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Araştırma Makalesi - Research Article

Marmara Bölgesinde Armut Bitkisinin Sulama Zamanının Planlanması

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ÖZ

Armut; beslenmeye ve ülke ekonomisine sağladığı katkı bakımından meyvecilikte önemli yere sahip değerli meyve türlerimizden biridir. Armut yetiştiriciliğinde yüksek verim ve kaliteli ürün eldesinde en önemli ihtiyaç sulama ve gübrelemedir. Dolayısıyla, uygun sulama zamanı programlarının geliştirilmesi, uygun sulama yönteminin seçilmesi ve uygulanması gerekmektedir. Sulama yönteminin ve programının seçimine, üretim alanının iklim koşulları, toprak, topoğrafya ve su kaynağının özellikleri ile ekonomik durum etki etmektedir. Çalışmanın hedefi, ülkemizde aynı iklime sahip alanlarda kurulu armut bahçelerinin tarımsal üretiminin daha iyi koşullara ulaştırılmasında, uygun planlama ve projeleme ilkeleriyle doğru sulama yöntemi ve sulama programlarının seçilmesidir. Bu amaçla, Kocaeli ili Gölcük İlçesi Hisareyn Beldesi meyveciliğinde Armut bahçelerinde uygulanan sulama yöntemleri, toprak ve su kaynağı özellikleri incelenerek, mevcut koşullara uygun yeni sulama yöntemi ve programları seçilmiş, çiftçilere örnek bahçeler oluşturulmuştur. Ayrıca, örnek teşkil etmesi bakımından 1 da büyüklüğe sahip bir armut bahçesinde damla sulama yöntemi projelendirilmiş, aplikasyonu yapılmış ve işletmeye açılmıştır. Toprağın fiziksel ve kimyasal özellikleri ile Cropwat ve Irsis yazılımları kullanılarak bitki su tüketimleri belirlenmiş ve sulama zamanı planlamaları gerçekleştirilmiştir. Bu bölgede hesaplanan toplam bitki su tüketimi (ET) ve toplam sulama suyu miktarı (I), sırasıyla, yaklaşık 730 mm ve 570 mm bulunmuştur.

Anahtar Kelimeler- Damla Sulama, Sulama Projesi, Sulama Zamanı Planlaması, Verimlilik

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Irrigation Scheduling for Pear Orchards in Marmara Region of Turkey

ABSTRACT

Pear is the most important kind of fruit species which has an important place in fruit production in terms of its contribution to nutrition and the economy of the country. The most significant need in the Pear cultivation is irrigation and fertilization for high yield and quality. Therefore, it should be selected and applied the best irrigation scheduling and method. The choosing of irrigation method and scheduling is influenced by the climate conditions, soil, topography and water source characteristics and economic situation of the region. The aim of the study is to select the accurate irrigation method and scheduling with appropriate planning and project principles in order to achieve better conditions of agricultural production of pear orchards. For this reason, irrigation methods applied in pear orchards, soil and water source properties in Hisareyn town of Gölcük district of Kocaeli province were examined and new irrigation methods and programs were selected in accordance with the current conditions and sample gardens were created for farmers. Besides, a project for a pear orchard of 1 da to be drip irrigated was prepared and put into operation.The seasonal evapotranspiration and irrigation scheduling were determined using Cropwat and Irsis softwares. The calculated seasonal evapotranspiration and total irrigation level were found to be approximately 730 mm and 570 mm, respectively.

Keywords- Drip Irrigation, Irrigation Project, Irrigation Scheduling, Productivity

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I. INTRODUCTION

Pear is a type of fruit which is being cultivated in Europe and Asia for ages. The practice of pear agriculture has been around for over 3000 years. There are more than 20 types of pear in Europe and Asia [1]. Approximately 3 million hectares of fields are available for growing fruits in Turkey, whose ecological conditions allow the performing of orcharding all across the country. Our country offers the opportunity of growing 75 out of 138 types of fruit that are grown globally. Pear can be easily grown anywhere on the world that is favourable for apple cultivation. Due to its high resistance level to heat and drought, pear can be economically grown in hot climate regions as well. China, Italy and the United States of America rank the highest in pear cultivation in the world. Turkey ranks fourth in the amount of cultivated lands and sixth in production potential. The production capacity of our country is around 520.000 tons in 26.400 hectares area [2].

