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INVESTIGATION OF THE EFFECT OF PHOTOSELECTIVE SHADING NETS ON THE QUANTITY AND QUALITY PARAMETERS OF TWO DIFFERENT PEPPER CULTIVARS

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1. BACKGROUND AND OBJECTIVES

The sweet pepper is one of the most important and widely produced vegetable species in Hungary. The Hungarian consumption of peppers is also significant, it is over 14 kg/person per year. Peppers are a rich source of vitamins and minerals, they definitely have a place in a healthy diet. In addition, peppers are Hungaricums, they have been an integral part of our culture, Hungarian gastronomy and the food industry since the Turkish occupation. Pepper cultivation is a livelihood for many families, especially in the region of Dél-Alföld. The amount of their income is determined by the quantity and quality of this crop.

However, in today's extreme weather conditions, heat stress and intense irradiation of plants are a growing problem, which can result in sunscald and thus a decrease in yield and quality. Photoselective screening nets can provide a solution to these problems. In the Mediterranean and subtropical regions, the use of shading nets is now a widespread technology for protection against heat and light stress (LEGARREA et al, 2010). In addition, a number of studies demonstrate that a favorable microclimate with shading nets in the Mediterranean region increases marketable yields and reduces the risk of sunscald (SHAHAK 2008; RIGAKIS et al. 2014; FERREIRA et al. 2014). As a result of climate change, research has begun in Hungary as well, LEDÓNÉ et al. (2011) and OMBÓDI et al. (2015, 2016) have also published valuable results.

However, at the Hungarian climatic conditions, this topic has not been researched enough yet. Therefore, a study presenting both the advantages and disadvantages of the use of photoselective shading nets at Hungarian conditions, covering the most important value-measuring properties such as yield, quality and nutritional content, is very important. But these developments depends not only on light conditions and temperature, other factors such as variety, water supply, nutrient content, cultivation technology, maturity, etc. also affect.

Therefore, during our experiments we examined the most important value-measuring properties of kápia-type peppers, the yield, quality, vitamin C content and the total amount of carotenoids. In 2013, we conducted our experiments in open field, in 2014 in open field and in forcing, and in 2015 only in forcing. In the first year, we compared the effects of five photoselective nets, and in the second and third years, the effects of 3-3 nets with each other and with the control to examine the above-mentioned value-measuring properties.

During my doctoral work I aimed:

- the cultivation of 'Kárpia' and 'Karpex' cultivars, the monitoring of environmental factors during the growing season and the optimization of the harvesting time of each cultivar.
- an examination of the effect of photoselective shading nets of different colors on the yield, quality, vitamin C content, total carotenoid content and carotenoid composition of 'Kárpia" and 'Karpex' varieties,
- to evaluate whether, in the climatic conditions of Hungary, it is worthwhile to use photoselective shading nets of different colors for the protection against sunscald during the cultivation,
- maturation dynamics follow up of the 'Kárpia' and 'Karpex' varieties, giving the maturation stages and their carotenoid composition, quantifying and quantifying the components as measured by HPLC (High Performance Liquid Chromatography),
- a comparison of the two cultivation technologies (forcing and open field cultivation) and the two varieties ('Kárpia' and 'Karpex') on the basis of yield, quality, vitamin C content and total carotenoid content.

2. MATERIALS AND METHODS

We performed our experiments in Gödöllő, in the Horticultural Department of Szent István University GAK Kht. In 2013 we conducted our experiments in the open field, in 2014 in the open field and in the Soroksár 70 walk-in plastic tunnels, in 2015 in Richel 8 type plastic house.

We worked with two cultivars belonging to the kápia cultivar type, the 'Kárpia' F_1, and the slightly more vegetatively growing 'Karpex' F_1 '. The plants were planted in twin rows with a plant density of 6.06 plants / m^2. Irrigation was discharged with a drip system, the daily amount was 4.6 mm/m^2.Kemira Ferticare I complex was used as a nutrient at a concentration of 0.2%, which was regularly applied with irrigation, in weekly doses of 2 g/m^2. A cordon support system was used during cultivation.

