SEASONAL VARIATIONS IN GAS EXCHANGE PARAMETERS IN RED RASPBERRY CULTIVARS GROWN IN FIELD AT DIFFERENT LIGHT INTENSITIES

VARIAȚII SEZONIERE ALE PARAMETRILOR REZULTAȚI DIN MĂSURAREA SCHIMBULUI DE GAZE LA UNELE SOIURI DE ZMEUR CULTIVATE ÎN CÂMP ÎN CONDIȚII DIFERITE DE LUMINĂ

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Abstract. *Variations in photosynthetic responses to summer stress among crop species are poorly understood. In this work we investigated photosynthesis seasonality in three red raspberry cultivars (Ruvi, Opal and Cayuga) grown in the experimental field under 100% and 25% sunlight conditions. Plants were planted in the field on June 2011. After adaptation to field conditions, we placed a net over 50% of the plants which retained 75% sunlight. Photosynthetic rate, transpiration rate, stomatal conductivity, intracellular CO2 concentration and water use efficiency were calculated from gas exchange measurements made from July to September using a portable IRGA system. In plants grown in 100% sunlight the highest photosynthetic rate and water use efficiency were obtained for Opal. At 25% sunlight Ruvi and Cayuga showed higher values of the photosynthetic parameters than Opal. All cultivars exhibited large seasonal variations of gas exchange parameters.*
Key words: *raspberry, photosynthesis, gas exchange, photosynthetically active radiation, temperature*

Rezumat. *Variatiile în parametrii fotosintetici induse de stresul din perioada de vară este un aspect putin investigat la plantele de cultura. În această lucrare s-a investigat variația fotosintezei la trei soiuri de zmeur (Ruvi, Cayuga și Opal), cultivate în câmp în condiții de lumină diferite în perioada iulie-septembrie 2011. După adaptarea la condițiile de cultură, 50% dintre plante au fost acoperite cu o plasă care a reținut 75% din radiația solară. Rata fotosintezei, rata transpirației, conductivitatea stomatală, concentrația de CO_2 intracelular și eficiența utilizării apei au fost calculate din măsurătorile schimbului de gaze determinate cu ajutorul unui sistem de tip IRGA. În cazul plantelor cultivate la 100% lumină, valori maxime ale ratei fotosintezei și eficienței utilizării apei au fost determinate la soiul Opal, în timp ce la 25% radiatie solară valorile acestor parametri au fost mai mari la Cayuga şi Ruvi. În general, toate soiurile au prezentat variații sezoniere mari la toti parametrii calculați*
Cuvinte cheie. *zmeur, fotosinteză, schimb de gaze, radiația activă fotosintetic, temperatură*

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INTRODUCTION

Raspberry is one of the species largely cultured in Northern Hemisphere due to its potential health benefits. Therefore, many studies have been focused on the effects of growth conditions on berry fruit quality and plant productivity.

Although it is stated that raspberries grow best in full sunlight the irradiance level for the optimum photosynthesis at this specie is low (aprox 200-300 µmol $m^{-2}s^{-1}$) (Pritts, 2002). Studies have shown that high light intensities do not increase photosynthesis; instead they may have a heat effect on the leaf and, subsequently harmful effects on plant physiology including alterations in photosynthetic rate (Fernandez and Pritts, 1994) and evapotranspiration (Stafne et al., 2001).

However, when the photosynthetic apparatus absorbs irradiance in excess of the needs for metabolism the photosynthetic activity is depressed by photoinhibition due to the inactivation of photosynthetic reaction centres (Osmond, 1994, Bertaminia et al., 2006). On the other hand, low irradiance decreases ATP synthesis and, subsequently, carbon fixation and carbohydrate biosynthesis. Therefore, understanding plant response to light may improve crop productivity and environmental sustainability.

To date, no studies have been performed on how light intensity affects the physiology of raspberry in a field experiment. This study assesses seasonal variations in photosynthesis, transpiration, stomatal conductance, water use efficiency and internal CO_2 concentration on three red raspberry cultivars (Ruvi, Opal and Cayuga) grown in the experimental field under full (100%) and reduced (25%) sunlight.

MATERIAL AND METHOD

This study was conducted during summer (from July to September) in 2011 in the experimental field of USAVM Iasi.

Three raspberry cultivars (Ruvi, Opal and Cayuga) were planted in the field on June 2011. On July 8, we placed a net over half of the plants which retained 75% of the sunlight (LL, low irradiance) while the other half was exposed to full sunlight (HL, high irradiance). All plants were irrigated when the field capacity decreased below 90%.

