

# DESIGN AND OPERATION ANALYSIS OF DRIP IRRIGATION SYSTEMS USED IN THE IRRIGATION OF CHERRY (*PRUNUS AVIUM* L.) ORCHARDS IN ISPARTA-ULUBORLU REGION, TURKEY

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(Received 29<sup>th</sup> Dec 2017; accepted 1<sup>st</sup> May 2018)

**Abstract.** In this study, the existing drip irrigation systems of 20 cherry (*Prunus avium* L.) orchards in Isparta-Uluborlu (Turkey) region where cherry production is done intensively were evaluated with selected by purposive sampling method; were examined in terms of design and operation; problems related to the subject were determined. For this reason, drip and under tree micro sprinkler irrigation system was re-projected for each enterprise, elements of both irrigation systems compared with the present applications, and suggestions for both irrigation systems and irrigation scheduling are developed. As a result, it has been found that the system elements generally had not been designed properly, and the system layouts and operations were insufficient in all of the existing drip irrigation systems considered. Suggestions for both irrigation systems and irrigation scheduling are developed.

**Keywords:** *cherry orchard, Prunus avium L., drip irrigation, under tree micro sprinkler irrigation, irrigation scheduling*

## Introduction

Almost all new cherry orchards established in Turkey for export are established by the 0900 Agricultural variety of saplings. In general, the harvest of the export grade of 0900 Agricultural variety begins in the first week of May in Izmir province the early season and ends in the last days of July in Konya-Hadim and Nigde-Ulukisla districts as the late season (Taner, 2001). Parallel to the developments in cherry exports, cherry production, in many cities begun to increase, in recent years; though leading provinces in cherry production are Izmir, Manisa, Afyon, Bursa, Konya, Amasya, Isparta, and Denizli in Turkey (*Table 1*; Anonymous, 2016a). Denizli and Izmir are early; other provinces are mid-season cherry production regions.

Isparta province is an important cherry production region for export with high-quality mid-season production. It is in the 6th rank in mid-season production regions in terms of yield. In 2016, cherry production was 55657 tons, the total number of trees was 1197822, and average yield per tree was 46 kg. The major cherry producing areas are the districts of Senirkent and Uluborlu (*Table 2*; Anonymous, 2016b). Fresh cherries are the leading agricultural product that provides export income for the Isparta province. 60% of agricultural products in 2007 were provided by cherries. The value of cherry exports was \$5.7 million in 2005, \$7.9 million in 2006, and amounted to \$10.14 million in 2007 (Anonymous, 2009a).

**Table 1.** Data of leading provinces in cherry production in Turkey

Province in Turkey	Area of collective fruit trees (ha)	Total fruit yield (t)	Fruit yield per tree (kg tree <sup>-1</sup> )	Total number of trees
Izmir	12097	46574	15	3033963
Manisa	9886	46648	20	2325630
Afyon	4215	403387	63	645942
Bursa	6250	32468	23	1435434
Konya	6664	55426	33	1662921
Amasya	2529	25008	34	739425
Isparta	5427	55657	46	1197822
Denizli	3787	22695	33	686015
Nigde	2519	23386	46	507116
Kutahya	2769	35152	28	1235223
Others regions	28603	216249	24	7784421
Turkey	84745	599650	25	21313912

**Table 2.** Distribution of Isparta cherry production according to districts

District	Area of collective fruit trees (ha)	Total fruit yield (t)	Fruit yield per tree (kg tree <sup>-1</sup> )	Total number of trees (number)
Center	675	6993	30	149100
Aksu	7	48	42	1452
Atabey	300	1720	25	61120
Egirdir	61	375	35	11435
Gelendost	54	4188	35	89300
Gonen	140	603	35	64265
Keciborlu	226	910	33	44100
Senirkent	1750	22700	33	302500
Sutculer	31	274	35	11670
Sarkikaraagac	175	1157	30	45700
Uluborlu	1760	14905	33	353100
Yalvac	172	961	30	41000
Yenisarbademli	75	823	35	23080
Isparta	5427	55657	46	1197822

It is expected that the climate changes expected to occur as a result of global warming will have adverse effects on water resources as well as agricultural production. Depending on the expected changes in climate, such as temperature, precipitation, relative humidity and wind, the water consumption of the plant, which is important in terms of irrigation, and the feeding of the groundwater also change, and those affect the water resources negatively (Anonymous, 1995). In addition to the problems of climate change and drought that may be experienced in relation to this, rapid population

increase, increase in demand for water resources, the tendency of water usage to change gradually according to sectors, decrease in the water quality, and so on increase the importance of the utilization of water resources. According to the results of the assessment made by the World Meteorological Organization (WMO) among 87 member countries, Turkey is among the 74 countries affected by drought (WMO, 1992).

