



# Effects of irrigation regime and application of kaolin on canopy temperatures of sweet pepper and tomato

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## ABSTRACT

The effect of different irrigation regimes and the application of kaolin on the canopy temperatures of sweet pepper (*Capsicum annuum* L.) and tomato (*Lycopersicon esculentum* Mill.), determined by a nondestructive imaging method, is discussed in the paper. The research was conducted in an open field on carbonate chernozem soil at Stara Pazova (40 km north of Belgrade, Serbia), over a period of three years (2011, 2012 and 2013). The setup was a two-factorial, completely random block system, with three replications. The first factor was the irrigation regime and the second the application of kaolin. The experimental pepper plants were subjected to three different irrigation regimes: a) full irrigation (F), covering 100% of ETc (cultivar's evapotranspiration rate); b) deficit irrigation at 80% of ETc (R1); and deficit irrigation at 70% of ETc (R2). Two different irrigation regimes were monitored in the case of tomato: full irrigation (F), covering 100% of ETc, and b) deficit irrigation at 50% of ETc (D). The kaolin treatments of both crops were: a) control without kaolin (C) and 5% kaolin suspension (K).

The results of this research indicated that the irrigation regime had a very significant effect on the temperature of pepper and tomato; the higher the level of irrigation, the lower the temperature. The dual-effect of kaolin impacted the heat balance of the plants.

## 1. Introduction

One of the most important indicators of crop water stress is the canopy temperature, which helps determine the time of irrigation. Evaluation of the canopy temperature is of the utmost importance for monitoring the water regime of plants (Wang et al., 2010) and scheduling irrigation (Jones and Ilkka, 2003).

Associated with the leaf-transpiration process, there is a phenomenon known as 'evaporative cooling' whereby heat is dissipated by water-vapor loss from the stomata. With lower transpiration levels, the evaporative-cooling process is significantly reduced, typically raising the leaf temperature several degrees above the air temperature (Jones, 1999; Jones et al., 2002; Araus et al., 2008; Fuentes et al., 2012). These relationships establish the basis for monitoring the plant water status based on leaf/canopy temperature, since any situation that causes partial closing of the stomata (due to more or less prolonged water stress) will result in a significant rise in leaf temperature. Therefore, leaf temperature can be used as an indicator of the degree of water stress with the advantage that it can be remotely measured and in plants of different sizes under field as well as controlled conditions.

Thermal imaging is a rapid and non-destructive technique that uses leaf temperature as a component of crop water status related to water

availability (Chaerle et al., 2004, 2007; Jones, 2004; Nilsson, 1995; Costa et al., 2013). Therefore, it can be used for irrigation scheduling, as applied for several crops such as grapevine (Möller et al., 2007; Grant et al., 2006; Grant et al., 2007; Jones et al., 2002), olive trees (Ben-Gal et al., 2009) or citrus (García-Tejero et al., 2011b). However, according to Jones et al. (2009) and Jones and Vaughan (2010), there are many variables that determine the ultimate leaf temperature, which need to be taken into account when assessing the crop-water status using leaf temperature values. Variables such as the radiation level, air temperature, vapor-pressure deficit, relative humidity or the angle of radiation incident on the leaf surface decisively influence the absolute value of the leaf/canopy temperature. To optimize the use of leaf temperature, various stress indexes have been developed with the aim of minimizing the effect of these variables in studies related to crop temperature and its correlation with the water-stress response. These indexes try to normalize the absolute values of temperature, providing a second value at which the effects of this set of potentially influential variables are partially minimized. Among these indexes, the Tc-Ta index (difference between leaf/canopy and air temperature) would be the most 'user-friendly' because it is only necessary to know the absolute value of air temperature at the time of measurement. This index was applied in the present study.

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The canopy surface temperature measured with infrared thermometers (IRTs) or other remote infrared sensors provides an important tool for detecting crop water stress, which has been the practice for decades. The crop water stress index (CWSI) is the most often used index to quantify crop water stress based on canopy surface temperature. Many investigations have been undertaken to evaluate the application of CWSI in irrigation scheduling for different crops at different locations (Barnes et al., 2000; Alderfasi and Nielsen, 2001).

Kaolin-based particle film technology (Pft) has been developed over the past 15 years as a multi-functional and environment-friendly material that ensures effective insect control, mitigates heat stress, and contributes to the production of high-quality fruit and vegetables. It is also suitable for organic farming (Glenn and Puterka, 2005).

Originally, kaolin (Surround® WP) was developed for the suppression of pests in many crops (Pace and Cantore, 2009). It has been demonstrated that the white kaolin film formed on the leaf surface increases the reflection of incoming solar radiation, changing the radiation and heat balance and reducing the risk of leaf and fruit damage from high temperatures and solar injury (Glenn, 2012). The application of kaolin reduces the temperature of the crop and may thus increase the average fruit mass (tomato (Cantore et al., 2009); peach (Lalancette et al., 2005); orange (Saleh and El-Ashry, 2006)) and improve some of its qualitative features, such as color, total soluble solids, lycopene and anthocyanin concentrations (apple (Glenn et al., 2001; Wand et al., 2006); tomato (Pace et al., 2007); pomegranate (Melgarejo et al., 2004; Yazici and Kaynak, 2009); mango (Chamchaiyaporn et al., 2013) and red wine grape (Shellie and King, 2013a, b)), or reduce sunburn and the adverse impact of soil salinity (Boari et al., 2015).

