



The Effect of Intermittent Subsurface Drip Irrigation on Soil Water Distribution

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Abstract

In this study, the vertical and horizontal distribution of water under the soil was examined by applying the irrigation water with the classical method (continuous) and intermittently in the subsurface drip irrigation (SDI) system in order to provide a better water distribution. The trial area where the research was conducted had a clayey soil texture, and the field slope was less than 1%. Accordingly, four different intermittent irrigation methods were studied under field conditions. Before and after each irrigation, water was monitored in the soil at 0–30, 30–60, and 60–90 cm depths from the soil surface and at 5, 20, and 35 cm horizontal distances from the dripper. In both years of the research, the highest irrigation water use efficiency (IWUE) was obtained in the F1 treatment, with values of 0.22 kg m⁻³ and 0.23 kg m⁻³, respectively, indicating the longest interval between two irrigation events. The difference between treatments was found to be statistically significant ($p < 0.01$) for all vertical depths at a distance of 35 cm from the dripper point. At the furthest point from the emitter (35 cm), the amounts of water measured in the soil were 6% higher in the 0–30 cm and 30–60 cm layers for the F1 treatment compared to the other treatments. The study demonstrated that the lateral movement of water in SDI is increased with intermittent irrigation. The research holds significant implications for researchers working in this field and for SDI users in water-scarce areas and those facing deep percolation issues.

Keywords Pulse irrigation · Subsurface drip irrigation · Water distribution · Water management

Introduction

Due to the increasing demand for water by non-agricultural sectors, climatic changes and irregularities in precipitation, more efficient water use is needed for sustainable agriculture (Mukhopadhyay et al. [1]; Tian et al. [2]). Considering that water resources will become more and more strategically important in the near future, it is obvious that the available water should be used more efficiently. Various irrigation methods have been tried from past to present in order to use water with the highest efficiency in agriculture (Jha et al. [3]; Olgarenko et al. [4]). In these studies, ways have been sought to keep all kinds of water losses (deep percolation,

runoff, evaporation, etc.) that the plant cannot benefit from at the lowest level.

Subsurface drip irrigation (SDI) is one of the systems developed for the most efficient use of water (Hanson et al. [5]; Lamm and Trooien [6]; Vories et al. [7]). Knowing how water behaves in vertical and horizontal directions along the soil profile is important in terms of meeting optimum plant water requirement and efficient water use. As a result of the restriction of the lateral movement of water due to the negative pressure under the ground, deep percolation or wetting of the soil surface may occur. This situation reduces the efficiency of SDI systems (Rodríguez-Sinobas et al. [8]; Appels and Karimi [9]).

In the results of many studies, it has been reported that a lower wetting diameter occurs in SDI than in surface drip irrigation (Phene [10]; Shaviv and Sinai [11]; Rocha et al. [12]; Lazarovitch et al. [13]). The fundamental reason for this is that the factors influencing water movement in subsurface drip irrigation are different from those in surface drip irrigation. While water movement in subsurface drip irrigation can occur in all four axes, in surface drip

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irrigation, water generally moves vertically below the horizontal axis (Kandelous and Šimůnek [14]; El-Nesr et al. [15]; Norouzian and Ahmadi [16]). Therefore, the factors influencing water movement in subsurface drip irrigation are much more complicated compared to surface drip irrigation. The soil structure, slope of the terrain, characteristics of the drip irrigation system used, soil and irrigation water temperature, and quality and quantity of applied irrigation water are all crucial in determining the direction and velocity of water movement (Gil et al. [17, 18]; Nogueira et al. [19]). This situation necessitates a better understanding of the factors that affect water movement and the soil-water relationship in subsurface drip irrigation to achieve more effective water management. By gaining a deeper insight into these factors, farmers and irrigation managers can optimize the irrigation process, enhance water use efficiency, and ensure more targeted and efficient water delivery to the plant roots, leading to improved crop yields and sustainable agricultural practices. Understanding the complexities of water movement in subsurface drip irrigation allows for better control over irrigation, minimizing water wastage and environmental impacts.

From the past to the present, various intermittent or pulse irrigation practices have been tried, especially in furrow irrigation, to increase the lateral movement of water in the soil. In subsurface drip irrigation, methods such as the double lateral technique and the use of an impermeable artificial layer under the emitter have been experimented with to increase the lateral movement of water, in other words, the wetting diameter. However, these applied methods have either resulted in additional costs or have not provided valid results due to practical difficulties in implementation. As an additional result, apart from these methods, the intermittent irrigation technique used in furrow irrigation appears to be interesting as it helps us understand the soil-water relationship. This technique breaks the adhesion force in the soil, facilitating the horizontal movement of water on a wet layer. There are studies reporting that intermittent irrigation increases the distribution of water in the soil (Lozano et al. [20]; Mohammed and Abed [21]; Zamora et al. [22]; Abdelraouf et al. [23]). Therefore, the distribution of water in the soil in SDI is an important area of research and should be studied for effective irrigation.

