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The impact of cultivar and irrigation on yield, leaf surface temperature and SPAD readings of chili pepper

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SUMMARY

Paprika is an extremely popular and widespread plant species in Hungary. Chili peppers belongs to paprika and it can be consumed fresh or processed. The production of peppers began with the cultivation and control of some parameters for good results of paprika production. The aim of this article is to compare the water supply of four chili pepper hybrids ("Habanero", "Hetényi Parázs", "Unikal" and "Unijol") by means of investigation on open field and to examine how different temperatures and water stress factors influence the yield of chili peppers. The experiment area consisted of four different hybrids in three different irrigation treatments (control, deficit- and regular irrigation). The chlorophyll content was estimated with SPAD and the leaf surface temperature with Raytek MX4 TD. Our research concluded that deficit irrigation produced the highest yields for all cultivars and the lowest yields for the highest water supply.

Keywords: *Vitamin C, Brix, chlorophyll fluorescence*

INTRODUCTION

Several species of chili peppers are being consumed around the world. The interest in this condiment is due to the flavors that this spice offers the food besides contain high concentrations of provitamin A, vitamins E and C, and antioxidant compounds, and can be good sources of carotenoids and xanthophylls. Peppers are grown all over the world, although the most popular areas for paprika production are from wet tropics to dry deserts and cool temperate climates. The season and the weather are important for pepper because this spice is a light-demanding species. It requires summer and autumn rich in sunlight to produce a good quality crop. If the light conditions are inadequate for the peppers, the development of the plant is slowed down, flowering and harvesting are weakened (Zatykó and Márkus, 2010), and a significant decrease in yield is expected in shady areas (Nagy et al., 2017). The optimum temperature conditions for pepper cultivation are like other Solanaceae (tomatoes or eggplants), which require a long, frost-free period in the open field to produce high-quality, high-yield crops (Bosland and Votava, 2012). Besides the climatic conditions, another important factor to produce peppers is the water supply, and this factor is determined by the chosen variety, temperature and nutrient supply of the soil (Balázs, 2004). Irrigation is particularly important during the during the production phase, which is a critical period in the development of peppers (Ambrózy et al., 2015). An experiment has shown that the stress caused by water deficit in peppers causes less yield loss when the plant is exposed to water deficiency at young stage (Techawongstien et al., 1992). Most peppers are grown in open field as a one-year crop. As with most peppers, sandy and loamy soils, which are of medium texture and have good conductivity (EC), are good for peppers. Generally, most pepper varieties ripen earlier with the seedling technology, whereas with the opposite direct seeding technology it is shifted by 2–3 weeks (Balázs, 2004). Harvesting is done by hand and, as the pepper plants continue to bloom after ripening, it can be repeated several times (Po, 2011). The time elapsed between each harvest is determined by the type of growth of the plant, the continuous ones can be picked 2–3, the determinate and semi-definite varieties can be taken once, in rare cases twice (Zatykó and Márkus, 2010). Chili peppers are harvested at full ripen phase when they are red in color, but there are varieties that produce yellow or green at full maturity. (Bosland and Votava, 2012; Koncsek et al., 2016). The red-ripen varieties should be harvested in the so-called "red-ripe" stage, when the total surface of the fruit is red, because it contains the highest amounts of vitamin C and carotenes (Koncsek et al., 2018).

The purpose of the experiment was to compare how the impact of cultivar and application of different irrigation treatment would affect the leaf surface temperature and relative chlorophyll fluorescence (SPAD) factors of these chilli peppers and they can significantly influence its yield.

MATERIALS AND METHODS

Experimental area and yield

The experiment was conducted in 2018 in an open field in Gödöllő, Hungary, with four different hybrids of chili peppers ("Habanero" (HAB), "Hetényi Parázs" (HET), "Unikal" (UNIK) and "Unijol" (UNIJ)) in three different irrigation treatments. The control (K), this treatment did not receive any extra water, only natural precipitation. Deficit irrigation treatment (D), which received half of the optimal amount of water, with natural precipitation and water supply. The irrigation (R), received the total amount of irrigation water. (*Figure 1*). On a 4047 m^2 plot of land, the experiment with four successive harvests was performed at different periods in 2018, August 13, then on September 3, 24, and finally on October 15. Harvesting was done manually by participants in the experiment. During the harvest, the weight and number of the fruits

