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## ARAŞTIRMA MAKALESİ

## RESEARCH ARTICLE

**Yield and Water Use of Eggplant (*Solanum melongena* L.) Under Different Irrigation Regimes and Fertilizers**

Farklı Sulama Rejimleri ve Gübreler Altında Patlıcanın (*Solanum melongena* L.) Verim ve Su Kullanımı


Mahmud ALİ<sup>1</sup>, Cafer GENÇOĞLAN<sup>2</sup>, Serpil GENÇOĞLAN<sup>3</sup>, Ali Beyhan UÇAK<sup>4</sup>


**Abstract**

This study was conducted in Bandırma (Balıkesir, Turkey) during the growing season of the plant in 2017 and 2018 to determine the effect of four levels of irrigation water and three kinds of fertilizer on yield and water use of field-grown eggplant (*solanum melongena*). Treatments included four irrigation regimes, which were 100% (I<sub>100</sub>, control), 80% (I<sub>80</sub>), 60% (I<sub>60</sub>), and 40% (I<sub>40</sub>) of evaporation from Class A Pan and three different fertilizers, which were chemical fertilizer CHF; N, P, K (20-20-20+15 SO<sub>3</sub>) added as 40 kg da<sup>-1</sup> organic fertilizer (OF) added as 2000 kg da<sup>-1</sup> and developed organic fertilizer (DOF) added as 2000 kg da<sup>-1</sup>. Total irrigation water of 305 mm and 360 mm were applied to I<sub>100</sub> irrigation treatment, in which water use was determined as 447 mm and 436 mm, respectively. In both experiment years, the effect of irrigation level on fruit yield was found to be significant statistically (p<0.05) but the effect of fertilizers treatments and irrigation x fertilizer interaction was insignificant (p>0.05). The highest yield with 3681 and 4515 kg da<sup>-1</sup> was harvested from I<sub>100</sub> irrigation treatment, and the lowest yield with 3021 and 2792 kg da<sup>-1</sup> from I<sub>40</sub> irrigation treatment, respectively. As for fertilizer, the highest yield with 3462 and 3878 kg da<sup>-1</sup> was harvested from DOF, while the lowest yield with 3258 and 3629 kg da<sup>-1</sup> from OF, respectively. Water use efficiency (WUE) ranged from 8.26 to 12.54 kg mm<sup>-1</sup> and irrigation water use efficiency (IWUE) from 11.9 to 25.68 kg mm<sup>-1</sup> in the experimental years. Thus, in irrigation programming, the Kcp3: 0.80 plant-pan coefficient and in fertilizer application, DOF is recommended for field-grown eggplant.

**Keywords:** Chemical fertilizer, Drip irrigation, Eggplant, Organic fertilizer, Water-yield relationship

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## Öz

Bu çalışmanın amacı, üç farklı gübre ve dört farklı düzeydeki sulama suyu miktarlarının patlıcan bitkisinin verimine, kalitesine ve su-verim ilişkisine etkisini belirlemektir. Araştırma, Bandırma koşullarında 2017 ve 2018 yıllarında patlıcan bitkisinin yetiştirme sezonu boyunca yürütülmüştür. Çalışmada; 3 farklı gübre ve 4 farklı sulama düzeyi kullanılmıştır. Gübre konuları, kimyasal gübre CHF; N, P, K (20-20-20+15 SO<sub>3</sub>) 40 kg da<sup>-1</sup> olarak eklendi, organik gübre (OF) 2000 kg da<sup>-1</sup> olarak eklendi ve gelişmiş organik gübre (DOF) 2000 kg da<sup>-1</sup> olarak eklenmiştir. Dört farklı sulama konusu ise A Sınıfı Buharlaştırma Kabı'ndan oluşan buharlaştırmanın % 100 (I<sub>100</sub>, kontrol), %80 (I<sub>80</sub>), %60 (I<sub>60</sub>) ve %40 (I<sub>40</sub>)'nın verilmesi şeklinde oluşturulmuştur. Sulama suyu miktarı 2017 ve 2018 yıllarında sırasıyla 122 - 305 mm ile ve 147 - 360 mm ve bitki su tüketimi araştırma 2017 ve 2018 yılları için sırasıyla 264 - 447 mm ve 217 - 436 mm 533 la değişmiştir. Araştırma sonucuna göre patlıcanın verim değerleri üzerine sulama suyu konusunun etkisi istatistiksel olarak önemli bulunmuştur (P<0.05). Gübre uygulaması ve sulama konusu x gübre etkisi etkisinin önemsiz olduğu belirlenmiştir. Araştırmada en yüksek meyve verimi, 2017 ve 2018 yıllarında sırasıyla 3681 kg da<sup>-1</sup> ve 4515 kg da<sup>-1</sup> ile I<sub>100</sub> sulama konusundan, en düşük meyve verimi ise sırasıyla 3021 kg da<sup>-1</sup> ve 2792 kg da<sup>-1</sup> ile I<sub>40</sub> sulama konusunda elde edilmiştir. Gübre uygulamalarında her sulama konusu için en yüksek verim 3462 ve 3878 kg da<sup>-1</sup> DOF uygulamasında ve en düşük verim ise 3258 ve 3629 kg da<sup>-1</sup> OF gübre uygulamasında elde edilmiştir. Deneme yıllarında su kullanım randamanı (WUE) 8.26 ile 12.54 kg mm<sup>-1</sup>, sulama suyu kullanım randamanı (IWUE) ise 11.9 ile 25.68 kg mm<sup>-1</sup> arasında değişmiştir. Bu nedenle sulama programlamasında K<sub>cp3</sub>: 0.80 bitki katsayısı ve DOF gübre uygulamasında yetiştirilen patlıcan için önerebiliriz.

