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Water-Yield Relationships of Green Pepper (*Capsicum annuum*) Cultivated at Different Irrigation Levels[A]

Sinem YILMAZ[1], Hayrettin KUŞÇU[2*]

Abstract: A field experiment was carried out in Bursa ecological conditions to determine the effects of different irrigation strategies on water-yield relationships of green pepper cultivation. In the study, where the amount of water evaporated from the class A pan (E) was taken as reference, different pan-crop coefficients (kpc: 0.25, 0.50, 0.75, and 1.00) were used for four irrigation treatments (S25: E×0.25, S50: E×0.50, S75: E×0.75, and S100: E×1.00) was created. While statistically significant ($p<0.05$) higher yields were obtained from S100 and S75 treatments, the yield decreased significantly from S50 and S25 treatments. The decrease in irrigation levels also caused a decrease in the size and diameter of the fruit. The highest water productivity was achieved from the S75 irrigation treatment. According to the results obtained, S75 irrigation treatment can be recommended in Bursa ecological conditions to obtain higher fruit yield both per unit area and per unit volume of water. Regarding S75, seasonally applied irrigation water was found to be 368.4 mm, evapotranspiration was 516.6 mm, fruit yield was 3629 kg da^{-1} and water productivity was 7.02 kg m^{-3}.

Keywords: Irrigation strategies, Evapotranspiration, Water productivity, Yield components.

[A] Produced from a master's thesis. This study does not require ethics committee permission. The article has been prepared in accordance with research and publication ethics.

[1] Sinem Yılmaz, Bursa Uludağ Üniversitesi, Ziraat Fakültesi, Biyosistem Mühendisliği Bölümü, Nilüfer, Bursa, Türkiye, sinemctn794@gmail.com, OrcID 0000-0003-0150-7834

[*] **Sorumlu yazar/Corresponding Author:** [2] Hayrettin Kuşçu, Bursa Uludağ Üniversitesi, Ziraat Fakültesi, Biyosistem Mühendisliği Bölümü, Nilüfer, Bursa, Türkiye, kuscu@uludag.edu.tr, OrcID 0000-0001-9600-7685

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Farklı Sulama Seviyelerinde Yetiştirilen Sivri Biberin (*Capsicum annuum*) Su-Verim İlişkileri

Öz: Bu çalışmada, sivri biber yetiştiriciliğinde farklı sulama stratejilerinin su-verim ilişkileri üzerine olan tepkisini belirlemek amacıyla Bursa iklim koşullarında bir tarla denemesi yürütülmüştür. A sınıfı kaptan buharlaşan su miktarının (E) referans olarak alındığı çalışmada, farklı bitki-kap katsayıları (kpc: 0.25, 0.50, 0.75, and 1.00) kullanılarak dört sulama konusu (S25: E×0.25, S50: E×0.50, S75: E×0.75, and S100: E×1.00) oluşturulmuştur. İstatistiksel olarak önemli düzeyde ($p<0.05$) daha yüksek verimler S100 ve S75 konularından elde edilirken S50 ve S25 konularında önemli düzeyde verim azalmıştır. Sulama seviyelerindeki azalma meye boyu ve çapında da azalmalara neden olmuştur. En yüksek su kullanım etkinliği S75 konusundan elde edilmiştir. Elde edilen sonuçlara göre, hem birim alan başına hem de birim hacimdeki su başına daha yüksek meyve verimi elde etmek için Bursa ekolojik koşullarında S75 sulama konusu önerilebilir. S75 konusunda mevsimlik olarak uygulanan sulama suyu 368.4 mm, bitki su tüketimi 516.6 mm, meyve verimi 3629 kg da^{-1} ve su kullanım etkinliği ise 7.02 kg m^{-3} olarak saptanmıştır.

Anahtar Kelimeler: Sulama stratejileri, Bitki su tüketimi, Su üretkenliği, Verim bileşenleri.

Introduction

Pepper (*Capsicum annum* L.), one of the important species of the Solanaceae family, can be produced in different regions of the world. Its homeland is South America. It can be said that the center of different species, varieties and forms is Brazil. While it is grown as a perennial in regions with tropical climates, it is grown as annuals in temperate climates (Vural et al., 2000; Keleş et al., 2016).

Pepper is a very rich food in terms of organic matter. It contains various nutrients and light textured (loamy, loamy-sandy) soils are more suitable for the development period. Plant roots are sensitive and it is generally recommended to be grown in medium or high water holding capacity, medium texture, good soil depth and no drainage problems. Pepper plants give better yields in slightly acidic soils with relatively low salinity (below 1.5 ds m^{-1}) (Doorenbos and Kassam, 1979).

A total of 36,136,996 tons of pepper were produced in the world in 2020 (FAOSTAT, 2020). Pepper production in Turkey is increasing every year, and while the total pepper production was 1,700,000 tons in 2004, it increased to 2,782,354 tons in 2018 (Güvenç, 2020). A total of 2,624,537 tons of pepper production was carried out in our country in 2019, on an area of 920,890 decares, with a yield of 2850 kg da^{-1} (Anonymous, 2021). According to the provinces, the most important pepper cultivation is located in Bursa, Gaziantep, Hatay, İzmir, Kilis Kahramanmaraş and Samsun (Güvenç, 2020). According to 2019 TUIK data, 69,429 tons of pepper were produced from an area of 24,497 decares in Bursa, and the total yield after harvest was 2834 kg da^{-1}. In addition, in Bursa, red pepper (capija) is grown on an area of 21,646 decares and bell pepper is grown on an area of 4975 da. The area where pepper is grown in Bursa is in the second place after tomato (Anonymous, 2021).

