EFFECTS OF SOLAR RADIATION ON FRUIT TREES

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Abstract

Reflection spectra demonstrating the optical properties of leaves provide information on reflectance of some specific wavelength. The measurements were carried out with three types of leaves (sun, partial shade and shade) for the Santa Maria and Abbas pear varieties in an area under water. In both varieties, an increase in reflectance values is observed from 500 nm to 650 nm wavelength region, the green-orange region of the spectrum, and further there is a rapid increase between 680 nm-740 nm wavelength region, the of the spectrum. red and infrared. The green plants absorb less and reflect more in these two ranges. The content of chlorophylls (Chl a+b), total carotenoids (x+c) and pigment ratios Chl a/b and Chls to carotenoids (a+b)/(x+c) were determined on the green leaves of the fruit trees in three positions to solar radiation. In the narrow band of wavelengths 531 nm and 570 nm, the diffuse reflectance values allow the calculation of the photochemical diffuse reflectance index (PRI).

Key words: *Reflection spectra, Chl a, Chl b, x+c, R550, PRI.*

Përmbledhje

Spektrat e pasqyrimit të shpërhapur karakterizojnë vetitë optike të gjetheve dhe japin informacion mbi pasqyrimin në gjatësi vale specifike. Vlerat e pasqyrimit të shpërhapur japin mundësi të përcaktohen parametrat që vlerësojnë aktivitetin e aparatit fotosintetik. Matjet janë kryer për gjethe në tre pozicione (jug, veri dhe hije), për dy varietet dardhe, Santa Maria dhe Abbas në prani të ujit. Për dy variatetet vihet re një rritje e vlerave të pasqyrimit në zonën 500 nm në 650 nm të gjatësive të valës, zona e gjelbër-portokalle e spektrit dhe më tej një rritje e shpejtë në zonën 680 nm-740 nm të gjatësive të valës, zona e kuqe dhe infra e kuqe. Në dy intervalet e përmendura bimët e gjelbëra absorbojnë më pak dhe reflektojnë më shumë rrezatomim diellor. Përqendrimet e klorofilave Kl (a+b), karotenoideve *(x+c) dhe e raporteve të përqëndrimeve Kla/b dhe a+b/x+c për bimët e gjelbëra varet nga pozicionimi ndaj rrezatimit diellor. Në bandën e ngushtë të gjatësive të valës 531 nm dhe 570 nm, vlerat e pasqyrimit të shpërhapur lejojnë llogaritjen e indeksit fotokimik i pasqyrimit të shpërhapur (PRI).*

Fjalë kyçe: *Spektra reflektimi, Kla, Klb, R550, PRI.*

Introduction

Plant adaptation response to high irradiance refers to growth and development of the entire plant, to leaves, cells, and particularly to the structure, thylakoid arrangement and photosynthetic function of chloroplasts (Babani & Lichtenthaler, 1996; Anderson et.al, 1995). Thus, a leaf developed under full sunlight (sun leaf) has a higher photosynthetic activity as receiving high irradiance compared to a leaf that developed in the shade (shade leaf). Plant adaptations to different exposed light environment during their growth affect particularly the relative amounts of the photosynthetic pigments, the chlorophylls and carotenoids. Thus, reflectance signals of leaves contain the essential information used for monitoring of plants, from measurements on leaves to remote sensing of land vegetation (Babani & Lichtenthaler, 1996; Evert, et.al, 1996).

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. 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) (Lichtenthaler, Babani, 2004; Lichtenthaler et.al, 2013; Boardman, 1977). The purpose of the paper is to evaluate the photosynthetic apparatus in fruit trees (pears) in the presence of environmental conditions (solar radiation, temperature, humidity) to which they are exposed in Tirana region.

The objective of the paper: the evidence of changes induced by solar radiation on sun, blue-shade, shade/half-shade leaves by diffuse reflection spectra and optical indices.

Material and methods

1. Plants

Measurements were made with leaves selected in three types of positions (sun - southern part of the crown, blue shade - northern part and semi-shade/shade - inside a tree crown) for the varieties: Santa Maria (pear) and Abbas (pear), part of a group of *Pyrus Communis* L pear species in the rose family. The study of two varieties was done in an area underwater on September.

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.

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 (Bushmann 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 , et.al , 1997).

4. Photochemical index (PRI)

The photochemical index of diffuse reflectance serves as a photosynthetic indicator of radiation utilization efficiency (Gamon, Serrano, Surfus, 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, 1990; Gamon, Surfus, 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).

Results

1. Photosynthetic pigments

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

The ratios of the photosynthetic pigments, Chl a/b and (a+b)/(x+c), reflecting the light adaptation of the photosynthetic apparatus (Lichtenthaler 2013) 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).