Gas exchange measurements were taken at four times named T0 (July 6-8), T1 (on July 20-22), T2 (on August 10-12) and T3 (on September 5-7) on fully uppermost expanded leaves from each plant. Net photosynthetic rate (A), stomatal conductance gs transpiration rate (E), were measured with a portable photosynthesis system (LCi 600, ADC BioScientific Ltd., England) equipped with a leaf chamber with constant-area inserts (6.25 cm^2). Leaf internal CO_2 (iCO2) partial pressure was calculated automatically by the internal program of the device. Water-use efficiency (WUE) was calculated as the ratio between A and E. Photosynthetic active radiation (PAR) and leaf temperature were also measured with an IRGA sensor.

For each experimental category we investigated 5 plants. Data are given as the mean ± standard error (SE) values. Duncan's t-test at $p < 0.05$ for separation of differences between means was performed using SPSS 20.

RESULTS AND DISCUSSIONS

Figure 1 illustrates PAR intensity and leaf temperatures during experiment under full sunlight (HL) and shade (LL) conditions.

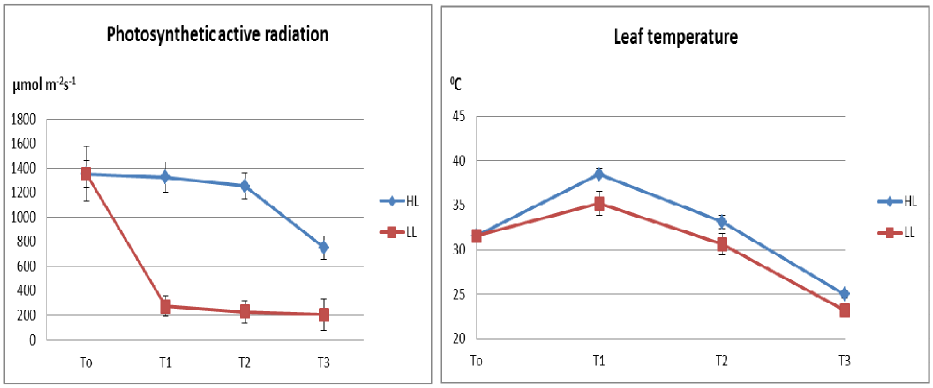

Fig.1 - Variations in PAR intensity and leaf temperature during experiments (for details, see Materials and Methods)

At T0 the highest values of photosynthetic rate (A) were recorded in Cayuga and Ruvi (Fig. 2). Both cultivars showed also higher values of stomatal conductance (gs) (Fig. 2D) which suggests a better CO_2 diffusion in leaf mesophyll (Chaves and Oliveira, 2004). Likewise, water use efficiency (A/E) was about 30% greater in Cayuga and Ruvi than in Opal (Fig. 2C). However, in these two cultivars the internal CO_2 concentration (iCO_2) was lower than in Opal possibly due to an increase in the efficiency of CO_2 assimilation in Calvin cycle (Yu et al., 2004).

During T0-T1 period, all plants were subjected to higher air temperatures (37°C) irrespective of the light treatment (Fig. 1). In all cultivars, the values recorded for A, E and gs at T1 were lower than at T0 (Fig. 2A-B, 2D). For instance, A values decreased about 40% in Opal, 20% in Cayuga and 10% in Ruvi (Fig. 2A). It is well known that in the field, leaf temperatures may exceed the air temperature by as much as 10°C (Haldimann and Feller, 2005).

Therefore these decreases may result from stomatal closure in response to low vapour pressure deficit caused by the heat stress (Zhang, et al 2001). This seems to be the case with Cayuga and Ruvi which showed similar reductions in gs values. However in Opal the gs values did not change while the iCO2 increased (Fig. 2D-E) fact suggesting the presence of non-stomatal limitations of photosynthesis (Dubey, 2005).