It is possible to predict the pressure over water resources occurred by the impacts of factors such as current growth rate and change of water consumption habits. Therefore, it is necessary to use water resources rationally to leave for healthy and sufficient water to the future generations of Turkey. This means the utilization of water should be planned and in the most efficient way.

In Turkey, both the consciousness and education levels of producers and excessive irregularity of irrigation studies and extreme and faulty water use due to the problems in transferring the results of those studies to the producers have negative effects on soil, environment, plants and water resources in particular. It was found in a study conducted in Sanliurfa-Harran irrigation that about 5 to 7 times of the needed water was supplied to irrigation and that the groundwater levels were higher than 150 cm, which is considered as the threshold of danger (Tekinel et al., 2001).

Turkey is the first sweet cherry producer cherry production with 494000 tons of sweet cherry a year (Anonymous, 2009b). Isparta-Uluborlu region has an important place in our country in terms of production quantity and product quality. In recent years cherry producers have started to prefer drip irrigation instead of surface irrigation methods. However, these orchards, which are established on the basis of traditional farming, are experiencing problems in designing and operating drip irrigation systems which are subsequently constructed.

In studies conducted to monitor and evaluate the existing drip irrigation systems. It was observed that farmers had generally preferred the drip irrigation system with low initial capital cost, thus planning, layout and operation of a system had been unsuitable and water distribution had not been uniform required. It was also found that drippers had rapidly clogged due to inconvenient filtration and poor water quality (Pitchford, 1979; Fry, 1985). In a few research to evaluate some drip irrigation systems in Turkey (Turkey), the system elements had not been designed properly, the filtration of irrigation water to prevent emitter clogging had not been supplied by installing an adequate control head, and the system layouts and operations were insufficient in all drip irrigation systems considered nine farms in the Antalya region (Yildirim and Orta, 1993), and it also found that drip irrigation systems were not projected as suitable according to project criteria, sufficient control unity was not established, excessive irrigation water was applied and planning and managing of the systems were not done as suitable with regard to current conditions in Sultanhisar and Eskisehir region (Ayran, 2009; Harman, 2013).

In this study, the existing drip irrigation systems of 20 cherry (*Prunus avium* L.) orchards in Isparta-Uluborlu (Turkey) region where cherry production is done intensively were evaluated with selected by purposive sampling method; were examined in terms of design and operation; problems related to the subject were determined. For this reason, drip and under tree micro sprinkler irrigation system was re-projected for each enterprise. Elements of both irrigation systems compared with the present applications. And suggestions for both irrigation systems and irrigation scheduling are developed.

## Materials and methods

The research was carried out in 20 cherry (*Prunus avium* L.) orchards in Isparta-Uluborlu (Turkey) region (Fig. 1), selected by purposive sampling method, among the enterprises where drip irrigation method is applied.



**Figure 1.** The placement of Isparta and Uluborlu in Turkey

During the research, a survey study was conducted primarily to determine the existing irrigation application skills and levels of the selected producers. The characteristics of the existing irrigation systems in all enterprises (drinker flow and distance, lateral pipe diameter and length, number of lateral pipes running in a row and to be supplied water at the same time, manifold pipe diameter and length, main pipe diameter and length, pipe materials) and control unit factors (filter system, gravel filters, hydro cyclone, sieve-disc filter, pressure regulator, fertilizer tank volume, manometer, valve etc.), were determined according to the measurements and observations conducted.

However, for all enterprises, the data that is essential for project design of the drip and micro sprinkler irrigation method has been obtained. For this purpose, some important characteristics of the enterprise's soil (texture class, field capacity, wilting point and volume weights) for irrigation was determined according to Demiralay (1993) and Tuzuner (1990). Deteriorated and intact soil samples were taken from different layers (0-30, 30-60, 60-90 and 90-120 cm) from the test site. The infiltration rates of the soil of the test area were determined according to the principles given by Gungor and Yildirim (1989) with double cylinder infiltrometer measurements. The dimensions of the enterprise areas were measured by steel tape meters and slopes with the aid of a leveling instrument. The flow rate of the water source was measured by the volume-time method and the sufficiency for cultivation was examined.

