009
Santa Maria–Above water	
Sun	0.336 ± 0.025
Blue-shade	0.297 ± 0.022
Half-shade/shade	0.273 ± 0.018

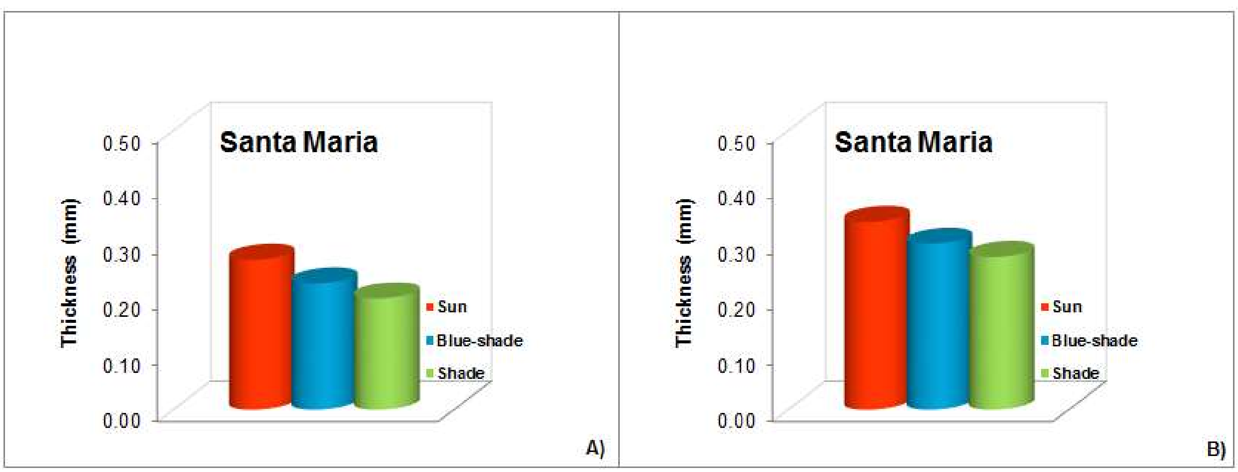

Figure 10. Thickness values of the leaves of the sun, blue-shade and shade type leaves; of Abbas (pear) variety; A) Area under water, B) Area above water.

The leaves in the shade are thinner; the concentration of chlorophylls is lower compared to the other two positions.

Conclusions

The pigment content Chl (a+b) represents the highest values on the sun leaves (sun position) and the lowest values on half-shade/shade leaves (inside a tree crown).

The reflectance spectra, as well as the values (R550, R750, R800) show the characteristics and differences between the analyzed leaves demonstrating structural changes in the photosynthetic apparatus as a result of adaptation to the environment.

In the areas under study (under water and above water), the values of the photochemical index (PRI) and thickness appear higher in the sun position, compared to the other two positions.

PRI as a parameter is related to the action of solar radiation on leaves. Direct action of solar radiation on the leaf also affects its thickness.

All calculated parameters such as: PRI, colorimetric parameters (brightness-y, "dominant" wavelength, luminosity) make it possible to distinguish between different areas of fruit trees and evaluate the impact of growth conditions on the photosynthetic apparatus.

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