PHYSICAL PROTECTION IN EXPERIMENTAL RASPBERRY PLANTATION

ФІЗИЧНИЙ ЗАХИСТ В ЕКСПЕРИМЕНТАЛЬНІЙ ПЛАНТАЦІЇ МАЛИНИ

Szalay K.1), Keller B.1), Kovács L.1), Rák R.1), Peterfalvi N.1), Sillinger F.2), Golub G.3), Kukharets S.4), Souček J.5), Jung A.2)

1)NAIK Institute of Agricultural Engineering / Hungary; 2)Szent István University, Faculty of Horticultural Sciences, Technical Department / Hungary; 3)National University of Life and Environmental Sciences of Ukraine / Ukraine; 4)Zhytomyr National Agroecological University / Ukraine; 5)Research Institute of Agricultural Engineering / Czech Republic

Tel: +380676653548; E-mail: kikharets@gmail.com

Keywords: shade tunnel, spectroscopy, raspberry production

ABSTRACT

One of the biggest challenges of raspberry production in Hungary nowadays is the reduction of unfavourable effect of climate changes. The maturation phase of main varieties within the Carpathian Basin falls in a period of extremely high temperature - reaching, or even exceeding, 35-40 °C - and atmospheric drought. This detains the desirable fruit growth. In order to restore or even save the domestic raspberry production and market, introduction of greenhouse or polytunnel solutions is needed. Experimental plantations of three different raspberry varieties were set in two repetitions: covered and uncovered versions. Each cover has characteristic light reflection /absorption/ transmission which should generate devious environmental conditions and also different plant growth. Besides the monitoring of elementary biological indicators a wide range of sensors (temperature, humidity, solar irradiation, spectroradiometer) were used to quantify the difference between cover materials to find the optimal tunnel material for maximal plant productivity.

INTRODUCTION

At least 80% of the world's raspberry production is covered by leading raspberry producers located in Eastern Europe. Climate change scenarios generate serious threat on raspberry plantations throughout this region. Plant growth, yield and fruit quality are all affected by the increased number of high temperatures, atmospheric drought and sunburn (Figure 1).

Fig. 1 – The symptoms of sunburn
Farmers regularly experience reduction in plant growth, leaf area, yield and fruit quality. Visual signs of heat stress, sunburn are often registered during the summer periods induced by excessive heat and direct radiation causing decreasing photosynthetic activity of plants. Dedicated plant breeding programs have been started to mitigate the effects of climate change (Dénes, 2016) but these programs need long time. Fighting alone by using biological ways is not enough. An immediate action is required to save the raspberry production. A physical protection against excessive direct radiation can be considered as the only way to restore the stability and quality of production on short term. Nevertheless, returning the site of raspberry production to the forests (where the species is originated from) or agroforestry systems (Nagy, 2017) can be also considered as a solution on middle and long term. Combining solar panels with agriculture (Hanley, 2017, Hajdú, 2018) in this particular place can offer an even more reasonable way to solve the question of excessive radiation. An accurately adjusted portion of radiation would be transferred to electricity while the rest can be used by the protected plantation below. In this case, the shading system would produce energy which would possibly offer a more sustainable way of fighting against the effects of climate change (Szalay K. et al., 2016) and energy scarcity. Beside the reduction of direct radiation various shading solutions and applied materials are expected to change the spectral characteristic of incident light and so the light utilisation of plants. In order to find a reasonable solution to protect the plants and increase the stability of the production a raspberry plantation with different varieties was established. A sun protective shade tunnel system was erected to create a test site at NARIC - Fruitculture Research Institute (FRI), Fruit Culture Research and Development Institute of Fertőd, Hungary. It provides opportunity to measure and evaluate relevant biological and physical parameters playing an important role in berry production (Keller et al., 2018). An additional problem is plant protection. The climate change results in the migration of different pests like Drosophylla Suzukii (Figure 2) which threatens the raspberry plantation and can cause 100% yield loss (Figure 3.). Protection against the pest is challenging especially in organic farms where chemical protection is limited. Within the frame of the project the effect of shade materials and possibility to use them against Drosophylla Suzukii was studied.
Modern remote sensing applications (Fenyvesi, 2008) such as portable spectroradiometers can widely be used both in field and under laboratory conditions. It is adequate to carry out independent, fast and precise evaluations in an economic way. ASD FieldSpec 3 MAX portable spectroradiometer (Csorba et al., 2014, Fekete et al., 2016) was used to evaluate the incident radiation within the polytunnels and the spectral response of the vegetation. The device extends the range of the detectable visible light (Lágymányosi and Szabó, 2009, Williams et al., 2010) to NIR (near infrared) and the SWIR (shortwave infrared) region and covers the range of 350 to 2500 nm (Szőke et al., 2011). The technology provides opportunity to reveal such differences in natural light conditions that are usually unmeasured by traditional weather stations and makes possible to study the correlation between light condition and plant growth in a more complex way.