Determining the lateral movement of water in subsurface drip irrigation under different irrigation water loads is crucial for effective water usage. Previous limited research in this field has often involved either costly methods or intermittent irrigation practices based on fixed irrigation intervals regardless of the applied irrigation water (Almeida et al. [24]; Mohammed and Abed [21]; Lozano et al. [20]). However, in this study, the total irrigation water amount was divided into equal portions, and irrigation intervals were established, resulting in more equitable water loads

underground. In the 2-year field study, the intermittent irrigation technique was tried as an alternative solution to the problem of water distribution in the soil in SDI systems. In the research, the lateral and vertical movement of water in SDI systems was monitored and the effect of intermittent irrigation applications on homogeneous water distribution in the soil was investigated. With the results of the study, it was aimed to save more water in SDI systems and to create a theoretical basis for similar studies to be done.

Material and Method

Site Description

This study was carried out between 2019 and 2020 years in General Directorate of Agricultural Research and Policies, Soil Fertilizer and Water Resources Research Center Institute Sarayköy Research and Application Station in the Kahramankazan district of Ankara Province of Turkey. The experimental area is located between +40°04'30.7" N latitude and +32°36'24.0" E longitude.

Experimental Design and Cultural Practices

The field experiment was conducted using a random blocks design with four irrigation treatments and three replications. The plot size was determined as 3.5 m × 6 m (W × L). In order to prevent side effects that may occur through infiltration after irrigation, 2.0 m of non-irrigated area was left between the parcels and 3.0 m between the blocks (Arıtürk and Erdem [25]). The experimental area was prepared for planting in spring by plowing with a plow and a rake, after deep plowing in autumn. Silage corn was used as the test plant in the study. Corn seeds were sown with a row spacing of 0.70 m. The water content in the soil profile was measured just before and one day after the irrigations during the crop irrigation period. The experimental area consisted of a total of 12 plots according to the randomized blocks design with 3 replications.

Irrigation

Subsurface drip irrigation system was used in the experiment. Irrigation water was provided from the well in the research area. Irrigation system consisted of pump, hydrocyclone, injection pump, screen filter, manometers, pressure regulator, main valve, control valves of each parcel, water meters, manifold pipelines, and lateral pipelines with in-line drippers.

In the irrigation system, pressure-adjusted lateral pipes with a diameter of 20 mm and 33-cm dripper space were used. Laterals were placed at 0.70-m intervals and 0.35 m

depth from the soil surface (Bilgen and Kodal [26]). Irrigation treatments in the research were formed as follows:

- F0: Irrigation water requirement was applied at once (control).
- F1: The irrigation water requirement was applied at two equal times.
- F2: The irrigation water requirement was applied at three equal times.
- F3: The irrigation water requirement was applied at four equal times.

In the study, irrigation water was applied to bring the available soil water to the field capacity when $30 \pm 5\%$ of the available water capacity in 0–60 cm soil depth consumed (Bilgen and Kodal [26]). ON_{time} and Off_{time} durations were kept equal in intermittent irrigation applications. For example, if 30 mm of irrigation water was applied, 15 mm of water was applied for F_1 treatment, then the cut time was applied as much as the time elapsed in irrigation, and the remaining 15 mm of water was applied again.

Neutronmeter method was used to determine the soil water content. For calibration, neutronmeter values were read from 0 to 30 cm, 30 to 60 cm, and 60 to 90 cm soil depths of the soil before irrigation. The obtained values were graphed with

the soil water values obtained by gravimetric method from the same depths and the calibration equation was created (Fig. 1).

Calibration equations obtained for each depth are used in converting neutronmeter readings into true moisture values. The principles stated in (Tüzün [27]) were taken into consideration for the neutronmeter calibration performed in the experimental area (Eqs. 1, 2, and 3).

Equation 4 has been used in calculating the amount of irrigation water (volumetric) applied to the parcels.

$$\theta_h = a + b(SO) \tag{1}$$

$$SO = \frac{S}{SS} \tag{2}$$

where θ_h is the soil volumetric water content (%); a is the calibration curve constant; b is the slope of the calibration line; SO is the count rate; S is the neutron meter count-reading value; SS is the standard count value.