In 2013, we examined the effect of 5 shading nets in the open field, one ordered from Israel, a red shading net called "CromatiNet Red Shade Net 40%" with a 40% shading factor. The other four nets were the pink, yellow, green, and white raschel nets manufactured in Hungary with a 40% shading factor. In 2014, we conducted our experiments in the open field and in the plastic tunnel (Soroksár 70). In 2014 and 2015 we compared the effect of the red, white and green shading nets with the control. The nets were placed perpendicular to the twin rows two weeks after planting. During the field experiment, they were stretched on 2 m high acacia poles, in the Soroksár

70 Plastic tunnel they were placed outside the plastic tunnel, in the Richel plastic house due to the ventilation system they could only be placed inside. The width of the shaded strips was 9 m.

From the plants belonging to one treatment, we randomly selected four replicates in which the measurements and observations were continued. We worked with four replicates, one replicates consisted of 4 plants, and in each treatment 16 plants were examined.

Harvest time was in the biological maturity of the peppers, at the 6th ripening stage, on a scale we set up on the basis of maturation dynamics studies. In 2013 there were two harvests in open field, on 27th of August and 2^{nd} of October in, and in 2014 on 28^{th} of August and 14^{th} of October. We harvested the peppers three times in forcing, on 31^{th} of July, 25^{th} of September and 31^{th} of October in 2014. In 2015 the harvest was on 11^{th} of August, 6^{th} of October, and 6^{th} of November. At harvest, the peppers were collected separately: in 2013, into "marketable," "sunscalded," and "infected" groups. From 2014, the grouping criteria were expanded to include the "cracked" category. The weights and number of peppers in these groups were recorded. For sampling, the 16 plants on which the recordings were made were collected per treatment.

The peppers were processed immediately after harvest. Carotenoid biosynthesis in peppers does not stop with harvest. The peppers received by the laboratory were chopped and the pericarp was homogenized for 30 seconds using a hand-held stick mixer. Subsequently, the extraction of vitamin C was started immediately, and the remainder of the homogenized sample was stored frozen at -18 ° C. When stored at this temperature until the samples are prepared, the carotenoid content does not decrease (LEONG & OEY 2012). During the analytical measurements, we always worked with 4 replication except for 2013, when we could only afford 3 replication due to lack of resources.

Vitamin C and carotenoid content were determined by high performance liquid chromatography using a Hitachi Chromastar HPLC instrument. Vitamin C extraction was performed by metaphosphoric acid (3%) extraction method. The extraction of carotenoids in peppers was based on the method of Biacs and Daood (1994). Eight different maturation phases were separated to monitor the changes in carotenoid content.

Temperature data and precipitation were provided by the Campbell CR21X meteorological measuring station located in the experimental field. In forcing in 2014 and 2015, we used the Voltcraft DL-121TH USB temperature data acquisition device to detect temperature differences under each net. In 2015, we also acquired an additional data acquisition device, the HOBO 64K Suspended Temperature and Light Intensity Meter. Leaf surface temperature and photosynthetically active radiation (PAR, µmol / m2 / s) were recorded with the AP4 Leaf Porometer. In 2013, we were able to collect data a total of 8 times. Measurements were always taken at noon. From 2014, the amount of radiation from the PAR light range was determined using a microsensor that can be connected to a PAM-2500 chlorophyll fluorometer. The SPAD value, i.e. the relative chlorophyll content, was measured with a SPAD 502 device 20 times in 2014 in forcing, 18 times in the open field, and a total of 8 times in 2015.

For statistical analyzes, we used IBM SPSS 22 and the data analysis module of Microsoft Excel. The relationship between net transmission and temperature, and the relationship between net transmission and relative chlorophyll content, was examined by Pearson's correlation analysis. Yield, average pepper weight, vitamin C content, and carotenoid content of each variety were evaluated by a two-factor ANOVA model. The dependent variables were yield, average pepper weight, vitamin C content, and carotenoid content, and the independent variables were harvest time, shading nets, and their interaction. Pairwise comparisons were performed using Tukey HSD post-hoc test. In the data analysis, alpha was 0.05. A pairwise t-test was used to compare the yield, average pepper weight, vitamin C content, and carotenoid content of the two pepper cultivars. An independent sample t-test was used to evaluate cultivation technologies. We examined whether there is a difference between open field and forcing cultivation technology in terms of yield, vitamin C content, and carotenoid content. If there was a significant difference between the standard deviations, the Welch test was used.