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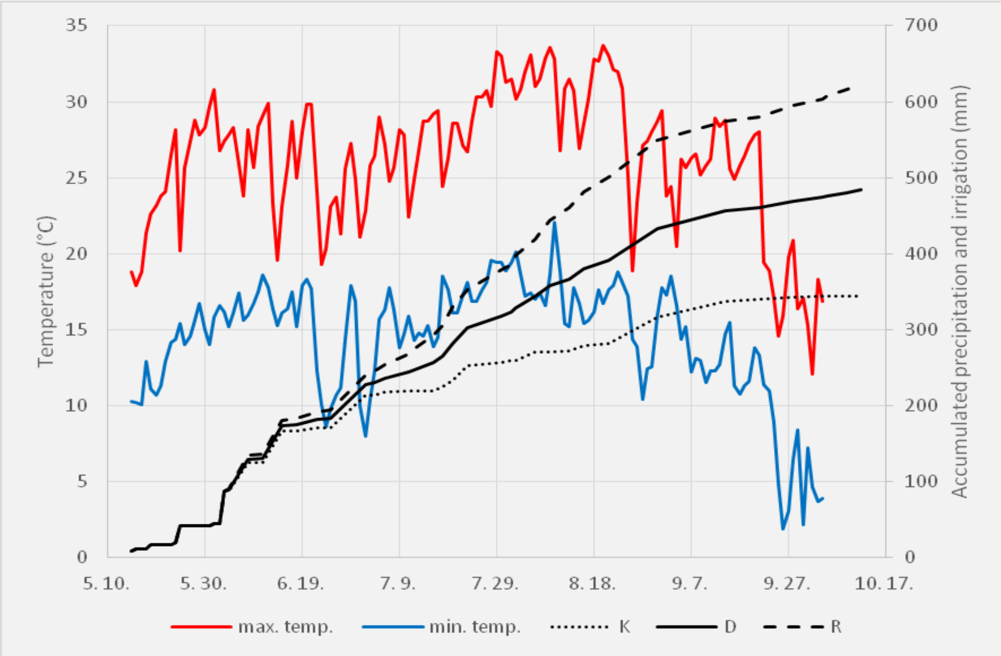
was measured, and the yield per hectare was calculated from these data.

The SPAD values were measured using a Konica Minolta SPAD-502 Plus portable non-destructive chlorophyll measuring instrument (http1). The device measures the relative chlorophyll content of a plant leaf based on absorbance of 650 nm wavelengths of light, using as a reference the 940 nm wavelength infrared light (Uddling et al., 2007). In our experiment eight specimens were selected from each treatment, which were measured four times each and then averaged to obtain SPAD values for each treatment.

Figure 1: **Irrigation water and rainfall conditions for different treatment chili peppers and seasonal temperature Soil Plant Analysis Development (SPAD)**



Leaf surface temperature

The leaf surface temperature was determined using a Raytek MX4 TD infrared remote thermometer. This portable battery-powered instrument is capable of measuring the surface temperature of objects. Its operating principle, which is capable of measuring 99% of the energy emitted by the object in the field of view of the telemetry unit with an error of ± 1%, makes it possible to determine the leaf temperature of plants. No calibration is required before using the instrument, however, environmental factors, especially clouds, should be taken into account when using the instrument. For this parameter, 16 leaves were randomly selected and measured per treatment and calculated the average.

Data were evaluated by analysis of variance (ANOVA) and analysis of regression using Microsoft Excel for Windows software. The average values of treatments were compared by Duncan Multiple Range Test at $P<0.05$.

RESULTS

Soil Plant Analysis Development (SPAD)

The SPAD values of the control treatment (K) fluctuated between 40 and 75 over almost two and a half months, the deficit treatment (D) fluctuated between 30 and 75 and the irrigation treatment (R) fluctuated between 28 and 75. Habanero had the lowest SPAD value in the case of all three water supply values (K, D and R) (*Figure 2*). In treatment K, the Unikal F1 had a higher SPAD value among the other hybrids. The Unikal F1 and Hetényi Parázs F1 had the similar response during the different periods that the parameter was analyzed, a factor also observed between the Habanero and Unijol F1 hybrids. In treatment D, all varieties had low values for SPAD in the month of October, end of the experiment (*Figure 2*). In treatment R, the Unikal F1 and Hetényi Parázs F1 hybrids had approximate values during the period from July to October, while Habanero and Unijol F1 hybrids had similar response but not the same values. Overall, the treatment that obtained the highest value for SPAD was control followed by water deficit and continuous irrigation (*Figure 2*).