Conversion of the obtained volumetric water content to mm for each soil depth (0–3, 0.3–0.6, 0.6–0.9) m:

$$AW = \theta_h \cdot \gamma t \cdot \frac{D}{10} \tag{3}$$

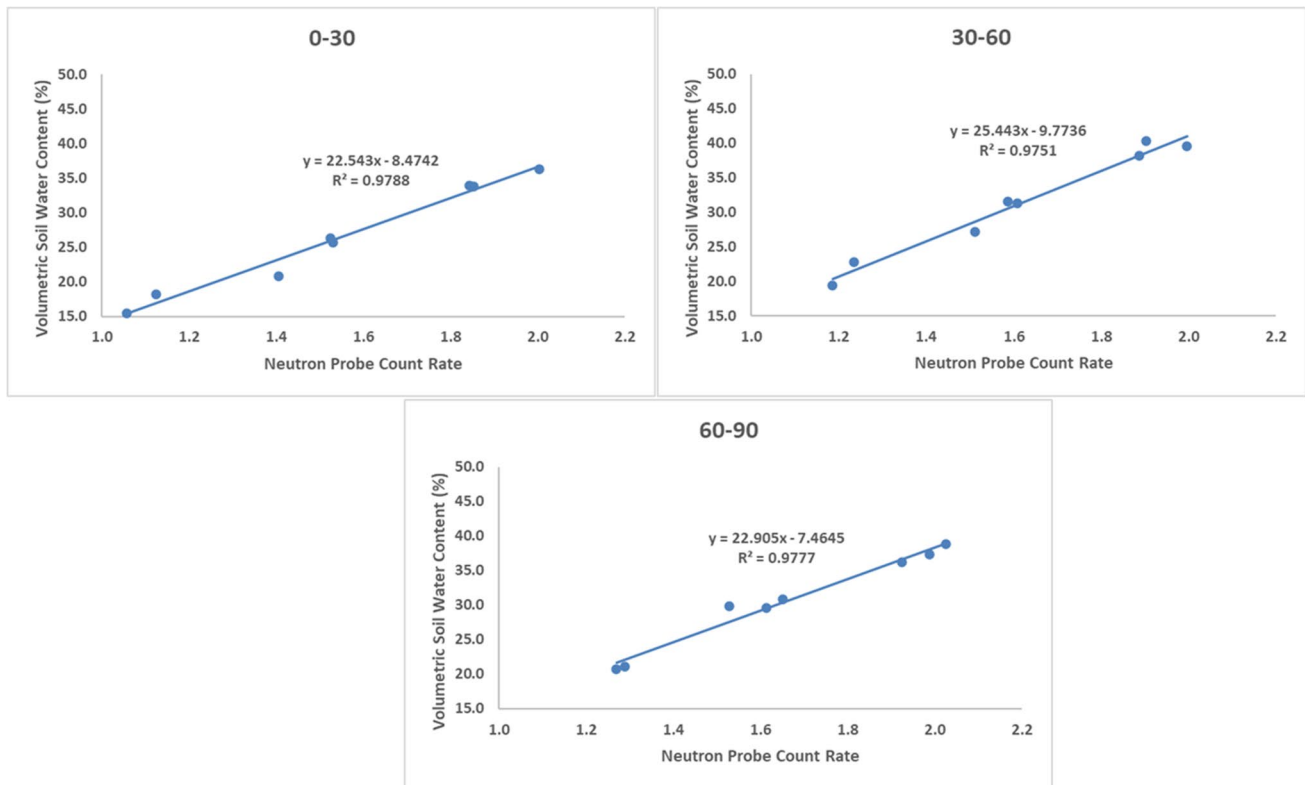
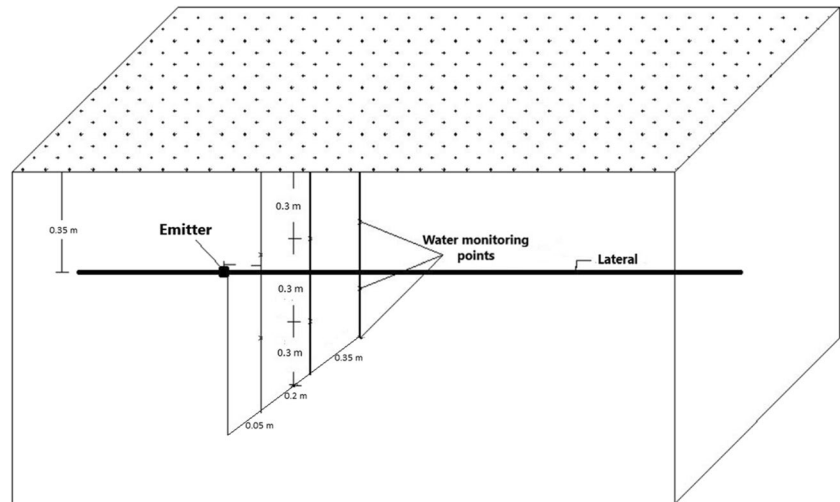


Fig. 1 Neutronmeter calibration equations

Fig. 2 Monitoring of water distribution in subsurface drip irrigation



In equality, AW is the available water (mm); γt is the volume weight of soil (g cm^{-3}); and D is the depth of soil to be wetted (mm).