Although pear cultivation is generally performed in the form of enclosed orchards, dispersed cultivation is also performed. Despite the fact that our country is among the homelands of the pear fruit and rich in variety, various problems are faced in terms of healthy growth of trees and sufficient and quality product yield due to insufficient care.

It has been determined that pear trees have a short term resistance to winter colds of -20 $^{\circ}$C and - 25 $^{\circ}$C in the resting period. Especially in regions with a risk of winter colds, it is necessary that carefully planned fertilization and irrigation programs be implemented. Researchers have carried out various studies on the necessary climate and soil requirements for good yield in pear cultivation [3, 4]. In order to be able to regularly blossom, pear trees definitely need winter resting and a heat total of 1000-1500 hours below 7.2 $^{\circ}$C. Therefore orchards should be set up on deep-set areas where the cold air descends. It is of importance that the orchards be set up in warm climate regions for high-quality cultivation. Orchards can be set up in many soil types ranging from sandy soil to clayey soil. In order to attain a yield of quality and sufficiency, soils that are pervious, deep, warm and that contain high amounts of organic matter with a pH rate of 6-7 should be preferred. Soils that are too sandy or too dry cause a decline in fruit quality.

Irrigation projects consist of facilities where water is applied to the soil in a controlled manner for agricultural production. And irrigation method is defined as the manner in which water is applied to the soil, more specifically to the root part of the plant. This study which is a drip irrigation system model project, has been carried out in orchards where Pear (the town of Hisareyn) cultivation is performed. Parameters that are of importance in terms of irrigation on the field were determined prior to the project design. The irrigation project was realized and applied to the field.

II. MATERIAL AND METHOD

A. Study area

The study was conducted in pear ochards located in the town of Hisareyn in the Gölcük district of the Kocaeli city. All of the orchards where pear cultivation was performed were set up based on the personal knowledge and experience of the growers. Most of the orchards were located on the plain whereas others were set up on high sloping lands, approximately 300-500 meters above sea level. The distance from the research area is 13 km to the city of Kocaeli and 7 km to the district of Gölcük. The research area is situated in a Black Sea climatic region. The averages of annual temperature, relative humidity, wind speed, sunshine duration and total precipitation are 15.3 ºC, 75.5%, 1.3 m s^{-1}, 3.3 h and 525 mm, respectively. Additionally, the climatic factors for experimental periods recorded by weather station are given in Table 1.

Orchards area in this research is given in Figure 1. The types of pear grown in the research area are Akça, Ankara, Musta Bey, Green, Demirci and Deveci pears as the indigenous types and Wilder, Santa Maris and Williams as foreign types. Generally, it is preferred the foreign types in the region due to the fact that they provide high yield, thin skin, post-harvest endurance and high income. The size of the selected project area is about 1 da with 78 pear fruit trees. Row and interrow spacing between trees is 4.0x4.0 m. The water resource was groundwater for irrigation.

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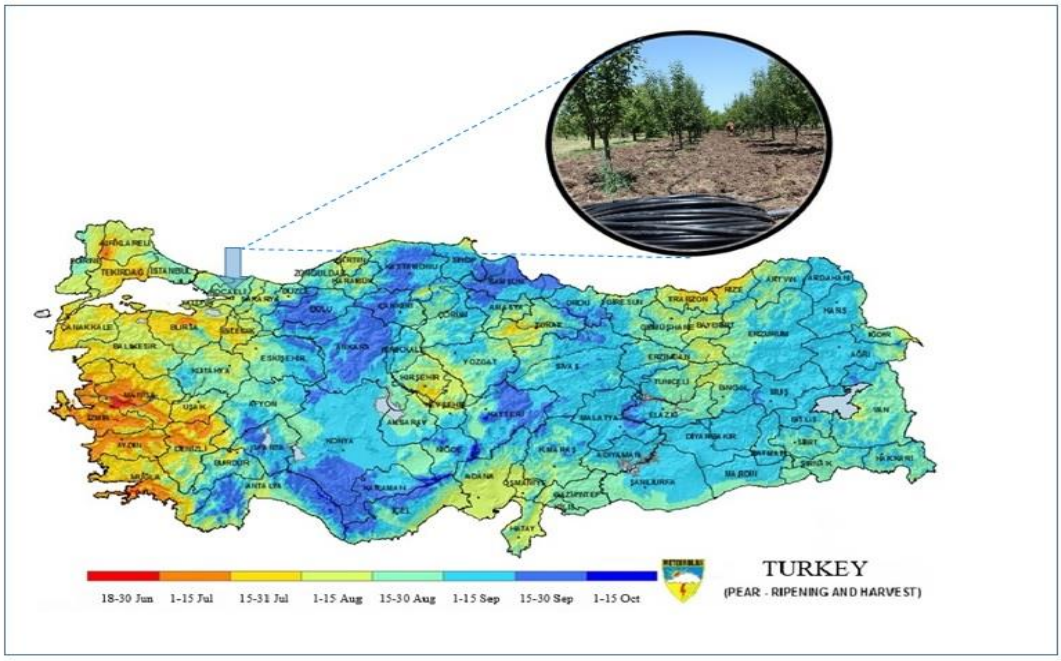

