Water-Smart Irrigation Strategies for Improved Walnut Orchard Performance

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Abstract

Walnut trees as well as their fruits represent an important sector of the agricultural industry. Walnut is a valuable fruit species and its cultivation contributes significantly to the economy in Turkey. Turkey with its 13.2 billion walnut trees is so important in terms of walnut cultivation among other countries in the world. There are many problems about irrigation during the growing period of walnut. Walnut trees need irrigation during the growing period. Irrigation is a key-factor for walnut cultivation. Generally, application of irrigation is recommended from the beginning of April until the end of October. Irrigation methods change according to orchard's soil characteristic and climatic conditions of the cultivation area. In this study, drip irrigation method was investigated in terms of suitability in the walnut orchards located in Panayır Village in the vicinity of Gölcük/Kocaeli in Turkey. According to physical observations, analyses of water quality and the determined of soil characteristics, irrigation method was assessed with the purpose of determining the most suitable ones for walnut orchard irrigation in the area. And also, a model drip irrigation project was prepared for walnut trees in the study area. Preliminary project design criteria for the drip irrigation method, particularly the infiltration rate of the soil, were established as 50 mm h^{-1} by double-cylinder infiltrometer tests. An irrigation program was prepared by taking into account all characteristics and 6-hour irrigation duration for approximately every 4 days were prescribed for the walnut plant in this area.

Keywords: *Infiltration, irrigation method, orchards, productivity, walnut.*

1. Introduction

In the recent years, walnut cultivation has been steadily increasing in Turkey, due its high economic value. It has over 4.5 million walnut trees as a result of the cultivation done so far. Due to its walnut production of nearly 120 thousand tons, Turkey ranks third in the world in this sector.

Walnut trees can easily adapt to various soil and climate conditions. Although it takes a long time to grow, walnut is one of those fruit species which is most common over the world, with its cooling requirement of 400-1800 hours (Ötken, 2022). In certain regions of our country, late frosts in the spring are among the most important factors which cause inefficiency in the walnut trees. Among the other most important factors are irrigation and the correct choice and application of the irrigation method.

Walnuts require a cool enough weather in winter and autumn to satisfy the need for cooling and a temperature of 25-35 ^{0}C in spring and summer which is enough to support normal growth and maturing. A total minimum yearly precipitation of 500 mm is sufficient for walnut cultivation. Especially in the summer, there should be enough water and humidity in the soil. If the precipitation in winter is not enough to wet the soil at least 180 cm deep, irrigation must be applied during the winter as well in order to make up for the water and humidity deficiency.

They grow well in deep soils which do not retain water, with a groundwater level of not more than 2.5-3 meters. The pH value of the soil should be around 6-7 without any problems of soil alkalinity or saltiness. The soil should be well-drained, rich in organic matter and well-aired. The level of water retention capacity of the soil is of additional importance for cultivation; the higher it is the better. According to studies, the yearly water demand of walnut trees is around 750-1500 mm. Some researchers and also FAO studied about crop yield response to water relation to irrigation of walnut trees (Goldhamer and Fereres, 1982; Ameglio *et al.,* 1984; Fulton *et al.,* 2001, 2014, 2017;

FAO, 2012; Salgada *et al.,* 2021; Calvo *et.al.,* 2023). There are many studies about irrigation modernization and available different design for irrigation projects (Andrade and Allen 1999; Fukui *et al.,* 1980; Ortega *et al.,* 2004; Rocamora *et al.,* 2013; Zapata *et al.,* 2013; Archer, *et al.,* 2001; Cohen, 1997; Xia *et al.,* 2023; Kandelous and Simunek 2010; Vollset *et al.,* 2020). Drip irrigation and quality of irrigation water for good crop production were studied by (Master *et al.,* 2007; Grattan *et al.,* 2004; Ayers and Wescott, 1985; Diaz and Grattan, 2009; Hanjara and Qureshi 2010; Dirwai *et al.,* 2021).