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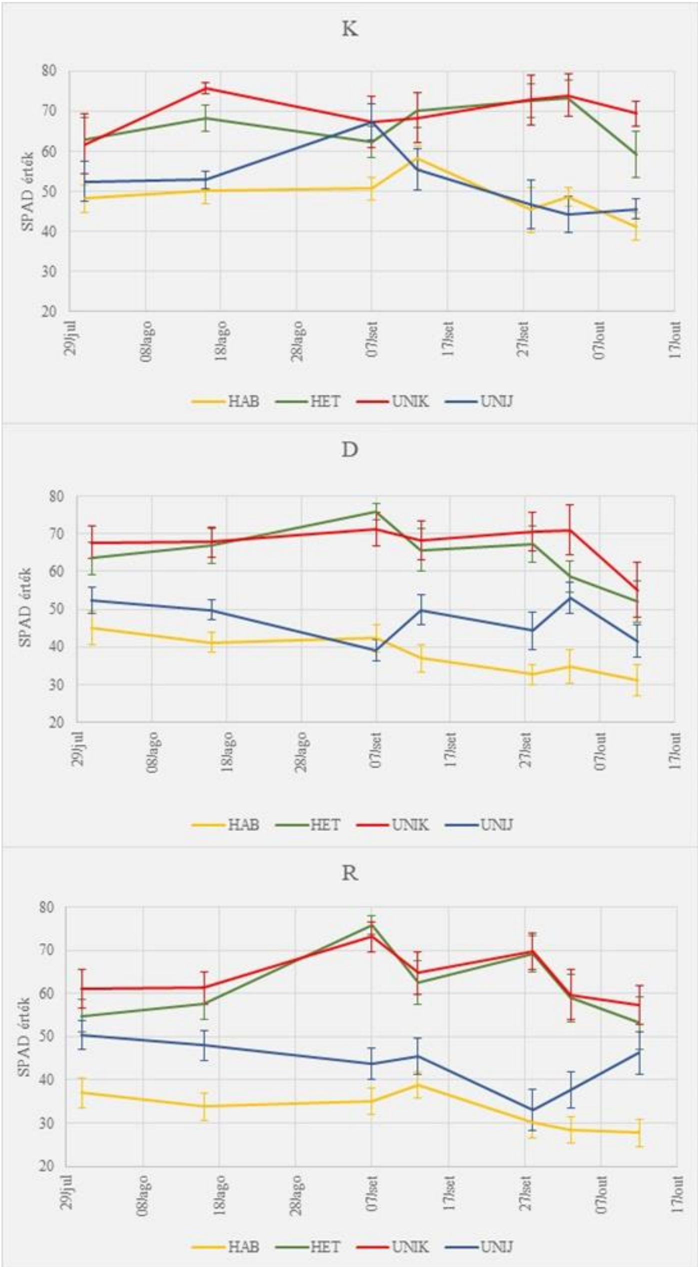
Figure 2: **Development of SPAD values in the treatment control (K), irrigation treatment (D) and irrigation (R) Leaf surface temperature**



In the regular irrigation treatment (R) with 616 mm water the first measurement (July 31) shows that at 31 °C the varieties were able to cool themselves down better, the Habanero and Hetényi Parázs F1 28.5°C Unikal F1 and Unijol F1 at 26–27 °C. On September 7th measurement (338 mm), it was observed Unijol decreased to 25.8 °C, Unikal F1 to 24.8 °C, Hetényi Parázs F1 to 24.3 °C and Habanero F1 to 23.8 °C due to precipitation before measurement. Until the next measurement there was no new precipitation, so on the September 13th measurement all four varieties showed leaf temperature of ~ 24.8 °C. On October 3, according to which, at an air temperature of 18 °C, all varieties had lower leaf surface temperatures of 3.5–4 °C (*Figure 3*). The control treatment was less able to cool itself by transpiration due to less water, so this treatment is closest to the air temperature in the *Figure 3*. This is followed by a deficit irrigation treatment, which, by better water supply, has been able to cool itself down better and is therefore 1.6 °C cooler than the air temperature. And finally, the regular irrigation treatment is mostly below the air temperature, as this treatment received the most water. Because the precipitation was above average during the experimental year, even the control treatment was able to obtain enough water to cool it to below ambient

