academicJournals

Vol. 10(44), pp. 4117-4125, 29 October, 2015
DOI: 10.5897/AJAR2015.10341
Article Number: EC9F86656025
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Supplemental irrigation levels in bell pepper under shade mesh and in open-field: Crop coefficient, yield, fruit quality and water productivity

Richard Alberto Rodríguez Padrón[1]*, Jerson Vanderlei Carús Guedes[2], Alexandre Swarowsky[3], Cicero Urbanetto Nogueira[4], Roxanna Rosales Cerquera[4] and Juan Carlos Díaz-Pérez[5]

[1]Center of Rural Science, Federal University of Santa Maria, Campus Camobi, Santa Maria, RS, Brazil.
[2]Department of Phytosanitary Defense, Federal University of Santa Maria, Santa Maria, RS, Brazil.
[3]Department of Environmental Engineering, Franciscan University, Santa Maria, RS, Brazil.
[4]Polytechnic School of the Federal University of Santa Maria, Santa Maria, RS, Brazil.
[5]Department of Horticulture, University of Georgia, 2360 Rainwater Road, Tifton, GA 31793.

Received 24 August, 2015; Accepted 18 September, 2015

This study aims to evaluate the effects of supplemental irrigation in bell pepper crop under shade mesh and in open-field to improve management of water resources. The experimental design was a randomized complete block with four replications and ten treatments in factorial arrangement (five irrigation levels combined with two shade levels). Irrigation treatments were 0.25, 0.50, 0.75 and 1.0 rate of crop evapotranspiration and the control (no supplemental irrigation). Shading treatments were 0 and 50% reduction of photosynthetically active radiation, compared to open field conditions. Crop coefficient was influenced by rainfall, especially during initial growth stage period when it was high and Kc values were 0.71, 1.17, and 0.92. Treatments under shade and open-field had no significant interaction effect, alike between the years of study. The yield in open-field and under shade mesh showed better performance in 0.75 and 0.50 of ETc, respectively. Maximum water productivity and irrigation water productivity was obtained in open-field and deficit irrigation plots. Under shade, highest fruit quality was obtained; heavier fruits, less dry matter, no sunscald and increasing value added to production. Comparing water consumption in open-field and shading, it can be obtained up to 14 to 25% water saving, significantly improving yield and fruit quality.

Key words: *Capsicum annuum*, dual crop coefficient, drip irrigation, strategies for efficient irrigation.

INTRODUCTION

Bell pepper (*Capsicum annuum* L.) is a member of the Solanaceous family, native to Mexico, Central America and northern South America (Echer et al., 2002; Filgueira, 2003). It is an important crop in many parts of the world, given their economic importance, ranking second in world production. Major producing countries

*Corresponding author. E-mail: rarpadron@gmail.com, richardpadron@mail.ufsm.br. Tel: (+55) 5532208158.

Table 1. Monthly climatic data of the experimental area during the 2013-2014 and 2014-2015 seasons.

Month	Relative humidity mean (%)		Insolation (hour)		Evaporation (mm)	
	2013-2014	2014-2015	2013-2014	2014-2015	2013-2014	2014-2015
Nov	71.60	71.0	229.2	173.1	144.5	131.8
Dec	69.45	76.1	286.2	211.0	175.2	142.2
Jan	73.15	78.3	219.2	212.4	158.3	142.0
Feb	73.79	79.7	211.2	218.0	137.9	123.9
Mar	76.87	77.6	212.6	208.4	112.8	114.1
Sum	-	-	1376.8	1189.6	850.8	804.7

are China, Mexico, Turkey, Indonesia, Spain and United States (FAOSTAT, 2013). It is considered one of the ten species of greatest economic importance in the Brazilian vegetable market. The area cultivated annually is about 13,000 ha, with fruit production close to 290,000 t, generally grown in open field (Marouelli and Silva, 2012).

The widespread lack of water for agricultural production has led to frequent need for strategies aimed at optimizing the efficiency of its use (Padrón et al., 2014). The strategy to ensure food supply to the world population for the next 25 years inevitably includes a parallel increase in agricultural production. A large part of this effort is relayed on irrigation; therefore the big challenge is to improve the efficiency and performance of agriculture, water and energy from existing irrigated fields (Mukherji and Facon, 2009; Melgarejo and López, 2012). The scarcity of water resources necessitates appropriate management and use of the available water, given that the agricultural sector is one of the activities that demand more water (Albuquerque et al., 2012). Therefore, techniques to minimize consumption of irrigation water and increase yield with water use efficiency are necessary.

Temperature affects the vital functions of plants such as germination, transpiration, respiration, photosynthesis, growth and flowering (Goto and Tivelli, 1998). Therefore, planting in a protected environment may reduce the effects of temperature to the plant (Santos et al., 2009). In agriculture, the use of shade mesh has increased to attenuate the flux of solar radiation received by the crop (Pezzopane et al., 2004). Excess radiation, usually accompanied by high temperatures can cause damage as: flower abortion; reduced yield and incidence of fruit physiological disorders such as: blossom end, rot and sunscald causing significant loss (Espinoza, 1991; Olle and Bender, 2009). Also, shade mesh reduces water requirements and increases the efficiency of irrigation water use (Möller and Assouline, 2007).

Effective management of water resources is the key to sustainability and profitability of the crop, thus encouraging the development of new techniques for the analysis and efficient water management. This study aims to evaluate the effects of supplemental irrigation levels in bell pepper crop yield and water use efficiency under shade mesh and in open-field.

MATERIALS AND METHODS

This field study was conducted at the experimental area of the Polytechnic School of the Federal University of Santa Maria (altitude of 110 m, and 29°41'25"S, and 53°48'42"W), during the Spring-Summer seasons of 2013-2014 and 2014-2015. The soil is classified as typical dystrophic yellow argissolo, with a loam texture (Streck et al., 2008). The climate of the region, according to the Köppen classification is subtropical humid (Cfa). According to the National Institute of Meteorology (INMET), mean annual evaporation, temperature and rainfall range from 800 to 1200 mm, 18 to 20°C and 1450 to 1650 mm, respectively. Table 1 shows the summary of the mean monthly climate data during the experiment. The insolation and evaporation in season 2013 to 2014 were higher than those in 2014 to 2015, except mean relative humidity which was reduced in 2013 to 2014. Solar radiation, evaporation, rainfall and daily temperature during the experimental period are shown in Figure 1. The monthly mean solar radiations, temperature and rainfall were higher in 2013 to 2014 than in 2014 to 2015. The daily mean temperatures in 2013 to 2014 were higher than those in 2014 to 2015 except December and March. The monthly maximum temperatures were higher in December, January and February. The rainfall cumulative was higher in 2013 to 2014 (892.8 mm) and 2014 to 2015 (834 mm); the maximum monthly rainfalls were in November and December, respectively. The monthly radiation in 2013 to 2014 was higher in December and January.