2. Materials and Methods

2.1. Study area

The study has been performed in the walnut orchards in the village of Panayır within the district of Gölcük, located in the city of Kocaeli. Gölcük/Kocaeli is located at 40.669270 latitude and 29.812078 longitude. Its altitude (height above sea level) is 348 meters. Gölcük GPS coordinates are 40° 40′ 9.3720" and 29° 48′ 43.4808". All of the orchards where walnuts were cultivated had been set up according to the cultivators' own knowledge and experiences. While some of the orchards were set up on the plain, the others were set up on high lands within the forest land, approximately 500-800 m above sea level.

The research area is 17 km from the city of Kocaeli and 10 km from the district of Gölcük. The climate of the district is under the influence of Black Sea climate, but it also shows climate properties of the Marmara Region. When average climatic values measured throughout many years (1950 - 2022) are studied, it is seen that the average temperature has been 23.8 ^{0}C and the highest average temperature has been measured in July as 29.6 ^{0}C. The lowest average temperature has been measured in January as 3.3 ^{0}C. Average number of rainy days has been the highest in January with 17.4 and the lowest in August with 5.2. Annual average rainfall is 768 mm m^{-2} in this region. Total monthly precipitation has been recorded to be the highest in December with the average being 110.0 kg m^{-2} and the lowest in July with the average being 37.1 kg m^{-2} (MGM, 2017).

The local walnut orchards have been visited and the problems they face in irrigation have been identified. The walnut species cultivated in the research area are Şebin and Bilecik as the local species and Chandler and Pikan as the foreign species. The most important reason why the foreign species are preferred in the area is that they provide high efficiency, high quality fruits that are full inside with thin shells and therefore also yield high incomes.

The size of the walnut orchards in the research area vary between 5 and 10 decars. The young trees in the orchards are generally planted within 9 x 9 m and 10 x 10 m spaces. As well as orchards where spring water is used, there are also certain walnut orchards where the cultivation is done without any irrigation. Non-irrigated orchards are mostly the cultivation sites set up within the forest land (Figure 1a-b).

(a) (b)

Figure: 1a-b. Walnut orchards in the research area

2.2. Medhods

Irrigation system is the whole of any and all the necessary structures for taking the water from the water source, transferring it to the area to be irrigated and its distribution. Therefore, prior to preparing the drip irrigation project for the walnut orchard where the survey is carried out, preliminary preparations were made by taking into account all factors such as the existing water source, soil, topography, plants and climate. All the information that was needed for planning the irrigation system, the sizing of the system elements, the configuration and operation of the system were obtained through terrain analyses. Following these efforts, the drip irrigation project was prepared and set up in the orchard.

The drip irrigation system consisted of water source, pumping unit, control unit, pipelines and drippers respectively. The irrigation water needed for irrigating the research plots was taken into the system with the help of gravity from the two 2-ton water tanks near the plot located on higher ground. Irrigation water was filtered so as not to clog the drippers and then mixed with the necessary nutrients. After the pressure and flow rate checks, it was distributed to the research plots. The control unit was made up of a fertilizer tank, a strainer filter and manometers for pressure measurements.

Soil samples have been taken and analysed according to Blake (1965) and soil texture was measured with a hydrometer as explained in Bouyoucos (1962). In addition, samples have been taken from the water sources used in irrigation and irrigation water quality analyses have been performed in the laboratory, according to Ayyıldız (1990). The actual value of infiltration rate needed for the preparation of the irrigation system has been identified (Huabing *et al.,* 2014; Göçmen and Erdem, 2019, Gürgülü and Ul, 2017; Kara, 2002) by double ring infiltrometer measurements.

3. Results

3.1. Results of project

Detailed project drawings were done in Autocad and the relevant details are shown in Figure 2. Infiltration rate was determined as 50 mm h^{-1} in the study area and attached water intake rates per unit of time were graphed (Fig. 3).