Figure 1. Research area

Table 1. Weather Parameters during 2016 year compare to long term means, [5]

	T^a (°C)		RH (%)		W (m/s)		n (h)		E_p (mm)		R (mm)	
	2016	**Long Term**	**2016**	**Long Term**	**2016**	**Long Term**	**2016**	**Long Term**	**2016**	**Long Term**	**2016**	**Long Term**
January	5.9	6.8	84.0	79.7	2.1	1.3	2.4	1.1	0.0	31.1	240.8	91.8
February	10.7	7.2	81.4	78.0	2.0	1.5	3.8	1.5	-	35.0	-	51.2
March	10.9	9.0	76.5	76.9	2.3	1.5	3.9	1.6	-	35.5	84.6	60.5
April	16.2	13.1	69.7	74.3	2.2	1.4	8.2	2.8	109.0	86.5	3.6	28.9
May	18.0	17.8	76.9	75.4	2.1	1.3	6.6	3.4	108.2	118.9	88.1	43.9
June	23.8	22.2	71.3	71.8	2.1	1.2	9.4	5.3	168.9	151.4	46.9	31.3
July	25.7	24.6	69.8	68.8	2.2	1.2	9.4	6.3	184.7	166.5	7.6	15.1
August	26.1	24.6	76.3	69.8	2.1	1.2	8.2	6.7	133.8	148.4	53.5	24.6
September	21.6	20.8	73.9	73.7	2.0	1.1	6.9	3.6	103.9	103.1	57.0	36.9
October	16.0	16.4	81.9	78.8	1.8	1.1	4.0	3.2	48.8	58.7	46.0	21.5
November	11.2	12.0	80.3	79.6	1.9	1.1	3.5	1.9	0.5	33.8	85,0	51.0
December	4.4	8.7	84.6	79.3	2.2	1.2	2.8	1.8	0.0	25.6	234,2	67.9
Average		15.30		75.50		1.30		3.30		82,79		43.72

T^a: Average temperature; RH: Average Relative Humidity; W: Average wind speed at 2m; n: Sunshine duration; Ep: Class A pan evaporation; R: Rainfall.

B. Method

Drip irrigation method is selected for the pear cultivation in the research area with respect to high productivity and no water stress. The cultivators fail to achieve the level of efficiency they desire with the irrigation system due to lack of knowledge and experience on technical project design. That's why, in the pear orchard where the study was conducted, preliminary efforts were made prior to the preparation of the drip irrigation project, taking into account the existing water source, soil, topography, plants, climate and all other factors. All information needed for planning the irrigation system, sizing the system elements, setting up and operating the system were obtained through land surveys. Following these efforts, the drip irrigation project was prepared based on the principles provided in [6] and then system elements were chosen and installed on the orchard.

Irrigation system consists of water source, pumping unit, control unit, pipelines and drippers respectively. The irrigation water needed for the irrigation of research plots was transferred to the system by an electric motor driven centrifugal pump from a nearby well. Irrigation water was filtered within the control unit in order not to clog the drippers, and it was then mixed with nutrients and distributed to the study plots under pressure and flow rate supervision. Control unit was composed of fertilizer tank, mesh filter and manometers for the purpose of measuring pressure.