In order to determine the irrigation water needs of the cherry plants cultivated in the examined enterprises, firstly the values of the plant water consumption are determined. Climate data of the region where the enterprises are located were taken from Isparta Meteorology Directorate and the values of plant water consumption were determined by the Penman-Monteith method for the process in plant vegetation period. For this, ten-day-long average values of the climate data between 1990 and 2010 were taken into account (Table 3; Anonymous, 2011), the reference plant water consumption was calculated, and actual plant water consumption values are obtained by correcting the obtained values with the plant coefficient. Plant coefficients were calculated according to a previous study (Evans et al., 1996).

**Table 3.** Some climatic values of Uluborlu District, including a ten-day long average

Date	Average steam pressure (h Pa)	Average temperature (°C)	Average wind speed (m s <sup>-1</sup> )	Average relative humidity (%)	Sunrise time (h)
01-10 May	898.66	13.7	2.75	56.30	9.60
11-20 May	899.43	15.7	2.33	52.46	9.60
21-31 May	898.48	17.5	2.49	55.99	9.40
01-10 June	898.97	18.4	2.50	55.24	9.60
11-20 June	898.78	20.2	2.41	51.11	11.30
21-30 June	898.34	21.4	2.50	49.41	11.00
01-10 July	897.10	22.7	2.32	47.46	11.30
11-20 July	897.64	23.0	2.35	49.19	11.30
21-31 July	896.76	23.3	2.45	46.77	11.60
01-10 August	896.25	23.5	2.35	49.26	11.20
11-20 August	897.64	23.1	1.93	48.25	11.10
21-31 August	898.37	21.6	1.83	48.19	10.90
01-10 Sept	899.23	18.8	1.91	52.90	9.90
11-20 Sept	900.18	17.7	1.90	53.55	9.30
21-30 Sept	900.99	15.9	2.28	60.54	8.20
01-10 Oct	901.92	14.9	2.25	59.75	8.00
11-20 Oct	902.00	13.3	2.37	64.14	6.20
21-31 Oct	902.37	10.5	2.33	66.57	6.20

For each enterprise, a re-drip and under micro sprinkler irrigation system has been designed. In determining the engineering characteristics of the system, the principles given in Yildirim (2008) were utilized. The equations used for the under tree micro sprinkler irrigation system's project design are summarized below.

Wetted area (P)

$$P = \frac{\alpha^*}{360^*} \frac{\pi D^2}{4 S_a S_s} \quad (\text{Eq.1})$$

Heading wetting diameter (D)

$$D = \sqrt{\frac{360 \ 4 S_a S_s \ 0,30}{\alpha \pi}} \quad \text{for } P = 0.30 \quad (\text{Eq.2})$$

$$D = \sqrt{\frac{360 \ 4 S_a S_s \ 0,50}{\alpha \pi}} \quad \text{for } P = 0.50 \quad (\text{Eq.3})$$

Precipitating rate (Pr<sub>y</sub>)

$$Pr_y = \frac{360^*}{\alpha} \frac{4 q}{\pi D^2} \quad (\text{Eq.4})$$

Evapotranspiration for micro irrigation methods (T)

$$T = ET \frac{Ps}{95} \quad (\text{Eq.5})$$

Amount of maximum net irrigation water ( $d_n$ max)

$$d_n \text{max} = d_k Ry D \frac{P}{100} \quad (\text{Eq.6})$$

Amount of total irrigation water ( $d_t$ )

$$d_t = \frac{d_n}{E_a} \quad (\text{Eq.7})$$

Maximum irrigation interval ( $SA_{\text{max}}$ )

$$SA_{\text{max}} = \frac{d_n \text{max}}{T} \quad (\text{Eq.8})$$

Amount of net irrigation water ( $d_n$ )

$$d_n = T (SA) \quad (\text{Eq.9})$$

Irrigation duration ( $T_a$ )

$$T_a = \frac{1000 d_t}{q N_d} \quad (\text{Eq.10})$$

Maximum number of operating units ( $N_{\text{max}}$ )

$$N_{\text{max}} = \left( \frac{T_g}{T_a} \right) (SA) \quad (\text{Eq.11})$$

Reference evapotranspiration for Penman-Monteith method

$$ET_0 = \delta / (\delta + \gamma^*) (Rn - G) \frac{1}{\lambda} + \gamma / (\delta + \gamma) u^2 \left( \frac{900}{t + 275} \right) (e_a - e_d) \quad (\text{Eq.12})$$