Although Bursa is a province where pepper production is carried out intensively due to its fertile lands and climatic conditions, both agricultural areas and water resources are under intense industrial and urbanization pressure. Due to the reduction in precipitation and the increase in temperatures in the summer months, the water consumption of plants increases and the need for irrigation occurs. The effective use of scarce water resources is increasing its importance day by day. In order to ensure the sustainable use of water resources, there is an urgent need for agricultural practices where water is used sparingly.

Particularly in conditions where water resources are scarce, deficit irrigation (DI) practices are vital for the effective and effective use of irrigation water resources, and studies have been carried out on many crops including vegetables and fruits (Pereira et al., 2009; Mushtaq and Moghaddasi, 2011; Patanè et al., 2011; Laribi et al., 2013; Zheng et al., 2013; Yang et al., 2018). Pepper is one of the most sensitive vegetables to drought stress, owing to its large leaf surface and high stomatal conductivity (Liu et al., 2012). DI during the total crop growing season can reduce pepper yield (Sezen et al., 2014, 2015; Yang et al., 2017). DI can reduce irrigation depths by 20-50% compared to full irrigation, resulting in a higher WP (Abayomi et al., 2012). When irrigation water is sufficient, it is suggested to fully water the pepper to achieve the highest yield. However, in agricultural areas where water is scarce, DI options should be considered in pepper farming (Nagaz et al., 2012; Sezen et al., 2015; Kırnak et al., 2016; Yıldırım et al., 2017; Çamoğlu et al., 2018, 2021).

Kuşçu et al. (2016) investigated the response of various irrigation strategies and nitrogen levels on the yield and quality of red pepper plants in Bursa climatical conditions. The researchers determined that under drip irrigation, full irrigation and 24 kg N da^{-1} application, maximum net income was obtained, and increased N levels under deficit irrigation conditions improved WP, dry matter and marketable fruit yield. When developing water saving techniques and preparing an appropriate irrigation program, it is crucial to recognize the responses of plants, considering scarce irrigation water resources of Bursa province. Although the responses of pepper on yield and quality under different irrigation programs have been studied by several researchers, the results may differ according to local conditions and crop varieties (Abayomi et al., 2012; Cosic et al., 2015; Sezen et al., 2015; Kuşçu et al., 2016; Koksal et al., 2017). It is also needed to conclude the local/regional susceptibility of the pepper to water stress to help farmers achieve higher fruit yields with less evapotranspiration, thereby increasing their net income with WP and adopting appropriate irrigation programs. Therefore, the aims of this study are (a) to investigate the responses of irrigation water applied at different levels by drip irrigation method on fruit yield and water productivity in pepper cultivation and (b) to determine an appropriate irrigation schedule for pepper cultivation in Bursa ecological environments.

Material and Method

Study area

A field experiment was conducted in the agricultural lands located in Bursa Uludağ University Görükle Campus in 2019. The field where the experiment was conducted is located at 40º 13' N latitude and 28º 51' E longitude, and its height above sea level is 112 m.

Bursa province is in the sub-humid climate class according to the annual total precipitation (Jensen, 1980). According to data received from the Turkish State Meteorology Service, Bursa province climate values are given in Table 1. In the pepper growing season, May-September, the monthly average temperature is 17.6-24.5 ºC, the monthly average relative humidity is 63.5-68.6%, the monthly average wind speed is 1.9-2.3 m s^{-1} and the average monthly total precipitation is 15.8-46.0 mm. According to the data for 2019, when the experiment was conducted, the lowest monthly average temperature was measured at 19.6 ºC in May, while the highest temperature was measured in August with 24.5 ºC. The average temperature (22.5 ºC) between May and September 2019 was higher than the long-term average (21.7 ºC) in the same period. On the other hand, while the precipitation totals in the May-September period were recorded as 160.1 mm for long-term, it was measured as 179.9 mm in 2019. The precipitation values in question are insufficient to obtain economic yields from the pepper plant. For this reason, irrigation is required in pepper cultivation in Bursa.

Table 1. Monthly average temperature, average relative humudity and total precipitation values of Bursa province for 2019 and long term years (1960-2019)

Months	Average temperature (ºC)		Relative humidity (%)		Precipitation (mm)	
	2019	1960-2019	2019	1960-2019	2019	1960-2019
May	19.6	17.6	67.3	68.1	40.4	46.0
June	23.7	22.0	68.6	62.3	51.2	36.7
July	23.6	24.4	64.6	59.6	37.9	15.8
August	24.5	24.2	64.3	61.5	39.1	18.9
September	21.3	20.3	63.5	66.8	11.3	42.7
Average / Total	22.54	21.7	65.7	63.7	179.9	160.1

The soil texture is clayey; the volume weight is 1.35-1.38 g cm^{-3} for a soil depth of 0-120 cm in the experimental area. The field capacity value in terms of dry weight percentage varies between 38.17-43.01% and the permanent wilting point value varies between 23.18 and 27.07%. The salinity of the soils was 0.45 dS m^{-1}, the average pH was 6.3, and the organic matter content was between 0.43 and 0.72% (Elmas et al., 2023) (Table 2).

Table 2. Properties of the soil of the experimental area in terms of irrigation

Soil depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture	Bulk density (g cm^{-3})	Field capacity (%)	Permanent wilting point (%)
0-30	24.32	26.18	49.50	Clay	1.35	38.17	27.07
30-60	23.28	26.22	50.50	Clay	1.36	40.01	27.03
60-90	21.88	24.62	53.50	Clay	1.34	43.01	26.75
90-120	21.64	37.86	40.50	Clay	1.38	40.05	23.18

Agronomic operations

The trial soils were plowed to a depth of 30 cm, processed with a disc harrow for the purpose of breaking up the clods and smoothing the field surface, and made ready for planting pepper seedlings with the soil milling applications made on 25 April 2019. Burkalem F1 pepper cultivar as plant material was used. The pepper seedlings with 3-4 leaf were planted on 14 May 2019 at 0.40 m distance in rows 0.70 m apart. During the research, at the recommended level according to the soil analysis results, 20 kg da^{-1} N, 20 kg da^{-1} P and 15 kg da^{-1} K were applied equally to the experimental plots. Fighting against weeds was done by hoeing method and no diseases and pests were found.

