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Changing Leaves Spectral Properties Of Variety Santa Maria (Pears) In The Presence Of Environmental Stresses

Matilda Mema[a*], Fatbardha Babani[b], Kejda Kristo[c], Emil Xhuvani[d]

[a,b,c,d] University of Tirana, Faculty of Natural Sciences , Department of Physics

***Abstract*—Spectral characteristics, fluorescence and reflectance, describe possible structural changes of these molecules in leaves and provide data (by comparing with those of absorption) on the yield of solar energy use. Reflection spectra demonstrating the optical properties of leaves provide information on reflectance of some specific wavelength. These spectra allow to define the color of the leaves by chromatic coordinates and in addition also the wavelength of the "dominant" color of the leaves. Reflectance images of various intact leaves were taken in four selected bands at 440, 550, 690, and 800 nm and compared with their reflectance spectra in the visible to near infra-red (range: 400 to 800 nm). In addition, the individual leaf samples were further characterized by their specific colorimetric values for visual impression (CIE 1931). The results demonstrate that leaf reflectance is determined by the following basic parameters: (a) the leaf pigment content (absorption of chlorophylls and carotenoids in the pigment protein complexes of chloroplasts and, in red leaves, also of epidermal anthocyanins), (b) the leaf tissue structure (size of aerial interspaces between cells, which influence leaf optical properties), and (c) the structure of the leaf surface (e.g., waxes and hairs). The measurements were carried out with three types of leaves (sun, half-shade and shade) for pear variety: Santa Maria.**

Keywords—reflection spectra; spectra fluorescence,Chla; Chlb

I. INTRODUCTION

Thus, reflectance signals of leaves contain the essential information used for monitoring of plants, from contact measurements of leaves to remote sensing of land vegetation [1].

In this study we present reflectance spectra of single leaves, acquired in a sequence of four spectral bands from the visible to the near infra-red that are of basic interest for leaf evaluation: blue (440 nm), green (550 nm), red (680 nm), and near infra-red (800 nm).

Reflectance consists of the interaction of light with a sample and is thus an optical technology which is often used for a non-destructive evaluation of plant status or plant product quality, for applications of both ecological and economic interest. Leaves comprise the largest surface area of a plant. Thus, reflectance signals of leaves contain the essential information used for monitoring of plants, from contact measurements of leaves to remote sensing of land vegetation (see, e.g., Lichtenthaler et al., 1996; Jones and Vaugham, 2010).

In this study we present reflectance images of single leaves, acquired in a sequence of four spectral bands from the visible to the near infra-red that are of basic interest for leaf evaluation: blue (440 nm), green (550 nm), red (680 nm), and near infra-red (800 nm).

In order to cover a wide range of different plants, we chose leaves with different amounts of photosynthetic pigments (chlorophylls and carotenoids) and epidermal anthocyanins, a different pattern of leaf veins and internal structure, as well as a different leaf surface (waxes and hairs) in order to determine the effect on the reflectance properties of leaves. Plant adaptations to different exposed light environment during their growth affect development of the entire plant and particularly to chloroplasts and their structure, thylakoid arrangement as well as the relative amounts of the photosynthetic pigments, the chlorophylls and carotenoids. Thus these adaptations implicate both structural and functional differences [7], [8]. Sun leaves with their sun chloroplasts (low and narrow grana stacks) possess higher values for the ratio Chl a/b and lower values for the weight ratio total chlorophylls to total carotenoids, ratio (a+b)/(x+c), as compared to shade leaves with their shade chloroplasts (broad and high grana stacks) [6]. Within a tree crown there also exist the leaves of the north crown of trees termed blue-shade leaves which differ in their reception of light quality and quantity from sun and shade leaves. These leaves are receiving only blue sky light but never full sun light [8]. In addition, trees possess half-shade leaves which are in the shade during the major part of the day, but that also receive full sunshine for a short period during the course of the day.

The purpose of this study is to evaluate the activity of photosynthetic apparatus of some fruit trees in Tirana area in the presence of environmental stresses to that are exposed.

II. MATERIAL AND METHODS

A. PLANTS

Measurements were carried out with leaves selected on three kinds of positions (sun - south part of crown, blue shade - north part and half-shade/shade - inside a tree crown) for variety of Santa Maria(pear), which is part of the group of species Pyrus Communis L pears and family of a rose.

B. 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 [4], [5]. The represented values are the mean of six determinations from six leaves.