where P is wetted area (%), D is head wetting diameter (m),  $S_a$  is tree spacing (m),  $S_s$  is row spacing (m),  $Pr_y$  is precipitating rate ( $\text{mm h}^{-1}$ ),  $\alpha$  is wetting angle, q is head flow ( $\text{l h}^{-1}$ ), T is evapotranspiration for micro sprinkler irrigation method ( $\text{mm day}^{-1}$ ), ET is evapotranspiration ( $\text{mm day}^{-1}$ ), Ps is ratio of the area shaded by the plant to the total area (%),  $d_n$ max is amount of maximum net irrigation water (mm),  $d_k$  is available water holding capacity (mm/m), Ry is allowable part of  $d_k$ , D is watering soil depth (mm),  $E_a$  is water application efficiency (%),  $SA_{\text{max}}$  is maximum water application interval (days), SA is irrigation interval (days),  $T_a$  is irrigation duration (h),  $d_t$  is amount of total

irrigation water (mm),  $N_d$  is number of head in a decare area (pieces  $da^{-1}$ ),  $N_{max}$  is maximum number of operating units,  $T_g$  is daily irrigation duration ( $h\ day^{-1}$ ),  $ET_o$  is reference evapotranspiration ( $mm\ day^{-1}$ ),  $\delta$  is slope of the vapor pressure curve ( $kPa\ ^\circ C^{-1}$ ),  $\gamma^*$  is modified psychometric constant ( $kPa/^\circ C$ ),  $R_n$  is net radiation on the plant surface ( $MJ\ m^{-2}\ day^{-1}$ ),  $G$  is heat flow in the ground ( $MJ\ m^{-2}\ day^{-1}$ ),  $\lambda$  is evaporation latent heat ( $MJ\ /kg^{-1}$ ),  $u^2$  is equivalent of wind speed at 2 m height ( $m\ s^{-1}$ ),  $t$  is average temperature ( $^\circ C$ ),  $e_a$  is saturated vapor pressure at average air temperature (kPa) and  $e_d$  is actual vapor pressure at average air temperature (kPa) in *Equations 1-12*.

## Results and discussion

The average values of soil texture, field capacity, wilting point, volume weight and available water holding capacity of the soil samples taken from the enterprises obtained from the physical analyzes and the values of infiltration rate measured by the double cylinder infiltrometer are given in *Table 4*. The soil texture class was generally clayey, loamy and sandy-loamy and the infiltration rate values of the enterprise's soil ranged from 6.5 mm/h to 18.1 mm/h.

*Table 4. Some physical properties of the enterprise's soil*

Orchard number	Soil texture class	Infiltration rate ( $mm\ h^{-1}$ )	Field capacity (%)	Wilting point (%)	Volume weight ( $g\ cm^{-3}$ )	Available water holding capacity ( $mm\ 120\ cm^{-1}$ )
1	L	12.4	26.10	12.32	1.40	230.68
2	SL	18.1	18.99	8.58	1.49	185.51
3	L, SL	13.0	22.14	11.88	1.58	194.84
4	L, CL, SICL	9.0	28.53	18.48	1.64	197.48
5	L, SIL	10.6	25.92	13.53	1.49	220.79
6	SL	16.0	18.81	9.02	1.53	179.74
7	L	12.5	26.55	12.76	1.40	230.84
8	CL	6.9	31.68	22.44	1.69	187.39
9	CL	7.0	29.79	20.79	1.78	192.51
10	L	11.0	26.19	13.64	1.46	219.50
11	L, SCL	10.8	27.36	16.17	1.45	194.71
12	L	12.0	25.65	12.65	1.44	223.25
13	C, CL	6.5	27.99	19.80	1.85	181.33
14	SCL, C	9.0	27.90	19.14	1.81	190.27
15	L	12.0	24.84	12.65	1.43	209.55
16	L, SICL	9.5	26.10	12.98	1.40	220.81
17	SL	17.0	21.06	9.35	1.26	177.06
18	CL	7.0	29.34	20.13	1.76	193.96
19	SL, CL	14.0	22.68	9.79	1.35	208.82
20	SL	16.0	21.87	11.11	1.42	183.67

C: clayey, L: loamy, SL: sandy loam, SCL: sandy clayey loam, SICL: silt clayey loam, SIL: silt loam

The results of the survey study to determine the existing irrigation application skills and levels of the producers of cherry farming in the enterprises and the factors of the

existing drip irrigation systems in the enterprises (dripper flow and distance, lateral pipe diameter and length, number of lateral pipes running in a row and to be supplied water at the same at the same time, manifold pipe diameter and length, main pipe diameter and length, pipe materials, etc.) and the results of measurements and observations made on the elements of the control unit (filter system, gravel filter, hydro cyclone, sieve-disk filter, pressure regulator, volume of fertilizer tank, manometer, valve etc.) are given in *Table 5*.