3. RESULTS AND DISCUSSION

3.1 Environmental conditions

In 2013, the weather was warm and dry during the growing season, especially in the period before the first harvest. From planting to the last harvest, 252.3 mm of rain fell. There were two harvests in 2013, on 27^{th} of August and on 1^{st} of October. The mean temperature for the 15 days before the first harvest was 20.9 ° C, by the second harvest 8 ° C lower, 12.9 ° C,

There was much more precipitation in 2014 than the previous year and the temperature was also lower than in 2013. The distribution of precipitation was even. From planting to the last harvest, a total precipitation was 415.5 mm, one and a half times more than in 2013. There were two harvests in the open field, on 28^{th} of August and on 14^{th} of October. The mean temperature for the 15 days before the first harvest was 17.3 ° C and for the second harvest 14 ° C. The average temperature in August was much cooler than usual (4-5 ° C) in this region. We harvested three times in forcing, on July 31, September 25, and October 31. Fifteen days before the first harvest, the average temperature in the plastic tunnel was 25.1 ° C, 18.1 ° C before the second harvest and 11.5 ° C before the third.

In 2015, the total precipitation was 305 mm during the growing season. The number of heat days (above 30 ° C) was almost double that we experienced in 2014, however, larger temperature fluctuations accompanied the growing season. There were three harvests in 2015, on 11th of August, 6th of October and 11th of November. Fifteen days before the first harvest, the mean temperature was 24.33 ° C, 16.81 ° C for the second, and 13.69 ° C for the third harvest.

Transmission of nets in the photosynthetically active (PAR) range

	Control	**White**	**Red**	**Green**	**Yellow**	**Pink**	**Open air**
2013 Open field	100 %	78-80%	63-68 %	75-84%	82-87 %	84-93 %	**100 %**
2014 Open field	100 %	77 %	58 %	67 %	-	-	**100 %**
2014 Forcing	100 % **73 %** *-27 %*	79 % **58 %** *-21 %*	53 % **39 %** *-14 %*	72 % **53 %** *-19 %*	-	-	**100 %**
2015 Forcing	100 % **55 %** *-45 %*	79 % **44 %** *-35%*	56 % **31 %** *-25 %*	71 % **40 %** *-31 %*	-	-	**100 %**

In bold: transmission compared to the external environment; *in italics*: the difference between the transmission compared to control and to external environment.

The amount of shading factor given by the manufacturers differed significantly from the values we measured in the PAR range. Most of the light was transmitted by the pink net, followed by the yellow, white, green, and red net. At the Soroksár 70 plastic tunnel, the single-layer polyethylene cover alone reduced the exposure by 27% compared to the open field, the double-layer cover by 45%.

In 2015, with the HOBO 64K Suspended Light Intensity Meter, we found that, compared to the control, the white net transmitted 86.7%, the green net 74.2%, and the red net in 63.23% from the incident radiation for the light spectrum between 200 and 1200 nm. The degree of transmission of different colored shading nets showed a significant positive correlation with the average temperature under different colored cover nets (R = 0.97; p = 0.03), i.e. the higher the degree of transmission, the warmer the air temperature.

3.2 Relative chlorophyll content (SPAD)

Based on the measurements in 2015, we found that ‘Karpex’ peppers have a significantly strong positive correlation ($p = 0.002$; $R = 0.998$) between the degree of transmission and the SPAD value. The more light was transmitted by the shading nets, the higher was the relative chlorophyll content of the plant’s leaves. Consistent with this are the results published by LEGARREA et al. (2010), DÍAZ-PÉREZ et al. (2013), JANG et al. (2014), and OMBÓDI et al. (2015). According these publications, increasing photosynthetically active radiation (PAR) was associated with significantly higher chlorophyll content when examining pepper cultivars. No significant correlation was found for ‘Kárpia’ peppers ($p = 0.074$; $R = 0.926$).

3.3 Yield and quality

We achieved the highest average yield at the first harvest, in forcing and in the open field as well. In the open field, among the shading nets, the yellow netting resulted in a significantly higher yield compared to the control. In 2014, under open field conditions, the yield of ‘Kárpia’ peppers was significantly lower in case of green netting than in control ($p=0.021$). In forcing, there was no difference between the yields under the shading nets and by the control in 2014. In 2015 the red shading net resulted in significantly lower yields for both cultivars than the control without shading net (' Kárpia': $p <0.01$). ; 'Karpex' $p = 0.014$). This is due to the double-layer plastic cover of the Richel plastic house, than has already filtered out too much light.