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* and *Abbas* varieties of pear trees. 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			
Sun	7.022 ± 0.067	2.38	4.80
Blue-shade	6.022 ± 0.083	2.25	5.38
Half-shade/shade	4.234 ± 0.045	2.12	5.72
Abbas			
Sun	8.028 ± 0.042	2.46	4.51
Blue-shade	5.887 ± 0.017	2.30	5.21
Half-shade/shade	3.902 ± 0.083	2.02	5.48

Sun leaves displayed lower values of the ratio (a+b)/(x+c) as compared to two other leaf types (Tab. 1). Variations in pigment content may provide information concerning the physiological state of leaves. Chlorophyll tends to decline more rapidly than carotenoids when plants are under stress or during leaf senescence (Gitelson & Merzlyak, 1994a, Gitelson & Merzlyak, 1994b, Merzlyak et al., 1999).

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, Fig. 2). The observed variations correspond to the absorption region of the in-vivo chlorophyll bands.

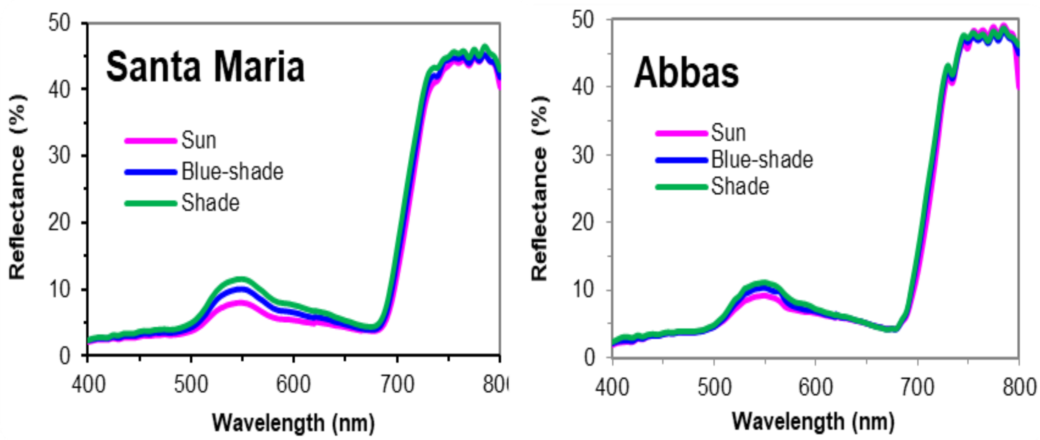

Figure 1. Reflection spectra of the sun (south part), blue-shade (north part) and shade/half shade leaves of Santa Maria and Abbas pear varieties.

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. 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 highest diffuse reflectance values R550 represents the Santa Maria variety compared to the Abbas variety.

It is observed that the highest values R550 of the two varieties are presented in the shade position compared to the other two positions (Tab 2). The values of R700, R750 and R800, in two varieties 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.

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

Leaf-type	**R550**	**R700**	**R750**	**R800**
Santa Maria				
Sun	8.00 ± 0.86	11.9	43.5	40.3
Blue-shade	10.0 ± 0.63	14.0	44.4	41.7
Half-shade/shade	11.6 ± 0.50	15.9	44.9	42.9
Abbas				
Sun	9.30 ± 0.34	12.1	45.8	40.1
Blue-shade	10.3 ± 0.36	14.2	46.7	44.9
Half-shade/shade	11.2 ± 0.32	15.1	47.2	46.2

The values of R550 are higher in the shade position for both varieties Santa Maria and Abbas of pear trees in the period of study, while the content of chlorophylls is lower in comparison to the other two positions (Fig. 3).

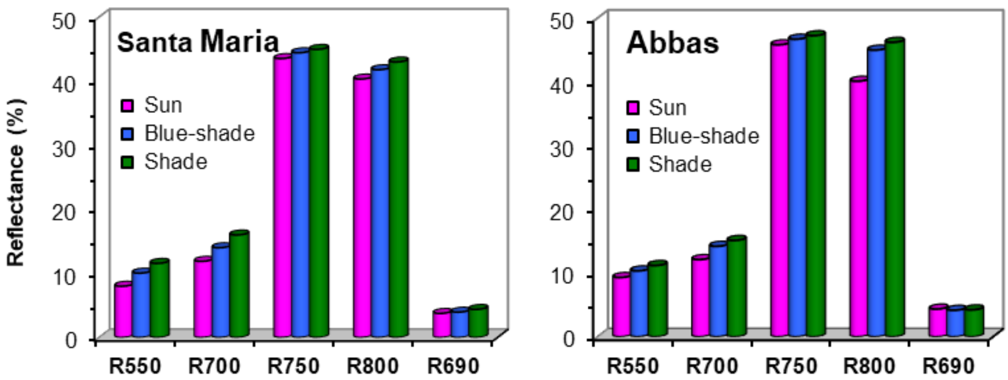

Figure 2. Reflectance on 550nm, 700nm, 750nm, 800nm and 690nm of the sun (south part), blue-shade (north part) and shade/half shade leaves of Santa Maria and Abbas pear varieties. Mean of 6 reflectance spectra per leaf-type.