MATERIALS AND METHODS

Field measurements were carried out in the control area and under two different types of tunnels. Data acquisition was made with ASD FieldSpec 3 MAX portable spectroradiometer. As a reference the full sky irradiation in the control plantation was measured without any cover material above (Figure 4). A reference panel was used as a standard surface that reflects 95% of all incident radiation. Using this etalon the light conditions between treatments (tunnels) could be compared.

Following this, further measurements were carried out under black and white tunnels. Measurements were carried out in the range of 350 to 2500 nm. In parallel, with in situ meteorological sensors, temperature, humidity and global radiance (400-1100 nm) were measured with Almemo 2890-9 data logger (Figure 5).

Beside the above described non-contact data acquisition contact measurements were also carried out. In order to compare the light utilization efficiency, the water and nitrogen management of plants under various circumstances PlantProbe was used to measure the reflectance characteristic of plant leafs within each treatments (Figure 6).
From these spectra, photochemical reflectance index (PRI), water index (WBI) and normalizes nitrogen index (NDI) were calculated with the following equations:

\[
PRI = \frac{\rho_{531} - \rho_{570}}{\rho_{531} + \rho_{570}}, \quad WBI = \frac{\rho_{970}}{\rho_{900}}
\]  

\[
NDI = \frac{\log \left( \frac{1}{\rho_{1510}} \right) - \log \left( \frac{1}{\rho_{1680}} \right)}{\log \left( \frac{1}{\rho_{1510}} \right) + \log \left( \frac{1}{\rho_{1680}} \right)}
\]  

Results showed rather high differences within spectra and global radiance but relatively small difference could be detected between other environmental indicators.

RESULTS

While the white tunnel’s material absorbed 15 to 30 percent of the light the black material absorbed 40 to 50 [%] of the irradiation. In case of the white material the absorbance level seems more wavelength sensitive than in case of the black material (Figure 7 and Figure 8).

In comparison with the control area, in the tunnel the temperature (Figure 9) was lower, especially in the black tunnel.

The light utilization efficiency was higher under both tunnels than it was in the control area. In case of black tunnel the photochemical index was even higher. In case of water and nitrogen content of leafs no significant difference could be found (Table 1). It means that the soil preparation, nutrient supply and irrigation could create the favourable homogeneity for the plantation. It indicates that the only variable between treatments really is the difference in illumination.
**Fig. 7** – Reflectance curves: Full sky (bright blue), black tunnel (dark blue), white tunnel (green)

**Fig. 8** – Absorbance curves: Full sky (bright blue), black tunnel (dark blue), white tunnel (green)

### Table 1

Spectral plant indicators in different treatments

|                      | White tunnel | Black tunnel | Control |
|----------------------|--------------|--------------|---------|
| Photochemical reflectance index | 0.048        | 0.075        | 0.044   |
| Water reflectance index       | 2.946        | 2.950        | 2.956   |
| Normalized nitrogen index     | 0.143        | 0.139        | 0.143   |
The yield results of year 2016 and 2017 show interesting correlation between different varieties. Results indicate both different effects in total yield and mean berry weight. Certain varieties reacted with higher yield to both types of cover material compared to the control while others did not react significantly to the cover materials (Table 2, Table 3).