Examining the differences in the years, we found that the yield in the open field in 2013 was significantly lower than in 2014 ($p = 0.004$). In forcing, there was no difference between the yields of the two years.

In the open field, it was the green net where no sunscald peppers were found in any of the cultivars, and when used, we found uniform peppers in almost all cases. We also found that both cultivars showed almost the same proportion of sunscalded symptoms. The ‘Karpex’ variety is slightly more susceptible to disease and the ‘Kárpia’pepper is more prone to cracking. However, in terms of total yield, there was a higher proportion of marketable peppers in forcing than in open field cultivation. Furthermore, we found more disease-infected peppers in the open field than in forcing. However, longitudinal dry cracks on peppers were more common in forcing.

3.4 Vitamin C content

In our experiments, the vitamin C content ranged from 484.4 to 4288.6 μg/g. The peppers we grown had more than twice the vitamin C content as the peppers grown by SIMONNE et al. (1997), MARTÍNEZ et al. (2005) or DEEPA et al. (2006). In our experiments, the highest vitamin C content was measured in the open field in 2013 under the pink shading net, and the lowest value in 2015 in forcing under the green net.

Only the pink net resulted in significantly higher vitamin C content in open field than the control in 2013 ($p = 0.024$). The pink net transmitted most of the light among the shading nets. This is consistent with the statement of MASHABELA et al. (2015) where the most light-transmitting pearl net in peppers was the best. It has also been found that light in the blue range and the red range is what can stimulate vitamin C content. In these two regions, the absorbance of the pink net in the PAR region is low, i.e., the pink net transmits these two region.

In the field experiments, in each year the second harvest resulted in significantly higher vitamin C content, than the first, despite of the fact, the average temperature of the second harvest was cooler with 8 ° C in 2013 and with 3.3 ° C in 2014 than the first. Before the first harvests, more times and much more precipitation fell than before the second harvests. Overcast skies and high temperatures of 29-34 ° C were not favorable to vitamin C biosynthesis. This is consistent with the findings of NAGY et al. (2016) measured in chili peppers.

In forcing, in each year we found higher vitamin C content by the first two harvests than by the third due to the better light supply. In 2014, in forcing there was no significant difference between the nets in 'Kárpia' ($p = 0.13$). In the 'Karpex', the highest vitamin C content was measured in the unshaded control ($p = 0.034$), the shading nets had a negative effect on the vitamin C content, and the poor light conditions already reduced the assimilation of vitamin C in forcing.

Examining the years, we found that 2014 was the most favorable year for vitamin C accumulation ($p < 0.001$). This year the 15 days before the harvest was cooler than usual, the daily maximum in open field did not reach 30 ° C, the highest vitamin C content occurred at maximum 22 ° C. In 2015, maxima of 39-44 ° C did not stimulate vitamin C biosynthesis either. This suggests that vitamin C production (not just carotenoids) is also negatively affected by high temperatures above 30 ° C.

3.5 Accumulation of carotenoids and carotenoid content

By the maturation dynamics studies, 8 different ripening stages were distinguished, from green peppers containing only 5 yellow carotenoids in an amount of 10.29 ± 0.4 μg/g to overripe, deep burgundy peppers which contained about 60 carotenoids in an amount of 728.58 ± 164.96 μg/g. Capsanthin, the most significant red carotenoid in peppers, appears at the beginning of color breaking. In the last ripening stage, the total carotenoid content of peppers and the proportion of red carotenoids are the highest. The amount of biologically active components gradually increases during maturation. In the experiment with photoselective nets, the harvest was always timed to the sixth ripening stage, when the peppers were already completely red. More than 60 carotenoids were separated in both cultivars by high performance liquid chromatography (HPLC). Of these more than 60 components, 56 were identified and quantified. A similar carotenoid composition was detected in paprika by BIACS and DAOOD (1994) and in red-ripening chili peppers by GIUFFRIDA et al. (2013). The carotenoids in our samples can be classified into three groups, free pigments, monoesters, and diesters.

