Djurović, N., Ćosić, M., Stričević, R., Savić, S., Domazet, M. (2016). Effect of irrigation regime and application of kaolin on yield, quality and water use efficiency of tomato. In Scientia Horticulturae, Elsevier, Amsterdam., 201, 271-278.

https://doi.org/10.1016/j.scienta.2016.02.017conv_5711

Effect of irrigation regime and application of kaolin on yield, qualityand water use efficiency of tomato

Nevenka Djurović[a,*], Marija Ćosić[a], Ružica Stričević[a], Slađana Savić[b], Milka Domazet[c]

[a] *University of Belgrade, Faculty of Agriculture, Nemanjina 6, 11080 Zemun, Serbia*
[b] *Faculty of Biofarming, John Naisbitt University, Marsala Tita 39, 24300 Backa Topola, Serbia*
[c] *Electric Power Industry of Serbia, Vojvode Stepe, 412, Beograd, Serbia*

Keywords:
Morphological properties, Biochemical quality,
Crop evapotranspiration, Deficit irrigation

A b s t r a c t

Modern agriculture is faced with two tasks: (1) to produce enough food for a growing global population, and (2) to ensure satisfactory crop quality while using water resources efficiently. A study of the effect of kaolin on the yield, quality and water use efficiency of tomato (*Lycopersicon esculentum* Mill.), grown under different irrigation regimes, is reported in the paper. 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). The experimental 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. Two irrigation treatments were studied: (a) full irrigation (F), covering 100% of ETc (crop evapotranspi- ration), and (b) deficit irrigation (D) at 50% of ETc. The kaolin treatments were: (a) control treatment, without kaolin (C) and treatment with a 5% suspension of kaolin (K).

On average, the highest fresh tomato fruit yields were achieved under full irrigation, with kaolin (FK) (21.0 kg m^{-2}). The FK treatment also resulted in the greatest dry weight of the fruits (1.1 kg m^{-2}). The average fruit weight was rather uniform and ranged from 71.7 g with DC to 75.4 g with DK. The average sugar and lycopene content was quite uniform over the study period, while the irrigation regime had a significant effect on the average organic acid content and total antioxidant activity. Deficit irrigation treatments resulted in a higher organic acid content and higher total antioxidant activity than full irriga- tion. The application of kaolin had a greater effect of the water use efficiency of tomato than the irrigation treatment.

Introduction

Under climate change conditions, lack of precipitation becomes a limiting factor for farming. Serbia experiences drought nearly every year, to a greater or lesser extent. Given that water is a limited resource, there are numerous research projects aimed at devising various water saving approaches and measures, while achieving economically viable yields. Deficit irrigation and the application of kaolin could mitigate climate change/drought impact and save water in agriculture (Boari et al., 2015).

A deficit irrigation (DI) strategy exposes crops, in a pre- programmed manner, to some water stress during a certain period of time or over the entire growing season. This reduces yields but saves water and increases water use efficiency (English and Raja, 1996; Fereres et al., 2003; Ferreira and Carr, 2002; Pereira et al., 2002; Perry et al., 2009; Steduto, 2006; Steduto et al., 2007; Topcu et al., 2007). Mild deficit irrigation of tomato tends to improve root development (Marouelli et al., 2004; Marouelli and Silva, 2007; Shahnazari et al., 2007), as roots reach greater depths for water uptake. With deficit irrigation, vegetable crops, such as tomato (Topcu et al., 2007), sweet pepper (Kang et al., 2001), eggplant (Kirnak and Demirtas, 2006) or cucumber (Mao et al., 2003), improve water use efficiency proportionally to yield and fruit weight losses. In regions with sparse water resources, higher water productivity is more cost-effective for farmers than the achievement of high yields (Pereira et al., 2002). The water demand of tomato (*Lycopersicon esculentum* Mill.) is high, such that DI can save significant amounts of irrigation water (Costa et al., 2007).

According to Glenn and Puterka, (2005), the application of a kaolin-based particle film over the canopy improves fruit quality, controls some pests, and reduces heat stress. The kaolin creates a canopy cover (over the above-ground part of the plant and fruits), which reduces water use. Many research reports highlight the favorable effect of kaolin on sunburn, such as in the case of pomegranate, apple, walnut, citrus fruits and tomato (Boari et al., 2015; Cantore et al., 2009; Glenn, 2012; Pace et al., 2007; Saavedra Del et al., 2006; Weerakkody et al., 2010).