### Table 2

| Name of the variety          | Total yield (g) | Ratio | Mean berry weight (g) | Ratio |
|-----------------------------|-----------------|-------|-----------------------|-------|
| **Julcsi** (covered with white) | 80769           | 172.2 | 2.68                  | 90.2  |
| **Julcsi** (control)         | 46910           | 100.0 | 2.97                  | 100.0 |
| **Julcsi** (covered with black) | 47151           | 141.8 | 2.67                  | 96.0  |
| **Julcsi** (control)         | 33250           | 100.0 | 2.78                  | 100.0 |
| **Fertodi succulent** (covered with white) | 51440           | 108.2 | 2.61                  | 103.2 |
| **Fertodi succulent** (control) | 47525           | 100.0 | 2.53                  | 100.0 |
| **Fertodi succulent** (covered with black) | 26378           | 99.1  | 2.40                  | 99.6  |
| **Fertodi succulent** (control) | 26617           | 100.0 | 2.41                  | 100.0 |
| **Eszterhaza productive** (covered with white) | 24057           | 240.5 | 1.93                  | 104.6 |
| **Eszterhaza productive** (control) | 10004           | 100.0 | 1.84                  | 100.0 |
| **Eszterhaza productive** (covered with black) | 16345           | 244.3 | 1.76                  | 97.2  |
| **Eszterhaza productive** (control) | 6691            | 100.0 | 1.81                  | 100.0 |

The analysis of the yield and berry weight in 2016 showed that the ratio of average total yield in a white tunnel to control was 173.6 and in a black tunnel – 161.7. The ratio of mean berry weight in a white tunnel to control was 99.4 and in a black tunnel – 97.6.

The analysis of the yield and berry weight in 2017 showed that the ratio of average total yield in a white tunnel to control was 145.0 and in a black tunnel – 90.8. The ratio of mean berry weight in a white tunnel to control was 111.2 and in a black tunnel – 109.0.

The number of pests collected by traps in the plantation showed minor differences between treatments (Figure 10). The negative effect of the decreasing temperature is visible on the falling number of *Drosophylla suzukii.*
Table 3
Yield and berry weight in 2017

| Name of the variety                          | Total yield (g) | Ratio | Mean berry weight (g) | Ratio |
|----------------------------------------------|-----------------|-------|-----------------------|-------|
| *Julcsi* (covered with white)                | 75092           | 124.19| 2.26                  | 113.57|
| *Julcsi* (control)                           | 60465           | 100.00| 1.99                  | 100.00|
| *Julcsi* (covered with black)                | 69474           | 98.62 | 2.15                  | 118.13|
| *Julcsi* (control)                           | 70446           | 100.00| 1.82                  | 100.00|
| *Fertodi succulent* (covered with white)     | 141818          | 106.58| 2.58                  | 83.23 |
| *Fertodi succulent* (control)                | 133057          | 100.00| 3.10                  | 100.00|
| *Fertodi succulent* (covered with black)     | 112024          | 105.36| 2.51                  | 91.94 |
| *Fertodi succulent* (control)                | 106326          | 100.00| 2.73                  | 100.00|
| *Eszterhaza productive* (covered with white) | 30797           | 204.24| 1.90                  | 136.69|
| *Eszterhaza productive* (control)            | 15079           | 100.00| 1.39                  | 100.00|
| *Eszterhaza productive* (covered with black) | 18406           | 68.27 | 1.86                  | 116.98|
| *Eszterhaza productive* (control)            | 26960           | 100.00| 1.59                  | 100.00|

Fig. 10 – The number of pests found in the plantation from September to November

CONCLUSIONS

The preliminary results show significant differences between covered and uncovered plantations. Physical parameters reveal differing characteristics of the two experimental cover materials. It seems there is a strong variety-specific effect. Certain varieties showed no reaction to the covering materials. On the other hand, some varieties increase their yield and average fruit size decisively. The analysis showed that the ratio of average total yield in a white tunnel to control was 159.3 and in a black tunnel – 126.2. The ratio of mean berry weight in a white tunnel to control was 105.3 and in a black tunnel – 103.3.

With an appropriate covering material and shade tunnel solution the latter can provide huge advantage for the farmer on the market. Based on the data obtained, Photochemical Reflectance Index is a good indicator to find optimal light conditions for the plants and the spectroscopy in general proved to be a good solution to find potential cover materials.

An ecological friendly solution to protect the plantation against Drosophyilla suzukii is to totally close the plantation. This would increase the positive effects of the shade net by providing closed microclimate for the plants and also a physical, chemical-free protection against the pests.
The biological indicators such as growth, flowering, yield (quantity and quality) are also registered and are still under monitoring. Although the first synthesis show close correlation with the registered physical parameters the continuation, further measurements and analysis are necessary to describe all correlations and identify the best production practice.