C. 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 attachme [2], [3]. Leaf reflectance spectra were recorded against barium sulphate as a white reference standard. Reflectance (R) was represented as the ratio of the radiation intensities reflected by the leaf sample and the white standard respectively.

D. 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 [2]. 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, 2002). The coordinates x and y, which define a visual color in the CIE 1931 color space chromaticity diagram, were determined using the reflectance data and the color matching functions for daylight illumination (D65). Furthermore, we determined the brightness (values between 0 = dark and 100 = completely bright), the dominant wavelength (the wavelength characteristic for the color of the sample determined by the intersection point with a curved outer boundary line, also called spectrum locus, of the line connecting the achromatic point, i.e., “white” with x = y = 0.33, and the detected color point), and the color saturation (percentage of distance of the color point between the achromatic point and the boundary line: 100% at the spectrum locus, 0% at the achromatic point).

III. RESULTS

A. PHOTOSYNTHETIC PIGMENTS.

For leaves of Santa Maria (pear) variety selected in the period from May to October of 2015, can be demonstrated that the contents of Chl a, Chl b, Chl (a+b) and carotenoids are higher on May, as the period with optimum conditions compared to October that can be considered a stress period.

Table 1. Levels 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* and *Abbas* variety trees. Mean values of 6 determinations per leaf-type.

Leaf-type	Chl a+b (mg dm^{-2})	Carotenoids (mg dm^{-2})	Chl a/b	(a+b)/(x+c)
***Santa Maria* - May**				
Sun	8.59 ± 0.29	1.76 ± 0.08	2.53 ± 0.04	4.88 ± 0.07
Blue-shade	7.73 ± 0.44	1.83 ± 0.08	1.80 ± 0.02	4.22 ± 0.06
Half-shade/shade	5.17 ± 0.38	1.18 ±0.05	1.63 ± 0.10	4.38 ± 0.22
***Santa Maria*-October**				
Sun	5.92 ± 0.50	1.04 ± 0.11	2.62 ± 0.26	5.25 ± 0.74
Blue-shade	4.93 ± 0.46	1.02 ± 0.15	2.38 ± 0.43	5.47 ± 0.31
Half-shade/shade	4.52 ± 0.35	0.73 ±0.09	2.35 ± 0.21	5.97 ± 0.42

Also the photosynthetic pigment contents of chlorophylls and carotenoids on the period May-October for variety, Santa Maria represented higher values in sun leaf (south part of crown tree) than other leaf types (Tab. 1).
The ratios of the photosynthetic pigments, Chl a/b and (a+b)/(x+c), that reflect the light adaptation of the photosynthetic apparatus (Lichtenthaler 2013) shown different values in the three leaf types.

B. REFLECTANCE SPECTRA.

Reflectance spectra of the three types of leaves for pear variety exhibited a higher reflectance between 500nm and 650nm, in the green-to-orange range of the spectrum, and mainly at wavelengths between 680nm and 740nm in the near infra-red. In addition reflectance spectra exhibited a low reflectance between 400nm and 500nm in blue part of visible spectra and also near 680nm in red part of visible spectra (Fig. 1, Fig. 3). The observed variations correspond to the absorption region of the in-vivo chlorophyll bands.

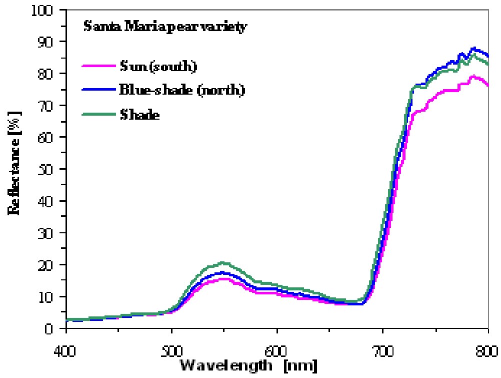

Fig. 1. Reflectance spectra of the sun (south part), blue-shade (north part) and shade/half shade leaves of *Santa Maria* pear variety on April (upper side). Mean of 6 reflectance spectra per leaf-type.