Water and irrigation system

The water source was an irrigation pond located in Bursa Uludağ University Görükle campus. It is transmitted to the agricultural lands in the campus by a piped irrigation network, and water distribution is made by hydrants. The water taken from the nearest hydrant was brought to the trial area with a 75 mm HDPE pipe. It was measured that the pH value of the irrigation water used in the experiment was 7.12, the electrical conductivity (salinity) value was 0.31 dS m^{-1}, and the sodium adsorption rate (SAR) was 0.23. The water taken from the hydrant is passed through the control unit and given to the main pipe. In the control unit, there was a hydrocyclone with 2.5” inlet and outlet, sieve filter and manometers. A 50 mm PE main pipeline was used to direct the irrigation water from the transmission line to the experimental area with a ball valve. Manifold pipes were 32 mm PE. A water meter was placed per each block to deliver the irrigation water to the plots in a controlled manner. The laterals were connected to the manifold pipelines by a mini-valve. Drip irrigation pipes were drawn one lateral to each plant row. Drip pipes with an outer diameter of 16 mm, a distance between the drippers of 20 cm and a dripper flow rate of 2 L h^{-1} under 1 bar pressure were used. The drippers used in this experiment are pressure regulators.

Irrigation treatments

The experiment were carried out using a randomized blocks design with three replications. The dimensions of a trial plot are 2.8 m x 6.0 m = 16.8 m^2. A distance of 3 m was left between blocks and 2 m between plots.

In the study, four irrigation treatments (S25, S50, S75 and S100) were formed at different irrigation levels. The irrigation level was determined by applying different levels of crop-pan coefficients (kpc: 0.25, 0.50, 0.75 and,1.00, respectively, according to the experimental treatments) to the amount of water evaporated from a standard class A pan. Accordingly, the value of the applied irrigation water amount in terms of volume was calculated with Equation 1 (Oktem et al., 2003; Tüylü and Akın, 2023).

$$I = A \times Epan \times kpc \times P \tag{1}$$

Where, I shows the irrigation water amount (liter) applied to the experimental plot, A shows the area of a plot (m^2), $Epan$ shows the cumulative pan evaporation amount (mm) between two irrigations, kpc pan-crop coefficient and P wetted area ratio (%). The plant-pan coefficient was determined according to the treatments. The P value was 0.90 (Çetin et al., 2003). Irrigation duration was determined by using the determined amount of irrigation water (as volume), both by using the pressure-flow rate relationship and by controlling the amount of water passing through the water meter. The irrigation interval was 3-4 days. Irrigation was continued until it was determined that the plants reached physiological maturity.

Measurements

A soil-water budget equation was used to determine the seasonal evapotranspiration (ETa) of pepper plants (James, 1988; Tüylü and Akın, 2023).

$$ETa = I + P \pm \Delta S - D - R \tag{2}$$

Where, I is the amount of irrigation water applied (mm), P is the effective rainfall during the growing season (mm), ΔS is the change between two soil water contents (mm), D is the amount of drainage (mm) and R is the amount of runoff (mm). Rainfall values were obtained from the Nilüfer meteorology station in the university. Soil mouisture was determined via the gravimetric method on samples taken from the middle two rows of all plots in the middle block, and between two drippers, at 120 cm soil depth, using an auger set for each 30 cm layer. Since the drip irrigation method was used in the study, the runoff and drainage were neglected in the equation (Oktem et al., 2003; Tüylü and Akın, 2023).

The first harvest for the pepper plant was made on 10 July 2019, and the harvest was made as the fruits ripened. The weights of the pepper fruits harvested from each plot were weighed separately and the cumulative totals from the first harvest to the last harvest were taken. Pepper yields are expressed as kg da^{-1}. The length of 5 randomly selected fruits from the fruits collected in each harvest was measured with a ruler half and their diameter was measured from the midpoint of the fruits with a digital caliper.

There was a 2nd degree polynomial relationship ($Y = aS^2 + bS + b$) between the irrigation water amount and pepper fruit yield (Y), and a linear relationship ($Y = aET + b$) was determined between seasonal evapotranspiration and fruit yield. MS Excel spreadsheets and graphing features were used to determine the aforementioned relationships and determination coefficients. The a, b and c values in the equation represent the variables in the line or curve.

To determine the relationship between evapotranspiration and yield, the dimensionless parameters of proportional yield decrease and proportional evapotranspiration were used and the following equation was used:

$$1 - \frac{Ya}{Ym} = ky\left[1 - \frac{ETa}{ETm}\right] \tag{3}$$

Where; *Ya* is pepper fruit yield (kg da^{-1}), *Ym* is highest fruit yield (kg da^{-1}), *ETa* actual evapotranspiration (mm), *ETm* is maximum evapotranspiration (mm), and *ky* is yield response factor (Doorenbos and Kassam, 1979).

Irrigation water productivity (IWP) and water productivity (WP) values were calculated as given in Equation 4 and Equation 5 (Çamoğlu et al., 2019).

$$IWP = Y / I \quad (4)$$

$$WP = Y / ETa \quad (5)$$

In the equations, *Y* is the yield (kg ha^{-1}), *I* is the seasonal depth of irrigation water applied (mm) and *ETa* is the seasonal plant water consumption (mm) counting soil moisture, irrigation water quantity and rainfall values (Yang et al., 2018).