The experimental design was a randomized complete block with four replications and ten treatments in factorial arrangement (four irrigation levels combined with shade mesh). Irrigation treatments were: 25% ($I_{0.25}$), 50% ($I_{0.50}$), 75% ($I_{0.75}$), and 100% ($I_{1.0}$) rate of crop evapotranspiration (ETc) and the control [no irrigation (I_0)]. Shading treatments were 50% reduction of the photosynthetically active radiation (according to the manufacturer) and open field conditions (control, 0% shading). There were 40 experimental plots, each of 5.0 m long and 2 m wide (10 m^2), for a total area of 400 m^2, not including border plants. The variety of bell pepper was Arcade, widely used in the region. Two-month old plants were transplanted in the field, with 1.0 m separation between rows and 0.4 m between plants (density of 2.5 plants m^{-2}) on 16 November 2013 and 23 November 2014. Shade mesh (polyethylene black shade mesh) was supported with metallic cable and forming rectangular structure with the highest point at 2 m. The shade mesh was set two weeks before transplanting. The level of shading was verified by using digital radiometer (Model MS-100). Leaf temperature was measured in each plot with an infrared thermometer gun (Model: AR 320).

One drip irrigation tape was placed next to each row; emitters were spaced 0.2 m apart and had a flow rate of 0.8 L h^{-1} per

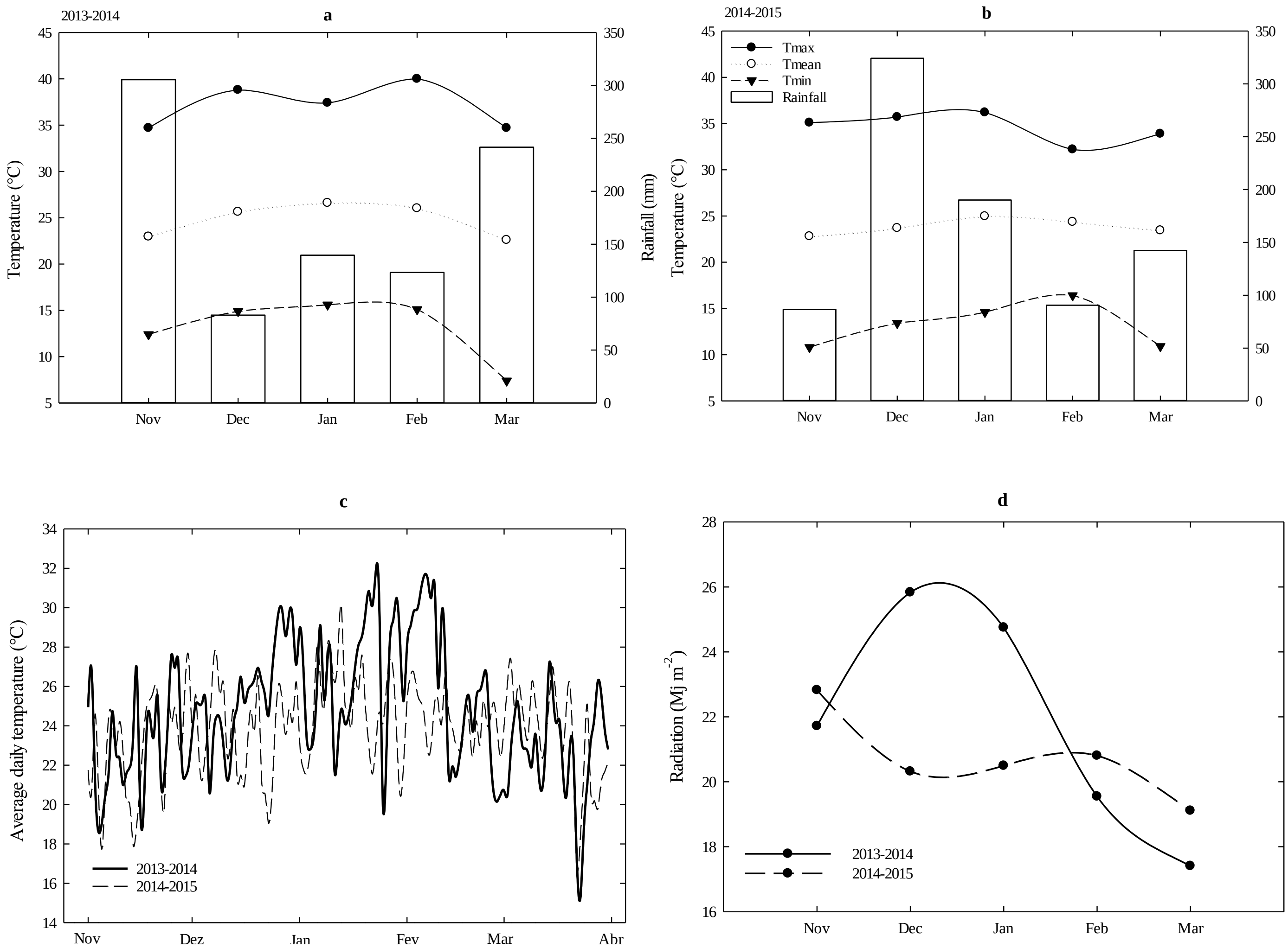

Figure 1. (a, b) Climograph of the experimental area, (c) average daily temperature and (d) radiation during the seasons 2013-2014 and 2014-2015.

emitter. In each experimental plot there was a ball valve for regulating irrigation time, pressure, and uniformity.