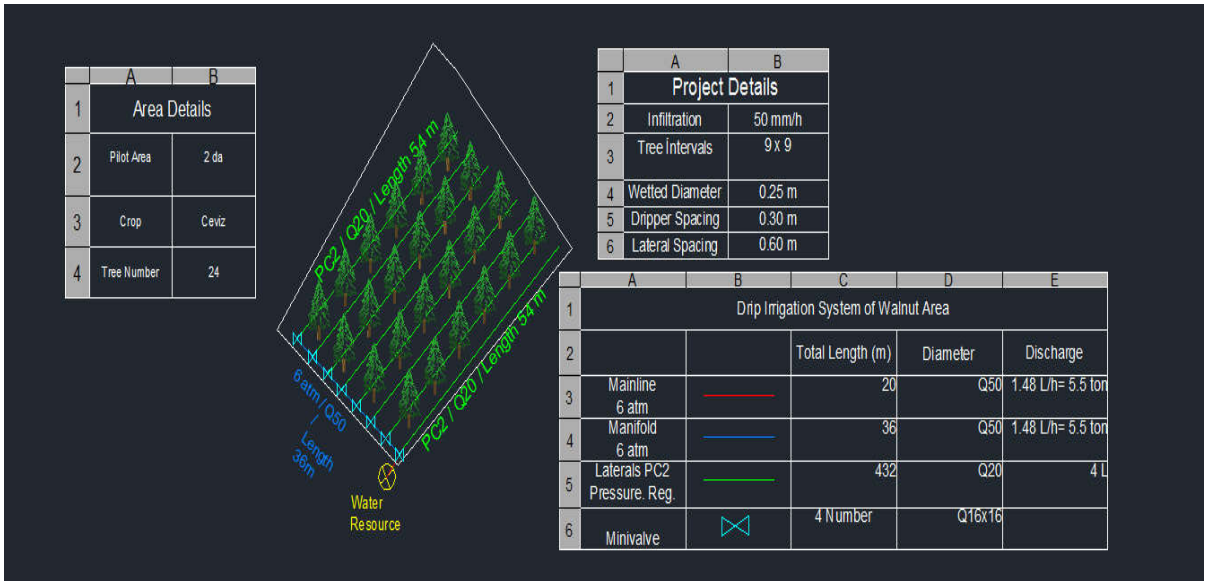

Figure: 2 The detailed of walnut project area in Autocad

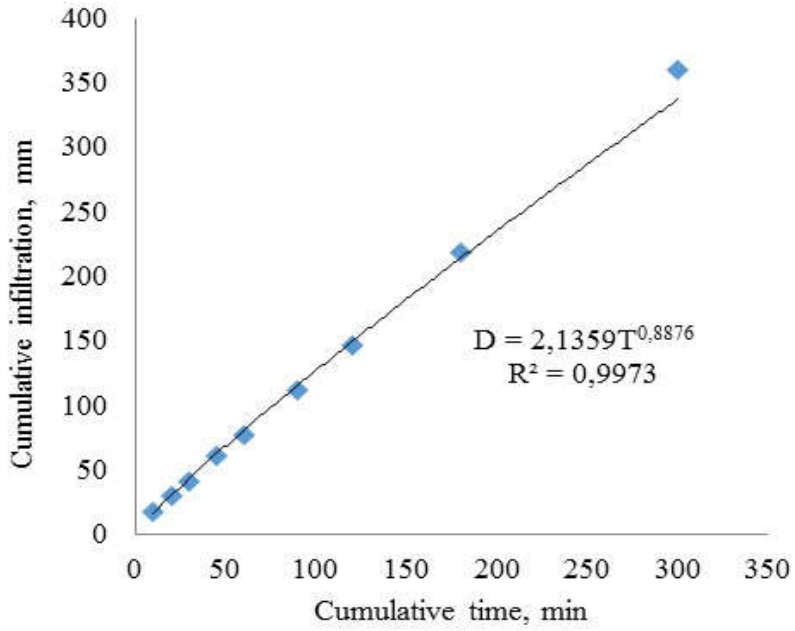

Figure: 3 Cumulative water intake curve in the research area

Project area consists of 2 da and 24 walnut trees. Row spacing between the trees and intrarow distances are 9.0 x 9.0 m and 2 laterals are placed in each plant row. In determining the wet area percentage the calculations were made by taking into account the wet line that is formed during irrigation and the P value was found be 60 % (Keller and Bliesner, 1990). In the irrigation system, there are hard PE pipes of 50 mm external diameter with 6 atm operating pressure for the main pipe and manifold pipelines. And for the laterals, soft PE pipes of 16 mm diameter with inline drippers of 1.0 atm pressure and 4 L h^{-1} flow rate whose spacing and flow rate were determined based on the infiltration rate of the soil are used (Figure 4a,b). Dripper spacing was determined to be 30 cm based on the dripper flow rate identified based on the preferred operating pressure and the water intake rates of the soil (Doorenbos, 1979; Lecina *et al.,* 2006; Ortega *et.al,* 2004).

(a) **(b)**

Figure: 4a-b. Drip irrigation in the walnut orchard

3.2. Results of chemical and physical analyses in soil

Physical properties of soil samples taken from two different profiles within the research area (soil texture, bulk density, field capacity, wilting point and available water holding capacity) are given in Table 1. According to the results in Table 1, texture of the soil in each layer of the research area is generally Loamy (0-30 cm) and Sandy Loamy (30-60 cm). Soil bulk density values are respectively 1.22 and 1.29 g cm^{-3} for each layer. Applicable water retention capacity in 0-30 cm is determined as 27.25 mm and as 26.63 mm in 30-60 cm.

Table 1: 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 30 cm^{-1})
		%	mm	%	mm		
0-30	CL	48.98	179.41	41.54	152.16	1.22	27.25
30-60	CL	47.15	182.75	40.28	156.12	1.29	26.63

Results concerning the analysis of the soil samples taken from 0-20 cm and 20-40 cm soil depths in the research plots for the purpose of yield analysis are given in Table 2. A fertilization program to be applied in soil preparation and plant growing periods was prepared based on the soil analysis results in Table 2 as well as taking into account the recommended fertilizer amounts for walnut cultivation in Panayır Village of Gölcük District of the city Kocaeli and the nutrient levels used by the walnut plant during the vegetation period.