The data obtained from the field experiment were subjected to analysis of variance (One-Way ANOVA) using SPSS software (Version 23.0, SPSS Inc., USA). Mean values for yield, length and diameter of pepper fruits were compared using Duncan's multiple distribution test at 0.05 level of significance.

Results and Discussion

Amount of irrigation water applied and evapotranspiration

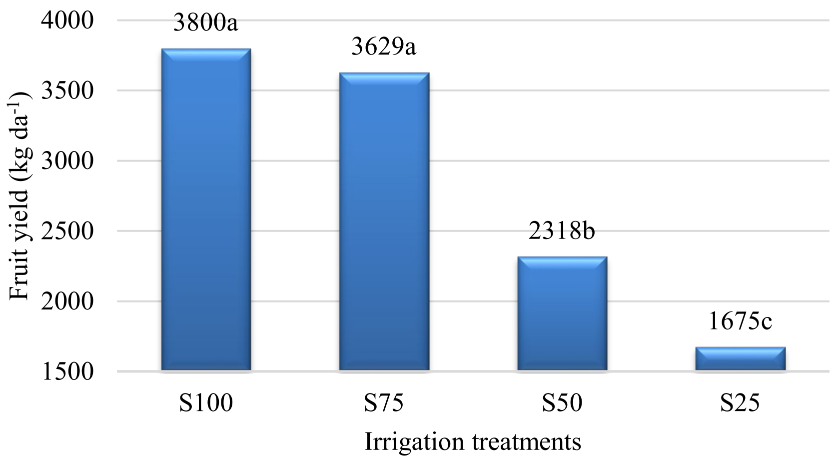
The amount of irrigation water applied to the root zone of the plant, the amount of precipitation, soil moisture change and seasonal ET values during pepper cultivation are given in Table 3. On the day of staggering on the experimental plots of pepper seedlings, 30 mm of life water was applied. According to the experimental treatments, irrigations were started on 31 May 2019. Irrigation was suspended on rainy days. A total of 481.2 mm of irrigation water was applied to the pepper plants under the S100 treatment, where irrigation was carried out taking into account 100% of the water vaporized from the class A pan, while 368.4 mm, 255.6 mm and 142.8 mm of irrigation water were applied to the S75, S50 and S25 irrigation treatments, respectively. A total of 140.2 mm of precipitation occurred during the trial period. The highest evapotranspiration of pepper plant was 617.4 mm for S100 and the lowest was 323.0 mm for S25. It was determined that when the amount of irrigation water applied was increased for each treatment, evapotranspiration values increase in the same way. Accordingly, a linear relationship was determined between the irrigation water amount (S) and seasonal evapotranspiration (ETa) in the form of ETa=0.87S+200.27 (R^2=0.99). Sezen et al. (2016) applied irrigation water to the pepper plant at levels ranging from 385-770 mm. Demirel et al. (2012) reported that in the first year of the experiment, seasonal evapotranspiration and applied irrigation water amount values ranged between 333-855 mm and 30-567 mm, respectively, and in the second year, they ranged between 311-736 mm and 62-489 mm. Azder et al. (2020) calculated the seasonal total irrigation amount as 469-935.5 mm, and evapotranspiration as 457.0-935.5 mm. Certain differences were obtained between the amount of irrigation water and evapotranspiration values applied in these studies and the irrigation amount applied in this study and evapotranspiration. The reason for these differences is due to the diversity of irrigation programs and the fact that the study is conducted in regions with different climates and soil characteristics.

Table 3. Seasonal evapotranspiration

Treatments	Irrigation water amount (mm)	Precipitation (mm)	Soil water change (mm)	Seasonal evapotranspiration (mm)
S100	481.2	140.2	-4	617.4
S75	368.4	140.2	+8	516.6
S50	255.6	140.2	+28	423.8
S25	142.8	140.2	+40	323.0

Fruit yield

The effect of irrigation levels on Burkalem chili pepper yield was statistically significant at the $P<0.01$ level. The highest pepper fruit yield values were determined as 3800 kg da^{-1} and 3629 kg da^{-1} from S100 and S75 irrigation levels, respectively. On the other hand, lower pepper yields were obtained in S50 and S25 treatments due to the decrease in irrigation levels (Figure 1). The study results show that the pepper plant was sensitive to irrigation levels. When the S100 treatment is taken as a reference, the level of decrease in the yields obtained from the S75, S50 and S25 treatments was calculated as 5%, 39% and 56%, respectively. For this reason, in conditions where there is no difficulty in supplying irrigation water, the treatment S100, in which the irrigation program is created by applying the coefficient kcp=1.00 to the amount of water evaporated from the class A pan, can be recommended. The irrigation water level that can be recommended when there is difficulty in providing irrigation water or when limited irrigation is mandatory is S75 (kcp=0.75). Because, compared to the S100 treatment, a 25% saving in irrigation water is achieved, while the rate of reduction in fruit yield is only 5%. If the amount of irrigation water is reduced by more than 50% compared to the S100 treatment, yield losses increase to significant levels (39-56%). Taş and Kırnak (2011) determined the highest yield as 4703 kg da^{-1}. They determined the lowest yield as 2444 kg da^{-1} from S6 Kcp3, where the irrigation level is the lowest. Consistent with the results of this study, they reported that the decrease in yield was parallel to the reduction of the kcp coefficient. Şen (2015) reported that the highest pepper fruit yield was obtained from 3-days irrigation interval and 125% ET, while the lowest yield was obtained from 3-days irrigation interval and 25% ET. It is thought that the differences in yields in these studies are due to the planning of irrigation time and the different climate and soil characteristics of the regions where irrigation treatments were carried out.