**Anahtar Kelimeler:** Damla sulama, Kimyasal gübre, Organik gübre, Patlıcan, Su-verim ilişkisi.

## 1. Introduction

In our century, the world's population has been constantly increasing, agricultural lands and clean water resources have been gradually decreasing, access to food and water will be more difficult for countries, and agriculture will continue to be the most strategic sector of the two thousand years. In addition to providing basic nutrients by agriculture, the production of fresh fruits and vegetables, in general, is of vital importance in terms of supplying healthy nutrition. With the limited water resources availability in the Middle East and the rapid and unplanned consumption of water in industry and agriculture in recent years, these existing resources are threatened in terms of quality and quantity. Therefore, it is necessary to know the amount of water consumed by cultivated crops for water resources sustainability. In this context, it is necessary to determine the water consumption for eggplant and other vegetables that have a high economic and healthy value. Application of deficit irrigation in crop production is an approach to save water in areas of water shortage and longer drought during the production period to maximize water productivity. Deficit irrigation saves a large amount of irrigation water and increases water use efficiency (Kirda, 2002). Kırnak et al. (2002) results show that eggplant can be drip-irrigated with 8-day irrigation intervals at 80% of Class A Pan evaporation without decreasing yield but with significant water savings and improve fruit quality compared to control. Diaz-Perez (2015) concluded that eggplant tolerate moderate water stress, and plants irrigated at 67% ET<sub>c</sub> produced fruit yields similar to those of plants irrigated at 100% ET<sub>c</sub>. So, there is a possibility to save water by decreasing current irrigation rates without negatively affecting the fruit yields. Demirel et al. (2014) reported that yield reductions of 18.16 % and 27.13 % were observed under low and moderate water stress. It was observed that the highest average eggplant fruit weight was in treatment exposed to full irrigation amount (100%). Kırnak et al. (2001) studied the effects of irrigation regime on eggplant and observed that water stress led to a significant decrease in chlorophyll content, leaf water content and vegetative growth, and fruit yield and quality. Chaves et al. (2003) concluded that crop vegetative growth and yield decrease with increasing water stress. Lovelli et al. (2007) illustrated that eggplant fresh yield ranged from 48.2 t ha<sup>-1</sup> in kcp:100%, to 11.4 t ha<sup>-1</sup> in kcp:25%. Aujla et al. (2007) determined fresh eggplant yields varying from 43.1 to 103.1 t ha<sup>-1</sup> in India. Mohawesh and Karajeh (2014) reported that water deficit reduced the growth of eggplant components. The common cause of the reduced vegetative growth of vegetables under water deficit conditions has been thought to be accelerated leaf senescence, as reported by Kırnak et al. (2002). El-Miniawy (2015) concluded that irrigation using different irrigation regimes significantly affected the eggplant vegetative growth parameters, i.e., plant height, number of branches and leaves, leaf area, and fresh and dry weights of leaves. Among irrigation regimes, the highest plant vegetative growth characters were observed in irrigation treatment after depletion of 70-75% of available soil water. Provided 509 mm of irrigation water led eggplant to intercept 35% of the active light radiation. Therefore, applying irrigation water of 509 mm in semi-arid regions for eggplant production seems to be a more appropriate level for getting a higher yield (Yıldırım, 2015). Ertek et al. (2006) reported irrigation water values varied between 372 mm and 689 mm for furrow irrigated eggplant in Turkey. Aujla et al. (2007) concluded that irrigation water amounts changed between 413 and 826 mm for different treatments for drip-irrigated eggplant in India. The seasonal average ET of drip-irrigated eggplant changed between 905 and 1375 mm by Kırnak et al. (2002) in the Harran plain of Turkey and 719 mm and 1196 mm by Aujla et al. (2007) in India and 147 and 469 mm by Lovelli et al. (2007) in Southern Italy and 150 and 590 mm by Karam et al. (2011) in the central Bekaa Valley of Lebanon, and furrow irrigated between 420 mm and 689 mm by Ertek et al. (2006) in the Mediterranean region of Turkey. Karam et al. (2011) founded the highest WUE value in the deficit irrigation treatment as 5.6 kg mm<sup>-1</sup> in Lebanon. Eggplant WUE increased under water stress conditions (Kırnak et al. 2002). Amiri et al. (2012) demonstrated that WUE for eggplant varied from 4.36 to 11.6 kg mm<sup>-1</sup>; the highest amount of WUE was recorded in plants irrigated every 6 days and received 120 kg nitrogen per hectare. Supplying plants with an optimum level of all plant nutrients are primary for the production of top-quality fruit and good production levels (Hochmuth et al., 1993). Nitrogen is one of the main elements for plant growth and development which plays an important role in plant nutrition and thus, it is one of the factors that limit plant yield and growth in many areas. Nitrogenous fertilizers often have mobility in soils, and they can contaminate soils and groundwater. And therefore, management of N rate, type, application time is very important (DePascale et al., 2006). Rosati et al. (2001) observed that by increasing nitrogen, leaf area index, light interception, and dry matter of eggplant increased. Aminifard et al. (2010) studied the effect of four rates of nitrogen fertilizer on growth and yield of eggplant and found that plant height, branch numbers, leaf chlorophyll content, flower number, fruit weight, and fruit yield