Table 2: Chemical chracteristics of soil in the research area

Profile depth (cm)	pH	EC (µs cm^{-1})	Lime $CaCO_3$ (%)	Organic matter (%)	Phosphorus P_2O_5 (kg da^{-1})	Potassium K_2O (kg da^{-1})
0-30	6.68	148	-	1.25	24.43	28.938
30-60	7.13	1141	6.4	1.37	13.85	25.661

According to this; as in all orchards, in order to carry out a balanced and orderly fertilization process, soil analyses must be made every year and leaf analyses must be made every three years in walnut orchards as well. Based on the results of these analyses, the fertilizer requirements of the orchard should be determined. Fertilizers must be applied within the crown projections of trees, but they should not have any contact with the roots. Macro elements must be provided almost every year and micro elements must be provided in accordance with the needs of the plants. Walnut is not a very sensitive plant in terms of fertilization unless there is a severe problem in the soil. The macro elements that the walnut plant needs the most are nitrogen and potassium.

With the help of the drip irrigation system that was set up in the project area and through the use of fertigation technique, fertilizers with macro and micro nutrients can be applied in melted form and varying proportions. In the irrigation of walnut gardens, a balanced fertilization program is crucial for hardened texture and increased fruit bud count. Prior to planting, only fertilizers containing phosphate and potassium should be applied, avoiding any nitrogen-containing fertilizers. For each tree, applying 4-5 shovels of fertilizer mixed with 250 g triplephosphate and 250 g potassium sulfate is recommended.

3.3. Results of chemical analyses of irrigation water

Irrigation water analysis results are shown in Table 3. According to the data given in Ayyıldız (1990), water quality class is identified as C_2A_1 (moderately salty-little amount of sodium). It is categorized as second-class irrigation water and electrical conductivity value is determined as 722 micromhos cm^{-1}. pH value is 7.50 and can be deemed neutral. It is used in the irrigation of all plants except those that are overly sensitive to salt. In case soils that are low in permeability are irrigated with such water, the soil may need to be washed. On lands where there is some cultivation activity, soil should be analyzed once a year in order to check if there is any salt accumulation in the soil.