Among the quantitatively and qualitatively determined components, zeaxanthin, β-cryptoxanthin, β-carotene and their cis-isomers and fatty acid esters are the biologically active components, which ranged from 22.6 ± 10.7 to 110 ± 23.7 μg/g. This means 2-11 mg of bioactive carotenoid in an average size of 100 grams of freshly harvested peppers. The lowest value was detected in 2013 by the first harvest /'Karpex'/ yellow net combination, the highest value was given in 2015 by the second harvest /'Karpex'/ control combination in forcing. In 2013, 'Kárpia' contained almost twice as many biologically active components than 'Karpex', in 2014 'Kárpia' was also better in open field than 'Karpex'. In forcing, we found no significant difference between the two cultivars.

In terms of qualitatively important groups, free capsanthin and its mono- and diesters were highest in 2015. There was also no significant difference between the cultivation methods and between the cultivars. In open field, we found that the 'Karpex' contained more red and less yellow carotenoids than 'Kárpia', i.e. a higher proportion of red/yellow pigments in 'Karpex' peppers, which is showing the degree of real redness and giving the stability of the color.

Total carotenoid content was obtained by summing all identified components. In our experiments, the amount of total carotenoids varied between 57.25 ± 11.43 and 541.44 ± 120.14 μg/g. HWA et al. (2007) measured total carotenoid content between 20 and 1043 μg/g in six red-ripening pepper varieties at full maturity. The values we measured are within this range. The highest total carotenoids were measured in forcing in 2015 without shading by 'Karpex', and the lowest value was obtained in open field in 2013, also without shading, by 'Karpex'. Examining the difference between the years, the statistical analysis shows that 2015 resulted in the highest total carotenoid content, separated from the results of all other experiments (p <0.001). Of the two cultivars, ‘Kárpia’ pepper had higher total carotenoid content in each year and for each treatment. Based on paired t-tests, ‘Kárpia’ had significantly higher total carotenoid content in open field in 2013 for white, yellow and pink nets, and for control treatment. The same was observed in 2014 in forcing for white net and control treatment.

The comparative analysis of cultivation technologies shows that in terms of carotenoid content, significantly higher total carotenoid content can be achieved in forcing than in open field (p=0.039).

In open field, shading nets had no significant effect on carotenoid content. In forcing, in 2014, the white net resulted in significantly higher total carotenoids in ‘Kárpia’ than the control or red net (p <0.01). The third harvest was statistically distinct from the other two harvests, we found the highest total carotenoid content (p <0.001) at the third harvest. In ‘Karpex’, the highest total carotenoid content was by the second harvest. The red shading net resulted in significantly lower carotenoid content than all other treatments (p <0.01).

In forcing in 2015, the amount of total carotenoids in both cultivars was significantly higher by the second harvest than by the first harvest. The average daily temperature for the 15 days before harvest ranged from 23.88 to 24.87 °C at the first harvest and from 16.61 to 17.18 ° C at the second harvest. In the period prior harvest, there were several times above 30 °C (and even occurred above 40 °C), which can disturb the carotenoid biosynthesis (LEE et al. 2005; HELYES et al. 2007). At the second harvest, the temperature was rarely higher than 30 °C. This can explain that this year we experienced significantly higher carotenoid content in the second harvest than in the first. This is also supported by RUSSO and HARWARD’s (2002) experiment, which showed that the more protected conditions and lower exposure increase total carotenoid content.

In 2015, green net and control treatments for ‘Kárpia’ peppers had significantly higher total carotenoid content than those measured under white net (p <0.005). ‘Karpex’ peppers had the highest total carotenoid content measured in the control, 541.4 ± 120.1 μg/g, and this result differed significantly from the values measured in red and green net treatment (p = 0.038). The content of vitamin C and total carotenoids was measured for healthy parts of sunscalded peppers and marketable peppers. Based on the independent sample t-test, we found no difference in vitamin C content (p = 0.217), but we found significant difference in carotenoid content (p <0.0001). This means that carotenoids are sensitive to strong radiation, while it does not negatively affect vitamin C biosynthesis.