Note: The values shown with different letters on the columns in the figure show significant differences at the P<0.05 level

Figure 1. *Pepper fruiting yields under different watering levels*

Fruit size and diameter

The effect of irrigation levels on fruit length and diameter of Burkalem chili pepper was significant at the level of $p<0.05$. The highest fruit size and diameter were achieved from S1 and S2 treatments and the lowest from S4. Azder et al. (2020) determined that fruit height values vary between 11.6 cm and 16.8 cm depending on irrigation levels. Demirel et al. (2012) reported the fruit size as 6.0-7.1 cm. Sezen et al. (2016) reported that the fruit length of the red pepper plant varies between 6.1-6.8 cm and the fruit diameter varies between 33.1-44.0 mm according to different irrigation treatments (50%, 75% and 100% of the pan evaporation value). It is thought that the difference in the fruit size parameters obtained as a result of the study among other studies is due to the difference in climate and soil characteristics, especially the difference in pepper varieties.

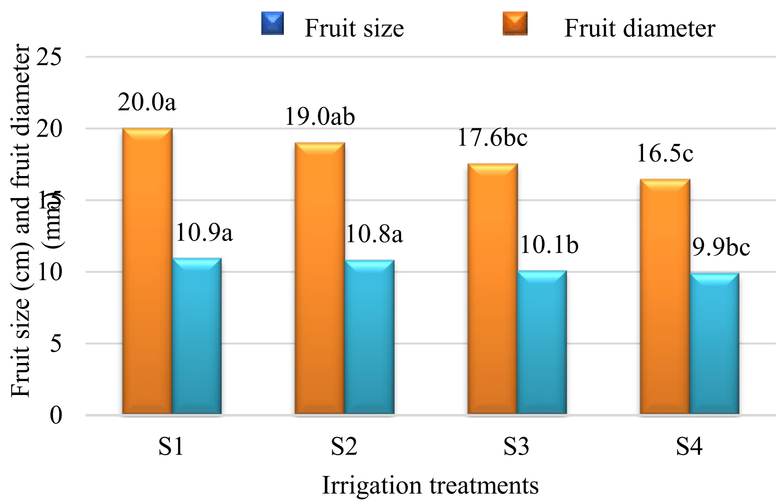


Figure 2. *Pepper fruit length and diameter*

Water-yield relationships

The relationship between pepper yield and the irrigation amounts in pepper plant is given in Figure 3, and the relationship between fruit yield and evapotranspiration values is given in Figure 4. Second degree polynomial equation was obtained between the seasonal irrigation amount (S) and the pepper fruit yield (Y) as $Y = -0.0093S^2 + 12.601S - 25.676$ (Figure 3). The coefficient of determination of the equation in question was determined as $R^2 = 0.95$. The high coefficient of determination indicates that the degree of accuracy of the obtained equation in estimating the yield for different irrigation levels is high. On the other hand, the linear relationship equation between evapotranspiration (ETa) and yield (Y) was found to be $Y = 7.8425ETa - 832.05$ and the determination coefficient was $R^2 = 0.92$. The coefficient of determination was found to be significantly higher. Using this equation, pepper growers in Bursa can predict fruit yield versus evapotranspiration with 92% accuracy.

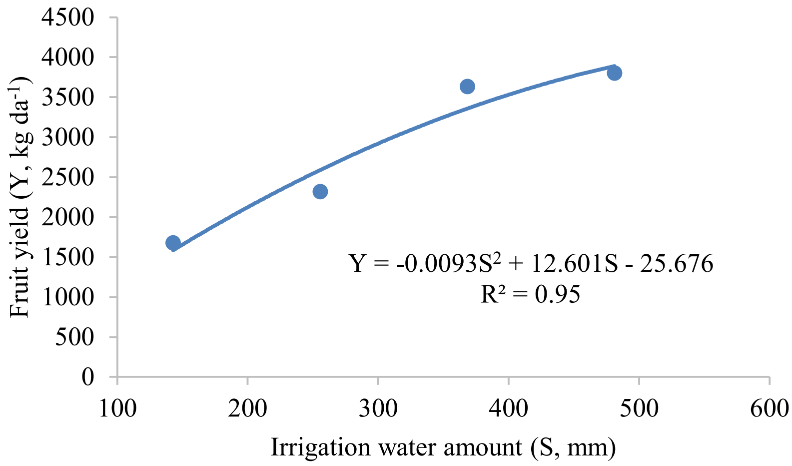


Figure 3. *Relationship between the seasonal irrigation amount and pepper fruit yield*

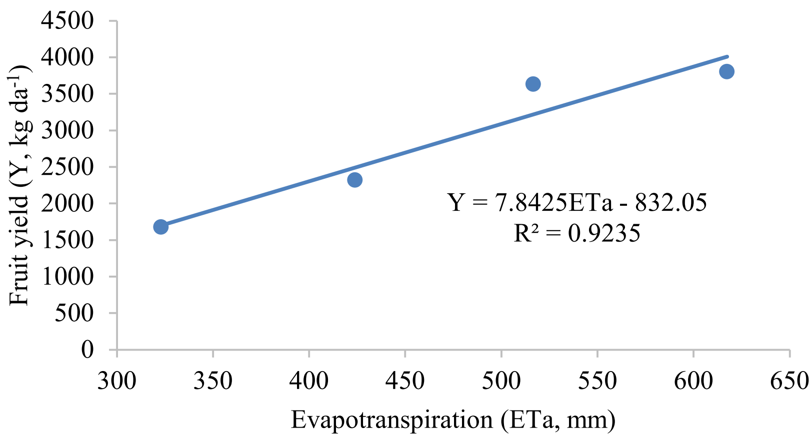


Figure 4. *Relationship between evapotranspiration and fruit yield*

Yield response factor

The seasonal yield response factor was calculated as ky = 1.12 (Figure 5). Şen (2015) Şen et al (2000) reported ky values as 0.996 and 0.615 for 3 and 6-day irrigation intervals, respectively. In the study conducted by Dağdelen (2001) under the conditions of Aydın province using the furrow irrigation method, the ky in pepper cultivation was found to be 0.55, and Ersöz and Avcı (1999) found this rate to be 0.62 under Bafra plain conditions. The yield response factor value obtained in this study is higher than the values given above. The reason for these differences is; It can be said that it varies depending on the pepper variety, climate and soil characteristics.