Irrigation strategy

During the first 20 days after transplanting 100% of crop evapotranspiration (ETc) was applied to all treatments to ensure plants establishment. Levels of supplementary irrigation were applied from 20 to 119 days after transplant and the frequency of daily watering was established. After effective rainfall exceeded reference evapotranspiration, irrigation was applied two days after the event.

Crop reference evapotranspiration (ETo) and crop evapotranspiration (ETc) were calculated using Equations 1 and 2. The use of reference evapotranspiration leads to increasing uncertainty comparing actual evapotranspiration. There are other models that can estimate evapotranspiration reference than have had successful results. Also, they are useful for selecting the best model when researchers must apply temperature-based models on the basis of available data (Valipour and Eslamian, 2014; Valipour, 2014a, b, c; Valipour, 2015a, b). Weather data were collected from an automatic weather station located 1 km from the experimental area. Crop reference evaporation was calculated based on the method of FAO Penman-Monteith (Allen et al., 2006), (Equation 1) as follows:

$$\mathrm{ETo} = \frac{0.408\,\Delta\,(Rn - G) + \gamma\,\frac{900}{T + 273}\,U_2.(e_s - e_a)}{\Delta + \gamma\,(1 + 0.34\,U_2)} \quad (1)$$

where ETo is the reference evapotranspiration (mm day^{-1}), Rn, G and T are net radiation value at crop surface (MJ m^{-2} day^{-1}), soil heat flux density (MJ m^{-2} day^{-1}) and mean daily air temperature at 2 m height (°C), respectively. Also, u_2, e_s e_a, (e_s - e_a), Δ and γ represent wind speed at 2 m height (m s^{-1}), saturation vapor pressure (kPa), actual vapor pressure (kPa), saturation vapor pressure deficit (kPa), slope of the saturation vapor pressure curve (kPa/°C) and psychrometric constant (kPa/°C), respectively.

Crop evapotranspiration (ETc) was calculated with the method of dual crop coefficients for each crop phoenological stage (Allen et al., 2006), (Equation 2) as follows:

$$\mathrm{ETc} = (K_{cb} + K_e) \times \mathrm{ETo} \quad (2)$$

where ETc is crop evapotranspiration (mm), ETo is reference crop evapotranspiration (mm) and splitting K_c into two separate

Table 2. Average soil attributes of the experimental area.

Soil layers (m)	Bulk density (g cm^{-3})	Field capacity (m^3 m^{-3})	Wilting point (m^3 m^{-3})	Water content (m^3 m^{-3})	Infiltration (mm h^{-1})	Texture
0-0.2	1.42	0.31	0.14	0.18		Loam
0.2-0.4	1.38	0.34	0.17	0.17	15.0	Clay-loam
0.4-0.6	1.36	0.37	0.23	0.13		Clay

Table 3. Crop evapotranspiration, effective rainfall and irrigation applications during two seasons in bell pepper.

Treatment	2013-214				2014-2015			
	Etc (mm)	Rainfall^Z (mm)	Irrigation^Y (mm)	Days irrigation	ETc (mm)	Rainfall^Z (mm)	Irrigation^Y (mm)	Days irrigation
I_0	-		-	-	-	543.8	-	-
$I_{0.25}$	140.1		100.4		125.2		70.4	
$I_{0.50}$	280.1	345.1	200.9	74	250.4		140.8	57
$I_{0.75}$	420.2		301.3		375.5		211.2	
$I_{1.0}$	560.2		401.8		500.7		281.5	

^{Z}Effective rainfall; ^{Y}Effective Irrigation.

coefficients, basal crop coefficient (K_{cb}) and soil water evaporation coefficient (K_e).

Before the plants were transplanted, sampling points in the experimental area were randomly selected to determine basic soil attributes, including soil texture, bulk density, field capacity, and permanent wilting point (Table 2). Also, an infiltration test of wet bulb was performed to design the irrigation system.

Soil water content over the season was measured before and after irrigation every two days (four readings per experimental plot), with a portable time domain reflectometry (TDR-100). The two metallic sensor (0.2 m rods of the TDR) were inserted vertically within the row between plants. Also soil water monitoring was performed with neutron probe (CPN Model 503, DR), with calibration previous to execution of the experiment (Padrón et al., 2015). PVC tubes (50 mm) were installed between row (1 m distance) and plant of each experimental plot at a depth of 0.7 m. Readings was performed once a week at 0.125, 0.30 and 0.50 m of soil depth.

Fruit were picked weekly during two months (60-120 day after transplanting) for yield, in both years. Fruit yield per plot was determined by harvesting 20 plants from center rows. To evaluate incidence of sunscald, number of affected fruit was determined. Fruit diameter, length and dry weight were determined at each harvest, using fruit from five plants per plot. Fruit samples were dried at 65°C until constant weight was obtained. Water productivity (WP) and irrigation water productivity (IWP) were calculated with the fresh total yield (kg ha^{-1}) divided by crop evapotranspiration (ETc) Equation (3) and total irrigation water applied Equation (4), respectively (Heydari, 2014; Molden et al., 2010), as follows:

$$\mathrm{WP} = \frac{\text{Total yield (kg ha}^{-1})}{\text{evapotranspiration (mm)}} \quad (3)$$

$$\mathrm{IWP} = \frac{\text{Total yield (kg ha}^{-1})}{\text{Irrigation water applied (mm)}} \quad (4)$$

Herbicides, fungicides and insecticides were applied as necessary. Fertigation was according to the nutritional needs of the crop and chemical analysis of the soil. Fertigation was performed with irrigation (daily) calculated to produce 40 t ha^{-1}. All plants received 368 kg ha^{-1} of a complete fertilizer (13N-14P_2O_5-13K_2O), 290 kg h^{-1} of ammonium nitrate (36% N) and 396 kg ha^{-1} of potassium nitrate (35% K_2O). Statistical analysis was performed using the SPSS software package (SPSS V17.0). Significant differences between means for different treatments were compared using Tukey test at P<0.05. Data from all years were pooled when no treatment interactions were found.

RESULTS AND DISCUSSION

Crop evapotranspiration, effective rainfall and effective irrigation are shown in Table 3. In 2013-2014, crop was irrigated 74 times and total irrigation applied was 401.8 mm. In 2014 to 2015, crop was irrigated 57 times and total irrigation was 281.5 mm. Thus, in 2014 to 2015 number of irrigations and irrigation volume were reduced. ETc in 2014-2015 was 59.5 mm lower than in 2013 to 2014. Effective rainfall was also higher in 2014 to 2015 than in 2013 to 2014.