4. NEW SCIENTIFIC RESULTS

- I have proved that under Hungarian climatic conditions, the yellow net is suitable for increasing the yield of ‘Karpex’ peppers belonging to the kapia type in open field between the photoselective shading nets. By using a green shading net, it can cause a decrease in yield, but it has a positive effect on quality.
- I found that under our climatic conditions, the vitamin C synthesis of ’Kárpia’ peppers can be stimulated by pink net under field conditions. Red and white nets, on the other hand, have a negative effect on their quantity.
- I have demonstrated that in open field the shading net does not influence the development of the total carotenoid content of ‘Kárpia’ and ‘Karpex’ varieties under our climatic conditions.
- I found that the green net is suitable for preventing the tissue damaging effect (sunscald) of strong UV radiation.
- I have proved that there is no difference in the vitamin C content between the healthy tissues of a sunscalded pepper and the tissues of intact peppers, and the synthesis of vitamin C is not disturbed by strong radiation overall.
- I have shown that the healthy tissues of sunscalded peppers have significantly lower carotenoid content than those of healthy peppers.
- In ‘Kárpia’ and ‘Karpex’ cultivars higher total carotenoid content can be achieved the in forcing, than under open field conditions In Hungary.

5. CONCLUSIONS AND RECOMMENDATIONS

In the open field, we can recommend yellow shading net among the photoselective nets, as its use resulted in a significantly higher yield compared to the control. The pink net stimulated the vitamin C content. In the open field experiments in 2014, it was proved that, the green net, which is widely used by growers can have a negative effect on yield. Although it may cause a decrease in crop yield, we found that green netting had a clear positive effect on crop quality. In the open field, it was the green net where we found no sunscalded peppers in any of the cultivars. Therefore, in the open field, the green net was suitable for the protection of the tissue-damaging effect of strong ultraviolet (UV) and most of all UV Ba radiation, and uniform peppers were found in almost all cases when used. However, it still resulted in lower yields, so its use is not recommended for the cultivation of sweet peppers for market purposes. In addition, the green net also negatively affected the vitamin C content and total carotenoid content of ‘Karpex’ in 2015.

In 2015, in forcing, the red shading net resulted in lower yields for both cultivars than the control without shading net. Furthermore, it had a negative effect on vitamin C content in the open field, in 2014 the red net clearly reduced the total carotenoid content of peppers in both cultivars, and in 2015 also in ‘Karpex’. This net had the lowest light transmission, which explains why there were no sunscalded peppers in the forcing under the red net, except for one case in 2014 for the second harvest. The reason for the lower yield and total carotenoid content values is that the double-layer plastic cover of the Richel plastic house has already filtered too much light together with the shading net. Therefore, the use of nets with a high shading factor (red, green) is not recommended with a double- layer plastic cover.

In shoot, the white net reduced the vitamin C content of ‘Karpex’ peppers in 2014. In the same year it increased the total carotenoid content of ‘Kárpia’ peppers, and it reduced this parameter in 2015. The difference in the setup of the two experiments is manifested in the light transmission of the aforementioned Richel plastic housing double-layer UV stable foil coating and the Soroksár 70 plastic tunnel single-layer polyethylene film coating. It follows that the white net can increase the total carotenoid content at the appropriate light intensity, but below the threshold, a reducing effect can be achieved by using it. This may be the reason for the carotenoid-reducing effect of red and green nets, as these nets transmit even less light.

For pepper growers, we recommend the ‘Karpex’ as opposed to the ‘Kárpia’ peppers. In our experiments, we found that it gives a higher marketable yield and the average pepper weight is also higher for ‘Karpex’ peppers than for the other cultivar. Furthermore, we also found that both types showed symptoms of sunscald in almost equal proportions. The ‘Karpex’ variety is slightly more susceptible to disease and the ‘Kárpia’ pepper is more prone to cracking.

No difference was found between the vitamin C content of ‘Kárpia’ and ‘Karpex’ peppers. The genotype determines how high the vitamin C content of peppers can typically be and these two cultivars have similar genetic backgrounds. Thus, both cultivars are recommended for the cultivation of peppers with a high vitamin C content. Of the two cultivars, ‘Kárpia’ is the ones that contained, on average, more biologically active components, so if this variety is grown, we get peppers with higher biologically active carotenoids. Of the two cultivars, ‘Kárpia’ peppers have the higher total carotenoid content. However, from an economic point of view, the cultivation of ‘Karpex’ is more advantageous due to its more intense red color, as it contains more red and less yellow carotenoids than ‘Kárpia’.