were affected by nitrogen rate. El-Miniawy (2015) concluded that irrigation of eggplants after the depletion of 70-75% of the available soil water plus the application of 100 or 150 kg K<sub>2</sub>O feddan<sup>-1</sup> resulted in the highest vegetative growth and yield of eggplant. De et al. (1996) concluded that increasing K application for eggplant increased vegetative growth parameters, i.e., plant height and crop growth rate as well as dry matter accumulation. Inorganic fertilizers are known as their high cost and their bad environmental effects if managed poorly (Morris et al., 2007). In a certain experiment, the researchers found that using the organic application had the potential to increase the growth and chemical composition of two cultivars of safflower and therefore, it may be a good alternative to chemical fertilizers (Naderi and Bijanzadeh, 2014). Louisa and Taguiling (2016) resulted that compost motivate plant growth parameters such as height, number of leaves, fresh weight of plant biomass, and yield of eggplant (*Solanum melongena*). Organic fertilizer was obtained from microbial composting of organic agricultural and domestic wastes. It was found that organic fertilizer application for eggplant it will be superior to chemical fertilizers in terms of vegetative growth, fruit yield, and quality attributes. Organic fertilizer slightly decreased the vegetative period and improved the yield components and total marketable fruit yield. Organic fertilizer could be recommended as a complete alternative for chemical fertilizers in eggplant production (Dinh Hoa, 2008). Mechanochemical activation can be defined as a process being able to induce structural disorder through intensive grinding. In certain conditions, it may increase the chemical reactivity of the processed material (Tole et al., 2019). Therefore, the objective of this study was to determine the effects of different irrigation levels on the yield and quality parameters of the eggplant under field conditions using Class A Pan evaporation calculations and different plant-pan coefficients and to study the effect of organic and inorganic fertilizer on growth and yield of eggplant (*Solanum melongena*).

## 2. Materials and Methods

The experiment was carried out in Bandırma in a field located at 40° 16 '44.4252" North and 28° 4' 18.9552 " Eastern latitudes and longitudes and its altitude is 41 m. The prevailing climate in Bandırma is the Mediterranean Sea and the Black Sea. Besides, because it is located in the transition area of the terrestrial climate of the Balkans, the average lowest and the highest temperature of 52-years are 5.3 °C and 23.9 °C with an annual mean of 14 °C. Rainfall, wind speed, and relative humidity are 14 °C, 703.3 mm, 15 km h<sup>-1</sup>, and 73%, respectively (Anonymous, 2017).

Disturbed and undisturbed soil samples belong to the experiment area were taken from 0-30, 30-60, and 60-90 cm soil layers and then physical and chemical analyses were performed on these samples (*Table 1*). The pH of soil ranged from 8 to 8.1, EC 0.76 to 0.84 dS m<sup>-1</sup>, organic matter %0.68 to %1.2, total nitrogen %0.090 to %0.097, phosphorus 1.44 to 1.69 kg da<sup>-1</sup>, potassium 59.8 to 83.8 kg da<sup>-1</sup>, and volume weight (As) 1.28 to 1.31 g cm<sup>-3</sup>. The soil texture in the first layer (0-30 cm) is sandy clay; in the second layer (30-60 cm) sandy silt clay; the third layer (60-90 cm) silty.

In experiment there is 36 parcels, parcel dimensions were 8 x 4.2 m = 33.6 m<sup>2</sup> The total area of parcels is 1209.6 m<sup>2</sup>. The distance between the rows in each parcel 70 cm, the distance between plants in the row is 40 cm. In every row There are 20 plants the total plants in each parcel is 120 plants in. for avoiding interaction between parcels 2 meters' buffer zone was created, so the total area of the experiment was 2380.8 m<sup>2</sup>. Total number of eggplant seedlings transplanted in the experiment area is 4320 seedling.

Irrigation water is pumped from the deep well near the experiment plot into a pool. Samples were collected from the irrigation water and then analyzed. The class of irrigation water is determined as C3S1 (*Table 2*), so this water is suitable for irrigation of eggplant as it was reported by Ünlükara et al. (2010).

In the experiment, eggplant cv. Karnaz variety was used as experiment material.

**Table 1. Some physical and chemical properties of soil at the experiment area**

Profile (cm)	PH	EC dS cm <sup>-1</sup>	OM %	Total N%	P <sub>2</sub> O <sub>5</sub> Kg da <sup>-1</sup>	K <sub>2</sub> O Kg da <sup>-1</sup>	As (g m <sup>-3</sup> )	WP (P <sub>w</sub> )	FC (P <sub>w</sub> )	Sand %	Silt %	Clay %	Texture
0-30	8.0	0.76	1.20	0.094	1.69	83.8	1.28	20.4	38.95	30.6	12.1	57.3	Sandy Clay
30-60	8.1	0.82	0.97	0.090	1.44	67.9	1.31	19.8	38.72	30.7	16.0	53.3	Sandy Silt clay
60-90	8.1	0.84	0.68	0.097	<0.7	59.8	1.28	20.3	39.15	28.6	16.0	55.4	silty

As; volume weight of soil, FC; field capacity, OM; organic matter, WP; wilting point.

**Table 2. Chemical properties of water used in irrigation**

PH	EC µs cm <sup>-1</sup>	K <sup>+</sup> me L <sup>-1</sup>	Ca <sup>++</sup> me L <sup>-1</sup>	Mg <sup>++</sup> me L <sup>-1</sup>	Na <sup>+</sup> me L <sup>-1</sup>	CO <sub>3</sub> <sup>-</sup> meL <sup>-1</sup>	HCO <sub>3</sub> <sup>-</sup> me L <sup>-1</sup>	Cl <sup>-</sup> me L <sup>-1</sup>	SO <sub>4</sub> <sup>-</sup> me L <sup>-1</sup>	SAR	RSC me L <sup>-1</sup>	PS me L <sup>-1</sup>
7.3	1052	0.06	4.36	3.99	2.51	--	6.18	1.85	2.89	1.23s <sub>1</sub>	--	3.295

SAR; sodium absorption rate, RSC; residual sodium carbonate, PS; potential salinity.

