PHYSICAL PROTECTION IN EXPERIMENTAL RASPBERRY PLANTATION
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ФІЗИЧНИЙ ЗАХИСТ В ЕКСПЕРИМЕНТАЛЬНІЙ ПЛАНТАЦІЇ МАЛИНИ

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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.

РЕФЕРАТ

Одним з найбільших викликів виробництва малини в Угорщині сьогодні є зменшення несприятливого впливу змін клімату. Фаза дозрівання основних сортів в межах Карпатського басейну потрапляє в період надзвичайно високих температур та посухи - досягає, або навіть перевищує 35-40°C. Це затримує бажаний ріст плодів. Для того, щоб відновити або навіть зберегти виробництво малини, необхідно впроваджувати парникові або політунельні рішення, щодо її вирощування. Експериментальні плантації трьох різних сортів малини були встановлені в двох повторах: покриті і відкриті способи вирощування. Кожне покриття мало характерне відбиття /поглинання/ світла, яке повинне генерувати умови навколишнього середовища, а також різне зростання рослин. Крім моніторингу елементарних біологічних показників для кількісного визначення різниці між покривними матеріалами для пошуку оптимального тунельного матеріалу для максимальної продуктивності рослин використовувався широкий спектр датчиків (температура, вологість, сонячне опромінення, спектрорадіометр).

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 threats 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.
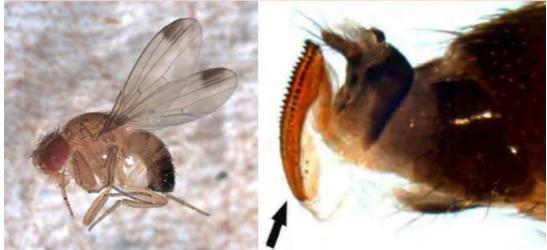

Fig. 2 – Drosophylla suzukii

Fig. 3 – Fruit damaged by *Drosophylla suzukii*

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.

Fig. 4 – Tunnels with different cover materials and white reference measurement under open sky

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).
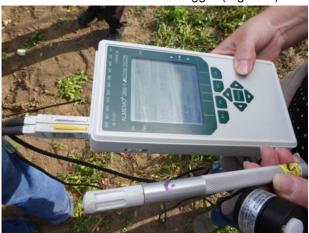

Fig. 5 – ASD FieldSpec3 MAX and Almemo 2890-9 data logger

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).

Fig. 6 – Contact reflectance measurement with PlantProbe

From these spectra, photochemical reflectance index (PRI), water index (WBI) and normalizes nitrogen index (NDNI) were calculated with the following equations:

$$PRI = \frac{\rho_{531} - \rho_{570}}{\rho_{531} + \rho_{570}}, \; WBI = \frac{\rho_{970}}{\rho_{900}} \tag{1}$$

$$NDI = \frac{\log\left(\frac{1}{\rho_{1510}}\right) - \log\left(\frac{1}{\rho_{1680}}\right)}{\log\left(\frac{1}{\rho_{1510}}\right) + \log\left(\frac{1}{\rho_{1680}}\right)} \tag{2}$$

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.
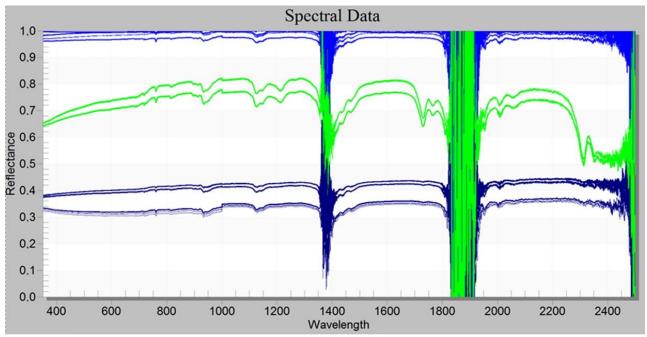
Fig. 7 – Reflectance curves: Full sky (bright blue), black tunnel (dark blue), white tunnel (green)

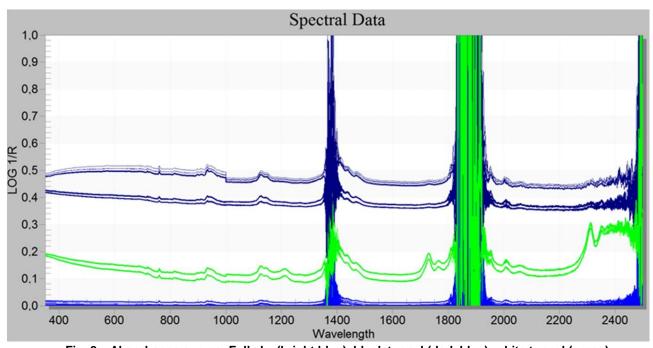**Fig. 8 – Absorbance curves: Full sky (bright blue), black tunnel (dark blue), white tunnel (green)**

Table 1

Spectral plant indicators in different treatments

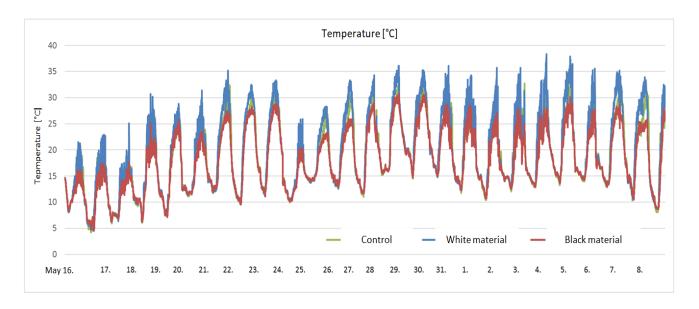|	White tunnel	Black tunnel	Control
Photochemical reflectance index	0.048	0.075	0.044
Water reflectance index	2.946	2.950	2.956
Normalized nitrogen index	0.143	0.139	0.143

Fig. 9 – Temperature in different treatments

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

Yield and berry weight in 2016

Yield 2016				
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

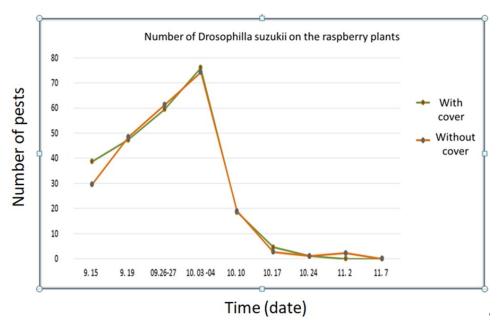| Yield 2017				
Name of the variety	**Total yield (g)**	**Ratio**	**Mean berry weight (g)**	**Ratio**
Julcsi **(covered with white)**	75092	124.19	2.26	113.57
Julcsi **(control)**	60465	100.00	1.99	100
Julcsi **(covered with black)**	69474	98.62	2.15	118.13
Julcsi **(control)**	70446	100.00	1.82	100
Fertodi succulent **(covered with white)**	141818	106.58	2.58	83.23
Fertodi succulent **(control)**	133057	100.00	3.10	100
Fertodi succulent **(covered with black)**	112024	105.36	2.51	91.94
Fertodi succulent **(control)**	106326	100.00	2.73	100
Eszterhaza productive **(covered with white)**	30797	204.24	1.90	136.69
Eszterhaza productive **(control)**	15079	100.00	1.39	100
Eszterhaza productive **(covered with black)**	18406	68.27	1.86	116.98
Eszterhaza productive **(control)**	26960	100.00	1.59	100

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 Drosophylla 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.

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