Soil moisture and daily effective rainfall is shown in Figure 2. The 0-0.25 m soil profile presented sharp moisture decrease between irrigations. Soil moisture below 0.250 m depth remained almost constant in all treatments. Soil moisture under shade remained near field capacity and presented an average decrease of 0.02 m^3 m^{-3} when compared to treatments on open field. In general, under shade mesh soil water content was higher compared to treatments in open field. Shading reduces demand for crop evapotranspiration, causing reduction of transpiration, resulting in decreased soil water uptake in bell pepper (Díaz-Pérez, 2013; Möller et al., 2004; Kittas et al., 2009).

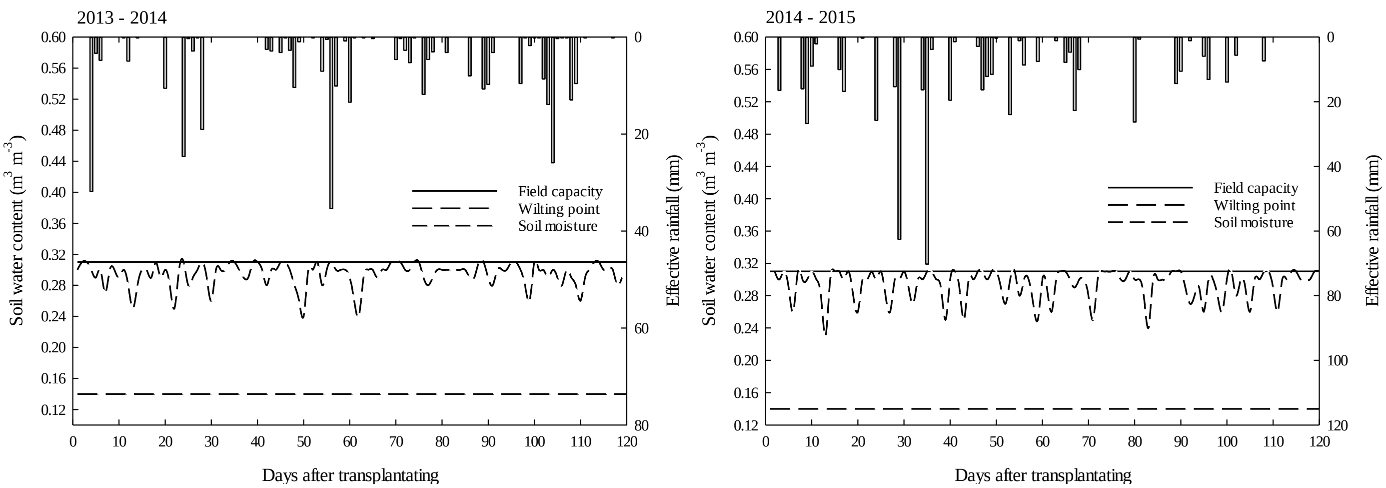

Figure 2. Soil moisture and effective rainfall. Soil moisture in the 0-0.30 cm depth layer and effective rainfall.

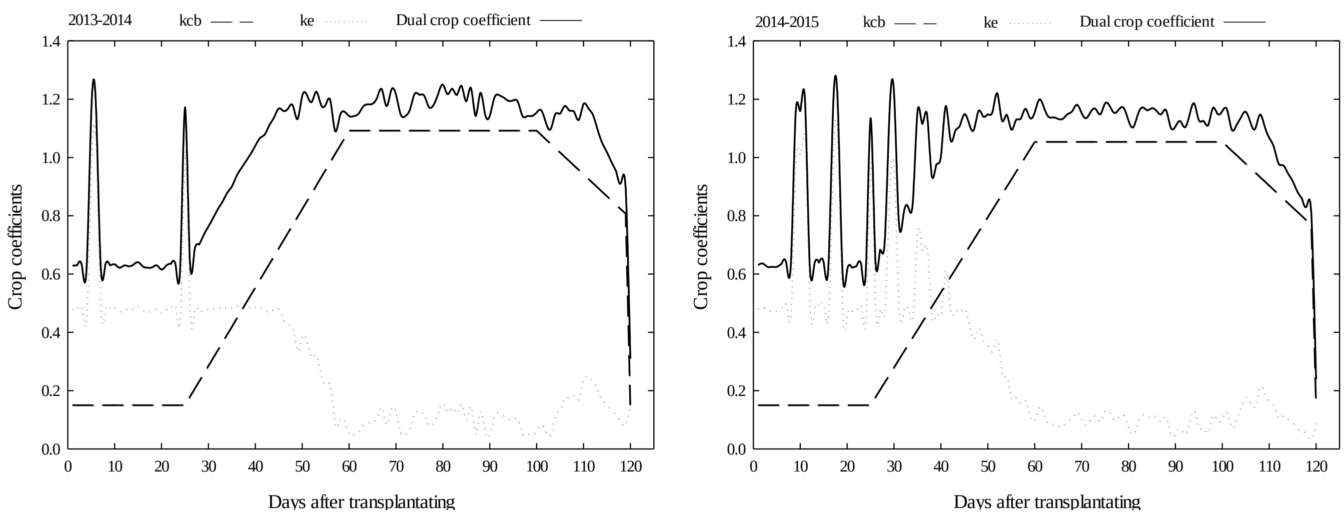

Figure 3. Dual crop coefficient for bell pepper in a sub-tropical region.

The dual crop coefficient during the study is shown in Figure 3. In both seasons, crop coefficient K_{cb} gradually increased reaching the highest values between 60 and 100 days after transplanting. Coefficient K_e was highest during the first 50 days after transplanting and then decreased. Both factors were most affected by the frequent rainfall in the 2014 to 2015 season. The biggest difference between the values of K_c and K_{cb} occurred in the initial crop growth stage where evapotranspiration was mainly composed of soil evaporation, while crop transpiration, was relatively small.