In the study, treatments were selected to the determinate effect of four different irrigation levels and three different fertilizers on fruit yield, some vegetative growth indicators, and water yield relationship of eggplant. Irrigation and fertilizer treatment was planned in the main and sub-parcels, respectively, and formed in a split plots randomized block design with three replicates. Irrigation treatments were established with 100% (I<sub>100</sub>, control), 80% (I<sub>80</sub>), 60% (I<sub>60</sub>), and 40% (I<sub>40</sub>) of the total amount of evaporated from Class A Pan when total evaporation was 40 mm or more. Fertilizer treatments were organic fertilizer (OF) with 2000 kg da<sup>-1</sup>, developed organic fertilizer (DOF) with 2000 kg da<sup>-1</sup>, and chemical fertilizer (CHF) with 40 kg da<sup>-1</sup>, which was the control for fertilizers. CHF, which was called compound fertilizers, contains major elements of N, P, K (15-15-15 + 20 SO<sub>3</sub>). OF and DOF consists of 75% cow manure and 25% chicken manure, prepared in anaerobic fermentation method. The difference between Normal Organic fertilizer (OF) and developed organic fertilizer (DOF) is that 20% of developed organic fertilizer prepared by a mechanical activation process using a high energy ball milling machine (Ibrahim et al., 2010). OF and DOF were granulated up to a grain size of 1 to 8 mm to make slow-release organic fertilizers. In both organic fertilizers, OM content is 33%, the humic + fulvic content is 18.4% and the pH is 7.4 (Table 3).

**Table 3. Chemical properties of organic fertilizers (OF and DOF)**

PH	OM. (%)	Moisture (%)	Humik+volvik (%)	Total N (%)	P <sub>2</sub> O <sub>5</sub> (%)	K <sub>2</sub> O (%)
7.4	32.9	10.7	18.4	1.88	2.04	1.2

In both research years, the experimental area was tilled, plots were created, and fertilizers were applied, and then fertilizer was mixed into soil by hoeing machine. After that, the drip irrigation system was installed, eggplant seedlings were planted in the two research years on 02.06.2017 and 22.05.2018 according to the experiment plan, and also to establish seedlings, irrigation of 50 mm was applied to all experimental plots. Then, scheduled irrigations started based on the amount of evaporation from Class A Pan when the total evaporation amount was equal to or more than 40 mm. The spacing between rows was 70 cm, the spacing within rows was 40 cm, and each parcel with 120 plants contained 6 rows, one of which has 20 plants. Plots size was 8 m x 4.2 m (33.6 m<sup>2</sup>). The total number of the plots was 36, the space between the plots was 2 m, the total area of the experiment was 2380.8 m<sup>2</sup>. Doing every irrigation before 24 hours, soil samples from layers of 0-30, 30-60, and 60-90 cm were taken by spiral auger method to determine the moisture content in the soil profiles and dried at 105° C in the oven for 24 hours. Evapotranspiration (ET) was calculated with the equation (Eq. 1) (Garrity et al., 1982; James et al., 1982; Gençoğlu et al. 2006, Demirel et al., 2012):

$$ET = I + P \pm DSW - Dp - Rf \quad (\text{Eq. 1})$$

Where ET is the evapotranspiration (mm), I the amount of irrigation water applied (mm), P the precipitation (mm), DSW the soil water content change (mm) in the 60 cm soil profile (effective rooting depth of eggplant), Dp the deep percolation (mm), and Rf the amount of runoff (mm). Since the amount of irrigation water was controlled, the runoff was assumed to be zero. Monitoring soil water content in the plots revealed that deep percolation was negligible below 60 cm depth.

In the calculation of the amount of irrigation water, the method is given by Allen et al. (1998) was followed: Crop evapotranspiration is calculated directly using Equation 2.

$$ET_c = K_{cp} E_{pan} \quad (\text{Eq. 2})$$

Where ET<sub>c</sub> is the crop evapotranspiration (mm), K<sub>cp</sub> is the crop-pan coefficient and E<sub>pan</sub> is pan evaporation (mm). Four crop-pan coefficients, K<sub>cp1</sub> = 0.40, K<sub>cp2</sub> = 0.60, K<sub>cp3</sub> = 0.80 and K<sub>cp4</sub> = 1.00 were used to determine response of eggplant to different level of water. For this aim, a screened Class A Pan (1210 mm in diameter and 250 mm depth and made of Galvanized metal with 0.8 mm thickness) was located on a wooden



base next to the experimental field, surrounded by vegetation but no shadowing (Doorenbos and Pruitt, 1977). Daily evaporation was measured from Class A Pan at 09:00 using by hook gauge. The water level in the pan was kept between 150 - 200 mm, whenever the water level in the pan dropped below 150 mm; the pan was again filled with water up to 200 mm. The daily pan evaporation was calculated by subtracting the hook gauge measurement values from the previous day to the next day. Daily pan evaporation was added and when cumulative pan evaporation was 40 mm and more, irrigations started. The amount of irrigation water was calculated from Equations 3 and 4.

$$I = ETc \text{ fw} \quad (\text{Eq. 3})$$

$$V = IA \quad (\text{Eq. 4})$$

Where fw is the wetting factor, V is the volume of irrigation water applied to irrigation plots (L), and A is the plot area (m<sup>2</sup>). Eq. (5) was used in the determination of the wetting factor according to plant coverage (Ertek and Kanber, 2003).

$$fw = \frac{a}{b} \quad (\text{Eq. 5})$$

Where: (a); plant canopy diameter (cm), (b); row spacing (cm).