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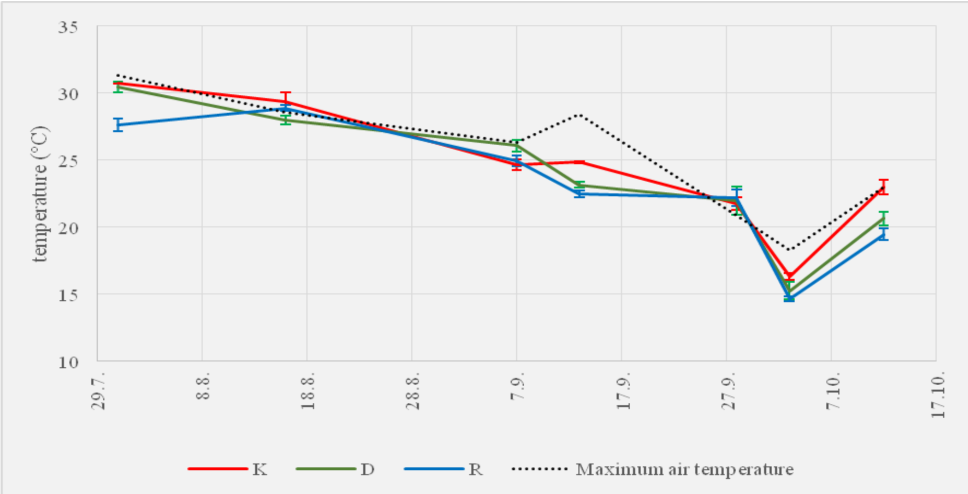
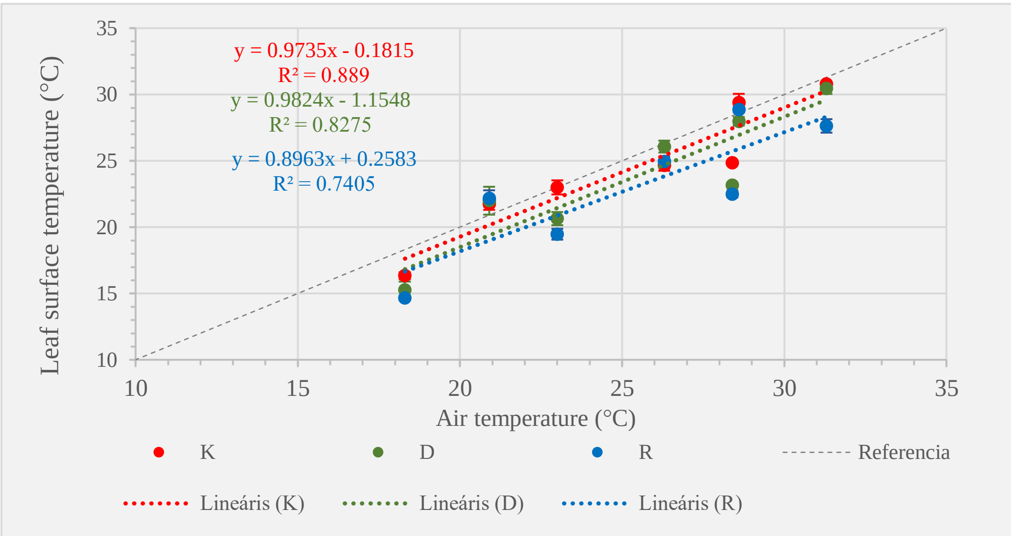
temperature. At the last measurement, the difference between the three treatments was most noticeable, as this was the largest difference in water supply between the different treatments. Compared to the control treatment, the deficient treatment received 139 mm more water and the continuous irrigation treatment received 279 mm more water. In practice, this meant that the control treatment at 0 °C, the deficient treatment at 2.3 °C and finally the regular irrigation treatment at 3.5 °C had lower leaf surface temperatures than the air temperature.

Figure 3: **Comparison of average leaf temperatures for different treatments**



All three treatments received enough water to keep their own temperatures below the air temperature. The control treatment (K) shows 17.5 °C at 18.5 °C and 30 °C at 31 °C, so this treatment is optimal for chili peppers at 25 °C. It reached an air temperature of 26 °C. Deficit (D) and continuous irrigation treatments (R) all reached 16.5 °C at 18.5 °C, but due to different water supply, deficient irrigation treatment at 31 °C was 29.5 °C and continuous irrigation treatment shows 28 °C. From this it can be concluded that the continuous irrigation treatment, as it received more water, was able to cool itself more with the rise of the air temperature than the deficient irrigation treatment (*Figure 4*).