Dual crop coefficient values at different stages of bell pepper crop growth are shown in Table 4. At different stages Kc values were similar or higher than those recommended by FAO-56 values. Shukla et al. (2013) reported that early in the season Kc values were higher than those of the classic Kc curve reported in the literature (e.g., FAO-56) and increased as the crop developed until it reached maximum values at crop maturity. Due to increased water table at the time of transplanting, soil evaporation losses were higher than those of other regions leading to increased ETc and as a result increased Kc; Kc for bell pepper reached values of : Kc_{ini}=0.86, Kc_{med}=1.21, Kc_{fin}=1.28. Also, rainfall during the initial stage further increased the surface soil water content, which resulted in increased soil evaporation. Results show that Kc for pepper grown using sub-irrigation is highly dependent on the soil water content of the bare soil area. In semiarid climate, Kong et al. (2012), reported increased Kc values (Kc_{ini}=0.66-0.69; Kc_{med}=1.19-1.30; Kc_{fin}=0.89-0.93) (FAO 56).

There was no significant interaction effect for treatments

Table 4. Average of dual crop coefficients (Kc) for bell pepper irrigation in a sub-tropical region.

Crop growth stage	2013-2014	2014-2015	Average	FAO-56[z]
Initial growth	0.67	0.74	0.71	0.6
Crop development	1.03	1.05	1.04	
Mid-season	1.19	1.15	1.17	1.15
Late season	0.97	0.87	0.92	0.80

[z]Kc recommended by FAO-56.

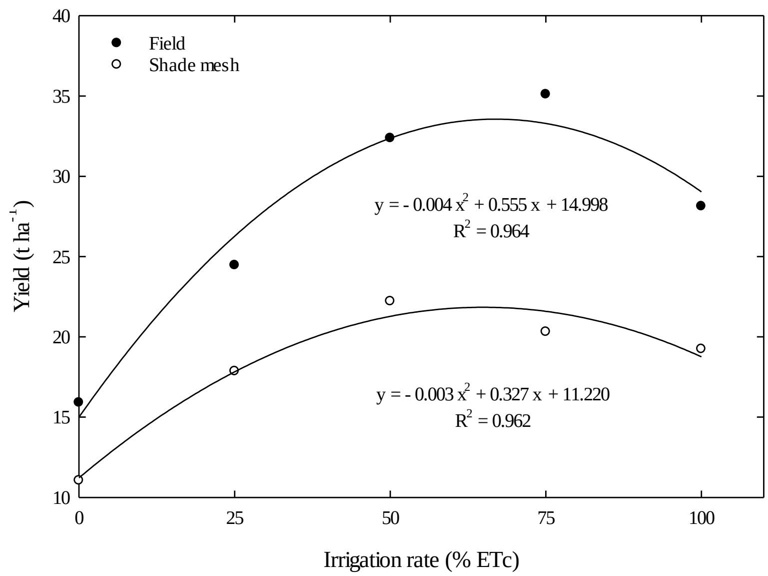

Figure 4. Relationship between fruit yield and irrigation rate applied as fraction of crop evapotranspiration in bell pepper grown under shade mesh or in open field.

under shade mesh and open-field between the years of study for yield data. Ilahy et al. (2013) reported that there were no significant differences between shaded and non-shaded conditions in commercial yield of sweet pepper 'Herminio'. However, statistical difference between the levels of irrigation on yield, fruit weight, fruit dry matter and number fruit per plant was found. Fruit weight showed significant interaction between treatments under shade netting and open field.

The relationship between fruit yield and irrigation rate under shade mesh and open-field is shown in Figure 4. Fruit yield in open-field was increased with $I_{0.50}$ and $I_{0.75}$. In the 2013 to 2014 season, values ranged from 13.8 t ha^{-1} in I_0 to 37.1 t ha^{-1} in $I_{0.75}$. Treatment I_0 showed a reduction in yield of 54.7% and that of $I_{1.0}$ was reduced by 19.9% relative to maximum yield ($I_{0.75}$). Kara and Yıldırım (2015), reported similar results in *Capsicum annuum* L. cv. Carliston with different irrigation levels (0.2, 0.5, 0.8, 1.0 and 1.2 ETc); yields were 18.78, 20.60, 21.57, 18.90 and 15.16 Mg ha^{-1}, respectively, with maximum yield with 0.8 ETc. Padrón et al. (2014), evaluated irrigation frequency and irrigation rates finding that daily irrigation resulted in better crop performance compared to irrigation every other day; crop yields were similar with daily irrigations at 60, 80 or 100% ETc. Moreover, Sezen et al. (2015), reported the highest yield values with full irrigation (44.2-47.8 t ha^{-1}) and deficit irrigation of 50 and 75% (34.9-36.0 t ha^{-1} and 40.8 to 47.2 t ha^{-1}, respectively).

Our results showed that cultivation of bell pepper was affected by deficit irrigation as well as excess water caused by high rainfall. Bell pepper crop irrigated more frequently tends to be more efficient in water use, without affecting yield, compared to a crop irrigated less frequently. Also, Yildirim et al. (2012), studying the effect of different irrigation treatments (0.0, 0.2, 0.5, 0.8, 1.0, 1.2 of ETc) in bell pepper to determine stress with a fixed interval of 7 days throughout the whole drought season, reported yields of 3.25, 8.64, 16.93, 20.08, 27.67 and 24.61 t ha^{-1}, respectively. They mentioned that the most important factor that affect growth and yield in pepper crops is the amount of irrigation water applied throughout the development period.