The reduction in crop temperature with the application of kaolin can increase the average fruit weight (Cantore et al., 2009; Lalancette et al., 2005; Saleh and El-Ashry, 2006) and improve some fruit properties, such as color, total soluble solids, vitamin C content, and anthocyanin concen- tration (Chamchaiyaporn et al., 2013; Glenn et al., 2001; Melgarejo et al., 2004; Shellie and King, 2013a, 2013b; Wand et al., 2006; Yazici and Kaynak, 2009). It should be noted that kaolin is a natural sub- stance, used in organic farming, such that treated crops can readily be consumed. Boari et al. (2014) studied the effect of kaolin appli- cation to tomato gas exchange. Their results indicate that kaolin had the greatest effect in reducing stomatal conductance, which decreased transpiration, improved the plants' water status, and reduced net assimilation. Moreover, the same authors underline that in pest control and heat stress mitigation, kaolin can effec- tively be used as an anti-transpirant, to reduce the effects of drought stress and soil salinity, and to conserve water in arid regions such as the Mediterranean. Kaolin decreases citrus fruit temperate by 1 to 6 °C, on average, and thus reduces sunburn and improves fruit quality (Miranda et al., 2007). The temperature of kaolin-treated tomatoes at noon on the warmest day was about 3.5 °C lower than that of untreated tomatoes. The application of kaolin increases the lycopene content of tomato fruits and thus improves their quality (Cantore et al., 2008; Pace et al., 2007; Saavedra Del et al., 2006), as well as results in a considerable WUE increase, with no effect on the organoleptic properties of the fruits (Lukic et al., 2012).

The objective of the present research was to study the effect of kaolin on the yield, fruit quality and water use efficiency of tomato grown under different irrigation regimes, or, in other words, to gain insight into the possibility of saving water and increasing water use efficiency.

1. Material and method

1.1. 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 (44° 59ʳ N; 19° 51ʳ E, alt. 96 m), located 40 km north of Belgrade, Serbia. 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. Two irrigation treatments were studied: (a) full irrigation (F), covering 100% of ETc (crop evapotranspiration), and (b) deficit irrigation (D) at 50% of ETc. The kaolin treatments were: (a) control treatment, without kaolin (C), and treatment with a 5% suspension of kaolin (K). These two treatments were selected because, based on past experience, unexpected rainfall events make it difficult to ensure treatment consistency with a milder deficit. The tomato was of the determinate type, Rio Grande cultivar. The tomato was trans- planted in paired rows. The space between the rows was 0.5 m, and to 18 August) in the year 2012, and 97 days in 2013 (from 20 May to 24 August). The soil in the study area is of the carbonate chernozem type, developed in loess. Its morphological,

between the plants in a row 0.3 m. The center distance betweentwo paired rows was 1.5 m. Each treatment covered five rows, 20 m long. The stand density was 30,000 plants per hectare. Buffer rows of tomato were planted along the perimeter to reduce any impact of adjacent plots. The size of the entire study area was 1200 m^2. The soil in the paired rows, under the plants, was covered with black plastic mulch. In the year 2011 the growing season of tomato lasted 87 days (from 18 May to 12 August), 92 days (from 19 May

hydrophysical and agri- chemical properties are conducive to farming. It features a great cross-sectional depth and the mechanical composition is with nearly equal proportions of sand, silt and clay fractions. The tex- ture is fine—clayey loam (USDA, 2006). It is a deep soil, whose water storage capacity is high and where roots can spread arbi- trarily and draw moisture and nutrients from a considerable depth. Water accessible in the active part of the tomato's rhizo- sphere (0.6 m) amounted to 103.62 mm. The field capacity of the tomato's rhizosphere (0.6 m) was 31.3 $cm^3\ cm^{-3}$ and the wilting point 14.0 $cm^3\ cm^{-3}$. The soil provided an average supply of nitro- gen, readily accessible phosphorus, and an abundant supply of potassium. The soil was mildly alkaline, due to the presence of carbonates whose content increased with depth.

The climate in the study area is continental, with Central Euro- pean and Mediterranean components. The annual precipitation average over the past 20 years is 637 mm (high 911 mm and low 352 mm). The average precipitation total during the growing sea- son (from April to September) is 366 mm (high 663 mm and low 193 mm). All three study years were hot, with extremely dry peri- ods in July and August. The hottest year was 2012 while 2013 was relatively mild. Fig. 1 shows average monthly precipitation totals and mean monthly air temperatures. The average air temperatures and precipitation totals in the study area during the study period are shown in Table 1.