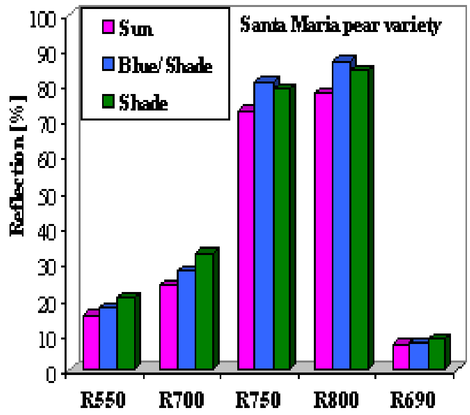

Fig. 2. Values reflectance of the sun (south part), blue-shade (north part) and shade/half shade leaves of *Santa Maria* pear variety on April (upper side).

The reflection spectra of two varieties exhibit the highest value in the green-orange range of the spectrum of shade leaves compare to two other leaf types. Also, could be observed a blue shift of the "red edge" (inflection point of the rise of signal at wavelengths between 680nm and 740nm) towards shorter wavelengths to the shade leaves. These variations among three types of analysed leaves are related to the chlorophyll content being lower in shade leaves and higher in sun leaves (Tab. 1). The higher values of reflectance in the green-orange range of the spectrum detected in the leaves of Santa Maria variety compared to the Abbas variety could be explained by the differences on chlorophyll content too. Higher signals of reflection spectra of shade leaves of Santa Maria pear variety on April (Fig. 1), a period with optimal growth conditions, could be related to the higher leaf water content as comparing to the sun and blue-shade leaves.

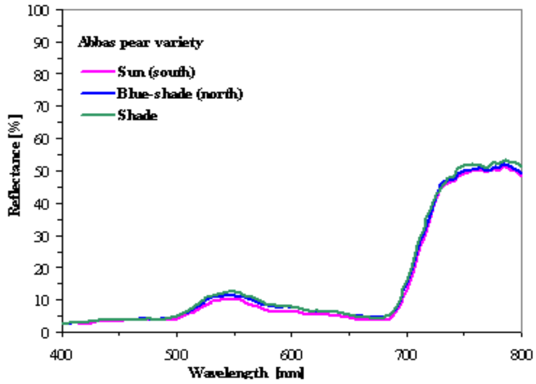

Fig. 3. Reflectance spectra of the sun (south part), blue-shade (north part) and shade/half shade leaves of *Abbas* pear variety on June (upper side

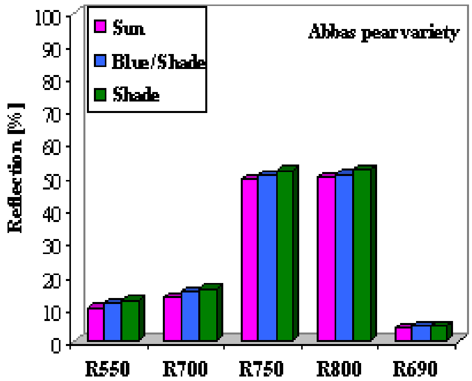

Fig. 4. Values reflectance of the sun (south part), blue-shade (north part) and shade/half shade leaves of *Abbas* pear variety on June (upper side). Mean of 6 reflectance spectra per leaf-type.

C. COLORIMETRY

The reflectance spectra of the leaf samples of three leaf types on both pear varieties were used to define the color as x and y chromaticity coordinates in the CIE 1931 color space (Fig. 5).

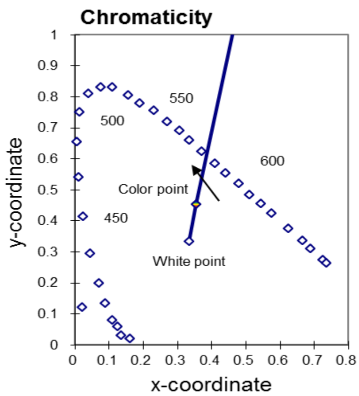

Fig 5. Calculation of chromaticity parameters by the leaf reflection spectra and CIE chromaticity color diagram using line centered from white point (0.33, 0.33): chromaticity coordinates x = 0.35; y = 0.45, brightness Y = 10.84, dominant wavelength 561 nm and color saturation 42.7%.

Colorimetric data of two varieties displayed differences showing grater values for Abbas variety than Santa Maria variety (Tab.2) following the variations on chlorophyll content in these two varieties actually being higher on leaves of Santa Maria variety and lower on leaves of Abbas variety (Tab. 1).

Table 2. Colorimetric determination according CIE 1931 for the leaf samples: sun, blue-shade, shade/half-shade leaves of *Santa Maria* and *Abbas* variety trees. Mean from 6 reflectance spectra per leaf-type.