The amount of irrigation water to be applied:

$$I = \frac{FC-AM}{100} \cdot \gamma t \cdot D \tag{4}$$

where I is the net amount of irrigation water (mm); FC is the field capacity (%); AM is the available moisture (%); γt is the soil bulk density (g cm^{-3}); and D is the depth of soil to be wetted (mm).

Equations suggested by Howell et al. ([28]) are used in determining water use efficiency (WUE) and irrigation water use efficiency (IWUE).

$$WUE = \frac{Y}{ETc} \tag{5}$$

$$IWUE = \frac{Y}{I} \tag{6}$$

where Y is the yield (kg da^{-1}) and ETc is the crop water consumption (mm).

The daily actual evapotranspiration amounts for the silage maize plant during the growing season were calculated with the following equation according to the water budget method (Jensen et al. [29]).

$$ETc = I + P + C_r - D_w - R_f \pm \Delta S \tag{7}$$

where

ETc is the crop water consumption (mm)

I is the amount of water given by irrigation (mm)

P is the amount of precipitation (mm)

C_r is the capillary amount (mm)

D_w is the amount of penetration (mm)

R_f is the runoff amount (mm), and

ΔS is the moisture change amount in the soil (mm).

Since there is no ground water problem in the experimental area, capillary rise (C_r) was not taken into account.

Water Monitoring in Soil Profile

In order to determine the water distribution in the soil profile, water measurements were made 24 h after irrigation at 5 cm, 20 cm, and 35 cm horizontal distances from the emitter point and 0–30, 30–60, 60–90 cm vertical soil profiles (Elnesr and Alazba [30]). Measurements were made regularly after each irrigation. According to the irrigation treatments, the available water amount measured from the dripping point in the vertical and horizontal directions was evaluated statistically (Fig. 2).

Statistical Analysis

The data obtained from the study were analyzed with Duncan test using the SPSS v25 computer package program.

Results and Discussion

According to the analysis results, some properties of the soil in the trial area are given in Table 1.

Table 1 Some physical and chemical properties of the trial field soil

Depth (m)	Sand (%)	Loam (%)	Clay (%)	Texture	Bulk density (g cm ⁻³)	Field capacity (%)	Wilting point (%)	Available water content (mm)
0.0–0.3	16.90	31.20	51.90	C	1.18	40.0	22.3	63
0.3–0.6	12.80	32.00	55.20	C	1.15	40.3	23.7	57
0.6–0.9	11.70	34.30	54.00	C	1.19	42.2	24.0	63
	EC (dS m ⁻¹)		pH (Sat.Mud.)	Organic matter (%)	Phosphorus P ₂ O ₅ (kg da ⁻¹)	Potassium K ₂ O(kg da ⁻¹)	Total nitrogen (%)	CaCO ₃ (%)
0.0–0.3	0.91		7.87	0.26	6.70	178.98	0.055	12.81
0.3–0.6	0.85		7.84	0.34	5.86	205.87	0.062	12.56
0.6–0.9	0.88		7.79	0.22	6.25	191.42	0.058	11.05

The soil texture was clay (C). As seen in Table 1, the bulk density of the soil at a depth of 0–0.6 m varies between 1.15 and 1.19 g cm⁻³, the moisture content of the soil at field capacity varies between 40.0 and 42.2%, and the wilting point varies between 22.3 and 24.0%. The available water capacity of the soil was 120 mm / 0.6 m.

It has been determined that the irrigation water used in the research is T₃A₂ class. Accordingly, the irrigation water was acceptable in terms of salinity and moderate in terms of alkalinity (Table 2).

Water Use Efficiency and Distribution of Water in Soil

The water usage efficiency (WUE) and irrigation water usage efficiency (IWUE) obtained in the study are given in Table 3. The results regarding the effects of the study on yield and quality parameters of silage maize were given in Gültekin and Ertek ([31]).

In both years of the research, the highest and lowest WUE values were obtained as 16.8 and 14.9 kg m⁻³ in the first year, and 19.5 and 14.6 kg m⁻³ in the second year from F₀ and F₁ treatments, respectively. The highest and lowest IWUE values were obtained as 21.5 and 18.7 kg m⁻³ in the first year and 22.9 and 17.5 kg m⁻³ in the second year from F₀ and F₁ treatments, respectively. In the study conducted, WUE and IWUE values were higher in intermittent irrigation applications compared to continuous irrigation applications. This situation shows that intermittent irrigation applications are important for yield increase. While the WUE and IWUE values obtained were similar to Dağdelen et al. ([32]), Arıttürk ([33]), Okursoy ([34]), and Kiziloglu et al. ([35]), they were higher than the findings of Zhang et al. ([36]) and Kanani et al. ([37]). In the study, positive effects of intermittent irrigation applications on yield and water use efficiency are observed. On the other hand, when the number of intervals is more than 2, there is a relative decrease in yield and water use efficiency, indicating that the number of intervals for subsurface drip irrigation should be limited.