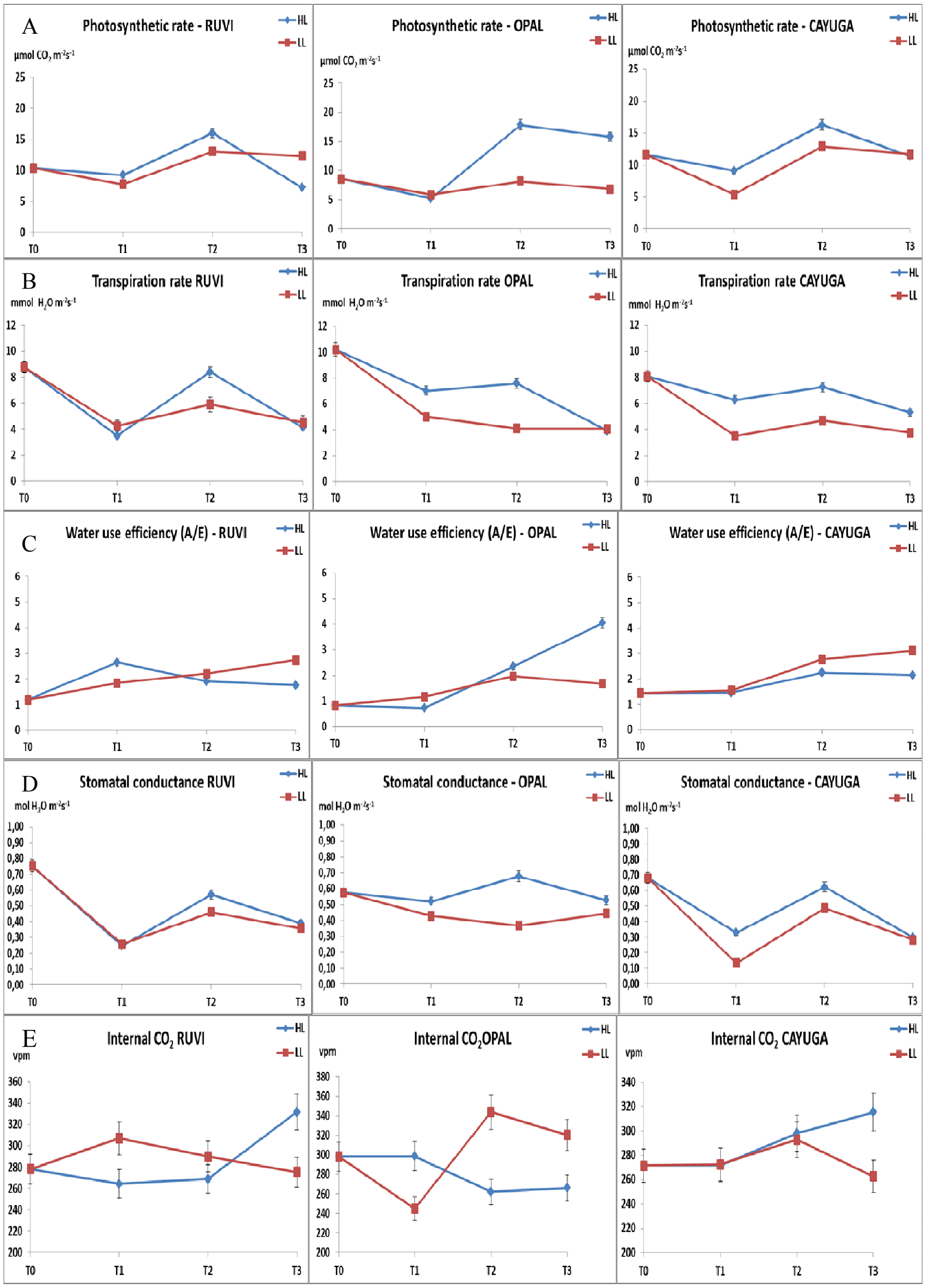

Fig. 2 - Seasonal variations in photosynthetic rates (A), transpiration rates (B), water use efficiency (C), stomatal conductance (D) and internal CO_2 (E) in three red raspberry cultivars grown in the field under full sunlight (HL) and shade (LL) conditions (for details, see Materials and Methods)

During acclimation to low irradiance (T0-T1) there was a different pattern of responses among cultivars. In Cayuga the photosynthetic and transpiration rates and the stomatal conductance decreased, but iCO_2 and WUE did not change. In Ruvi, the stomatal conductance did not change but the iCO_2 increased. Here WUE decreased due to the decrease of photosynthetic rate and a slight increase in the transpiration rate. In Opal, the stomatal conductance, transpiration rate and iCO2 decreased but the WUE slightly increased. All these changes suggest the presence of both stomatal and non-stomatal limitations as regulatory mechanisms of photosynthesis during acclimation to low irradiance (Dubey, 2005).