**Table 5.** Features of the existing drip irrigation systems in enterprises

Irrigation system parameters	Enterprise number																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Area (ha)	1.0	0.23	4.8	0.5	0.95	0.95	4.8	1.45	0.47	1.45	1.0	3.3	0.63	2.0	0.63	0.9	2.9	0.55	1.05	2.4
Tree distance (m)	8	8	7	5	5	8	6	6	6	7	7	8	6	7	7	7	5	5	7	7
Row distance (m)	8	9	6	10	8	6	6	5	6	7	7	8	6	7	7	7	3	3	6.5	6
Land slope (%)	0.1	0.5	0.1	1	0.1	4	1.5	2	5	2	0.5	0.5	0.5	1.5	2	3.5	2	1	0.2	4
Fertilizer tank volume (l)	50	-	150	50	-	100	100	50	50	50	100	50	50	50	100	100	100	50	50	50
Filter	+	-	+	+	+	-	+	+	+	+	-	+	-	+	+	+	+	+	+	+
Main pipe material	PE	PE	PVC	PE	PE	PVC	PVC	PVC	PE	PE	PE	PVC	PE	PVC	PE	PE	PE	PE	PVC	PVC-PE
Main pipe diameter (mm)	75	75	110	75	75	110	110	110	90	90	90	110	90	110	90	90	90	90	110	75-110
Main pipe length (m)	50	55	120	50	50	85	240	0	65	105	100	223	45	88	150	152	225	145	109	246
Manifold pipe diameter (mm)	75	50	110	50	63	75	90	90	50	63	63	63-110	63-90	75-110	75	63	50-90	90	90	75
Manifold pipe length (m)	65	42	110	50	50	75-110	200	110	110	70	200	416	75	190	50	50	55-145	48	115	77
Lateral pipe diameter (mm)	16	16	20	16	16	16	16	16	16	16	16	16	16	16	20	16	16	16	16	16
Lateral pipe length (m)	75	56	282	50	100	60	30	100	50	50	50	48-100	55	63	75	45	45	45-62	40	42-78
Lateral pipe number of a tree line (number)	2	4	2	4	5	4	2	2	2	4	4	4	4	4	4	4	2	4	4	2
Dripper range (m)	0.5	0.33	0.5	0.4	0.5	0.4	0.4	0.5	0.2	0.5	0.5	0.33	0.5	0.5	0.4	0.5	0.4	0.4	0.5	0.33
Operating pressure (m)	15	15	18	18	15	15	18	12	12	15	10	15	20	10	10	15	20	20	25	20
Dripper flow (l h <sup>-1</sup> )	2	3	2	2	2	2.4	2	2.2	2	4	4	4	3	4	2	1.6	2	2	4	2
Irrigation interval (days)	7	7	10	8	5	8	7	7	15	15	-	7	7	12	7	7	8	7	7	5
Irrigation duration (h)	6	13	12	12	6	12	24	12	8	8	8	10	6	8	10	7	12	10	10	9
Applied irrigation water amount (mm)	45.9	95.9	13.5	126	220	19.5	59.3	37.8	432.1	21	32.5	88.8	31.5	28.6	56	139.9	104.4	172.3	113.6	82.4
Wetted area (%)	15	26	17	38	60	24	16	20	8	34	34	20	40	34	35	34	19	38	34	11

As can be seen from *Table 5*, the enterprises participated in the research have a size ranging from 0.23 to 4.8 ha. Eleven of the enterprises (55%) are small (<1.0 ha) family businesses. Operation flows in almost all of the enterprises are sufficient to allow the irrigation systems work efficiently.

It has been determined that the diameters of the main pipes used in the twelve enterprises (60%) in the research (1, 2, 7, 8, 9, 10, 13, 14, 15, 16, 18 and 19) are oversized. This situation increases the initial installation costs of the systems. In addition, in three enterprises (15%) (3, 5 and 11) the employed main pipe diameters were less than the required value. Side pipe diameters are larger than the required values in twelve enterprises (60%) (1, 2, 7, 8, 12, 13, 15, 16, 17, 18 and 20) and smaller in seven enterprises (35%).