In order to determine the effect of intermittent irrigation practices on water distribution in the soil, water changes were followed from the depths of 0–30, 30–60, and 60–90 cm from the soil surface and at a horizontal distance of 5, 20, and 35 cm from the emitter point. One day after irrigation, the water values measured in the soil profiles were analyzed for each soil depth, and it was determined whether the effect of intermittent irrigation applications on the water distribution in the soil was statistically significant. The variance analyses regarding the water distribution in the soil obtained in the research are given in Table 4 and Duncan grouping is given in Table 5. Graphs of water distribution in the soil are given in Figs. 3 and 4.

Table 2 Characteristics of the irrigation water used in the experiment

EC (dS m ⁻¹)	pH	Exchangeable cations (meL ⁻¹)				
		Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	Tot
2.05	8.51	1.27	6.2	10.9	0.2	18.6
SAR	Class	Soluble anions (meL ⁻¹)				
		CO ₃	HCO ₃	Cl ⁻	SO ₄	Tot
5.63	T ₃ A ₂	0.69	5.38	7.27	5.25	18.6

Table 3 Water and irrigation efficiency

Seasons	Treatments	Seasonal irrigation (mm)	Seasonal ET (mm)	Fresh yield (t ha ⁻¹)	WUE (kg m ⁻³)	IWUE (kg m ⁻³)
2019	F ₀	436.4	546	81.5	14.90	0.19
	F ₁	399.5	510	85.9	16.80	0.22
	F ₂	415.7	536	86.3	16.10	0.21
	F ₃	425.5	541	84.2	15.60	0.20
2020	F ₀	456.5	546	79.9b	14.60	0.18
	F ₁	390.0	459	89.5a	19.50	0.23
	F ₂	396.0	462	87.8a	19.00	0.22
	F ₃	403.7	481	83.2ab	17.30	0.21

Values followed by the same letter are not significantly different at 0.05 level of probability

Table 4 Variance values for water distribution in soil

2019 year			2020 year					2019–2020 average			
Depth from soil surface (cm)	Variance sources	Horizontal distance from emitter						Variance Sources	Horizontal distance from emitter		
		5 cm		20 cm		35 cm			5 cm	20 cm	35 cm
		P	P	P	P	P	P		P	P	P
0–30	Treatments	ns	*	**	**	ns	**	Treatment	**	**	**
	Error	14.5	22.2	34.5	16.3	60.6	100.1	Year*Treatment	*	ns	ns
	CV (%)	3	4.3	5.8	3.6	6.9	10.4	CV (%)	3.4	5.7	8.4
30–60	Treatments	ns	**	**	ns	**	**	Treatment	ns	**	**
	Error	15.3	53.6	32.1	25.8	53.6	83.4	Year*Treatment	ns	**	ns
	CV (%)	2.8	4.8	5.5	3.7	7	9.2	CV (%)	3.2	6.1	7.6
60–90	Treatments	ns	ns	*	**	ns	*	Treatment	**	ns	**
	Error	46.4	61	35.5	38.1	64.4	79.8	Year*Treatment	ns	ns	ns
	CV (%)	4.6	5.7	4.9	5	6	7.6	CV (%)	5	6	6.4

nsnot statistically significant; *significant at the 5%level; **significant at the 1%level

According to the 2-year averages of the water distribution in the soil for the distance of 5 cm from the emitter point, the difference between the treatment and year-treatment interaction in the 30–60 cm part of the soil profile was not statistically significant, while the difference between the treatment in the 0–30 and 60–90 cm part of the soil profile was statistically significant. Accordingly, in the 0–30 cm part of the soil profile, the lowest water value was found at 121.9 mm in the subject where the water was given at one stage (F₀), while the highest water level was obtained in the intermittent

irrigation treatments (F₁, F₂, and F₃). In the 60–90 cm part of the soil profile, the highest and lowest water content were found at 150.9 and 143.6 mm, respectively, in F₀ and F₂ treatments. The water levels in this region were determined to increase by approximately 20% from the soil surface to a depth of 90 cm in all treatments.