Plant canopy diameter (a) was taken before every irrigation from the average of 5 plant diameter in each irrigation treatment. Water-use efficiency (WUE) and irrigation water-use efficiency (IWUE) values were calculated as fresh eggplant fruits yield divided by seasonal ET and total seasonal irrigation water applied, respectively (Tanner and Sinclair, 1983; Howell et al., 1990). Regression analysis was used to determine production functions for eggplant yield versus I and ET. Marketable eggplants were hand-harvested five times and weighed from August 9<sup>th</sup> to October 5<sup>th</sup> in the first season and from July 19<sup>th</sup> to September 12<sup>th</sup> in the second season. After the last fruit harvest, removing them from the soil with their roots and cleaned from the soil, all the plants in each parcel were weighed.

Analysis of variance was performed on yield and plant fresh weight, 5% level of significant difference (LSD at P<0.05) was used in ANOVA to test the effect of irrigation and fertilizers treatments on different response variables (Steel and Torrie, 1980).

### 3. Results and Discussion

#### 3.1. Applied irrigation water (I) and evapotranspiration (ET)

In two growing season, total pan evaporation was measured as 579 and 599 mm, and precipitation were 143 and 86 mm, and treatments were irrigated 12 and 13 times (Table 4). Total amounts of applied irrigation water changed between 122 and 305 mm in 2017, and between 147 and 360 mm in 2018. The differences in irrigation water between the two experiment years related to the differences in precipitation (Table 4). Evapotranspiration ranged from 264 to 447 mm in the first year and 217 mm to 436 mm in the second year (Table 4). The relations between irrigation I, evapotranspiration ET and yield were defined respectively as  $Y = 3.6 \cdot I + 2575$ ,  $Y = 8.2 \cdot I + 1683$ ,  $Y = 3.6 \cdot ET + 2064$ ,  $Y = 8.0003 \cdot ET + 1144$ . Significant linear relationships were obtained between the irrigation water (I, mm) and evapotranspiration (ET, mm) versus eggplant yield for irrigation treatments ( $P < 0.05$ ) (Figure 1). It can be concluded that as the amount of irrigation water and ET value increased from I<sub>40</sub> to I<sub>100</sub>, the yield of eggplant fruits increased, and also the seasonal evapotranspiration (ET) increased with the increasing amount of irrigation (I). Ertek et al. (2006) reported that the amount of irrigation water ranged from 372 to 689 mm, while the average plant water consumption values vary between 420 and 689 mm. Ayas (2017) concluded that irrigation water and evapotranspiration of eggplant ranged from 85 to 464 mm 170 to 472 mm. Şenyiğit et al. (2011) found the amount of the applied irrigation water and evapotranspiration (ET) ranged between 95.2 and 238.7 mm, and from 93.1 to 466.3 mm in the greenhouse. Çolak et al. (2017) reported that the total amount of the applied irrigation water changed between 243 mm and 495 mm among the surface drip-irrigated treatments and it varied from 228 mm to 446 mm in the subsurface drip plots. He found that evapotranspiration (ET) of eggplant was between 339 and 543 mm in surface drip system treatments and 306 and 495 mm in subsurface drip system treatments. Lovelli et al. (2007) found that eggplant evapotranspiration (ET) varied from 339 to 543 mm and from 306 to 495 mm in surface drip and from 306 to 495 mm in subsurface drip

treatments, respectively. The results were obtained by Ayas (2017), Çolak et al. (2017), and Şenyiğit et al. (2011) are compatible with this research results. However, the results obtained by Ertek et al. (2006) are somewhat different due to different irrigation management and climatic conditions in the research area. About the effect of fertilizer on ET, no effect has been noticed, because the same amounts of water have been applied to all fertilizer treatments in every irrigation treatment depending on Class A Pan evaporation.

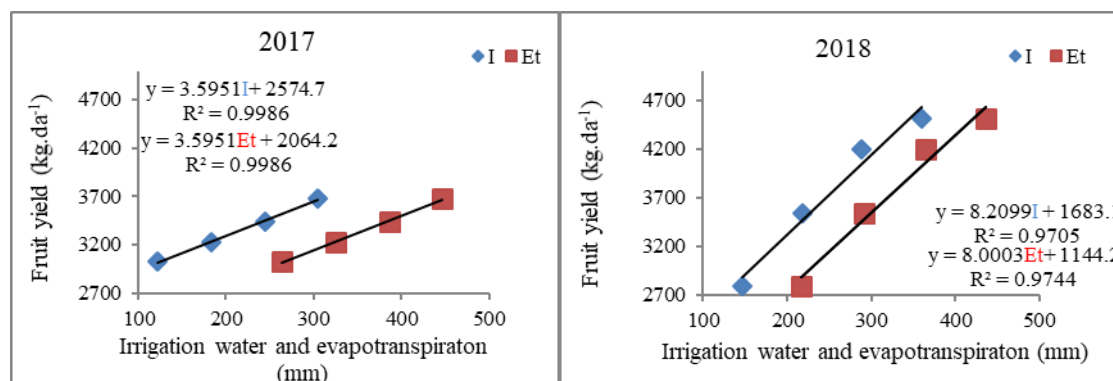


Figure 1. Yield and irrigation water and evapotranspiration relationship (2017-2018)

Table 4. Applied irrigation water amounts and calculated evapotranspiration in irrigation plots