Table 3: Chemical chracteristics of irrigation water in the research area

Parameters							
CO_3 (mg L^{-1})	Electrical Conductivity (EC)(µs cm^{-1})	Ca (mg L^{-1})	Cl^- (mg L^{-1})	pH	Na (mg L^{-1})	SO_4 (mg L^{-1})	$CaCO_3$ (mg L^{-1})
197	722	131	16.9	7.50	22.63	5	328

4. Discussion

Flood irrigation and wetting the whole orchard are methods commonly used in irrigation. The number of orchards where drip irrigation method is used is very low and they are set up without a project, according to the cultivators' own knowledge and experiences. Therefore, the cultivators are unable to reach the desired efficiency levels with these irrigation systems.

Walnut is a fruit species which responds very well to drip irrigation. Thus, the walnut cultivators in the research area were advised to make use of the drip irrigation method. The purpose of the drip irrigation method is to apply at once, a low amount of irrigation water, only to the area where the plant roots grow with the help of a pressure pipe and drippers so as not to cause a tension resulting from a deficiency in humidity. With this system a wet surface is created only along the plant rows without wetting the whole cultivation site and the ground between the rows remains dry. When irrigation is applied this way, the benefits obtained from the irrigation water are maximized. And the water loss due to evaporation is minimized. In addition, since the setup cost for the drip irrigation system is lower in comparison with other irrigation systems and that it saves water and has a positive influence on keeping the fertile soil in cultivation gardens, it should be a preferred choice among cultivators. The plots were irrigated by drip irrigation. Irrigation was taken by a pump from a water tank near the experimental site.

Working schedule of the drip irrigation project that was prepared based on all terrain analyses and project data is as follows:

Irrigation schedule for the beginning was prescribed as 6-hour irrigation durations almost every 4 days in the walnut area, based on soil humidity and the properties of the irrigation system. However, in the following years, based on the water consumption ETc rates (964 mm seasonally) for the walnut plant in the city of Kocaeli published in the water consumption guide for irrigated plants in Turkey (GTHB , 2017) it was decided that irrigation can be done from the middle of March until the end of November. Water consumption is the highest in June, July and August and the average daily water consumption was calculated as 6.0 mm day^{-1}. According to this value, it is prescribed that in summertime 7-10-hour durations every 3-4 days and in other months 5-6-hour durations can be applied.

The results of this research indicate that walnut trees, known for their broad branches and leaves, demand ample water, especially in the first two years after planting. Adequate irrigation is vital during spring growth, fruit formation, and maturation. Insufficient water can stunt growth and reduce fruit quality. Despite their drought tolerance, regular irrigation enhances efficiency, particularly post-fruit sizing to ensure proper meat development. Drip irrigation, coupled with fertigation, optimizes nutrient delivery. A balanced fertilization regimen, excluding nitrogen pre-planting, is recommended. Spring to autumn irrigation is essential, with tailored schedules based on climate and soil. In dry years, extending irrigation into autumn and winter is advised. Consultation for science-driven cultivation, especially regarding irrigation, is recommended for optimal orchard establishment.

5. Conclusion

It is of great importance that irrigation water reaches all of the roots of walnut trees. Therefore, when the irrigation system is being set up, it is a must that the irrigation project is prepared in a wat that enables the irrigation water to reach the capillary roots that are spread over the crown projection areas of the trees.

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Authors' Contributions

Conceptualization: Dökmen F, Ahi Y, **Data curation:** Dökmen F, Ahi Y, Köksal DD, **Formal analysis:** Dökmen F, Ahi Y, Köksal DD, **Funding acquisition:** Dökmen F, **Investigation:** Dökmen F, Ahi Y, Köksal DD, **Methodology:** Dökmen F, Ahi Y, **Project administration:** Dökmen F, **Supervision:** Ahi Y, **Writing-Orjinal draft:** Dökmen F, Ahi Y **Writing-review & editing:** Dökmen F, Ahi Y.

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Declarations

Competing interest The authors no competing interest.

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