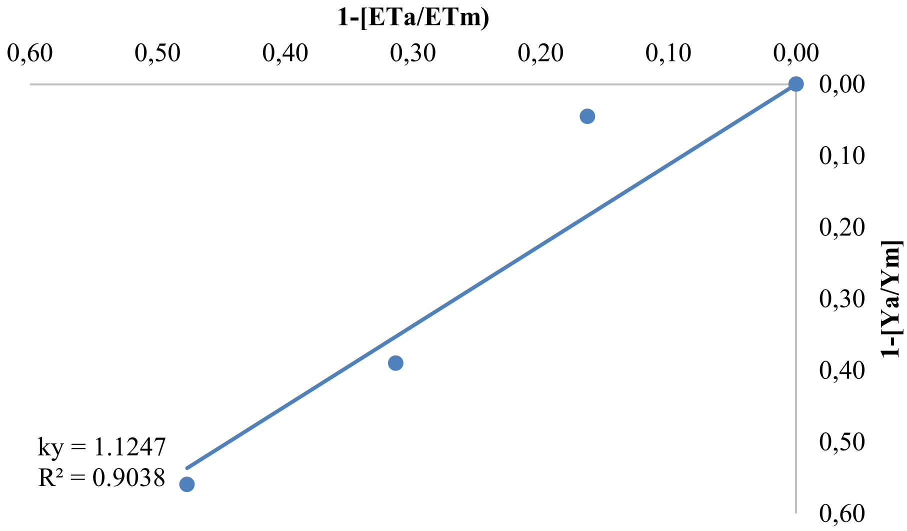


Figure 5. *Yield response factor*

Water productivities

IWP and WP values of the Burkalem green pepper plant for experimental treatments at different irrigation levels are given in Figure 6. IWP values varied between 7.90 and 11.73 kg m^{-3}. The highest IWP was calculated from the S25, and the lowest was calculated from the S100. The IWP value obtained from topic S75 ranked second. WP values varied between 5.19 and 7.02 kg m^{-3}. The highest WP was calculated from the S75 and the lowest was determined from the S25. When efficiency and other parameters are evaluated together, the S75 treatment stands out among other treatments. Sezen et al. (2016), WP values varied between 5.5-7.1 kg m^{-3} in 2010 and 5.8-7.5 kg m^{-3} in 2011. Çömlekçioğlu and Şimşek (2017) determined the IWP values as 3.41-5.88 kg m^{-3} and the WP values as 3.90-6.77 kg m^{-3}. Azder et al. (2020) reported that IWP values were obtained as 4.84-6.19 kg m^{-3} depending on irrigation treatments, and WP values varied between 4.16 and 4.56 kg m^{-3}. According to the results of the study, it is thought that the difference in IWP and WP values is owing to the fact that different irrigation strategies are addressed in the research and productivity levels differ depending on the variety.

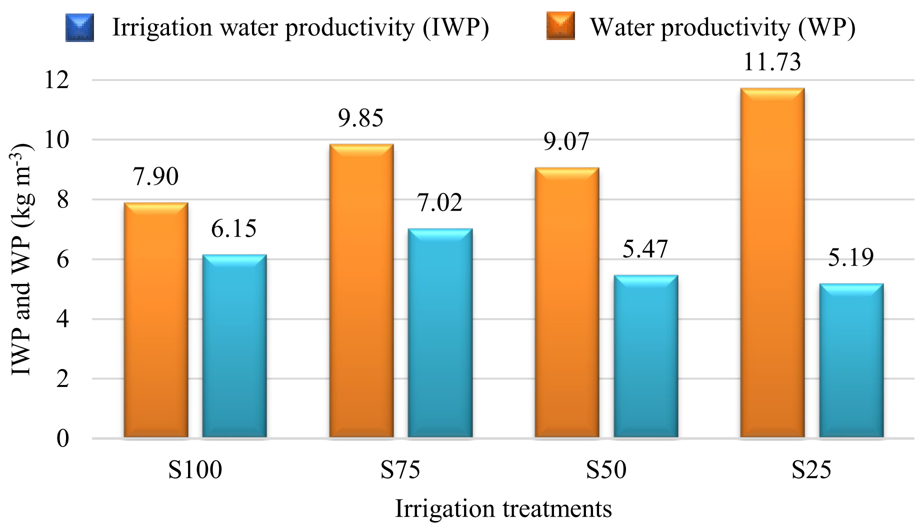


Figure 6. *Water productivities*

Conclusion

In Bursa ecological conditions, a field experiment was conducted in which different irrigation levels were discussed in order to plan the irrigation time and determine the water-yield relations on the green pepper (Burkalem variety) plant irrigated using the drip irrigation method. According to the results of the study, with the aim of ensuring maximum efficiency over the unit amount of irrigation water applied and protecting water resources and taking into account the water productivity, it can be recommended to prepare an irrigation program by applying the coefficient kpc = 0.75 to the water evaporated from the Class A evaporation pan in the cultivation of table green pepper in Bursa conditions. Under this condition, maximum water productivity can be achieved while saving 25% of water compared to irrigation with a coefficient of kpc = 1.00.