Irr. no.	2017						2018					
	I <sub>40</sub> (mm)	I <sub>60</sub> (mm)	I <sub>80</sub> (mm)	I <sub>100</sub> (mm)	P (mm)	ET (mm)	I <sub>40</sub> (mm)	I <sub>60</sub> (mm)	I <sub>80</sub> (mm)	I <sub>100</sub> (mm)	P (mm)	ET (mm)
1	5.0	5.0	5.0	5.0	0	47	5.0	5.0	5.0	5.0		48
2	2.7	4.1	5.37	8	0	97	2.29	3.43	4.57	5.71	27.53	40
3	6.31	9.4	12.14	15.6	59.0	42	3.60	5.40	7.20	9.00	1.5	68
4	7.11	10.8	14.4	18	0	47	8.60	12.90	17.20	21.50	16.9	43
5	8.5	12.9	17.2	21.49	0	50	9.60	14.40	19.20	24.00		42
6	11	18.2	25.71	32.14	21.6	42	11.30	17.00	22.60	28.30		44
7	12	18.0	24.02	30.02	6.8	40	12.60	18.90	25.10	31.40		72
8	11.8	17.8	23.77	29.71	0	41	14.40	21.60	28.80	36.00		42
9	12.4	19.3	25.77	32.21	0	45	14.90	22.30	29.70	37.10		40
10	15	22.6	30.85	38.57	37.6	40	16.00	24.00	32.00	40.00		40
12	15	22.3	29.71	37.14	0	40	16.80	25.20	33.60	42.00	39.85	40
12	15	22.3	29.71	37.14	17.9	48	16.00	24.00	32.00	40.00		40
13							16.00	24.00	32.00	40.00		40
Top.	122	183	244	305	142.9	579	147	218	289	360	86	599

### 3.2. Fruit yield

Plants flowered about one month after planting and the fruit was harvested five times from 09 August 2017 to 05 October 2017 and from 19 July 2018 to 12 September 2018. In both years, the highest fruit yields were obtained from I<sub>100</sub> irrigation treatment with 3681 and 4515 kg da<sup>-1</sup> followed by I<sub>80</sub> (3440, 4203 kg da<sup>-1</sup>) and I<sub>60</sub> (3227, 3546 kg da<sup>-1</sup>) while the lowest yield was 3021 and 2792 kg da<sup>-1</sup> harvested from I<sub>40</sub> irrigation treatment, respectively. In the fertilizer treatments, the highest yields were harvested from DOF with 3462 and 3878 kg da<sup>-1</sup>, in both seasons respectively followed by CHF with 3307 and 3784 kg da<sup>-1</sup> while the lowest yield was 3258 and 3629 kg da<sup>-1</sup> from OF, respectively as seen in Figure 2.

The effects of irrigation levels on yield were found to be statistically significant ( $P < 0.05$ ) and the LSD test formed the average yield of 3 groups. In the rank, I<sub>100</sub> and I<sub>80</sub> were first in group A so I<sub>80</sub> irrigation level would be recommended to eggplant producer where water consumption is lower and at the same time they were in the same level of yield, I<sub>60</sub> second in group B, and I<sub>40</sub> third in group C. It was found to be insignificant ( $P > 0.05$ ) for



fertilizer treatment and irrigation x fertilizer interaction (Table 5). The reason why the eggplant yield varied in experimental years is the difference in the previously cultivated crops and weather conditions.

The results showed that as the amount of irrigation water increased the eggplant yield increased (Figure 1). On the other hand, among the fertilizer treatments, the highest fruit yield of eggplant was harvested from DOF (Figure 2), the reason for this is that DOF fertilizer is developed and activated in a way that makes nutrients more easily available and absorption by the plant (Ibrahim et al., 2010; Tole et al., 2019). These results coincide with that obtained by Aujla et al. (2007) who found that fruit yield of eggplant had a positive response to the increase of nitrogen fertilizer under different irrigation levels. Amiri et al. (2012) concluded that the influence of irrigation on fruit yield was found significant and higher than the influence of N fertilization and he found among all treatments, irrigation in 6 days interval and application of 120 kg N ha<sup>-1</sup> had the highest fruit yield (51.12 ton ha<sup>-1</sup>). Gaveh et al. (2011) demonstrated that total marketable yield in the season increased with increasing irrigation. Kırmak et al. (2001) demonstrated that water stress resulted in a reduction of fresh fruit yield and fruit size of the eggplant. Also, Şenyiğit et al. (2011) reported that the highest yield was obtained from full irrigation treatment and 10% reduction of full irrigation amount. Gaelen (2012) demonstrated that the highest yield (3154 kg da<sup>-1</sup>) was at full irrigation and the lowest yield (1321 kg da<sup>-1</sup>) at no irrigation. In other eggplant studies, Karam et al. (2011) reported eggplant yields varying between 13.4 and 33.8 t ha<sup>-1</sup> for full and deficit irrigation regimes and Ertek et al. (2006) found that the yield of eggplant fruits ranged between 1010 and 2114 kg da<sup>-1</sup> and Lovelli (2007) reported that eggplant yields varying between 11.4 t ha<sup>-1</sup> at kcp: 0.25 and 48.2 t ha<sup>-1</sup> at kcp: 0.1. Yenigün and Erdem (2019) found that the yield of eggplant fruits ranged between 2180 and 4760 kg da<sup>-1</sup>. As a result, deficit irrigation reduces the yield of eggplant (English, 1990; Pereira et al., 2002; Karam et al., 2006; Fereres and Soriano, 2007).

As a result, deficit irrigation reduces the yield of eggplant (English, 1990; Pereira et al., 2002; Karam et al., 2006; Fereres and Soriano, 2007). All these results are consistent with the results of this research but the changes in yield were due to the difference in irrigation management, soil, eggplant varieties, and climatic conditions. Overall, the result of most studies 'related to eggplant productivity, morphological, and physiological responses under water-conditions limited' showed reductions in fruit yield, quality, and plant vegetative development.