It was stated that if the wetted area percentage (p) is less than 30%, in the case of using two laterals for each tree row in the irrigation of the fruit trees according to the

drafting criteria of the drip irrigation system project, a micro-sprinkler system for this area will be more suitable (Anonymous, 2011). Seven of the farms (35%) surveyed in the research had two laterals laid along each plant row, but the wetted areas did not reach the desired level in any of them. In the other thirteen enterprises (65%), irrigation is carried out by 4-5 laterals laid along each tree row. In this case, the cost of the first installation of the irrigation system increases, as well as problems in terms of management occurs. However, in the nineteenth of the enterprises (95%) (except for the operation of 15) the lateral pipe diameters are in required ranges.

Besides, there is no problem in the operation of the irrigation system except for the 3rd enterprise. However, there is a problem in the operation of the irrigation system in the 3rd enterprise. Sufficient amount of irrigation water in sufficient time to apply the appropriate irrigation program to the enterprises located in the area where this enterprise is also located, cannot be supplied by the legal entity with the duty of operating the water mains. The infrastructure of the irrigation system has not been set up properly to provide enough water for agricultural land. It is not believed that the dispute between the company, which established the irrigation system that is located here, and the legal entity of the village can be resolved by the courts, either.

In the examined cherry orchards, the plant row spacing ranges from 5 to 8 m. Dripper spacing ranges from 0.2 to 0.5 m between the laterals used in existing irrigation systems. Therefore, 4-5 laterals in each plant row should be laid in order to obtain a sufficient level of wetting in the root area of the plant. A sufficient wetting zone in the plant root area cannot be established in 50% of the enterprises surveyed. The irrigation interval is longer than necessary for all enterprises except the 5th and 20th (90%). In other words, irrigation practices are not done in the form required by the drip irrigation. As is known, the plant root area is kept moist at the appropriate level by giving a little water at short intervals by drip irrigation method. In addition to this, although the irrigation duration is favorable in four enterprises (20%) (1, 4, 12 and 13), more irrigation periods are being implemented in ten enterprises (50%) (2, 3, 6, 7, 8, 14, 15, 17, 19 and 20), which in turn, causes excess irrigation water to be used in the mentioned enterprises. In the other six enterprises (30%) (5, 9, 10, 11, 16 and 18), less irrigation water is given to the plants because of the less irrigation time applied.

Similar to this research findings, in a few research to evaluate some drip irrigation systems in Turkey (Turkey), the system elements had not been designed properly according to project criteria (Ayran, 2009; Harman, 2013), the filtration of irrigation water to prevent emitter clogging had not been supplied by installing an adequate control head, and the system layouts and operations were insufficient in all considered drip irrigation systems (Yildirim and Orta, 1993).

While *Table 6* gives information on irrigation systems that are re-projected, considering the characteristics of soil, plant and water resources for each enterprise examined whereas the recommended irrigation scheduling at the meetings held with the producer is summarized in *Table 7*. Moreover, the hypothetical irrigation scheduling to be applied if the irrigation was continued with the existing irrigation system in the enterprises is given in *Table 8*.

It was suggested that in the pressurized system; the main pipeline should be constructed from PVC pipes and the manifold pipelines from PE pipes while the T pipelines should be installed as buried in the ground (Kekec, 2006; Yilmaz, 2011). And it was concluded that it would be more appropriate to place the control unit at a single point and at the start of the main pipeline for easier operation in micro irrigation

systems and it would be more appropriate to place the required sand separator and sand-gravel filter tank at the beginning of the water distribution network in the case of collective micro-irrigation systems. Also, the control unit elements in individual irrigation systems in each operation should be formed of the fertilizer tank, sieve filter, and pressure regulator, if necessary (Yildirim, 2008). In the project of the reconstructed irrigation system for the surveyed enterprises, the main and manifold pipelines were designed according to the principles proposed by Kekec (2006) and Yilmaz (2011) whereas mass irrigation system and selected control unit elements (except pressure regulator) for individual gardens were made according to the principles recommended by Yildirim (2008). The possibility of applying drip irrigation method for each enterprise unit in the survey was examined by taking the principles given in Yildirim (2008) into account. Since the plant and soil characteristics of the enterprises do not allow the installation of the drip irrigation system by laying two laterals along each plant row, it is decided that the more suitable irrigation method for the operators is under tree micro-sprinkler irrigation and the proposed irrigation system is designed accordingly.