Acknowledgments

This study does not require ethics committee permission. The article has been prepared in accordance with research and publication ethics. Author 1 contributed 60% and Author 2 contributed 40% to the publication. There is no conflict of interest between the authors.

References

Abayomi, Y. A., Aduloju, M. O., Egbewunmi, M. A. and Suleiman, B. O. 2012. Effects of soil moisture contents and rates of NPK fertilizer application on growth and fruit yields of pepper (*Capsicum* spp.) genotypes. *International Journal of AgriScience*, *2*(7): 651-663.

Anonymous. 2021. Bitkisel Üretim İstatistikleri. Türkiye İstatistik Kurumu (TUİK), http://www.tuik.gov.tr/PreTablo.do?alt_id=1001. (Erişim Tarihi: 01.06.2021).

Azder, G., Göçmen, E. ve İstanbulluoğlu, A. 2020. Tekirdağ koşullarında farklı sulama seviyelerinin kapya biberin (*Capsicum annum Cv. Kapija)* verim ve verim bileşenleri üzerine etkileri. *Tekirdağ Ziraat Fakültesi Dergisi*, 17(3): 443-431.

Cosic, M., Djurović, N., Todorović, M., Maletić, R., Zečević, B. and Stričević, R. 2015. Effect of irrigation regime and application of kaolin on yield, quality and water use efficiency of sweet pepper. *Agricultural Water Management*, 159:139-147.

Çamoğlu, G., Demirel, K. and Genc, L. 2018. Use of infrared thermography and hyperspectral data to detect effects of water stress on pepper. *Quantitative InfraRed Thermography Journal,* 15(1): 81-94.

Çamoğlu, G., Demirel, K., Akçal, A. ve Genç, L. 2019. Su stresinin sofralık domatesin verimi ve fizyolojik özellikleri üzerine etkileri. *Bursa Uludag Üniv. Ziraat Fak. Derg.*, 33(1): 15-29.

Çamoğlu, G., Demirel, K., Kahriman, F., Akcal, A., Nar, H., Boran, A., Eroglu, I. and Genc, L. 2021. Discrimination of water stress in pepper using thermography and leaf turgor pressure probe techniques. *Agricultural Water Management*, 254:106942.

Çetin, Ö., Köksal, E.S. and Tarı A.F. 2013. Damla Sulamada Bitki Su Tüketimi ve Sulama Suyu Hesabına İlişkin Temel Yaklaşımlar. T.C. Gıda Tarım ve Hayvancılık Bakanlığı Tarımsal Araştırmalar vePolitikalar Genel Müdürlüğü Toprak ve Su Kaynakları Araştırma Daire Başkanlığı, Yayın No: TAGEM 2013-22, Ankara, 23 s.

Çömlekçioğlu, N. ve Şimşek, M. 2017. Kontrollü kısıtlı sulamanın biber (*Capsicum annum* L.) verim ve verim bileşenlerine etkileri. *Akademik Ziraat Dergisi*, 6: 297-304.

Dağdelen, N. 2001. Büyük Menderes havzası koşullarında sanayi biberinde farklı sulama aralığı ve sulama düzeyinin verim ve kalite üzerine etkileri. *Doktora Tezi, Ege Üniversitesi, İzmir*.

Demirel, K., Genç, L. ve Saçan, M. 2012. Yarı kurak koşullarda farklı sulama düzeylerinin salçalık biberde (*Capsicum annum* cv. Kapija) verim ve kalite parametreleri üzerine etkisi. *Tekirdağ Ziraat Fakültesi Dergisi*, 9(2): 7-15.

Doorenbos, J. and Kassam, A. H. 1979. Yield response to water. *Irrigation and Drainage Paper*, 33: 257.

Elmas, İ., Yetik, A.K. and Kuşçu, H. 2023. Effects of different irrigation intervals and irrigation levels on yield and quality components of processing tomatoes and economical analysis. *Bilecik Seyh Edebali University Journal of Science*, 10(1): 129-139.

Ersöz İ. K. ve Avcı, K. 1999. Bafra Ovası koşullarında Kısıtlı Su Uygulamasının Salçalık Biber Verimine Etkisinin Saptanması, KHGM, APK Dai. Bşk., Toprak ve Su Kaynakları Araştırma Yıllığı, Yayın No: 115, s. 16-30, Ankara.

FAOSTAT. 2020. Food and Agriculture Organization of the United Nations (FAO). FAOSTAT, http://www.fao.org/faostat/en/#data/QC. (Erişim tarihi: 08.06.2020).

Güvenç, İ. 2020. Türkiye'de biber üretimi, dış ticareti ve rekabet gücü. *Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi*, 23(2): 441-445.

James, L. G. 1988. Principles of Farm Irrigation System Design, New York, p. 543.

Jensen, M. E. (Ed.). 1980. Design and operation of farm irrigation systems (No. 631.587/J51). *American Society of Agricultural Engineers*.

Keleş, D., Rastgeld, U., Karipçin, Z., Karagül, S., Soylu, M.K., Çömlekçioğlu, N. ve Büyükalaca, S. 2016. Seleksiyon yoluyla Şanlıurfa biber ıslahı. *Alatarım*, 15 (1): 39-44.

Kırnak, H., Gökalp, Z., Demir, H., Kodal, S. and Yildirim, E. 2016. Paprika pepper yield and quality as affected by different irrigation levels. *Journal of Agricultural Sciences*, 22(1): 77-88.