Table 5. Eggplant fruit yield (kg da<sup>-1</sup>)

Year	2017					2018				
Treatment	I <sub>40</sub>	I <sub>60</sub>	I <sub>80</sub>	I <sub>100</sub>	Average of fer.	I <sub>40</sub>	I <sub>60</sub>	I <sub>80</sub>	I <sub>100</sub>	Average of fer.
DOF	3128	3403	3604	3714	3462	2928	3678	4312	4593	3878
CHF	2999	3111	3424	3693	3307	2727	3611	4218	4579	3784
OF	2937	3168	3293	3635	3258	2722	3340	4079	4375	3629
Average of irrigation	3021 <sup>(c)</sup>	3227 <sup>(bc)</sup>	3440 <sup>(ab)</sup>	3681 <sup>(a)</sup>		2792 <sup>(c)</sup>	3546 <sup>(b)</sup>	4203 <sup>(a)</sup>	4515 <sup>(a)</sup>	
LSD (0.05)	267					233				

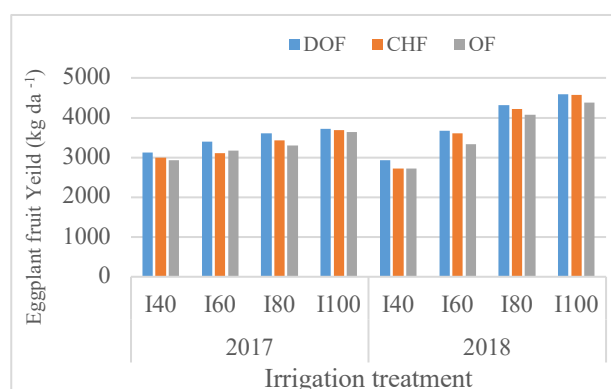


Figure 2. Eggplant fruit yield harvested from irrigation and fertilizer treatment

### 3.3. Water use efficiency (WUE) and irrigation water use efficiency (IWUE)

WUE and IWUE changed depending on irrigation levels and as the amount of irrigation water increased in general, the WUE and IWUE decreased (Table 6). As it presented in Table 6, in both year, the highest WUE obtained from I<sub>40</sub> as 11.44 and 12.87 kg mm<sup>-1</sup>, respectively and followed by I<sub>60</sub> (9.93 and 12.14 kg mm<sup>-1</sup>) and I<sub>80</sub> (8.91 and 11.52 kg mm<sup>-1</sup>) while the lowest WUE from I<sub>100</sub> as 8.23 and 10.36 kg mm<sup>-1</sup>, respectively. The highest IWUE in both seasons obtained from I<sub>40</sub> as 24.76, 18.99 kg mm<sup>-1</sup>, respectively, and followed by I<sub>60</sub> (17.65 and 16.27 kg da<sup>-1</sup>) and I<sub>80</sub> (14.10 and 14.54 kg da<sup>-1</sup>) while the lowest IWUE from I<sub>100</sub> as 12.07 and 12.54 kg mm<sup>-1</sup>, respectively.

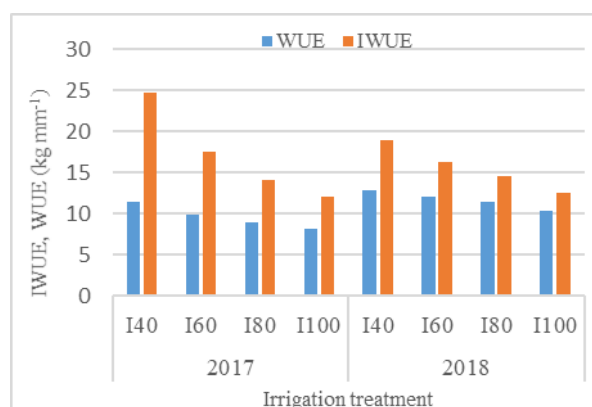
Even though the highest irrigation water was applied to the I<sub>100</sub> treatment, that's IWUE and WUE value was the lowest. On the other hand, in the I<sub>40</sub> treatment applied the lowest irrigation water, the values of IWUE and WUE were higher. Aujla et al. (2007), Lovelli et al. (2007), and Karam et al. (2011) concluded to be the highest WUE value with 11.9 kg mm<sup>-1</sup>, 10.3 kg mm<sup>-1</sup>, and 5.6 kg mm<sup>-1</sup> in the limited irrigation application, respectively. Ayas (2017) found to be maximum both WUE and IWUE values with 9.48 kg mm<sup>-1</sup> and 13.14 kg mm<sup>-1</sup> from Kcp4: 0.25 treatments.

The results of this experiment are similar to those given above. Kirnak et al. (2002) found increased WUE values under water stress conditions for eggplant. The higher WUE of plants under stress conditions is because stressed plants wilt far more than unstressed plants and wilting invariably occurs in times when the saturation deficit of the atmosphere is large (Bloch et al., 2006).

Generally, it could also be observed that as the eggplants were exposed to water stress, the water use efficiency of eggplants increased. The lowest amount of water applied (I<sub>40</sub>) recorded the highest WUE value, whereas the highest amount of water applied (I<sub>100</sub>) resulted in the lowest WUE values in that order. The phenomena whereby water-stressed plants give the higher WUE indicates that as the crops are exposed to water stress there is high dry matter accumulation in the fruit. According to Birhanu and Tilahun (2010), this observation can be attributed to the fact that as total plant biomass decreases with water stress level, fruit dry matter increased, hence there is an increase in water use efficiency when water stress level increases. It was found that the highest WUE and IWUE was in DOF followed by CHF and OF. The reason for higher WUE and IWUE in DOF plot was that DOF increased eggplant yield (Figure 3).