During the second decade of July leaf temperature decreased to 30°C and most of the gas exchange parameters increased in all plants irrespective of the light treatment. Under full sun conditions higher values of photosynthetic rate, stomatal conductance and water use efficiency were recorded in Opal and Cayuga, which seems to better adapt to field conditions than Ruvi. Under shade conditions, Cayuga and Ruvi showed higher values of photosynthetic rate than Opal. This might be due to an increase in stomatal conductance which allowed a better CO_2 diffusion in leaf mesophyll. Parallel, an increase in the transpiration rate suggests a contribution to leaf cooling thus reducing the negative effect of high temperature. As a consequence the water use efficiency increased and the values were 25% higher in Cayuga than Ruvi. On the other hand, in Opal, the stomatal conductance decreased while iCO_2 increased causing reductions in both transpiration and photosynthetic rates. These responses suggest that Opal has a higher sensitivity to low light intensities.

In the late summer (T3) the PAR intensity decreased to 750 μmol $m^{-2}s^{-2}$ and leaf temperature to 24-26°C. In these conditions, the photosynthetic rate of plants grown in full sunlight decreased in Ruvi (by 55%) and Cayuga (by 40%) and only by 12% in Opal. Ruvi and Cayuga also exhibited significant lower values in stomatal conductance and transpiration rate which resulted in a reduction of water use efficiency. On the contrary, in Opal, there were minor changes in stomatal conductance and photosynthetic rate and the WUE increased. These responses in Ruvi and Cayuga could be induced by changes in PAR and temperature but may also be related to leaf senescence and chlorophyll breakdown.

CONCLUSIONS

The variations in gas exchange parameters were related closely to changes in air temperature and indicate an adaptation of metabolic rates to the temperature variations in all cultivars. The cultivars vary in heat tolerance (when temperature increased over 35°C), with Ruvi being more tolerant to heat stress than Opal, and Cayuga being intermediate. High photosynthetic rates and stomatal conductance, together with low transpiration values, suggest that Cayuga and Ruvi cultivars have also a greater ability of acclimation to low light environments than Opal.

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REFERENCES

1. **Bertaminia M, Muthuchelianb K, Rubinigga M, Zorera R, Velascoa R.**, **2006** - *Low-night temperature increased the photoinhibition of photosynthesis in grapevine (Vitis vinifera L. cv. Riesling) leaves*., Environ. Exp. Bot., 57 (1 – 2), p. 25 – 31.
2. **Chaves MM, Oliveira MM.**, **2004** - *Mechanisms underlying plant resilience to water deficits: prospects forwater-saving agriculture*, Journal of Experimental Botany, 55, p. 2365–2384.
3. **Dubey R.S.**, **2005** - *Handbook of photosynthesis*. In: Pessarakli ,M. (Ed.), Book sin Soils, Plants, and the Environment. Taylor & Francis, Boca Raton, FL, p. 717–737
4. **Fernandez G.E., Pritts M.P.**, **1994** - *Growth, carbon acquisition and source–sink relationships in 'Titan' red raspberry,* J. Amer. Soc. Hort. Sci., 119, p. 1163–1168.
5. **Haldimann P., Feller U.**, **2005** - *Growth at moderately elevated temperature alters the physiological response of the photosynthetic apparatus to heat stress in pea (Pisum sativum L.) leaves*, Plant Cell Environ., 28, p. 302-317.
6. **Haldimann P., Feller U.**, **2005** - *Growth at moderately elevated temperature alters the physiological response of the photosynthetic apparatus to heat stress in pea (Pisum sativum L.) leaves*, Plant Cell Environ., 28, p. 302-317.
7. **Osmond C. B.**, **1994 -** *What is photoinhibition? Some insights from comparisons of shade and sun plants*. In Photoinhibition of Photosynthesis: From Molecular Mechanisms to the Field . N. R. Baker and J. R. Bowyer, eds., BIOS Scientific, Oxford, p. 1–24.
8. **Pritts M.P.**, **2002** - *From plant to plate: How can we redesign Rubus production system to meet future expectation?* Acta Horticulturae, 585, p. 537-543.
9. **Rama Shanker Dubey**, **2005** - *Photosynthesis in Plants under Stressful Conditions*, in: Handbook of Photosynthesis by Taylor & Francis Group, LLC, p. 712-731.
10. **Stafne E.T., Clark J. R., Rom C. R.**, **2001** - *Leaf gas exchange response of 'Arapaho' blackberry and six red raspberry cultivars to moderate and high temperatures*, HortScience, 36, p. 880–883.