The objective of this study was to investigate how the application of kaolin and different irrigation regimes affect the canopy temperature of pepper and tomato and whether irrigation can be reduced and water saved by the application of kaolin.

## 2. Materials and methods

### 2.1. Experimental setup

The experiment was conducted over a period of three years (2011, 2012 and 2013), in an experimental field of the Napredak AD farm in Stara Pazova. The soil is of the carbonate chernozem type. The town of Stara Pazova (44° 59' N; 19° 51' E; alt. 80 m) is located 40 km north of Belgrade, Serbia. Three irrigation regimes in the sweet pepper experiment, two irrigation regimes in the tomato experiment, and two kaolin treatments of both plants were compared. The pepper irrigation regimes were: i) full irrigation (F) ensuring 100% of crop evapotranspiration (ETc), ii) deficit irrigation at 80% ETc (R1), and iii) deficit irrigation at 70% ETc (R2). The two tomato irrigation regimes were: i) full irrigation (F), covering 100% of ETc, and ii) deficit irrigation (D) at 50% of ETc. The kaolin treatments of both plants included: i) a control without kaolin (C), and ii) treatment with kaolin (K). The setup was a two-factorial, completely random block system, with three replications. The first factor was the irrigation regime and the second the kaolin application.

The pepper cv *Elephant Ear* (paprika) was transplanted in paired rows on 19 May 2011, 18 May 2012 and 20 May 2013. The space between the rows was 0.5 m, and between the plants in a row 0.3 m. The center distance between two paired rows was 1.5 m. There were a total of six rows (three paired rows), such that the entire study area occupied 1800 m<sup>2</sup>.

The tomato was of the determinate type, *Rio Grande* cultivar. It was transplanted in paired rows on 18 May 2011, 19 May 2012 and 20 May 2013. The space between the rows was 0.5 m, and between the plants in a row 0.3 m. The center distance between two paired rows was 1.5 m. Each treatment covered five rows, 20 m long. The stand density was 30,000 plants per hectare. The size of the entire study area was 1200 m<sup>2</sup>. In both treatments the soil in the paired rows, under the plants, was

covered with black plastic mulch. Buffer rows of both pepper and tomato were planted along the perimeter to reduce any impact of adjacent plots.

### 2.2. Irrigation regime

Tomato and pepper were irrigated immediately after transplanting by the drip method, up to the field capacity. After that, no irrigation was applied for 7 days, to ensure better rooting. Then, over 30 days all treatments received the same amount of water, from either rainfall or irrigation. Afterwards, irrigation differed by treatment (tomato: 100% of ETc (F) and 50% of ETc (D); pepper: 100% of ETc (F), 80% of ETc (R1) and 70% of ETc (R2)). Irrigation was applied up to the end of the growing season (until the last harvest). The irrigation depth was the same (18 mm) in all the treatments, but the irrigation interval differed. The irrigation frequency depended on current climate conditions (amount and distribution of rainfall and ETc) and was three days for FC and FK and six days for DC and DK for tomato, and three days for FC and FK, four days for R1C and R2K and six days for R2C and R2K for pepper.

### 2.3. Application of kaolin

The application of kaolin began after the phase of intensive growth. Kaolin was applied to both plants three times in 2012 and four times 2013. The interval between the applications was 15 days. In 2011, kaolin was applied to pepper seven times and to tomato five times. This was necessitated by several heavy rainfall events in July, during which the kaolin suspension was washed away from the plants (Table 1).

### 2.4. Measurement of canopy temperature

Canopy temperature measurements were carried out with an infrared camera (FLIR, T335) seven times over three years for pepper, and for tomato seven times during the growing seasons of 2011 and 2013 and six times in 2012. To obtain a representative average canopy temperature, 15 spots were analyzed by FLIR Quick Report 1.2 SP2 for every irrigation and kaolin treatment. At the beginning of the experiment the water-air and physical soil properties were analyzed to determine total available soil water throughout the soil profile. During the growing season, soil moisture was measured by the gravimetric method at 7-day intervals, up to 0.6 m every 0.2 m. Detailed climate and soil characteristics of the experiment are available in Ćosić et al. (2015).

Air temperature data were taken from the meteorological station located near the experimental field (Table 2).

According to Idso's definition (Idso et al., 1981), CWSI can be expressed as:

$$CWSI = \frac{(T_c - T_a) - D_2}{D_1 - D_2} \quad (1)$$

where:  $D_1$  is the maximum canopy/air temperature difference of a

**Table 1**  
Kaolin application.

Years			
2011		2012	2013
Pepper	Tomato	Pepper and tomato	Pepper and tomato
5 July	5 July	9 July	3 July
8 July	8 July	26 July	18 July
21 July	21 July	12 August	31 July
27 July	27 July		15 August
11 August	11 August		
26 August			
9 September			

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