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Effect of irrigation regime and application of kaolin on yield, quality and water use efficiency of sweet pepper

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ABSTRACT

The present paper reports research that focused on the effect of kaolin on the yield, quality and water use efficiency of the sweet pepper *Capsicum annuum* L., grown under different irrigation regimes. The research was conducted in an open field with carbonate chernozem soil, at Stara Pazova (40 km north of Belgrade, Serbia). It lasted for three years (2011, 2012, and 2013). Three irrigation regimes and two kaolin treatments were compared. The 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 kaolin treatments were: (i) control without kaolin (C) and (ii) treatment with kaolin application (K). The setup was a two-factorial, completely random block system, with three replications. The first factor was the irrigation regime and the second kaolin application.

On average, the highest fresh sweet pepper yields were achieved under full irrigation (10 kg m^{-2}). Also, FC and FK treatments resulted in the highest first-class, second-class and first + second class yields. On average, the lowest percentage of sunburn was noted in the case of the FK treatment (10%), and the highest with the R2C treatment (about 27%). The sugar content of the pepper was quite consistent, while the organic acid content varied from 15.0 mL g^{-1} with R1C to 18.7 mL g^{-1} with FK. The application of kaolin and the irrigation regime did not have a statistically significant effect on the antioxidant activity of the pepper and ranged from 5538.4 to 6447.4 μmol TU g^{-1}. The highest yield water use efficiency (yWUE) of first-class and first + second class yields was recorded with the FC, FK and R1C treatments. Throughout the study period, yWUE levels of the second-class yields, and of the total yield, were rather uniform, regardless of the type of treatment.

1. Introduction

Population growth on the planet Earth and global climate change require constant research and discoveries that will ensure the production of healthy food with limited natural resources, such as soil and water. One of the ways to mitigate drought, as well as save water, in agriculture is to apply deficit irrigation (DI), with the objective of reducing the irrigation water demand, increasing water use efficiency (WUE) and optimizing yields (Saleh, 2010; Topcu et al., 2007). DI involves pre-programmed exposure to a certain level of water stress, either during a specific period or throughout the growing cycle. It reduces yields but at the same time results in water saving and increases WUE (Pereira et al., 2002). The effect of DI on yields and fruit quality depends on the type of crop, agronomic practices, evapotranspiration rate, type of soil and available soil moisture. Before a decision is made to apply DI, it is important to assess its impact on different crops, based on long-term experimental research (Scholberg et al., 2000; Igbadun et al., 2008). At a moderate water deficit, vegetable crops like the sweet pepper (Kang et al., 2001), tomato (Topcu et al., 2007), eggplant (Kirnak and Demirtas, 2006) or cucumber (Mao et al., 2003), improved WUE proportionally to yield and fruit mass losses. Extensive research has been conducted to study the variation in sweet pepper yield as a function of water stress, corroborating a considerable decline in yield as the water deficit increased (Delfine et al., 2001; Antony and Singandhupe, 2004; Sezen et al., 2006). DI should be applied in phenophases least vulnerable to water stress. In the case of crops like the sweet pepper, water stress should be avoided at flowering

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Table 1
Dates of main pepper phenophases.

Year	Transplanting	Beginning of flowering[a]	Beginning of yielding	Harvest		
				1st	2nd	3rd
2011	19 May	21 June	28 June	18 August	2 September	15 September
2012	18 May	18 June	22 June	1 August	17 August	7 September
2013	20 May	26 June	30 June	5 August	23 August	13 September

[a] The pepper flowers in stages; flowering and yielding can continue until the ground begins to freeze.

and yield formation stages. This is a very difficult task, given the length of these phenophases of most pepper cultivars (Gonzalez-Dugo et al., 2007).