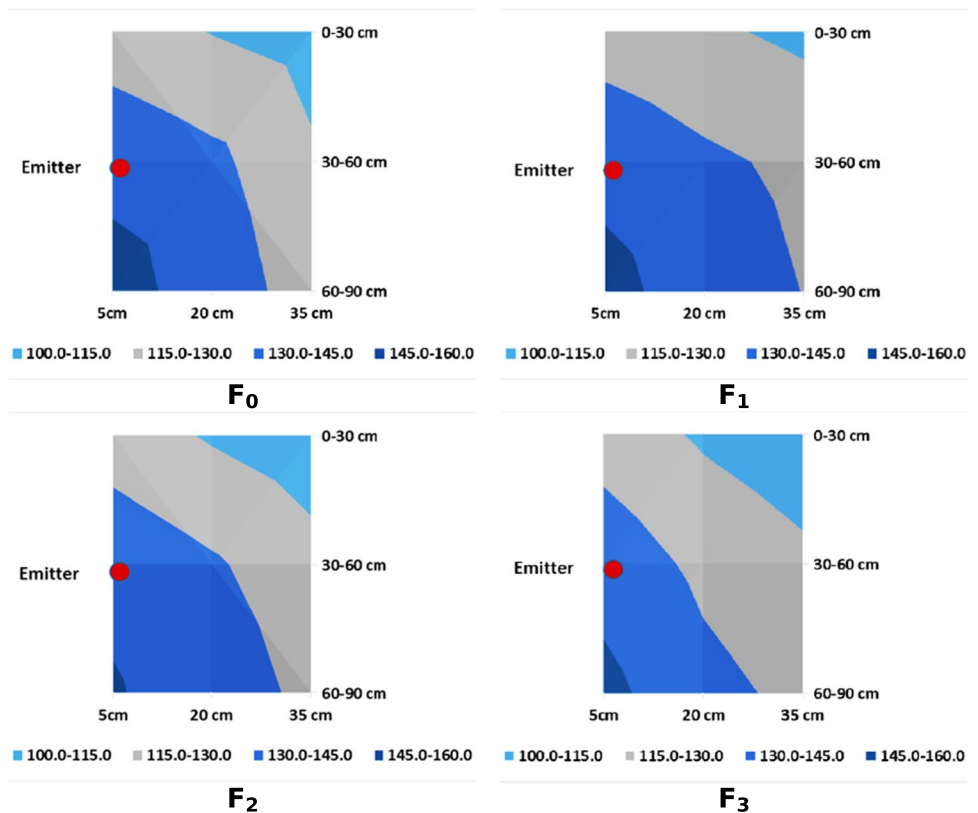
In the vertical profile at a distance of 20 cm from the emitter discharge point, it was observed that the water density showed a homogeneous distribution in the 30–60 cm and 60–90 cm regions. However, in the 0–30 cm layer close

Table 5 Duncan grouping for water distribution in soil

Depth from soil surface (cm)	Treatment	2019 year (mm)			2020 year (mm)			2019–2020 average (mm)		
		Horizontal distance from emitter								
		5 cm	20 cm	35 cm	5 cm	20 cm	35 cm	5 cm	20 cm	35 cm
0–30	F ₀	122.8	114.4ab	108.4ab	120.8b	113.7	103.5b	121.9b	114.1b	106.1b
	F ₁	123.4	117.5a	111.7a	126.5a	119.6	114.1a	124.9a	118.5a	112.9a
	F ₂	123.1	113.4b	105.7b	125.7a	115.5	104.6b	124.3a	114.4b	105.1b
	F ₃	123.8	112.9b	105.3b	125.0a	113.4	100.7b	124.4a	113.1b	103.1b
30–60	F ₀	140.0	133.7a	117.4b	141.0	123.6b	113.4b	140.5	128.8b	115.5c
	F ₁	140.4	132.8a	126.8a	136.8	130.6a	125.9a	139.1	131.7ab	126.4a
	F ₂	140.2	132.0a	120.6b	138.3	134.8a	120.2a	139.3	133.3a	120.4b
	F ₃	139.1	126.6b	118.4b	138.8	121.5b	110.5b	139.0	124.2c	114.6c
60–90	F ₀	151.4	137.7	124.0b	150.4a	131.4	119.9b	150.9a	134.6	121.9b
	F ₁	149.9	137.4	129.7a	146.3ab	132.3	127.3a	148.1ab	134.9	128.5a
	F ₂	146.6	135.3	127.8ab	140.4c	134.3	127.8a	143.6c	134.8	127.8a
	F ₃	149.3	134.7	126.3ab	142.1bc	130.7	121.3ab	145.8bc	132.8	123.9b

F₀: water applied continuously, F₁: water given once with interruption, F₂: water given twice with interruption, F₃: water was given by dividing it into 3 equal amounts, a→z indicates the level of importance from high to low