**Table 6.** The parameter of under tree micro sprinkler irrigation systems

Irrigation system parameters	Enterprise number																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Head flow ( $l\ h^{-1}$ )	160	300	40	200	160	160	200	90	90	200	200	250	90	160	200	160	100	100	200	200
Head wetting diameter (m)	6.5	7	5	5.5	5	5.5	5	4.5	4.5	5.5	5.5	6.5	6.5	5.5	5.5	5.5	3	3	5	5
Number of operating unit	1	1	3	1	1	1	2	1	1	1	1	2	1	1	1	1	3	1	1	3
Lateral pipe length (m)	75	56	50	50	50	60	60	65-70	50	50	50	56	55	63	75	70	25-90	45-62	62.5	48-60
Lateral pipe diameter (mm)	20	25	16	16	16	20	25	16	16	25	25	20	16	25	25	20	20-25	16	20	20
Manifold pipe length (m)	65	42	75-90	50	100	72	66-67	100	110	70	200	80	75	190	50	50	65-125	48	80	77
Manifold pipe diameter (m)	75	63	50-63	75	75	75	75	75	63	75	110	63	63	90	90	50	75	50	90	90-110
Number of operating unit to be supplied at the same time	1	1	1	1	1	1	3	1	1	1	1	2	1	1	1	1	2	1	1	1
Main pipe diameter (mm)	75	63	90	75	75	75	110	75	90	75	110	90-110	75	110	90	75	90-110	48	62.5	264
Wetted area (%)	46	47	41	47	43	42	48	47	39	43	43	46	39	43	43	43	41	41	38	41

**Table 7.** Irrigation scheduling for the under tree micro sprinkler irrigation systems

Enterprise number	May			June			July			Augustus			September		
	Ta (h)	SA (days)	dt (mm)	Ta (h)	SA (days)	dt (mm)	Ta (h)	SA (days)	dt (mm)	Ta (h)	SA (days)	dt (mm)	Ta (h)	SA (days)	dt (mm)
1	10.5	10	56.7	10.6	6	57.5	9.0	4	48.9	10.6	4	57.2	10.9	12	58.9
2	5.2	8	45.4	5.5	5	47.9	5.6	4	48.9	4.9	3	42.9	5.6	10	49.1
3	4.5	9	51.3	4.2	5	47.9	4.3	4	48.9	3.7	3	42.9	4.3	10	49.1
4	6.3	9	53.1	5.7	5	47.9	5.8	4	48.9	5.1	3	42.9	5.8	10	49.1
5	5.6	9	51.0	5.2	5	47.9	5.3	4	48.9	4.7	3	42.9	5.9	11	54.0
6	5.1	7	39.7	4.9	4	38.3	4.7	3	36.7	5.5	3	42.9	5.0	8	39.2
7	5.6	11	63.3	5.0	6	57.5	5.4	5	61.1	5.0	4	57.2	5.2	12	58.9
8	7.1	8	45.4	7.5	5	47.9	7.7	4	48.9	6.8	3	42.9	7.7	10	49.1
9	6.7	7	42.9	9.0	6	57.5	5.8	3	36.7	6.7	5	42.9	6.2	8	39.2
10	5.4	9	51.0	5.1	5	47.9	5.2	4	48.9	4.5	3	42.9	5.2	10	49.1
11	5.0	8	47.8	4.0	4	38.3	3.9	3	36.7	4.5	3	42.9	4.7	9	44.2
12	6.9	10	58.7	6.8	6	57.5	5.8	4	48.9	6.8	4	57.2	6.4	11	54.0

13	6.4	8	40.4	6.0	4	38.3	5.8	3	36.7	4.5	2	28.6	6.2	8	39.2
14	6.2	8	46.7	5.1	4	38.3	4.9	3	36.7	5.7	3	42.9	5.9	9	44.2
15	9.0	9	51.0	8.4	5	47.9	8.6	4	48.9	7.6	3	42.9	9.5	11	54.0
16	6.8	9	51.0	6.4	5	47.9	6.5	4	48.9	5.7	3	42.9	7.2	11	54.0
17	2.6	7	41.5	2.4	4	38.3	2.3	3	36.7	1.8	2	28.6	2.5	8	39.2
18	7.9	8	45.4	6.7	4	38.3	6.4	3	36.7	7.5	3	42.9	7.7	9	44.2
19	3.5	7	39.7	3.4	4	38.3	3.2	3	36.7	3.8	3	42.9	3.9	9	44.2
20	3.5	7	39.7	3.4	4	38.3	3.2	3	36.7	3.8	3	42.9	3.4	8	39.2