**Table 6. Irrigation amount, water requirement water, and irrigation water use efficiency**

Irrigation treatment	2017				2018			
	I (mm)	ET (mm)	IWUE (kg mm <sup>-1</sup> )	WUE (kg mm <sup>-1</sup> )	I (mm)	ET (mm)	IWUE (kg mm <sup>-1</sup> )	WUE (kg mm <sup>-1</sup> )
I <sub>40</sub>	122	264	24.76	11.44	147	217	18.99	12.87
I <sub>60</sub>	183	325	17.63	9.93	218	292	16.27	12.14
I <sub>80</sub>	244	386	14.10	8.91	289	365	14.54	11.52
I <sub>100</sub>	305	447	12.07	8.23	360	436	12.54	10.36



**Figure 3 Effect of irrigation level on WUE and IWUE**

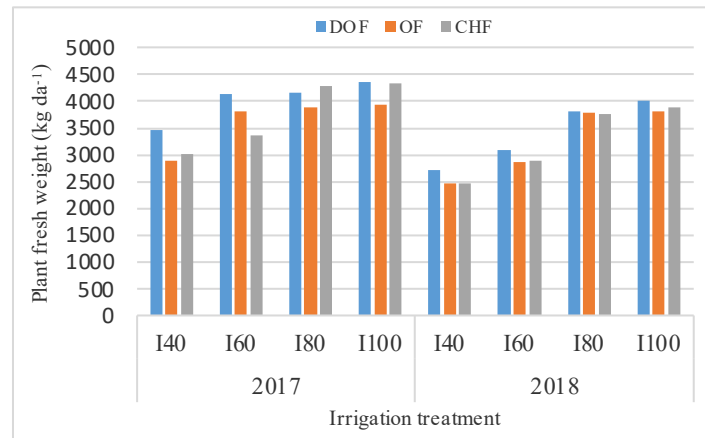
### 3.4. Plant fresh weight (PFW)

At the end of the growing season after the last harvest the plant fresh weight was determined, the highest PFW was obtained from  $I_{100}$  irrigation treatment as 4216 and 3906  $\text{kg da}^{-1}$  in 2017 and 2018 respectively, followed by  $I_{80}$  as 4117 and 3788  $\text{kg da}^{-1}$  then  $I_{60}$  as 3775 and 2953  $\text{kg da}^{-1}$  while the lowest PFW was obtained in two years with 3118 and 2548  $\text{kg da}^{-1}$  at  $I_{40}$  irrigation treatment, respectively as it presented in Table 7. For the effect of fertilizer treatment on PFW in every irrigation treatment, the highest was at DOF fertilizer treatment and the lowest was at OF fertilizer treatment as seen in Figure 4.

The effect of irrigation treatments on plant fresh weight values was statistically significant ( $P < 0.05$ ). According to the LSD test, it was in 3 groups,  $I_{100}$  and  $I_{80}$  in group A,  $I_{60}$  in group B, and  $I_{40}$  in group C in both seasons. This may be due to the role of water in translocation of photosynthetic assimilates (Inalpulat et al. 2014), thus reflected increases in most of PFW, or due to the depression effect of soil dryness on leaves formation, function, and growth development. It was found to be insignificant for fertilizer treatment and irrigation x fertilizer interaction ( $P > 0.05$ ). Bafeel and Moftah (2008) suggested that the negative effect of drought stress on the yield and its components may be related to the decrease in vegetative growth. Abdrabbo et al. (2017) reported that the highest plant fresh weight was 1399  $\text{g plant}^{-1}$  at  $I_{100}$  irrigation treatment, also Özbek and Kaman (2017) stated the highest plant fresh weight was 1285.5  $\text{g/plant}$  at  $I_{100}$  irrigation treatment. The results observed from this research is in agreement with those researches result.

**Table 7. Some plant growth and fruit variables result**

Year	2017				2018			
Irrigation treatment	$I_{100}$	$I_{80}$	$I_{60}$	$I_{40}$	$I_{100}$	$I_{80}$	$I_{60}$	$I_{40}$
Plant fresh weight ( $\text{kg da}^{-1}$ )	4216 <sup>(a)</sup>	4117 <sup>(a)</sup>	3775 <sup>(b)</sup>	3118 <sup>(c)</sup>	3906 <sup>(a)</sup>	3778 <sup>(a)</sup>	2953 <sup>(b)</sup>	2548 <sup>(c)</sup>



**Figure 4. Effect of irrigation level and fertilizers on Plant Fresh weight**

### 4. Conclusions

Under Bandırma climatic conditions in 2017-2018 growing years, in four irrigation levels applied by drip irrigation method, and three fertilizers, it was significant differences between the irrigation treatments in yield and plant fresh weight ( $P < 0.05$ ). But no significant differences were found between  $I_{100}$  and  $I_{80}$  treatments in yield and plant fresh weight in two experiment years. The data obtained from  $I_{100}$  and  $I_{80}$  treatments were taken place in the same group by LSD test and IWUE was higher in  $I_{80}$  ( $14.54 \text{ kg mm}^{-1}$ ), therefore we can say  $I_{80}$  most suitable irrigation program for eggplant. No significant effect noticed between fertilizers treatments in two experiment years ( $P > 0.05$ ), nevertheless, it can be said that chemical fertilizer can be replaced by developed organic fertilizer because the highest yield was obtained from DOF fertilizer treatment, at the other side to avoiding the health and environmental damage of chemical fertilizer.

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