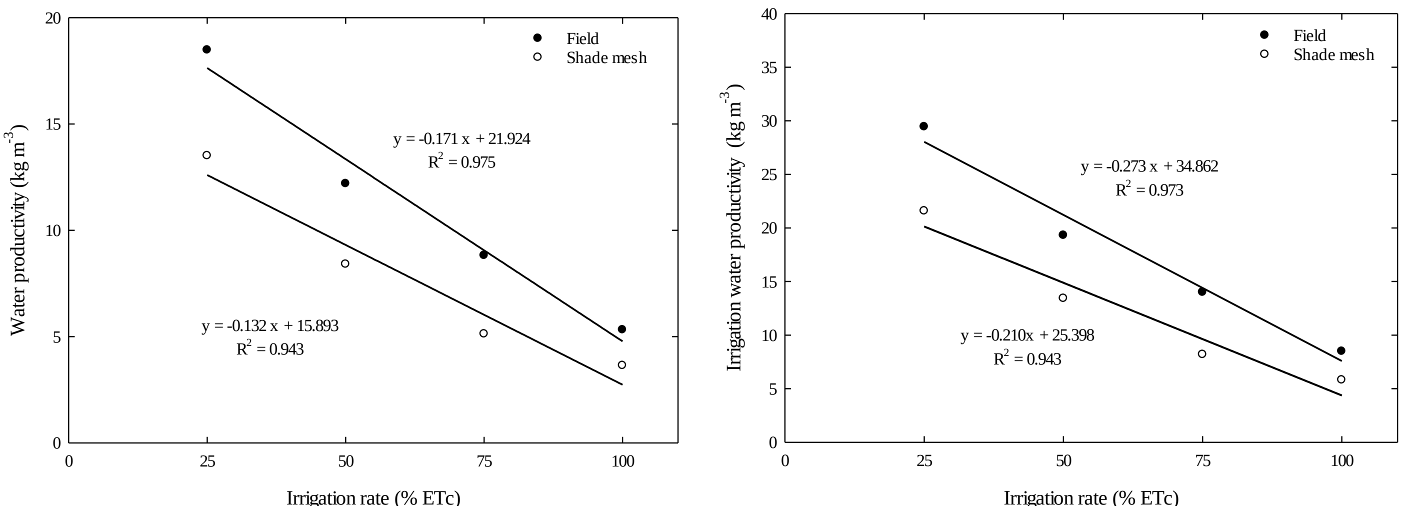

Figure 5. Water productivity and irrigation water productivity in bell pepper under shade mesh and in open-field.

The maximum yield under shade mesh was obtained at $I_{0.50}$. Yield ranged from 11.0 t ha^{-1} in I_0 to 22.2 t ha^{-1} in $I_{0.50}$. Treatment I_0 presented 50.3% reduction in yield and 13.4% reduction in $I_{1.0}$. Díaz-Pérez (2014), studying the effect of shade levels of 0, 30, 47%, 63 and 80% in *Capsicum annuum* cv. Heritage, reported that yield increased with increasing shade level up to 35% shade and then decreased with increasing shade levels; Möller and Assouline (2007), reported yield in Sweet pepper *C. annuum* cv. Selika between 5.93 and 9.26 kg m^{-2} in 30% shade. Ilahy et al. (2013), reported yield in (*C. annuum* cv 'Beldi'), grown at 0, 50 and 100% shade, varied between 0.9 kg/plant and 1.15 kg/plant, respectively. Also, López-Marin et al. (2012) reported that commercial yield of sweet pepper cv 'Herminio' ranged from 2.55 kg/plant under unshaded conditions compared to 2.53 kg/plant in shaded conditions.

The open-field treatments showed highest cumulative yields and the trend was observed throughout the harvest period, which is probably due to increased radiation and greater photosynthetic activity. López-Marin et al. (2012), reported highest yields with 40% shade. This was attributed to reduction of the incident radiation. Also, it was observed that the crop was negatively affected by high temperatures, with shading decreasing average daily temperature by 2.5°C at noon and 0.6°C in the morning, creating a micro climate favorable to crop development. Díaz-Pérez (2013), reported that moderate levels of shade (30 and 47%) were the most favorable for plant growth and function in bell pepper. Möller and Assouline (2007), reported that 30% mesh black shade reduces solar radiation, wind speed, water needs and increases the efficiency of water use in bell pepper.

In open-field, fruit sunscald was observed with greater intensity 55 to 85 days after transplanting, when the crop had reduced leaf area, with yield losses of 1.4, 2.2, 2.3%, 3.3 and 1.7% in irrigation treatments I_0, I_{25}, I_{50}, I_{75} and $I_{1.0}$, respectively. Under shade mesh fruit showed no sunscald. Ilahy et al. (2013), reported yield losses due to sunscald ranging from 0.69 kg/plant in open-field and 0.18 kg/plant in shady conditions.

Water productivity and irrigation water productivity both decreased with increasing irrigation rate (Figure 5). Both WP and IWP were higher in open field than under shade mesh. Plots without irrigation showed reduced WP (3.0 kg m^{-3} in the open-field and 2.1 kg m^{-3} under shade mesh). Values of WP in open-field oscillated between 18.5 kg m^{-3} in $I_{0.25}$ and 5.3 kg m^{-3} in $I_{1.0}$ and under shade mesh between 13.5 kg m^{-3} in $I_{0.25}$ and 3.6 kg m^{-3} in $I_{1.0}$. IWP values in open-field varied between 29.4 kg m^{-3} in $I_{0.25}$ and 8.5 kg m^{-3} in $I_{1.0}$ and under shade mesh between 21.6 kg m^{-3} in $I_{0.25}$ and 5.8 kg m^{-3} in $I_{1.0}$. The WP and IWP values of this study were similar to those previously reported. Kong et al. (2012), through drip irrigation determined WP values between 7.76 kg m^{-3} and 10.71 kg m^{-3} in bell pepper. Sezen et al. (2015), reports of WP of 6.9 kg m^{-3} and IWP of 5.7 kg m^{-3} by applying irrigation water of 570.4 mm for the whole growing season at intervals of 3 to 6 days. Guang-Cheng et al. (2010), determined the WP and IWP hot pepper in greenhouses values oscillate between 6.7 to 10.4 kg m^{-3} and 6.3 to 10.6 kg m-3, respectively. Demirel et al. (2012) determined the values WP and IWP in pepper grown in the Thrace region of Turkey varying from 2.4 to 7.0 kg m^{-3} and 0.3 to 9.1 kg m^{-3}, respectively. Kara and Yıldırım (2015), reported WUE in *C. annuum* L. cv. Carliston with irrigation levels of 0.2, 0.5, 0.8, 1.0 and 1.2% of ETc, between 6.0, 4.1, 3.6, 2.7, and 2.1 kg m^{-3}, respectively. Moreover, Yildirim et al. (2012), reported results of WUE and IWUE in bell pepper with irrigation treatments (0.0, 0.2, 0.5, 0.8, 1.0, 1.2 of ETc) of 1.6, 3.3, 5.3, 5.5, 6.9 and 5.7 kg m^{-3} and 2.0, 3.8, 6.0, 6.1, 7.5, and 6.2, respectively.