The two cultivation technologies (forcing and open field cultivation) are not decisive in terms of pepper size and marketable yield. However, in terms of total yield, there was a higher proportion of marketable peppers during forcing than in open field cultivation. Furthermore, we found more disease-infected peppers in the open field than in forcing. However, longitudinal dry cracks on peppers were more common in forcing.

By analyzing the nutritional value, we can achieve a significantly higher total carotenoid content in forcing than in the open field, so it is recommended to grow the peppers in forcing if the highest possible carotenoid content is the goal. There was no difference in terms of vitamin C, however, it is still worth choosing the forcing, because with the same vitamin C content, with forcing can win up to a month in the market, which is accompanied by a very significant profit surplus.

Examining the years of cultivation, we found that in 2014 there were far fewer sunscalded peppers than in 2013. In the open field, the yield in 2013 was significantly lower than in 2014. In forcing, there was no difference between the yields of the two years. The year 2014 was the most favorable not only in terms of yield, but also in terms of average pepper weight. This may have been due to the fact that in 2014, during the period of pepper formation, it was cooler than usual, so evaporation was also lower, allowing the plants to have relatively more water than in the drier and warmer 2013 year.

The conditions of the 2014 experiment were the most suitable for the formation of vitamin C, the highest vitamin C content was formed at 22 ° C maxima. In 2015, even the 39-44 ° C maxima did not stimulate vitamin C biosynthesis. This suggests that vitamin C production (not just carotenoids) is also negatively affected by high temperatures above 30 ° C. In addition, in 2015 we detected the significantly highest total carotenoid content, again the cooler average temperature experienced during autumn harvest resulted in higher values.

In open field experiments, cloudy skies and higher temperatures at the first harvest were not conducive to vitamin C biosynthesis. From this, we can conclude that vitamin C production is more affected by light intensity than temperature. Furthermore, we also found that in forcing, summer or early autumn harvest resulted in higher vitamin C content than a late autumn harvest, also due to the higher light supply.

In the open field, summer harvests brought higher total carotenoid content, and in forcing, autumn harvests. This is due to the fact that heat stress caused by temperatures above 40 ° C during the summer (often for up to 4 hours per day) in forcing inhibited carotenoid biosynthesis.

6. PUBLICATIONS RELATED TO THE TOPIC OF THE DISSERTATION

6.1 Scientific publications

6.1.1 Publications in international scientific journals (IF)

- AMBRÓZY, ZS., DAOOD, H., NAGY, ZS., DARÁZSI LEDÓ H., HELYES L. (2016): Effect of net shading technology and harvest times on yield and fruit quality of sweet pepper. *Applied Ecology and Environmental research*, 14 (1): p. 99-109. (IF: 0.547)
- NAGY, ZS., DAOOD, H., AMBRÓZY, ZS., HELYES L. (2015): Determination of polyphenols, capsaicinoids and vitamin C in new hybrids of chili peppers. *Journal of Analytical Methods in Chemistry.* Article ID 102125. http://dx.doi.org/10.1155/2015/102125 (IF:1.369)
- NAGY ZS., DAOOD H., NEMÉNYI A., AMBRÓZY ZS., PÉK Z., HELYES L. (2017): Impact of Shading Net Color on Phytochemical Contents in Two Chili Pepper Hybrids Cultivated Under Greenhouse Conditions. *Horticultural Science and Technology* 35 (4): p. 418-430. (IF: 0.365)

6.1.2 Publications in Hungarian scientific journals (without IF)

- AMBRÓZY, ZS. (2017): Az öntözés és a mikorrhiza kezelés hatása a 'Kárpia' F_1 étkezési paprika hibrid termés tömegének, koraiságának alakulására, valamint a beltartalmi paramétereire nézve. *Kertgazdaság*; 49 (4): p. 3-11.
- SZUVANDZSIEV P., LEDÓNÉ D. H., AMBRÓZY ZS., VAJNAI A. M. (2015): Fotoszelektív hálók hatása kápia paprikák spektrális tulajdonságaira és termésmennyiségére. *Kertgazdaság* 47 (4): p. 11-18.
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6.3. Educational articles

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