ACKNOWLEDGEMENT
Authors would like to express their acknowledgements to the Hungarian Ministry of Agriculture to fund this research project and to colleagues at the NARIC - Fruitculture Research Institute (FRI), Fruit Culture Research and Development Institute of Fertod, Hungary to measure and evaluate relevant biological parameters and for the everyday hard work to maintain and preserve the experimental site. Our special thanks go to Cubert GmbH, Germany, which made it possible to use and test the hyperspectral frame camera. Thanks go to the János Bolyai Research Scholarship of the Hungarian Academy of Sciences to support András Jung’s participation in the research project.

REFERENCES
[1] Csorba A., Lang V., Fenyvesi L., Micheli E., (2014), Identification of WRB Soil Classification Units from Vis-Nir Spectral Signatures. Proceedings of the 20th World Congress of Soil Science In Commemoration of the 90th Anniversary of the IUSS: Soils Embrace Life and Universe, pp. 539-545, Jeju / South-Korea;
[2] Dénes F., (2016), Strawberry technology and variety experiments in Fertodon (Szamócatechnológia és fajtakisérletek Fertődön), Kertészet és Szőlészet, vol. 35, pp. 18-20, Oldal / Hungary; Available: http://magyarmezogazdasag.hu/2016/08/31/szamoca-technologia-es-fajtakiserletek-fertodon, Access on: 12.07.2018;
[3] Fekete Gy., Issa I., Tolner L., Czinkota I., Tolner I. T., (2016), Investigation on the indirect correlation and synergistic effects of soil pH and moisture content detected by remote sensing. Proceedings of the 5th Alps-Adria Scientific Workshop Növénytermelés, pp. 203-206, Mali Lošinj / Croatia;
[4] Fenyvesi L., (2008), Characterization of the soil - plant condition with hyperspectral analysis of the leaf and land surface, Cereal Research Communications, Vol. 36, pp. 659-662, Stara Lesna / Slovakia;
[5] Hajdú J. (2018), Agro-photovoltaic equipment in agriculture (Agro-Fotovoltaik berendezések a mezőgazdasában), Mezőgazdasági Technika, vol. 49, no. 4, pp. 18-19, Miskolc / Hungary;
[6] Hanley S., (2017), Combining solar panels with agriculture makes land more productive, Clean Technica, Available: https://cleantechnica.com/2017/11/24/combining-solar-panels-agriculture-makes-land-productive/, Access on: 12.07.2018;
[7] Szalay K., Dénes F., Szakács A., Nagy R., Katkó T., Rák R., Bablana A., Kovács L., Deákvíri J., Gulyás Z., (2016), Preliminary study of various Sun protection solutions in experimental raspberry plantation, Proceedings of the International Conference on Agricultural Engineering, pp. 473-474 Aarhus / Denmark;
[8] Keller B.; Jung A., Nagy G. M., Dénes F., Péterfalvi N., Szalay K. D., (2018), Presentation of the applications of hyperspectral remote sensing through an example of a raspberry plantation (Hiperspektrális távérzékelés alkalmazási lehetőségeinek bemutatása egy málna ültetvény példáján keresztül), NAIK, pp 63-72, Gödöllő / Hungary;
[9] Lágymányosi A., Szabó I., (2009), Calibration procedure for digital imaging, Proceedings of the International Symposium “Synergy and Technical Development 2009”, Gödöllő / Hungary;
[10] Nagy G.M., (2017), Agroforestry – A new start in mixed-use plantations, Proceedings of the XVII International Conference of Forests of Eurasia, Kazan / Russia;
[11] Virág I., Szőke Cs., (2011), Filed and laboratory examinations of corn plants by means of hyperspectral imaging, Növénytermelés, vol. 60, pp. 69-72, Hungary;
[12] Williams P.C., Manley M., Fox. G. és Geladi, P., (2010), Indirect detection of Fusarium verticillioides in maize (Zea maize L.) kernels by NIR hyperspectral imaging, Journal of Near Infrared Spectroscopy, vol. 18, pp. 49-58, Australia.