Table 5. Average of fruit quality in bell pepper under shade mesh and in open-field.

	Treatments	Fruit per plant (number)	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Dry matter (%)
Field	I_0	6[b]	13.4	5.6[b]	126.50[bC]	5.3
	$I_{0.25}$	7[ab]	14.8	6.6[a]	134.00[bBC]	5.3
	$I_{0.50}$	9[a]	14.3	6.1[ab]	142.10[bAB]	5.3
	$I_{0.75}$	9[a]	14.9	5.9[ab]	153.20[bA]	5.2
	$I_{1.0}$	8[ab]	15.0	5.5[b]	144.70[bAB]	5.0
	Sig.	*	ns	*	*	ns
Shade	I_0	5[b]	16.9	6.0	154.20[aC]	5.1[a]
	$I_{0.25}$	7[ab]	16.5	6.5	176.60[aB]	5.0[ab]
	$I_{0.50}$	8[a]	18.0	6.7	179.50[aB]	5.2[a]
	$I_{0.75}$	8[a]	16.4	6.2	188.6[aAB]	4.9[ab]
	$I_{1.0}$	7[ab]	17.8	6.3	198.90[aA]	4.6[b]
	Sig.	*	ns	ns	**	*

Letters indicate significant differences at *P<0.05 and **P<0.01. Sig., significance.

The peaks were obtained from 1.0 ETc treatment.

Results on average of fruit quality in bell pepper under shade mesh and in open-field are presented in Table 5. Plots in open-field presented difference on fruit quality, number of fruits per plant, fruit diameter, fruit weight and under shade mesh, the number of fruit per plant, weight and fruit dry matter. The variable that showed interaction effect between under shade mesh and in open-field was the fruit weight. The quality of fruit in the open-field and under shade mesh were affected significantly, showing the smallest fruit diameter, length, and weight and lowest number of fruits per plant. Irrigation levels of 50 and 75% ETc obtained the best fruit quality. However, the maximum fruit weight and lower fruit dry matter content was presented by treatment $I_{1.0}$, under shade mesh. In summary, highest quality fruit (increased weight and reduced dry matter and sunscald incidence) was obtained under shade. Sezen et al. (2015), reported increased fruit yield to augmented fruit number In addition, a uniform supply of water in the soil throughout the growing season is needed to prevent poor fruit size and shape and to improve yield.

Rylski and Spigelman (1986), reported changes in plant development due to the shading affected. According to the authors, shading affected fruit set, number of fruits per plant, fruit location on the plant, fruit development and yield. Also, the lowest number of fruits per plant was obtained under 47% shading at 5 plants m^{-2} density, under 47 and 26% shading at 6.7 plants m^{-2} density. Under shading, individual fruits were larger and had a thicker pericarp. Shading reduced sun-scald damage of the fruits from 36% in full sunlight to 3 and 4% under 26 and 47% shading. The highest yield of high-quality fruits was obtained with 12 to 26% shade. On the other hand, Milenković et al. (2012), refer shading of pepper plants affected both fruit yield and quality. Total and marketable yield increased with 40% shading level and then decreased (with 50% shade). Shading of pepper (40%) may be an option to reduce heat stress conditions and extend the spring-summer season toward September and concludes the photoselective, light-dispersive shade nets provide a new, tool for crop protection. Changing the light intensity and radiation spectrum has a large impact on the total production system.

Maximum production efficiency in open-field was 34.2 t ha^{-1} with 69.4% of ETc; under shade mesh it was 20.1 t ha^{-1} with 54.5% of ETc. The difference of maximum production efficiency was of 14 t ha^{-1} and reduction of 14% of ETc. Bell pepper under 50% shade could save 14 to 25% of irrigation water. Moreover, the sunscald in fruit is improved by increasing the number of plant per square meter.

Conclusions

Yield of bell pepper in open-field was significantly higher with 75% of ETc; it was highest with 50% ETc under shade. The point of maximum production efficiency was 69.4% of ETc in open-field and 54.5% of ETc under shade. Thus, under 50% shades, there may be up to 25% water savings. Crop coefficients values found in this study will be useful for irrigation scheduling, dual crop coefficients in bell pepper, developed for a region with a humid subtropical climate. Results indicate that the WP and IWP values decreased with increasing irrigation level in both open field and shaded conditions. Irrigation with increased frequency tends to increase irrigation water use efficiency. Drip irrigations at 50% ETc and 75% of ETc may be recommended.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGEMENTS

The authors thank the Gran Mariscal de Ayacucho Foundation; Federal University of Santa Maria and Polytechnic School of the Federal University of Santa Maria by for support.

REFERENCES

Albuquerque FDS, Silva EFF, Filho JACA, Lima GS (2012). Water requirement and crop coefficient of fertigated sweet pepper. Irrigation 17(4):481-493.

Allen RG, Pereira LS, Raes D, Smith M (2006). Crop evapotranspiration (guidelines for computing crop water requirements). Irrigation and Drainage Paper No. 56, FAO, Rome. P 298.

Demirel K, Genç L, Saçan M (2012). Effects of different irrigation levels on pepper (*Capsicum annuum*) yield and quality parameters in semi-arid conditions. J. Tekirdag Agric. Fac. 9(2):7-15.

Díaz-Pérez JC (2013). Bell pepper (*Capsicum annuum* L.) crop as affected by shade level: Microenvironment, plant growth, leaf gas exchange, and leaf mineral nutrient concentration. HortSci. 48(2):175-182.

Díaz-Pérez JC (2014). Bell pepper (*Capsicum annuum* L.) crop as affected by shade level: fruit yield, quality, and postharvest attributes, and incidence of phytophthora blight (caused by *Phytophthora capsici* Leon.). HortSci. 49(7):891-900.

Echer MM, Fernandes MCA, Ribeiro RLD, Peracchi AL (2002). Evaluation of *Capsicum* genotypes for resistance to the broad mite. Hortic. Bras. 20(2):217-221.

Espinoza W (1991). Manual de Produção de tomate industrial no Vale do São Francisco. Brasília: IICA/CODEVASF, P. 301.

FAOSTAT (2013). Food and Agricultural Organization of the United Nations Statistical Database, Rome, Italy.