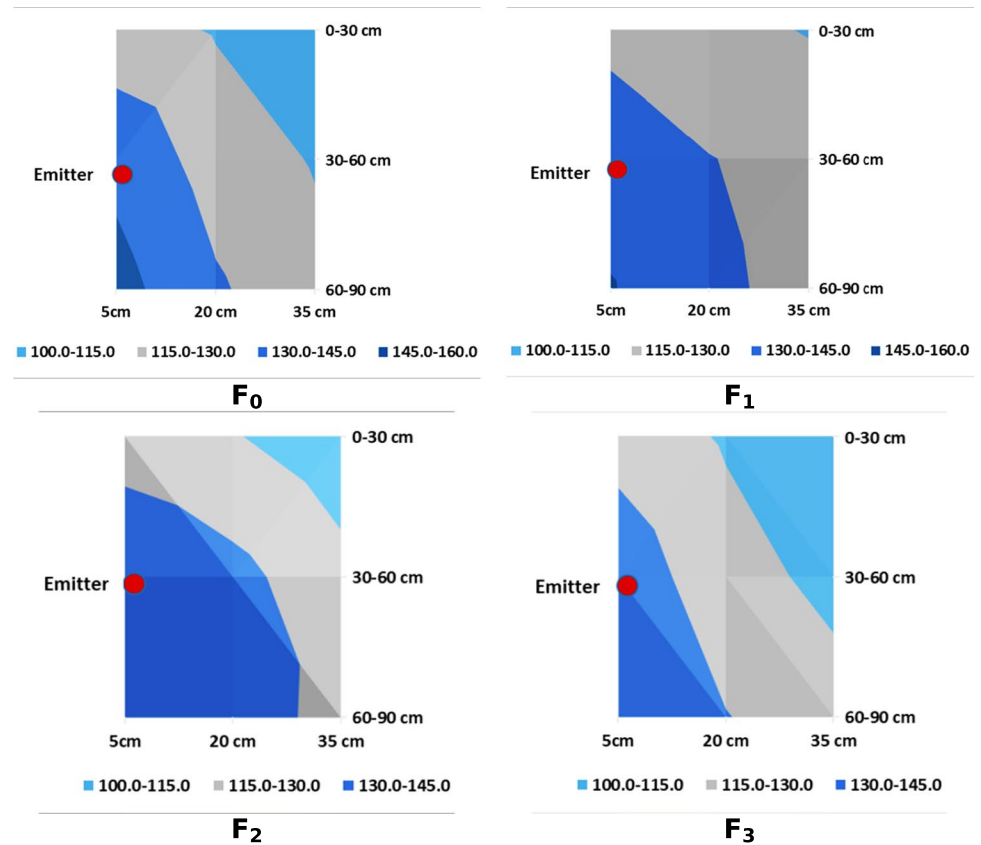
Fig. 3 The average of water distribution in the soil after irrigation according to irrigation treatments in 2019 (mm)



to the soil surface, it was determined that there is approximately 12% less water density. For the 20 cm distance from the emitter point, the highest 2-year average water value in the 0–30 part of the soil profile was found in the F₁ subject

with 118.5 mm, while the difference between the other subjects was not statistically significant. While the highest water value was obtained in F₁ and F₂ treatment with 131.7 and 133.3 mm in the 30–60 cm part of the soil profile, the lowest

Fig. 4 The average of water distribution in the soil after irrigation according to irrigation treatments in 2020 (mm)



water value was obtained in the F_3 treatment with 124.2 mm. In the 60–90 cm part of the soil profile, the difference between the subjects was not found to be statistically significant.

For the 35 cm distance from the emitter point, the highest amount of water was found in the 0–30 part of the soil profile as 112.9 mm in the F_1 subject, while there was no statistical difference between the F_0 , F_2 , and F_3 treatments. In the 30–60 cm part of the soil profile, the highest amount of water was found in the F_1 subject with 126.4 mm, while the lowest water values were obtained with 115.5 and 114.6 mm in the F_0 and F_3 subjects. In the 60–90 cm part of the soil profile, F_1 and F_2 subjects provided the highest water amount with 128.5 and 127.9 mm, while the lowest water values were obtained in F_0 and F_3 subjects with 121.9 and 123.9 mm, respectively. At a distance of 35 cm from the emitter discharge point, the water quantity in the middle profile (30–60 cm layer) was approximately 14% higher compared to the soil profile in the 0–30 cm layer. The average water level in the 60–90 cm layer was also approximately 19% higher compared to the 0–30 cm layer in all treatments. On the other hand, in the 0–30 cm and 30–60 cm soil profiles, the F_1 treatment provided an average of 6% more water compared to the other treatments.