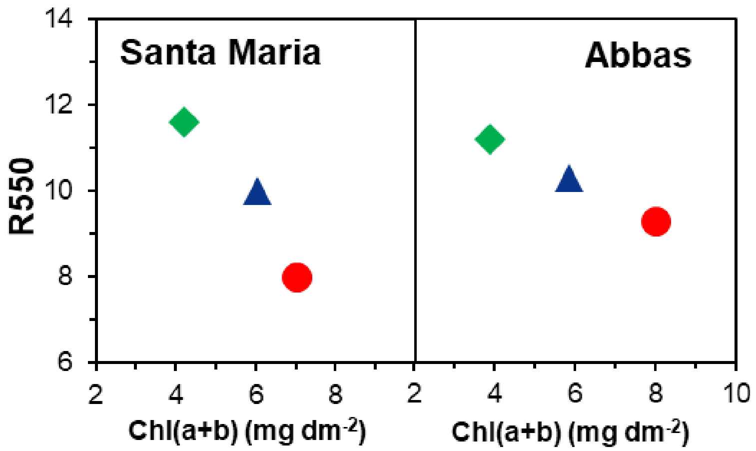

Figure 3. Relationship of diffuse reflection values R550 from the concentration of chlorophylls Chl (a+b) on Santa Maria and Abbas varieties.

3. Photochemical index (PRI)

The highest value of the photochemical index (PRI) is presented on south position by the variety Santa Maria (pear), while the lowest value is observed on shadow position by the variety Abbas (pear) (Tab 3).

Table 3. PRI values on Santa Maria (Pear) and Abbas (Pear) varieties.

Leaf-type	**PRI**
Santa Maria	
Sun	0.052
Blue-shade	0.044
Half-shade/shade	0.041
Abbas	
Sun	0.050
Blue-shade	0.041
Half-shade/shade	0.036

Santa Maria variety presents the highest values of the photochemical index (PRI) in the sun position (Fig.4).

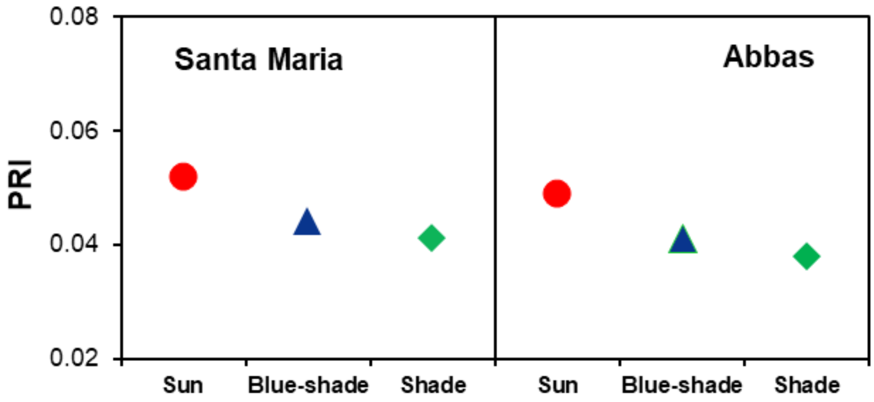

Figure 4. Photochemical index (PRI) values of the leaves of the sun, blue-shade and shade type leaves; of Santa Maria (pear) and Abbas (pear) varieties.

Conclusions

The phenomenon of leaf diffuse reflection, recorded reflection spectra and the determination of reflectance in certain wavelength (R550, R700, R750, R800, R690) allow to obtain the photochemical index values as an optical indicator of efficiency of solar radiation on photosynthetic apparatus.

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). Whereas blue shade leaves (northern part) show values lower of Chl (a+b) than sun leaves but higher than shade leaves.

The ratio Chl a/b decreases from the sun to blue shade and shade leaves while the ratio a+b/x+c increases representing higher values in shade leaves.

Higher values of diffuse reflectance at R550 are represented on the variety Santa Maria (pear) compared to the variety Abbas (pear). It is observed that the highest values in the two varieties are noticed in the shade position compared to the two other positions. Shade leaves absorb less sunlight and reflect more. Low absorption of sunlight leads to lower chlorophyll concentration. The photochemical index (PRI) displays lower values in the south position, compared to the other two positions related to the increase of the content of chlorophylls.

Our objective in this study was to develop spectral indices for prediction of leaf pigment content that are relatively insensitive to species and leaf structure variation.

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