Apart from DI, the application of kaolin could be one of the options for mitigating drought impact and saving water in agriculture (Boari et al., 2015). The use of kaolin creates a canopy cover (over the above-ground part of the plant and fruits), which reduces the water loss by transpiration. In addition to increasing WUE and improving fruit quality, kaolin increases the proportion of first-class yields. Treatments including kaolin also reduce sunburn to a large extent. Many researchers have noted less sunburn with kaolin, in crops like the pomegranate, apple, citrus fruits and tomato (Cantore et al., 2009; Glenn, 2012; Weerakkody et al., 2010). The application of kaolin reduces the temperature of the crop and may thus increase the average fruit mass (Cantore et al., 2009; Lalancette et al., 2005; Saleh and El-Ashry, 2006) and improve some of its qualitative features, such as color, total soluble solids, lycopene and anthocyanin concentrations (Glenn et al., 2001; Pace et al., 2007; Wand et al., 2006; Melgarejo et al., 2004; Chamchaiyaporn et al., 2013; Shellie and King, 2013a,b; Yazici and Kaynak, 2009). It should also be noted that kaolin is a natural substance used in organic farming, such that crops treated with kaolin can readily be consumed. Boari et al. (2013) monitored the effect of kaolin on various crops (tomato, pepper, zucchini, eggplant, beans and clementine). Their results indicate that kaolin exhibited the greatest effect by reducing stomatal conductance, which contributed to decreased transpiration, improved plant water status and lower net assimilation. In addition to performing well in pest control and heat stress mitigation, kaolin can effectively be used as an antitranspirant to reduce the effect of heat stress and salinity, and to save water (Boari et al., 2015). The application of kaolin reduced the temperature of citrus fruits by 1–6 °C, on average, which resulted in less sunburn and better crop quality (Miranda et al., 2007). The temperature of tomato fruits treated with kaolin, measured on the warmest day at noon, was found to be some 3.5 °C lower than the temperature of untreated tomatoes (Pace et al., 2007; Cantore et al., 2009). Besides the varietal effect on the tomato lycopene content (Cantore et al., 2008), this important quality parameter may also improve as a result of the application of kaolin (Pace et al., 2007; Cantore et al., 2009). The application of kaolin improved the tomato's WUE, with no effect on its organoleptic properties (Lukic et al., 2012).

In view of the growing interest in water-saving agricultural techniques and a lack of information concerning the response of the pepper to the combined effect of DI and kaolin application, the objective of the present research was to study the effect of different irrigation regimes and the application of kaolin on the yields, quality and WUE of sweet pepper.

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 a.s.l.) is located 40 km north of Belgrade, Serbia. Three irrigation regimes and two kaolin treatments were compared. The 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 kaolin treatments were: (i) control without kaolin (C) and (ii) treatment with kaolin application (K). The setup was a two-factorial, completely random block system, with three replications. The first factor was the irrigation regime and the second 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. Each treatment covered six rows (three paired rows), 20 m long. Buffer rows of the pepper were planted along the perimeter to reduce any effect of adjacent plots. Each treatment covered an area that was 10 m wide and 20 m long ($10 \times 20 = 200\ m^2$), such that the entire study area occupied $1800\ m^2$. The soil in the paired rows, under the plants, was covered with black plastic mulch. Table 1 shows the phenophases of the sweet pepper during the study period.

The soil in the study area is of the carbonate chernozem type, developed in loess. Its morphological, hydrophysical and agrichemical properties are conductive to farming. The quality of this soil is founded upon its cross-sectional depth, mechanical composition with nearly equal proportions of sand, silt and clay fractions, good texture – clayey loam (USDA, 2006), and superior physical and chemical properties (Table 2). It is a deep soil, whose water storage capacity is high and where roots can spread arbitrarily and draw moisture and nutrients from a considerable depth. Water available in the active part of the pepper's rhizosphere (0.5 m) amounted to 86.5 mm. Table 2 shows the physical, chemical and hydrological characteristics of the soil in the study area.

The climate is continental, with Central European and Mediterranean components. The annual precipitation average over the past 20 years is 637 mm (maximum 911 mm and minimum 352 mm). The average precipitation total during the growing season (from April to September) is 366 mm (maximum 663 mm and minimum

Table 2
Main physical, chemical and hydrological characteristics of the soil in the study area.

Soil parameters	Unit	
Particle – size analysis		
Total sand (2 > Ø > 0.02 mm)	$g\ 100\ g^{-1}$	33.1
Clay (Ø < 0.02 mm)	$g\ 100\ g^{-1}$	30.9
Silt (0.02 > Ø > 0.002 mm)	$g\ 100\ g^{-1}$	36.0
Chemical properties		
Total nitrogen	$g\ 100\ g^{-1}$	2.03
Available phosphorus	$mg\ 100\ g^{-1}$	31.4
Exchangeable potassium	$mg\ 100\ g^{-1}$	15.8
Humus	$g\ 100\ g^{-1}$	3.32
Total limestone	$g\ 100\ g^{-1}$	6.6
pH (pH in H_2O)		8.3
pH (pH in KCl)		7.4
Hydrological properties		
Field capacity	$cm^3\ cm^{-3}$	31.3
Wilting point (−1.5 MPa)	$cm^3\ cm^{-3}$	14.0
Bulk density	$kg\ dm^{-3}$	1.1