Soil samples taken from the research plot were analyzed according to [7, 8]. Soil structure was determined through measurements made by a hydrometer according to [9].

In addition, samples were taken from the water well (groundwater source and artesian) used in irrigation and water quality analyses for determining irrigation water quality were performed in the laboratory according to [10]. The actual water intake (infiltration) rate value needed for the preparation and projection of the irrigation system was determined by using a twin-cylinder infiltrometer [11] and determined as 8 mm h^{-1}.

The CROPWAT 8.0 and IRSIS softwares were used to determine actual evapotranspiration and irrigation water requirements based on climatic, topograhic, soil and crop parameters of area.

III. RESULTS AND DISCUSSION

A. Project Results

Project area contained 78 pear fruit trees with 4.0x4.0 m spacing. The area was irrigated by drip irrigation. Irrigation was taken by a pump from a water well near the experimental site. The control unit consisted of screen filter with 10 L s^{-1} capacity, a pressure regulator to control, a fertilizer tank to nitrogen applications and regulate the pressure in the system and manometers mounted on the inlet and outlet of each unit. Polyethylene (PE) tube was used for 50 mm main and 16 mm manifolds of the irrigation system. The diameters of the laterals were 16 mm PE and two lateral irrigated each plant rows. Pressure compensating drippers were used to supply uniform water distribution. Dripper discharge rate was 4 L h^{-1} above 10 m operating pressure. Dripper spacing was chosen as 0.75 m depending on the soil characteristics. Thus, the percentage of the wetted area (P) that relates dripper spacing to lateral spacing was determined as 45% by the methods described by [12]. The Autocad program was used for drawing the project details which are demonstrated in Figure 2.

B. Physical and Chemical Analysis Results of Project Plot Soils

Some physical and chemical properties of the soils taken from the research area as two different profiles are given in Table 2 and 3. According to the results in Table 2, textural classification of research area soils in each layer is generally loam (0-30 cm) and sandy loam (30-60 cm). Soil bulk density values for each layer are 1.44 and 1.43 g cm^{-3} respectively and the available water capacity at 0-60 cm is 99.06 mm. Water samples were taken and analysed with the purpose of determining the properties of the irrigation water used in the research (Table 4).

A fertilization program to be suggested in soil preparation and plant growth periods was designated based on the soil analysis results provided in Table 3 and taking into account the fertilizer amounts

recommended for fruit cultivation in the Hisareyn area of the Gölcük district in the city of Kocaeli. The pear tree requires a high amount of organic matter in the soil, therefore, soils that are low in organic matter should be enriched by adding organic matter. Generally, cultivators mostly use 70-100 kg da^{-1} of mineral fertilizer in the soil. Such a high amount increase the amount of salt in the soil year by year and causes orchards to become arid, resulting in low yields. Applying 10-15 L da^{-1} of liquid fertilizer in pear orchards will avoid infertilization of the soil. The application of fertilizers containing macro and micro nutrients in molten form and in varying rates will be possible through the use of fertigation technique with the drip irrigation system set up on the project plot. Nitrogen, phosphorus and potassium are the most important elements for the pear plant with 250-500 g of pure nitrogenous manure application per tree in the months of February and March every year. In general, 11 kg of N (nitrogen), 7 kg of P_2O_5 (phosphorus) and 12 kg of K_2O (potassium) are recommended for a pear orchard with a yield of two tons per decare. Phosphorous fertilizers with 3-4 tons of barnyard manure and 15 kg of superphosphate per decare should be applied to the soil every three years in autumun.

Based on the principles provided in Ayyıldız [10], water quality class was determined as T_2S_1 (Moderately Salty-Low-Sodium). Electrical conductivity rate was determined as 525 micromhos cm^{-1}, pH value is 7.95 which can be deemed neutral. This type of irrigation water can be used in the irrigation of all plants other than those that are very sensitive to salt. Irrigation water quality is as important as the water quantity for fruit growth and sufficient yield especially in pear trees.