1.2. Evapotranspiration

For an accurate assessment of water use by a certain crop in real time, evaporation and transpiration need to be addressed separately. Accordingly, ETc was determined as the product of reference evapotranspiration (ETo) and the dual crop coefficient (K_c). Reference evapotranspiration was calculated applying the FAO Penman-Monteith method. Daily values of weather parameters from a meteorological station at Surčin, in relative proximity to the study area, were used.

In D treatment, the plant was not well-supplied with water, on the one hand, such that the stress coefficient (K_s) was calculated, and on the other hand there was plastic mulch (65% coverage), such that K_e (evaporation coefficient) was reduced by 32.5% (Allen et al.,1998).

For full and deficit irrigation treatments the following formulas (1) and (2) were applied, respectively:

$$ET_c = ET_o \times (K_{cb} + K_e) \quad (1)$$

$$ET_c = ET_o \times (K_s \times K_{cb} + K_e) \quad (2)$$

where: ETc—crop evapotranspiration (mm), ETo—reference evap- otranspiration (mm), K_{cb}—basal crop coefficient, K_e—evaporation coefficient, and K_s—stress coefficient.

To accurately assess the effect of kaolin on water use, additional calculations were made applying the water budgeting method, using available rainfall, irrigation depth and soil moisture variation data.

$$ET_a = \frac{P + I \pm \Delta\theta}{n} \quad (3)$$

where: ET_a—actual evapotranspiration (mm day^{-1}), I—irrigation (mm), Δq—soil moisture variation between two measurements (mm), and n—number of days between two measurements.

Fig. 2 shows evapotranspiration by type of irrigation treatment during the study period, calculated via the dual crop coefficient.

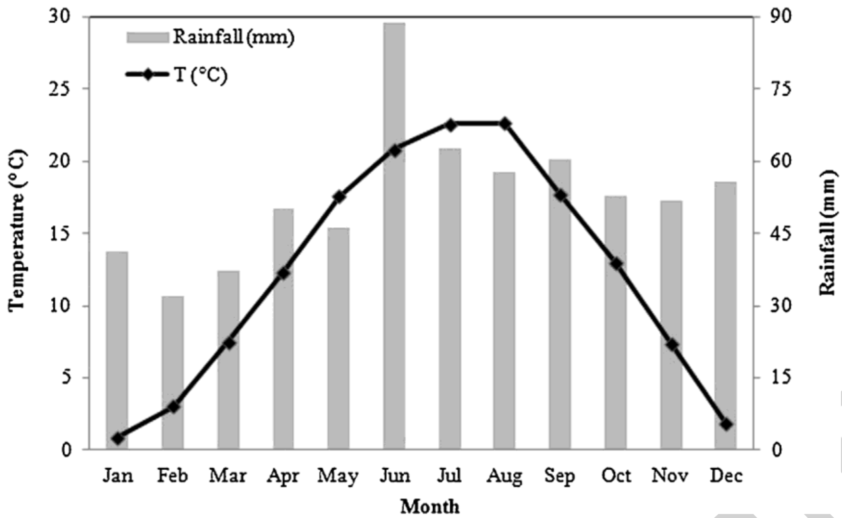

Fig. 1. Mean monthly air temperatures and precipitation totals.

Table 1
Montly mean temperature (T_{avg}) and precipitation during the growing cycles of tomato.

Month/Year	2011		2012		2013	
	$T_{avg.}$(°C)	Precipitation (mm)	$T_{avg.}$ (°C)	Precipitation (mm) (mm)	$T_{avg.}$ (°C)	Precipitation
May	16.9	94.8	17.1	75.4	18.0	98.6
June	21.3	23.0	23.3	15.8	20.3	39.2
July	23.3	41.1	25.8	18.5	22.8	13.7
August	23.7	5.3	24.7	3.6	24.1	13.3
Average/Sum	21.3	164.2	22.7	113.3	21.3	164.8

1.3. *Irrigation regime*

The tomato was irrigated immediately after transplanting by the drip method, up to 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, either from rain- fall or irrigation. Afterwards, irrigation differed by treatment (100% ETc (F) and 50% ETc (D)). 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 con- ditions (amount and distribution of rainfall and ETc) and was three days for FC and FK and six days for DC and DK. Irrigation depth varied from 162 mm in deficit treatments (DC and DK) in 2011 to 414 mm in full treatments (FC and FK) in 2012.