Leaf-type	x-coordinate	y-coordinate	Brightness Y	Dominant wavelength (nm)	Color saturation (%)
Santa Maria – April					
Sun	0.37	0.46	11.45	562.9	49.3
Blue-shade	0.37	0.48	12.83	563	54.3
Half-shade/shade	0.37	0.48	14.92	563.1	56.8
Abbas – June					
Sun	0.33	0.44	7.83	553	32.1
Blue-shade	0.33	0.44	8.66	554	33.7
Half-shade/shade	0.34	0.45	9.43	556	34.5

Also, differences can be detected on CIE parameters like the brightness, the dominant wavelength and the color saturation of each variety depending by leaf type (Tab. 2). The values of these three parameters increased while the pigment content decreased from sun leaf to shade leaf.

In the cases of Santa Maria variety on May and Abbas variety on June, where content of Chl a+b represented higher values in sun leaves (south part of crown tree) and lower values on shade leaves (inside a tree crown), can be noticed a decrease of the dominant wavelength with increasing of chlorophyll content of different type of leaves (Fig. 4).

In the cases of Santa Maria variety on April and Abbas variety on June, where content of Chl a+b represented higher values in sun leaves (south part of crown tree) and lower values on shade leaves (inside a tree crown), can be noticed a decrease of the dominant wavelength with increasing of chlorophyll content of different type of leaves (Fig. 6, Fig. 7).

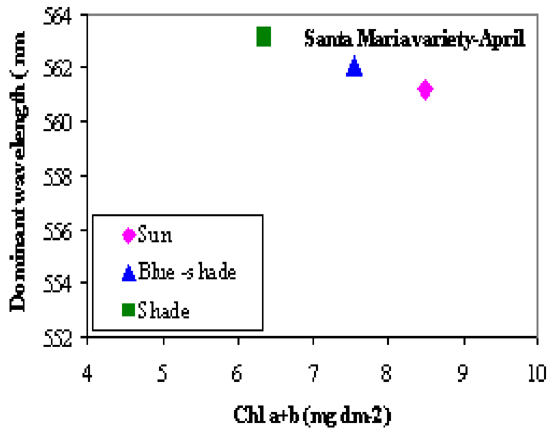

Fig 6. Decrease of the dominant wavelength with increasing of chlorophyll content of different type of leaves, from shade leaf to sun leaf, of the Santa Maria variety on April.

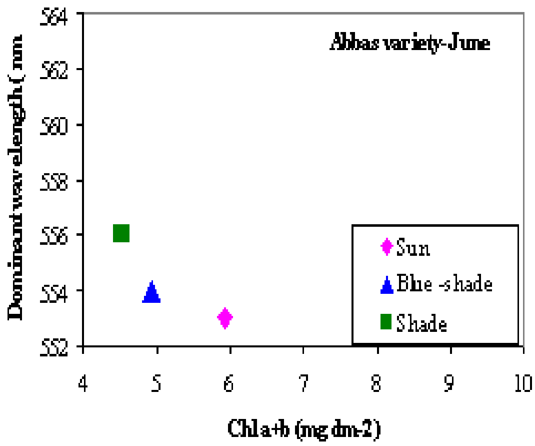

Fig. 7. Decrease of the dominant wavelength with increasing of chlorophyll content of different type of leaves, from shade leaf to sun leaf, of the Abass variety on June.

IV. CONCLUSIONS

Pigment contents on the period April-June in both analysed varieties, Santa Maria and Abbas, displayed higher values in sun leaf (south part of crown tree) than other leaf types. The values of the pigment ratio Chl a/b were higher, compared to blue-shade and shade leaves in both varieties.

The reflection spectra of two varieties exhibited the lowest value in the green-orange range of the spectrum of sun leaves compare to blue-shade and shade leaves and a blue shift of the “red edge” towards shorter wavelengths to the shade leaves demonstrating that the reflectance signals of leaves are determined by leaf pigment content and pigment absorption properties. The observed variations between analysed pear varieties, Santa Maria and Abbas, could be explained by the differences on chlorophyll content too.

Colorimetric parameters of two varieties exhibited grater values on Abbas variety than Santa Maria variety following existed variations on chlorophyll content being higher on leaves of Santa Maria variety and lower on leaves of Abbas variety. The values of CIE parameters like the brightness, the dominant wavelength and the color saturation of each variety increased while the pigment content decreased from sun leaf to shade leaf displaying dependency by leaf type.

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