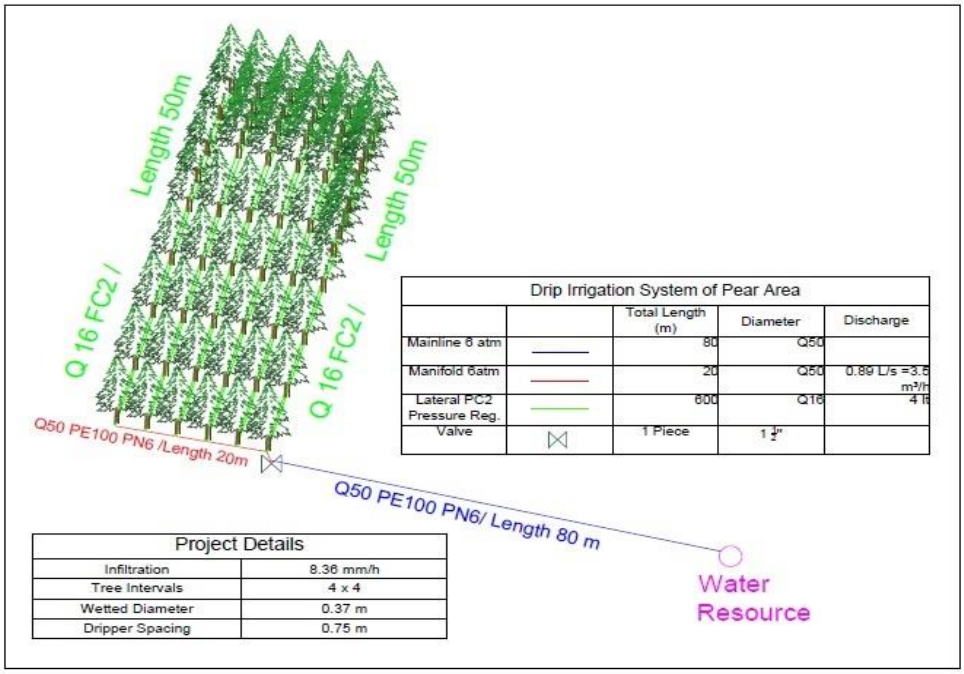

Figure 2. Details based on drip irrigation project

Table 2. Physical chracteristics of soil in the research area

Profile depth (cm)	Soil Texture	Field capacity		Wilting point		Bulk density (g cm^{-3})	Available water holding capacity (mm)
		%	mm	%	mm		
0-30	Loamy soil	39.00	168.48	26.00	112.32	1.44	67.20
30-60	Sandy clay	36.00	154.44	26.00	111.54	1.43	46.70
0-60			322.92		223.86		99.06

Table 3 Chemical chracteristics of soil in the research area (pear orchard)

Profile depth (cm)	Saturation perecentage of water (%)	Total salinity (%)	pH	Lime $CaCO_3$ (%)	Phosphorus P_2O_5 (kg da^{-1})	Potassium K_2O (kg da^{-1})	Organic Matter (%)
0-30	68.0	0.110	6.95	-	2.28	28.68	0.96
30-60	66.0	0.080	7.15	3.50	12.94	33.27	0.46
0-20	55.0	0.073	7.40	2.38	14.10	77.30	1.16
20-40	57.0	0.080	7.40	2.86	10.95	59.20	0.89

,Table 4. Chemical chracteristics of irrigation water in the research area

CO_3 (mg L^{-1})	Conductivity (EC) (µs $cm^{-1)}$	Ca (mgL^{-1})	Cl^- (mg L^{-1})	pH	Na (mgL^{-1})	SO_4 (mg L^{-1})	$CaCO_3$ (mg L^{-1})
137.0	525.0	90.0	6.9	7.95	28.55	2.0	227.0

C. Irrigation program 2

The irrigation scheduling results realized by Cropwat and Irsis software for the pear irrigated with drip irrigation are summarized in Table 5 and Figure 3.

The meteorological parameters, crop, soil and topography characteristics of the project area are given as input to the program. In programs, The length of the plant growing period were selected between the last frost date (March 12) and the first frost date (October 20) of the region as 223 days. Crop coefficients (kc) depending on growing periods for pear were taken from the guide of plant water consumption in Turkey [13] has been taken. In addition, some planning scenarios have been created such that the critical level (P) is 30, 40, 50%. In general, there are little differences along the softwares with respect to irrigation interval, irrigation amount and irrigation duration while there were significant differences in the irrigation components among irrigation regimes (P). The all irrigation components for 50% critical level was found to be higher than that of the 30, 40% levels.