Ta: irrigation duration; SA: irrigation interval; dt: amount of total irrigation water

**Table 8.** Irrigation scheduling for the existing irrigation systems

Enterprise number	May			June			July			Augustus			September		
	Ta (h)	SA (days)	dt (mm)	Ta (h)	SA (days)	dt (mm)	Ta (h)	SA (days)	dt (mm)	Ta (h)	SA (days)	dt (mm)	Ta (h)	SA (days)	dt (mm)
1	8	10	45	8	5	45	8	4	45	10.6	5	45	8	10	45
2	7	20	110	7	15	110	7	12	110	7	12	110	7	15	110
3	8.2	12	57.5	8.2	6	57.5	8.2	5-6	57.5	8.2	7	57.5	8.2	10	57.5
4	5.5	12	58	5.5	6	58	5.5	5	58	5.5	5	58	5.5	12	58
5	7.2	9	43.3	7.2	5	43.3	7.2	4	43.3	7.2	5	43.3	7.2	9	43.3
6	5	12	52.9	5	7	52.9	5	5	52.9	5	8	52.9	5	13	52.9
7	7	14	67.9	7	7	67.9	7	7	67.9	7	9	67.9	7	14	67.9
8	5.5	13	55.2	5.5	7	55.2	5.5	6	55.2	5.5	7	55.2	5.5	10	55.2
9	2.5	28	113.2	2.5	15	113.2	2.5	11	113.2	2.5	19	113.2	2.2	24	113.2
10	7.5	9	43	7.5	5	43	7.5	4-5	43	7.5	6	43	7.5	9	43
11	5	7	57.3	5	6	57.3	5	6	57.3	5	7	57.3	5	12	57.3
12	6-6.5	14	65.7	6-6.5	9	65.7	6-6.5	6	65.7	6-6.5	8	65.7	6-6.5	14	65.7
13	9.3	12	53.4	9.3	6	53.4	9.3	5	53.4	9.3	7	53.4	9.3	9	53.4
14	10	13	56	10	6-7	56	10	5-6	56	10	6	56	10	9	56
15	6	12	61.6	6	7	61.6	6	6	61.6	6	8	61.6	6	11	61.6
16	9.2	9	65	9.2	5	65	9.2	4	65	9.2	6	65	9.2	10	65
17	5	12	52.1	5	5-6	52.1	5	5-6	52.1	5	6	52.1	5	15	52.1
18	8.5	7	57	8.5	6-7	57	8.5	5	57	8.5	8	57	8.5	14	57
19	5.5	13	61.4	5.5	7	61.4	5.5	5-6	61.4	5.5	7-8	61.4	5.5	8-9	61.4
20	3.5	12	54	3.5	6	54	3.5	6	54	3.5	7	54	3.5	10	54

Ta: irrigation duration; SA: irrigation interval; dt: amount of total irrigation water

## Conclusion

As a result, if it is desired to receive the expected benefits and an increase in the irrigation application efficiency from irrigation systems in the enterprise; the importance of assigning the design and construction of the drip irrigation systems, which require knowledge and experience, to professionals, and to firms with the required expertise has been stated.

During the design of the irrigation systems projects, the soil characteristics of the enterprise (texture, field capacity, wilting point, volume weight, available water holding capacity texture, infiltration rate etc); plant characteristics (characteristics of rootstocks and root systems used, planting distances, development and yield of trees, etc.), and characteristics of water resources (flow, quality etc) should be taken into account; designing the project for each enterprise must be done individually, and specific to the enterprise.

After the irrigation system in the enterprises has been designed and installed in accordance with the criteria mentioned above; training of the operators on the operation of the irrigation system to by experts, and the necessity to apply the appropriate irrigation program considering the climate values of the regions where the enterprises are located, should be provided.

**Acknowledgments.** This study has been supported by the Suleyman Demirel University Scientific Research Projects Coordination Unit within the scope of the project number 3149-YL-12. We would like to thank the Suleyman Demirel University Scientific Research Projects Coordination Unit Directorate for their support.

**Conflict of interest.** The author confirms that this article content has no conflict of interest.

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