2.4. *Application of kaolin*

A 5% kaolin suspension (Surround WP, 95% purity) was applied from the time of flowering to the time of ripening. The above-ground part of the plant was sprayed. The 5% suspension was prepared *in situ*, immediately prior to use, and applied by means of 15 L backpack sprayers. The amount of kaolin varied depending on the plant's phenophase. In 2011, kaolin was applied five times, in 2012 three times, and in 2013 four times.

2.5. *Monitoring of soil moisture*

Soil moisture was monitored by the standard gravimetric method, every seven days. The soil was drilled and sampled by layer, at 0–20, 20–40, and 40–60 cm. Additionally, in the case of full irrigation, tensiometers were installed at a depth of 30 cm. Measurements were made to check soil moisture by type of treatment and the impact of kaolin on water use.

2.6. *Yield water use efficiency and biomass water use efficiency*

Water use efficiency (WUE) under the various irrigation treatments, with and without kaolin, was calculated from the relationship between total yields and seasonal actual evapotranspiration; YfWUE was determined for the fresh fruit yield and YdWUE for the dry fruit yield (Eqs. (4) and (5)) (Allen et al., 1998). Normalized dry biomass water use efficiency (B-WUE) was obtained by means of Eq. (6).

$$YfWUE = \frac{Yf}{ET_a} \quad (4)$$

$$YdWUE = \frac{Yd}{ET_a} \quad (5)$$

where: Yf WUE—fresh yield water use efficiency (kg m^{-3}); Yd WUE—dry yield water use efficiency (kg m^{-3}); Yf—fresh yield (kg ha^{-1}); Yd—dry yield (kg ha^{-1}); ETa—seasonal actual evapotranspiration (m^3 ha^{-1})

$$B - WUE = \frac{B}{\sum \frac{ET_a}{ET_o}} \quad (6)$$

where: B WUE—normalized biomass water use efficiency (g m^{-2}), B—total ground dry biomass (g m^{-2}), ETa—seasonal actual evapotranspiration (mm day^{-1}), and ETo—seasonal refer- ence evapotranspiration (mm day^{-1})