As a result of scheduling, seasonal evapotranspiration (ETc) was found as 768.2 mm for Cropwat and also as 690.3 mm for Irsis. The total irrigation amounts, irrigation intervals, irrigation duration per one depending on critical levels were calculated by the softwares (Table 5).

In addition, literatures of the world were evaluated and compared to these results in Table 6. Earlier studies have shown that drip irrigation is the most suitable method for pear and it is possible to increase yield, yield quality and water use efficiency (WUE) by well scheduled irrigation programs, such as regulated deficit irrigation (RDI) strategies based on ET_C and soil water [14, 15], plant monitoring depending on midday stem water potential [16], soil water potential monitoring with watermark sensors [17], deficit irrigation strategies using three treatments of 100%, and 25% of water requirement (ETc) and no irrigation in Colombia [18]. The suggested treatments in these literatures are in line with the results obtained in this manuscript. It should be recommended that critical level should be chosen as 30, 40 or 50% according to water resource condition, climatic conditions and economic power of farmers. But, highly suggested one is 40% in this experimental area for good yield and quality. The evapotranspiration components for suggested critical level was shown in Figure 4.

According to all results, the critical level 30 can be recommended inthe springperiod, also 200 kg ha^{-1} N application can be recommended in the autumn cultivation period.

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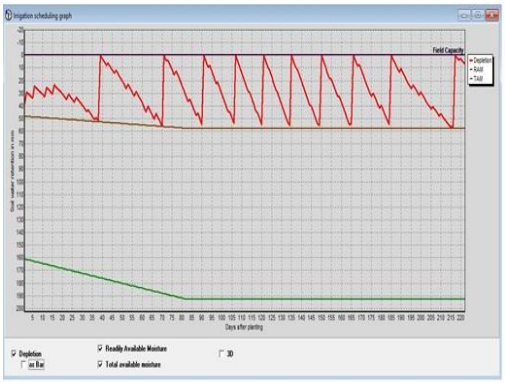
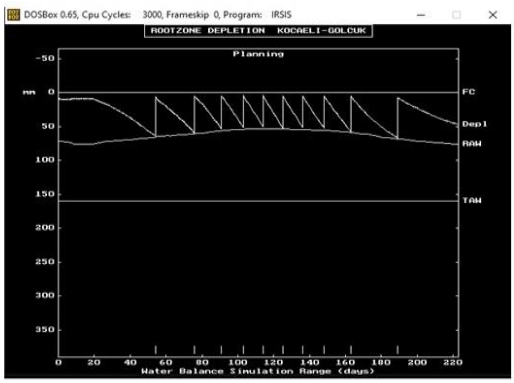
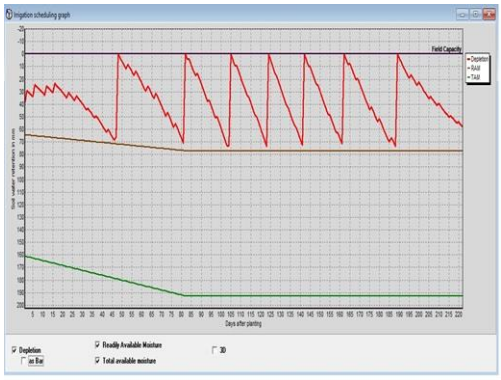
Table 5. Irrigation scheduling of pear via Irsis and Cropwat softwares