The lateral movements of water underground were observed at three different distances (5 cm, 20 cm, 35 cm) from the emitter discharge point and at three different depths

from the soil surface, just before each irrigation and 1 day after irrigations. The observations were visualized as shown in Figs. 3 and 4. When examining the figures, it is observed that in both years, a more homogeneous and dense water distribution in the soil is achieved in the treatment F_1 , where water is applied in two separate instances (one interval). It is known that one of the forces that limits the lateral movement of water in the soil is the adhesion force (Yao et al. [38]; Abuarab et al. [39]; Shekhar et al. [40]). After a sufficient wetting duration (off-time) to break this force, it is observed that in the second stage of irrigation, water masses move much more easily on the wet layer, increasing the lateral wetness (wetting diameter). This study has revealed that, under the specified soil and climatic conditions, providing a wide irrigation interval that creates a sufficient wet layer is much more beneficial in enhancing lateral water movement compared to using less water and shorter intervals of irrigation. On the other hand, it is observed that the water level just below the emitter discharge point remains much lower in the treatments of F_2 and F_3 , where water is divided into three and four equal amounts. This is an important finding, especially for soils with a high probability of deep percolation, suggesting that increasing the number of intervals would be more beneficial. In a study conducted in Brazil, it was reported that the water distribution in the soil is similar to continuous irrigation regardless of the number of intervals (Maller et al.

[41]). In a study comparing intermittent and non-intermittent irrigation applications, it was reported that intermittent irrigation applications provide a better water distribution at 0–15 and 15–30 cm depths of the soil (El-Abedin [42]). Elnesr and Alazba ([30]) reported that intermittent subsurface drip irrigation applications increase the soil water content up to 28% at 5 cm lateral distance from the emitter point, up to 24% at 25 cm lateral distance, and intermittent irrigation increases the lateral movement of water and prevents deep percolation. Ismail et al. ([43]) reported that the horizontal water distribution in the soil was statistically prominent in intermittent irrigation. Vyrilas and Sakellariou ([44]) reported that intermittent irrigation in subsurface drip irrigation increases the uniformity of the soil, especially at a depth of 30–90 cm. When the findings obtained in the conducted study are compared with the previous studies, it is seen that intermittent irrigation practices increase the horizontal water movement and water use efficiency in the soil, and in this respect, it is mostly in parallel with the previous studies. In the research, the F_1 treatment, which has the longest duration time between two irrigations stage, comes to the fore. The fact that water is easier to move over wet soil in the intermediate irrigations after sufficient wetting in the soil profile can be associated with the fact that the adhesion forces of the soil are significantly broken. This showed that in intermittent irrigation, longer time intervals should be applied instead of frequent time intervals in the time planning between two irrigations. Although the results obtained in this aspect seem contradictory to the findings of Elnesr and Alazba ([30]), it supports the view that increasing the number of intervals in wider intervals will increase the water distribution in the soil.

Conclusion

Due to the multi-directional movement of water in subsurface drip irrigation systems, the water distribution in the soil is different from the conventional surface drip irrigation system. Depending on the soil texture, factors such as the amount of irrigation water applied, the pressure at the dripper point, the dripper flow rate, and the interruption time between the two irrigation intervals can significantly affect the water distribution in the soil profile. One of the main problems seen in subsurface drip irrigation is that the wetting diameter is less than the surface drip irrigation system and the water accumulates under the plant root zone. In the 2-year field trials conducted, it has been revealed that this problem can be eliminated to a great extent with intermittent irrigation. After the first application phase of intermittent irrigation, when sufficient time is provided for the soil to be wetted, it has been observed that the lateral movement of water over a more slippery layer increases

in the second-third application. Another significant finding obtained in the research is that the problem of deep percolation, especially at the point of emitter discharge, is substantially alleviated by intermittent irrigation, and this could be a solution, particularly for light-textured soils with high infiltration rates. As a prediction, it is believed that a small amount of irrigation and short intervals between two irrigations in the intermittent method would be beneficial. However, further field studies are required to determine the optimum waiting period between two irrigations. Intermittent irrigation in subsurface drip irrigation is significant in increasing the soil's wetting rate, especially concerning water productivity. However, in areas where water resources are scarce, the effects of intermittent and limited irrigation practices have been recognized as an open research opportunity. Similarly, in intermittent subsurface drip irrigation, the impact of fertigation application on soil fertilizer distribution also needs to be investigated as a separate topic.

On the other hand, in intermittent irrigation method, taking too long of the irrigation duration was seen as a problem in practice. Considering that the F_1 issue comes to the fore, the total irrigation time increases 1.5 times in intermittent irrigation compared to continuous irrigation. This situation should be taken into account especially by users who have the opportunity to irrigate in limited time.

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Data Availability No dat-set was used in this study. Only data based on field results were used.

Declarations

Competing Interests The authors declare no competing interests.

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