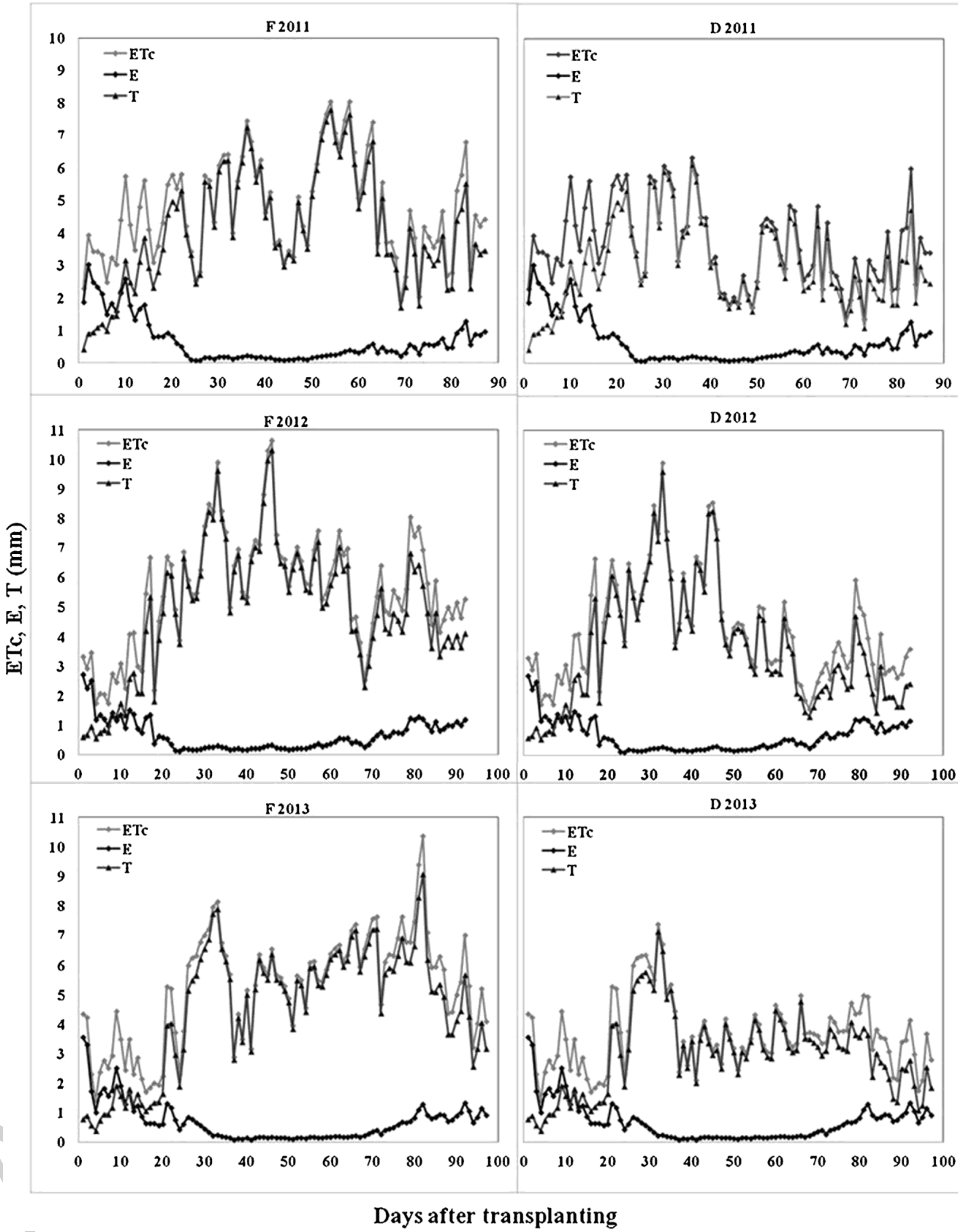

Fig. 2. Evapotranspiration by irrigation treatment, calculated via the dual coefficient: F—full irrigation, D—deficit irrigation, ETc—crop evapotranspiration (mm),E—evaporation, T—transpiration.

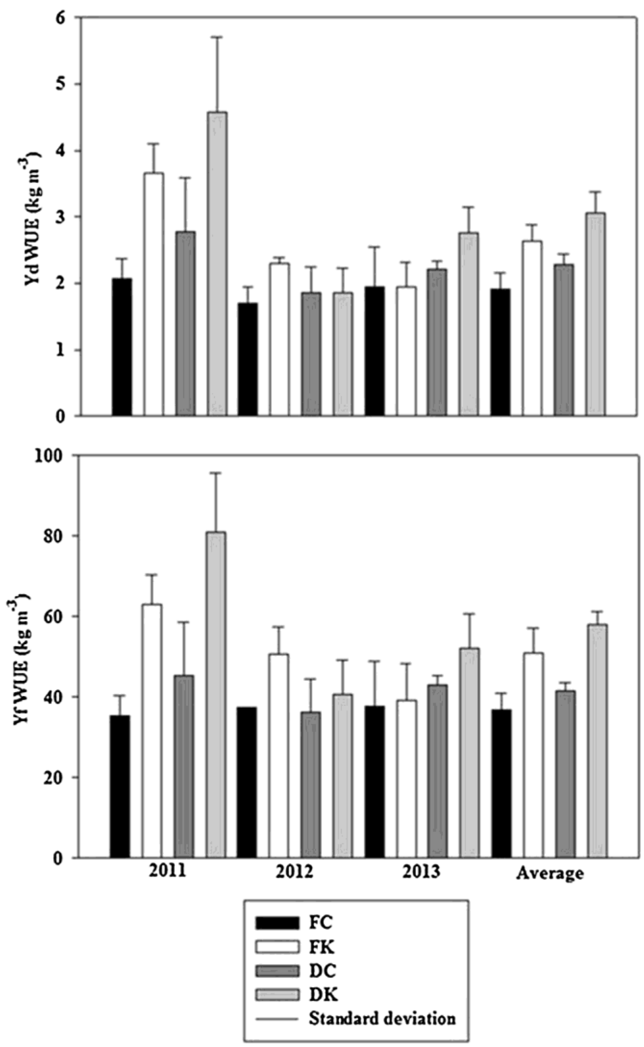

Fig. 3. Water use efficiency (WUE) of tomato: (a) dry weight (Yd WUE), (b) fresh weight (Yf WUE). FC—full irrigation without kaolin, DC—deficit irrigation without kaolin, FK—full irrigation with kaolin, DK—deficit irrigation with kaolin.