Figure 4: **Correlation between average leaf surface temperatures of different treatments and air temperature with equations of linear regression functions**



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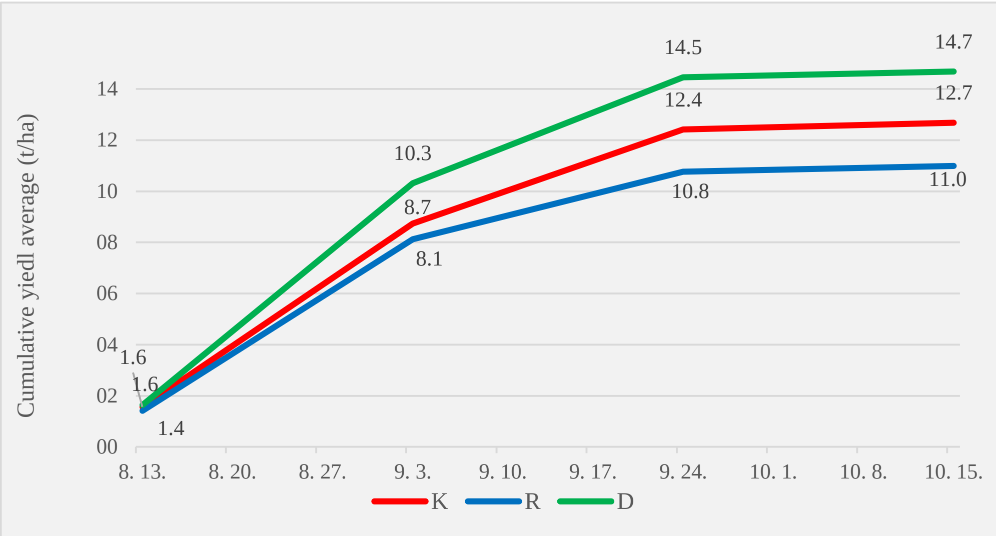
Yield

For all treatments the second harvest resulted the highest yield. Habanero production was lower in all treatments (K, D and R), minimum 0.05 kg m^{-2} and maximum 0.79 kg m^{-2} besides this variety did not have ripe fruits for the first harvest time. Comparing the three treatments, it can be observed that the largest amount of fruits could be harvested on 3rd of September. Deficit irrigated Hetenyi F1, Unikal F1 and Unijol F1 hybrids, had higher production throughout the year, being the maximum yield in the last harvest (1.84 kg m^{-2}, 1.97 kg m^{-2} and 1.28 kg m^{-2}) respectively. Only in Habanero had higher yield in control but was no significant difference compared with deficit water supply. Summarized, it can be stated that deficient irrigation produced the highest yields for all hybrids and the lowest yields with the highest water supply (*Figure 5*).

Figure 5: **Comparison of average cumulative yields of varieties in different treatments**



DISCUSSION

Comparing the three treatments with different water supplies, it can be observed that the highest SPAD values were produced by the control treatment, followed by the deficient irrigation, and finally the regular irrigation treatment reached the lowest values. Furthermore, it can be concluded that Hetényi Parázs F1 and Unikal F1 reacted similarly to different irrigation treatments in terms of SPAD values. The temperature of the foliage of the plants is a good indication of the water supply of a plant continuous irrigation treatment, upon receiving more water, was able to control more when increasing air temperature than poor irrigation treatment. Furthermore, from the linear regression equations of the three treatments, it is clear that the more water supply, the farther away they were from the air temperature, in the negative direction. When plants suffer from water deficiency, transpiration decreases and the surface temperature of the leaves increases (Ćosić et al., 2018; Wang et al., 2010). Knowing the leaf surface temperature, the need for irrigation can also be predicted (Schober et al., 2008). Comparing the average yields of the four varieties by the three different water supplies, it can be observed the deficit (D) irrigation treatment, followed by the control (K) treatment, and finally regular irrigation (R) treatment. All these prove the efficiency of water-saving irrigation, as it has been proved by several years of experiments with tomato from Solanaceae (Nemeskéri et al., 2019).

CONCLUSIONS

The combination of variety and water supply can significantly influence the yield of chili peppers. Deficit irrigation produced the highest yields for all cultivars and the lowest yields for the highest water supply. Although the former was only significant for the Unikal F1 and Unijol F1, while the latter harvest was only significant for the Habanero and Unijol F1 hybrids. Overall, deficit irrigation can be recommended for better chili pepper crop yields.

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