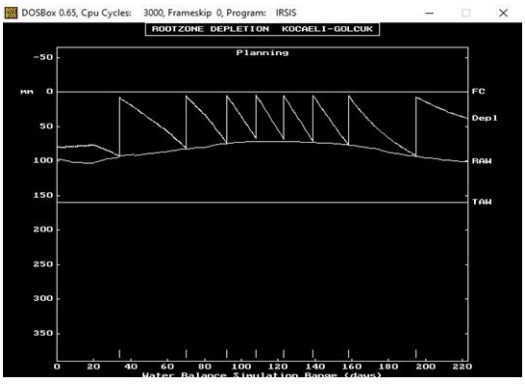
P-Factor	IRSIS				CROPWAT			
	Total irrigation level (I, mm/season)	Irrigation level (mm/irrigation)	Irrigation duration (h)	Irrigation Interval (day)	Total irrigation level (I, mm/season)	Irrigation level (mm/irrigation)	Irrigation duration (h)	Irrigation Interval (day)
30%	573.9	50.0	3.6	10	583.0	58	4.0	15
40%	578.0	70.0	4.8	15	547.0	78	5.5	18
50%	550.8	90.0	6.3	25	579.7	97	6.7	25





a. Ry=0.30





b. Ry=0.40

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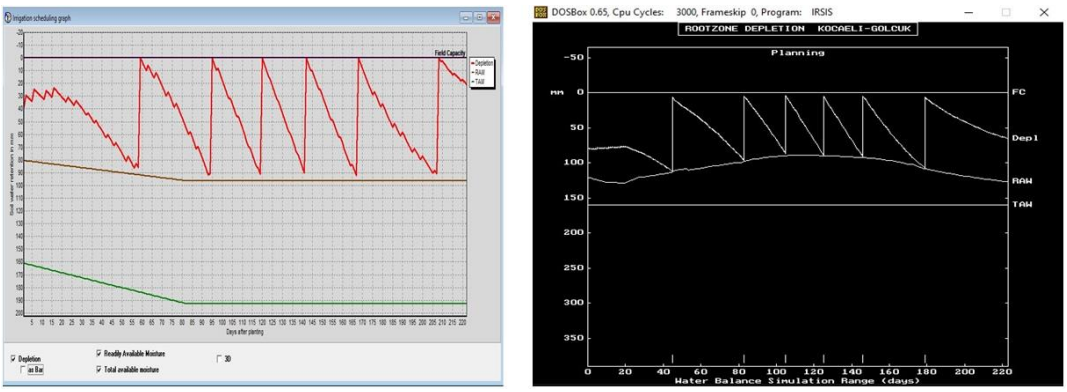