2.7. *Assessed yield parameters*

2.7.1. *Fresh fruit and biomass yield*

Three plants were selected to represent each treatment and replication, and the total fruit yield and total tomato mass were measured. Picked tomatoes were brought to the lab and weighed on a precision balance, both fruit mass per plant and plant biomass.Since three plants were sampled from each treatment and each replication, the fruit weight was summed up to arrive at the fresh fruit weight and total biomass.

2.7.2. *Morphological properties of fruits*

The morphological properties of the fruits were assessed based on their number, weight and diameter. For each treatment, fruits from the three representative plants, in three replications (a total of 36 plants), were counted. Each fruit was weighed on a preci-sion balance and the diameter measured with a digital slide rule (Plastical Ltd., UK).

2.7.3. *Biochemical quality*

Total soluble solids (°Brix) was determined by the refractometry method. Based on the NaOH demand (0.1 M NaOH), the concen-tration of organic acids was calculated and expressed in mL ofcitric acid per gram of fresh fruit weight (Dzamic, 1989). Based on absorbance, the concentration of lycopene was calculated via an extinction coefficient of 3400. The results were expressed as the concentration of lycopene in mg per kg of fresh fruit weight (Kuti and Konuru, 2005), and the total antioxidant activity (μ mol TU g^{-1}) was determined applying the method proposed by Miller et al. (1996), as modified by Böhm et al. (2002).

2.8. *Statistical analysis*

The collected experimental data were processed by statistical methods using IBM SPSS V. 20 statistical software. Each of the indicators was subjected to a statistical analysis, founded upon descriptive statistics of indicators on an annual basis (2011 to 2013 and the three-year average). The effects of the studied factors, the irrigation regimes and the kaolin application, as well as their interactions, were assessed applying the variance method for the two-factorial, completely random block system experiment. The LSD test for 5% and 1% probability was also used. In order to draw objective conclusions about the effects of the factors on the studied properties of tomato, and apply parametric tests (ANOVA and LSD), Levene's test was used to check the homogeneity of variance. The magnitude of the impact of each factor and their interactions were determined using the partial eta squared coefficient η^2, sorted according to Cohen's classification (Cohen, 1988).

2. Results

2.1. *Actual evapotranspiration*

Actual evapotranspiration was not significantly lower with kaolin than without kaolin; the difference was only 1–2%. The highest values were recorded under full irrigation conditions; they varied from 400–503 because 2011 was rather rainy, 2012 very dry and 2013 moderate. Deficit irrigation (DK) measured the lowest values, 268–386 mm. Daily ETc values varied from 2–8 mm day^{-1}, which is consistent with reports from other parts of the world(Steduto et al., 2012).

2.2. *Tomato yields, physical properties, biochemical quality and water use efficiency*

Table 2 shows the yields and morphological properties of tomato grown over the three-year period.
The average fresh tomato fruit yield with treatment F was 20.7 kg m^{-2}, or 21% higher than in the case of treatment D. The irrigation regime had a significant effect on the fresh tomato fruit yield in the three-year study period. The magnitude of this effect on the average fresh tomato fruit yield, based on the partial eta squared coefficient, was η^2 = 69%. The dry tomato fruit weight in treatment F (1.04 kg m^{-2}) was 16% higher than that in treatment D. The effect of kaolin had a significant effect on both fresh and dry tomato fruit weight. The application of kaolin resulted in 24% higher yields of fresh and 27% higher yields of dry tomato fruit yields, com-pared with kaolin-free treatments. The application of kaolin had a significant effect on the average dry biomass yield (η^2 = 54%).

On average, the greatest number of fruits per plant was recordedin 2013. The irrigation regime and the application of kaolin had a significant effect on the average number of fruits. In treatment F, the average number of fruits was 21% higher than in treatment D. Also, where kaolin was applied, the average number of fruits was 21% higher than without kaolin.

Table 3 shows the biochemical properties of the fruits and the yield water use efficiency. The lowest total soluble solids was recorded in 2011, the year with the lowest temperature sum. The irrigation regime and the application of kaolin did not have a signif-icant effect on the total soluble solids and lycopene content of the

Table 2
Effect of year, irrigation regime and application of kaolin on tomato yields, total biomass, fruit number per plant (*n*/plant) and average weight and width in the three-yearsstudy period.