Koksal, E. S., Tasan, M., Artik, C. and Gowda, P. 2017. Evaluation of financial efficiency of drip-irrigation of red pepper based on evapotranspiration calculated using an iterative soil water-budget approach. *Scientia Horticulturae*, 226: 398-405.

Kuşçu, H., Turhan, A., Özmen, N., Aydınol, P. and Demir, A. O. 2016. Response of red pepper to deficit irrigation and nitrogen fertigation. *Archives of Agronomy and Soil Science*, 62(10): 1396-1410.

Laribi, A. I., Palou, L., Intrigliolo, D. S., Nortes, P. A., Rojas-Argudo, C., Taberner, V. ... and Pérez-Gago, M. B. .2013. Effect of sustained and regulated deficit irrigation on fruit quality of pomegranate cv.'Mollar de Elche'at harvest and during cold storage. *Agricultural Water Management*, 125: 61-70.

Liu, H., Yang, H., Zheng, J., Jia, D., Wang, J., Li, Y. and Huang, G. 2012. Irrigation scheduling strategies based on soil matric potential on yield and fruit quality of mulched-drip irrigated chili pepper in Northwest China. *Agricultural Water Management*, 115: 232-241.

Mushtaq, S. and Moghaddasi, M. 2011. Evaluating the potentials of deficit irrigation as an adaptive response to climate change and environmental demand. *Environmental Science and Policy*, 14(8): 1139-1150.

Nagaz, K., Masmoudi, M. M. and Mechlia, N. B. 2012. Effects of deficit drip-irrigation scheduling regimes with saline water on pepper yield, water productivity and soil salinity under arid conditions of Tunisia. *Journal of Agriculture and Environment for International Development (JAEID)*, 106(2): 85-103.

Oktem, A., Simsek, M. and Oktem, A. G. 2003. Deficit irrigation effects on sweet corn (*Zea mays saccharata* Sturt) with drip irrigation system in a semi-arid region: I. Water-yield relationship. *Agricultural Water Management*, 61(1): 63-74.

Patanè, C., Tringali, S. and Sortino, O. 2011. Effects of deficit irrigation on biomass, yield, water productivity and fruit quality of processing tomato under semi-arid Mediterranean climate conditions. *Scientia Horticulturae*, *129*(4): 590-596.

Pereira, L. S., Paredes, P., Cholpankulov, E. D., Inchenkova, O. P., Teodoro, P. R. and Horst, M. G. 2009. Irrigation scheduling strategies for cotton to cope with water scarcity in the Fergana Valley, Central Asia. *Agricultural Water Management*, 96(5): 723-735.

Sezen, S. M., Yazar, A., Daşgan, Y., Yucel, S., Akyıldız, A., Tekin, S. and Akhoundnejad, Y. 2014. Evaluation of crop water stress index (CWSI) for red pepper with drip and furrow irrigation under varying irrigation regimes. *Agricultural Water Management*, 143: 59-70.

Sezen, S. M., Yazar, A., Şengül, H., Baytorun, N., Daşgan, Y., Akyildiz, A. ... and Gügercin, Ö. 2015. Comparison of drip-and furrow-irrigated red pepper yield, yield components, quality and net profit generation. *Irrigation and Drainage*, 64(4): 546-556.

Sezen, S.M., Yazar, A., Tekin, S. ve Şengül, H. 2016. Salçalık biber bitkisinde damla yöntemiyle uygulanan farklı sulama düzeylerinin verim üzerine etkileri ve ekonomik analizi. *KSÜ Doğa Bilimleri Dergisi*, 19(3): 310-318.

Şen, E. 2015. Sanayi biberinde (*Capsicum annuum* L.) damla sulama uygulamalarının bazı verim ve kalite özellikleri üzerine etkileri. *Yüksek Lisans Tezi, Adnan Menderes Üniversitesi, Fen Bilimleri Enstitüsü, Aydın, 57s*.

Taş, İ. ve Kırnak, H. 2011. Damla sulama yöntemiyle sulanan Şanlıurfa biberinin (*Capsicum annum* L.) sulama programı. *Tokat Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi*, 28(1): 103-112.

Tüylü, G.İ. ve Akın, S. 2023. Farklı sulama suyu seviyelerinin pamuk bitkisinin verim, verim bileşenleri ve lif kalite parametreleri üzerine etkisi. *Akademik Ziraat Dergisi*, 12(1): 91-98.

Vural, H., Eşiyok, D. ve Duman, İ. 2000. Kültür Sebzeleri (Sebze Yetiştirme). Ege Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü Bornova, İzmir.

Yang, H., Du, T., Qiu, R., Chen, J., Wang, F., Li, Y., ... and Kang, S. 2017. Improved water use efficiency and fruit quality of greenhouse crops under regulated deficit irrigation in northwest China. *Agricultural Water Management*, 179: 193-204.

Yang, H., Liu, H., Zheng, J. and Huang, Q. 2018. Effects of regulated deficit irrigation on yield and water productivity of chili pepper (*Capsicum annuum* L.) in the arid environment of Northwest China. *Irrigation Science*, 36(1): 61-74.

Yıldırım, M., Demirel, K. and Bahar, E. 2017. Radiation use efficiency and yield of pepper (*Capsicum annuum* L. cv. California Wonder) under different irrigation treatments. *Journal of Agricultural Science and Technology,* 19(3): 693-705.

Zheng, J., Huang, G., Jia, D., Wang, J., Mota, M., Pereira, L. S. ... and Liu, H. 2013. Responses of drip irrigated tomato (*Solanum lycopersicum* L.) yield, quality and water productivity to various soil matric potential thresholds in an arid region of Northwest China. *Agricultural Water Management*, 129: 181-193.