Filgueira FAR (2003). Solanáceas: agrotecnologia moderna na produção de tomate, batata, pimentão, pimenta, berinjela e jiló. Lavras, MG: UFLA, P. 333.

Goto R, Tivelli SW (1998). Produção de hortaliças em ambiente protegido: condições subtropicais. Sao Paulo: UNESP, cap. 01. P. 319.

Guang-Cheng S, Na L, Zhan-Yu Z, Shuang-En Y, Chang-Ren C (2010). Growth, yield and water use efficiency response of greenhouse-grown hot pepper under Time-Space deficit irrigation. Sci. Hortic. 126(2):172-179.

Heydari N (2014). Water productivity in agriculture: challenges in concepts, terms and values. Irrig. Drain. 63:22-28.

Ilahy R, R'him T, Tlili I, Jebari H (2013). Effect of different dhading levels on growth and yield parameters of a Hot Pepper (*Capsicum annuum* L.) Cultivar 'Beldi' G rown in Tunisia. Glob. Sci. Books 7(1):32-35.

Kara HO, Yıldırım M (2015). Water and radiation use efficiencies of pepper (*Capsicum annuum* L. cv. Carliston). Scholars J. Agric. Vet. Sci. 2(2A):87-93.

Kittas C, Rigakis N, Katsoulas N, Bartzanas T (2009). Influence of shading screens on microclimate, growth and productivity of tomato. Acta Hortic. 807:97-102.

Kong Q, Li G, Wang Y, Huo H (2012). Bell pepper response to surface and subsurface drip irrigation under different fertigation levels. Irrig. Sci. 30(3):233-245.

López-Marin J, Gálvez A, Conesa A, Martínez-Nicolás J, González A (2012). Comportamiento fisiológico del pimiento en invernadero bajo diferentes condiciones de sombreo. Acta Hortic. 60:337-342.

Marouelli WA, Silva WLC (2012). Irrigação na cultura do pimentão. Empresa Brasileira de Pesquisa Agropecuária. Circular Técnica 101:20.

Melgarejo MJ, López OMI (2012). Las identidades española y argentina: Agricultura, Agua y Energía. Estudios Rurales 1:1-39.

Milenković L, Ilić ZS, Đurovka M, Kapoulas N, Mirecki N, Fallik E (2012). Yield and pepper quality as affected by light intensity using colour shade nets. Agric. For. 58(1):19-33.

Molden D, Oweis T, Steduto P, Bindraban P, Hanjra MA, Kijne J (2010). Improving agricultural water productivity: between optimism and caution. Agric. Water Manage. 97:528-535.

Möller M, Assouline S (2007). Effects of a shading screen on microclimate and crop water requirements. Irrigation Sci. 25:171-181.

Möller M, Tanny J, Cohen S, Li Y, Grava A (2004). Water consumption of pepper grown in an insect proof screenhouse. Acta Hortic. 659:569-575.

Mukherji A, Facon T (2009). Revitalizing Asia's irrigation: to sustainable meet tomorrow's food needs. Colombo, Sri Lanka: International Water Management Institute. Rome, Italy: Food and Agriculture Organization of the United Nations, P. 38.

Olle M, Bender I (2009). Causes and control of calcium deficiency disorders in vegetables: A review. J. Hortic. Sci. Biotechnol. 84:577-584.

Padrón RAR, Nogueira HMCM, Cerquera RR, Albino GD, Nogueira CU (2015). Characterization physical-hydric of the yellow argisol soil for establishment of project and irrigation management. Acta Iguazu 4(1):36-47.

Padrón RAR, Ramírez LR, Swarowsky A, Daboín JR (2014). Effect of deficit irrigation and different frequencies in the production of bell pepper. Interciencia 39(8):591-596.

Pezzopane JEM, Oliveira PC, Reis EF, Lima JSS (2004). Microclimatological alterations caused by plastic screen uses. Eng. Agríc. 24(1):9-15.

Rylski I, Spigelman M (1986). Effect of shading on plant development, yield and fruit quality of sweet pepper grown under conditions of high temperature and radiation. Sci. Hortic. 29(1):31-35.

Santos CL, Seabra JRS, Lalla JG, Theodoro VCA, Nespoli A (2009). Performance of crispi lettuce cultivars under high temperatures in Cáceres-MT. Agrarian 2(3):87-98.

Sezen SM, Yazar A, Şengül H, Baytorun N, Daşgan Y, Akyildiz A, Tekin S, Onder D, Ağçam E, Akhoundnejad Y, Gügercin Ö (2015). Comparison of drip-and furrow-irrigated red pepper yield, yield components, quality and net profit generation. Irrig. Drain. 64(6):

Shukla S, Jaber FH, Goswami D, Srivastava S (2013). Evapotranspiration losses for pepper under plastic mulch and shallow water table conditions. Irrig. Sci. 31(3):523-536.

Streck EV, Kämpf N, Dalmolin RSD, Klamt E, Nascimento PD, Schneider P, Giasson E, Pinto LFS (2008). Solos do Rio Grande do Sul, 2 ed, Porto Alegre, EMATER/RS-ASCAR. P. 222.

Valipour M (2014a). Assessment of different equations to estimate potential evapotranspiration versus FAO Penman Monteith method. Acta Adv. Agric. Sci. 2(11):14-27.

Valipour M (2014b). Analysis of potential evapotranspiration using limited weather data. Applied Water Science. pp. 1-11.

Valipour M (2014c). Application of new mass transfer formulae for computation of evapotranspiration. J. Appl. Water Eng. Res. 2(1):33-46.

Valipour M (2015a). Calibration of mass transfer-based models to predict reference crop evapotranspiration. Appl. Water Science, pp. 1-11.

Valipour M (2015b). Evaluation of radiation methods to study potential evapotranspiration of 31 provinces. Meteorol. Atmos. Phys. 127:289-303.

Valipour M, Eslamian S (2014). Analysis of potential evapotranspiration using 11 modified temperature-based models. Int. J. Hydrol. Sci. Technol. 4(3):192-207.

Yildirim M, Demirel K, Bahar E (2012). Effect of restricted water supply and stress development on growth of bell pepper (*Capsicum annuum* L.) under drought conditions. J. Agro Crop Sci. 3(1):1-9.