Treatments	Total yield (f. w. kg m^{-2})	Total yield (d. w. kg m^{-2})	Biomass (f. w. kg m^{-2})	Biomass (d. w. kg m^{-2})	*n*/plant	Average weight (g)	Average width (mm)
Year (Y)	ns	ns	*	*	*	ns	ns
2011	18.5	1.1	3.9 **b**	0.7 **b**	69.2 **b**	88.0	49.8
2012	19.0	0.9	6.2 **a**	1.0 **a**	90.4 **a**	69.4	45.4
2013	18.0	0.9	4.8 **b**	1.0 **a**	93.5 **a**	64.7	44.3
Irrigation Regime (IR)	**	*	ns	ns	*	ns	ns
F	20.7 **a**	1.04 **a**	5.5	1.0	94.3 **a**	74.5	46.5
D	16.3 **b**	0.87 **b**	4.4	0.8	74.4 **b**	73.6	46.5
Kaolin Application (KA)	**	**	ns	*	*	ns	ns
C	16.0 **b**	0.8 **b**	4.4	0.8 **b**	74.5 **b**	72.9	46.3
K	21.0 **a**	1.1 **a**	5.6	1.0 **a**	94.2 **a**	75.1	46.7

(1) Separation of averages within columns with the LSD test ($P < 0.05$, $P < 0.01$): *F*-test not significant (ns); significant (*) ($P < 0.05$); highly significant (**) ($P < 0.01$).
f. w.—fresh weight; d. w.—dry weight; F—full irrigation; D—deficit irrigation; C—control without kaolin; K—with kaolin.

Table 3
Effect of year, irrigation regime and application of kaolin on certain qualitative features of tomato fruits (total soluble solids (TSS), organic acid and lycopene content, totalantioxidant activity) and fresh (Yf WUE) and dry (Yd WUE) yield water use efficiency.

Treatments	TSS (°Brix)	Organic acid content (mL citric acid g^{-1} f. w.)	Lycopene content(mg kg^{-1} f. w.)	Antioxidant activity (μmolTU g^{-1})	Yf WUE (kg m^{-3})	Yd WUE (kg m^{-3})
Year (Y)	*	*	ns	ns	*	*
2011	3.6 **b**	11.7 **b**	12.8	1518.8	56.2 **a**	3.3 **a**
2012	7.5 **a**	32.9 **a**	11.1	1174.4	41.2 **b**	1.9 **b**
2013	7.5 **a**	39.0 **a**	10.4	1164.0	43.0 **b**	2.2 **b**
Irrigation Regime (IR)	ns	*	ns	*	*	*
F	6,2	26.1 **b**	11.4	1053.8 **b**	43.9 **b**	2.3 **b**
D	6,2	29.7 **a**	11.5	1517.9 **a**	49.8 **a**	2.7 **a**
Kaolin Application (KA)	ns	ns	ns	ns	**	**
C	6.3	28.1	12.5	1316.5	39.2 **b**	2.1 **b**
K	6.1	27.6	10.3	1255.2	54.4 **a**	2.8 **a**

(1) Separation of averages within columns with the LSD test ($P < 0.05$, $P < 0.01$): *F*-test not significant (ns); significant (*) ($P < 0.05$); highly significant (**) ($P < 0.01$).
f. w.—fresh weight; d. w.—dry weight; F—full irrigation; D—deficit irrigation; C—control without kaolin; K—with kaolin.

fruits. The irrigation regime had a significant effect on antioxidant activity. Deficit irrigation measured higher antioxidant activity andorganic acid content.

Fig. 3 shows YWUE of dry (3a) and fresh (3b) tomato fruits over the three-year study period. Table 3 summarizes the statistical sig- nificance of the effect of the irrigation regime and kaolin application on YWUE. The highest YWUE of fresh and dry tomato fruits was recorded in 2011. The irrigation regime had a significant effect on YWUE of both fresh and dry fruits. Deficit irrigation resulted in a higher YWUE than full irrigation. Kaolin had a significant effect on YWUE of both fresh and dry tomato fruits. Treatments with kaolin had a significant effect on YWUE ($P < 0.01$) of fresh and dry fruits, compared to kaolin-free treatments.

Table 4 shows the normalized biomass water use efficiency (B-WUE) of tomato during the study period, by treatment. The B-WUEvalues were higher in all irrigation treatments with kaolin.