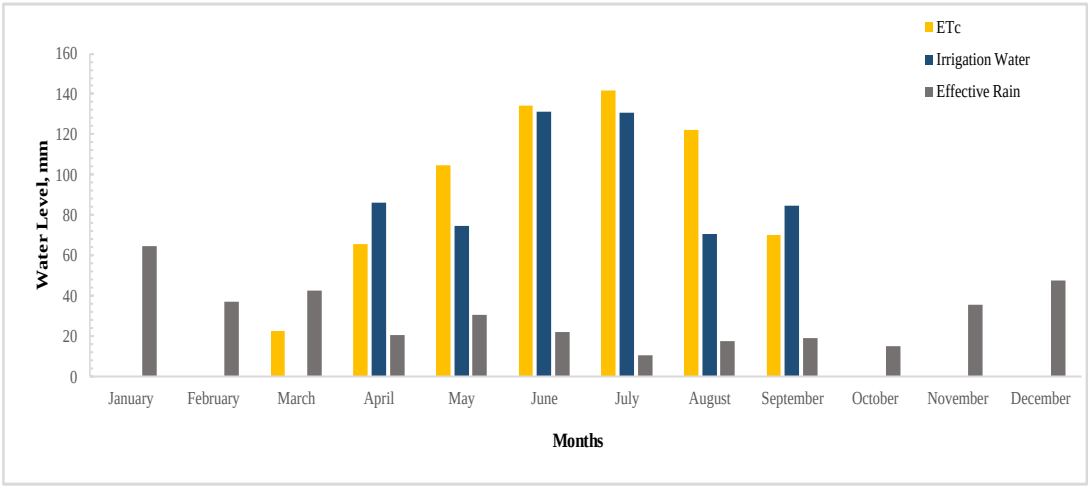
a. Ry= 0.50

b. Figure 3. View of Cropwat and Irsis sche2duling graphs

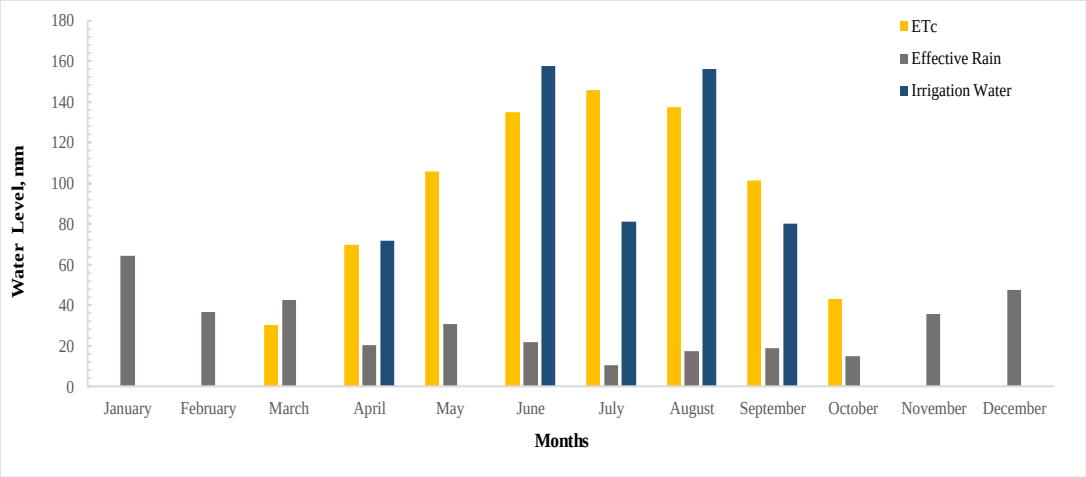
Table 6. Suggested results based on relevant literatures

References	Irrigation method	Irrigation interval (day)	Total irrigation (I, mm/season)	Total rainfall (mm/season)	Total ET (mm/season)
Yang et al., [19], China	Drip	7	70	671	1233
Anconelli and Mannini, [20], Italy	Drip	13	111	323	549
Marsal et al., [15], Spain	Drip	7	560	333	933
Asın´n et al., [21], Spain	Drip	12	463	46	-
Oron et al., [22], Israel	Drip	4/7	900	102	-
Wang et al., [23], Denmark	Drip	7/10	585	-	-

c. ET: Evapotranspiration



a. Irsis



b. Cropwatt

Figure 4. Evapotranspiration components for the critical level of 40% based on Irsis and Cropwat sofwares

IV. CONCLUSION AND RECOMMENDATIONS

In the pear orchards within the research area, irrigation as well as fertilization is of great importance for high-quality and sufficient production. In the region, pear orchards are generally irrigated by flood irrigation covering the whole garden, with the help of furrows opened at certain intervals. But irrigation performed in such settings will cause the fertile soil on the surface to be carried down if the land is sloped. They will also cause the upper tree roots to get lower, the lower tree roots to bulge and the root crown to remain under the ground. Another possible problem is a high rate of water loss due to evaporation and the failure to provide an even water distribution. This increases irrigation costs. Yet another important inconveniency is that it brings the salinization in the soil base up to the surface. Among other important inconveniencies are the forming of a duff layer on the soil surface and the resulting increase in the amount of weed due the fact that the pear orchard cannot be entered for a certain while after flood irrigation. Because of these reasons, it is recommended that pear orchard cultivators use drip irrigation. Also, application of organic liquid fertilizer with fertigation technique under drip irrigation allows considerable savings in fuel and labour.

Pear trees require a sufficient level of water and moisture in the soil, especially in the summertime. Although it may vary depending on the specific climate and soil conditions, it can be said that irrigation should be applied during the period from May until the end of September. When winter precipitation is insufficient, irrigation should be applied in winter months as well in order to compensate for the water and moisture deficiency. Number of irrigation numbers should be increased in hot and dry seasons.

According to data obtained from this research, it is recommended to start irrigation when the critical soil moisture level drops to 40% and the irrigation interval should be 15 days. The seasonal evapotranspiration was calculated as 730 mm, so irrigation water amount would be about 570 mm for pear in the Hisareyn area of the Gölcük district in the city of Kocaeli. With suggested irrigation conditions, it may be acquired in highly acceptable pear yield and quality under drip irrigation.

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