3. Discussion

The results of the present study indicate that deficit irrigation significantly reduced fresh and dry tomato fruit yields. Fresh tomato fruit yields in treatment D were 21% lower but 28% less water was used for irrigation. This is consistent with the results reported by other authors (Chen et al., 2014; Kirda et al., 2004; Kuscu et al., 2014,). In Serbia, similar findings in the case of tomato were presented by Savic et al. (2008), who state that deficit irri- gation (50% of field capacity) reduced yields by 23% and fresh biomass by 32%. The application of kaolin was found to increase both fresh and dry tomato fruit yields, by 24% and 27%, respectively. Similar results were reported by Pace et al. (2007). With regard to fruit quality, it should be underscored that the organic acid content and antioxidant activity were higher in the case of deficit irrigation. These results concur with Buttaro et al. (2015); Mitchell et al. (1991), Pek et al. (2014) and Zheng et al. (2013), whoreported reduced antioxidant activity and the deterioration of cer- tain fruit quality parameters as a result of greater water supply. Similar findings were described by Cahn et al. (2001), who recom- mend deficit irrigation up to 70–85% of the crop's ET as a sound compromise between tomato yield and quality, while Patane et al. (2011) propose deficit irrigation at 50% of ETc during the entire growing season, as a trade-off between water saving, WUE increaseand fruit quality of tomato.

The irrigation regime and the application of kaolin did not have a significant effect on the total soluble solids and lycopene content of the tomato fruits. This is not consistent with the findings of Cantore et al. (2009) and Saavedra Del et al. (2006), who reported lycopene concentration increases with kaolin treatments from 16% to 21%. These differences are likely attributable to envi- ronmental conditions, given that their research was undertakenin areas that feature higher air temperatures, which contributed to reduced lycopene concentrations in the case of kaolin-free controls, such that there was a larger difference between the kaolin treatments and control treatments, compared to the presentresearch.

Table 4
Normalized biomass water use efficiency (B-WUE) of tomato.

Treatment	2011 B-WUE ($kg\,m^{-3}$)	2012 B-WUE ($kg\,m^{-3}$)	2013 B-WUE ($kg\,m^{-3}$)	Avg. B-WUE ($kg\,m^{-3}$)
FC	13.63	22.90	16.94	17.70
FK	20.74	29.55	20.42	23.16
DC	14.83	22.22	19.20	18.84
DK	21.20	25.15	22.19	22.84

FC—full irrigation without kaolin; FK—full irrigation with kaolin; DC—deficit irrigation without kaolin; DK—deficit irrigation with kaolin.

Full irrigation yielded the largest number of tomato fruits. The kaolin treatments also resulted in a larger number of tomato fruits, relative to the treatments without kaolin. Neither the irrigation regime nor the application of kaolin had a significant effect on the average tomato fruit weight or diameter, which is consistent with the results reported by Patane and Cosentino, (2010), Favati et al. (2009), Topcu et al. (2007), Zheng et al. (2013), and Savic et al. (2008).

Deficit irrigation resulted in higher water use efficiency of both fresh and dry tomato fruits, compared to full irrigation. This is consistent with the research results of deficit irrigation in Turkey (Onder et al., 2005; Topcu et al., 2007) and Italy (Patane and Cosentino, 2010; Patane and Saita, 2015), as well as China, from where Wang et al. (2015) report very similar WUE for full and deficit irrigation. Also, kaolin treatments resulted in higher YWUE than kaolin-free treatments. On average, the highest B-WUE was achieved with treatment DK (22.48 kg m^3). Boari et al. (2015) and Lukic et al. (2012) arrived at similar conclusions, that deficit irrigation with kaolin increased both YWUE and B-WUE. The average values of B-WUE varied from 17.7 for FC to 23.16 kg m^3 for FK, which is consistent with the results reported from Spain (Battilani, 2006).

4. Conclusion

The results of the present research indicate that the highest tomato fruit yields were achieved with full irrigation. The application of kaolin resulted in fresh tomato fruit yields that were 24% higher than in kaolin-free treatments.

Different irrigation treatments and kaolin did not have an adverse effect on the organoleptic properties of tomato. Consequently, the fruit quality of the studied cultivar (Rio Grande), does not change in the event of water deficit.

Deficit irrigation and the application of kaolin increased both YWUE and B-WUE. Deficit irrigation increased YWUE by about 12%, relative to full irrigation. The application of kaolin increased YWUE by 28%, compared to kaolin-free treatments.

Given the above yields and YWUE under DK conditions, it appears that water use efficiency of tomato can significantly be increased with deficit irrigation, applying a 5% kaolin suspension, and that about 30% (about 100 mm) of water can be saved.

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