Impact of Using Subsurface Water Retention Technology on Improving Water Use Efficiency of Furrow Irrigation System

Fatima Sadoon Mushab [1,a]*, Ali Khairi Ibrahim [2,b]

[1]Department of Water Resources, University of Baghdad, Baghdad, Iraq.

[2] Department of Water Resources, University of Baghdad, Baghdad, Iraq.

[a] f.mushab@coeng.uobaghdad.edu.iq, [b] a.khairi@coeng.uobaghdad.edu.iq

* Fatima Sadoon Mushab

Abstract. Evaluation was carried out on the existing furrow irrigation system located in an open agricultural field within Hor Rajabh Township, south of Baghdad, Iraq (latitude: 33°09' N, longitude: 44°24' E). Two plots were chosen for comparison: treatment plot T1, which used subsurface water retention technology (SWRT) with a furrow irrigation system. While the treatment plot T2 was done by using a furrow irrigation procedure without SWRT. A comparison between the two treatment plots was carried out to study the efficiency of the applied water on crop yield. In terms of agricultural productivity and water use efficiency, plot T1 outperformed plot T2, according to the study's final findings. Compared with plot T2, the rate of increase in the efficiency of water and crop yield were found to be 44.9% and 14.2%, respectively. Additionally, compared to plot T1, the rate of increase in the applied water in plot T2 was 26.8%. The efficiency of plot T1 is attributed to the usage of SWRT membranes beneath the plant's root zone, which helped conserve water and nutrients, which affected crop yield and water consumption.

Keywords: Subsurface water retention technology, Furrow irrigation, Water use efficiency,Crop yield.

1. INTRODUCTION

Water is the most important input into agricultural production. Globally, agriculture is the largest user of available water; it consumes approximately 80% of readily available water. Therefore, irrigation systems must be modified so that they are applied appropriately to crops to avoid losing large amounts of water [1]. The most important of these modifications in irrigation systems is the use of today's technology called Subsurface Water Retention Technology (SWRT). This technology has improved growth in soil with a light texture by installing the membrane within the root zone. This particular membrane will keep the water as well as nutrients within the membrane and also prevent the dropped water from percolating seriously.

There is a shortage of irrigation water in Iraq, especially in dry and semi-arid areas, the areas which have increased in Iraq since the middle of the last century due to the building of irrigation projects in Turkey, Syria, and Iran. enforced the researchers and the scientists to develop and examine the best technologies for saving the applied water to the plants and crops, especially when farmers used the traditional systems in irrigation because there wasn't enough rain to meet the plants' needs and reach the stage of economic production [2].

Most of the agricultural land in Iraq is irrigated by surface irrigation. One of the surface irrigation methods is furrow irrigation, which is widely used in Iraq. Furrow irrigation is convenient for a wide domain of soil types, plants, and ground slopes [3]. Furrow irrigation is the oldest and most common type of surface irrigation system and is used to irrigate crops that are planted in lines Furrows are small channels having a continued, roughly regular slope and generally perpendicular to the main field canal [4]. Among the disadvantages of furrow irrigation are the loss of water through deep penetration or runoff, in addition to the low irrigation efficiency due to the low homogeneity of the applied water, as the irrigation efficiency is at best 30 to 40%.

In order to increase the efficiency of irrigation for this method, water losses during irrigation operations must be reduced by using modern irrigation methods and techniques, especially since water is the primary determinant of the agricultural process, because plant productivity and growth are directly correlated with the amount of ready and available moisture at the root zone [5]. Since 70% of potable water is wasted as a result of agricultural practices, technologies must be developed that increase agricultural production while reducing its water requirements [6]. One of these techniques is the soil water retention technique (SWRT). Subsurface water retention technology (SWRT) is a recent, long-term method that has been developed to increase the soil's water-holding ability to produce sustainable crops. It consists of subsurface polyethylene trough that are strategically placed at specific depths that serve to prohibit irrigation water loss via deep infiltration [7]

It was compound as U-shaped manually or by utilizing special drilling machines below the plant root zone, providing a suitable area for plant roots to grow and smoothing their movement with internal drainage during heavy rains. [8] explained that installing SWRT below the soil surface provides more than 40% of both nitrogen and potassium within the plant root zone, increases carbon retention in the soil, and reduces soil-borne diseases. Given the essential role that water resources play in human life and agricultural irrigation, improving the efficiency of water use in agriculture is a major strategic option. Therefore, many studies have been conducted to raise the efficiency of water use and maintain moisture content. Among these studies, [9] found

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that using the SWRT technique provides 35–74% of the soil moisture content in the plant's root zone when contrasted with the control (without SWRT). SWRT trough technology preserves the fertilizers and organic materials that the plant needs during its growth period. [10] conducted a field experiment inside a greenhouse for hot pepper in the City of Babylon in 2016–2017. The experiment included the use of three agricultural treatments. The first treatment (with SWRT) and the second treatment (organic material). And the third treatment (tillage). The three were compared in terms of efficiency of using field water added, where the comparison presented that the first treatment was more efficient than the second and third treatments by 50% and 59%, respectively. [11] studied the application of SWRT to the field water use efficiency of greenhouse-grown eggplants. The results showed that field water use efficiency increased by 52% in the plot with the trough compared to the plot without one. Further, 44% of the total amount of water applied was saved. [12] speculated the SWRT trough on water use efficiency for cucumber grown within a greenhouse in the season 2018. Two plots were utilized: T1 (with SWRT) and T2 (without SWRT) in southern Baghdad. The experiment's conclusions demonstrated that the increasing value of efficiency in water use and conserving the added irrigation water in plot T1 was greater than T2 by 103% and 64%, respectively. [13] conducted a field study east of Ramadi city, Ramadi governorate, in 2018–2019 to assess the ability of the SWRT to hold rainwater and thus improve the efficiency of added water use. The study included the use of SWRT technology in the first plot. And the second plot (without SWRT). Rainwater is the only source of water for cultivated wheat plants. The final results of the experiment presented an increase in field water consumption efficiency in the first plot by 30% compared to the second plot. Thus, this study aims to assess the effects of the membrane trough on water consumption efficiency and crop yield.
The goal of the evaluation was to investigate the consequences of subsurface water retention troughs on yield (production per cultivated area) and water consumption efficiency of hot pepper crops (Capsicum annuum L.) within the open field based on comparability with and without SWRT plots plus furrow irrigation methods, along with financial substitution as in contrast to the typical approach.

2. METHODOLOGY

2.1. Material and Method

2.1.1. The field study's location and the conditions of the experiment

The study was situated within Hor Rajabh Township; the target of the evaluation was to know the actual physical soil characteristics, including bulk density, field capacity, soil texture, and the long-term wilting stage. The field's soil texture is categorized as loam soil for level ranges of 0 to 30 cm. The field capacity (F.C.) was 22.65%, permanent wilting point (P.W.P.) was 9.73% (by volume), and the bulk density of the soil was 1.54. The growing particular date was initiated in the beginning week of October 2020, and the beginning of April 2021 was the particular date for harvesting. As for irrigation procedures, they were managed with the farmer. The date of each irrigation, the amount of water applied, and the duration of irrigation were registered.

2.1.2 Experimental treatment plots

Two treatment plots in place were utilized of complete place (4 m × 1.5 m) (each): membrane trough set up under soil surface was used in the original plot (T1), and the second plot without membrane trough (T2). The same quantities of nutrients and fertilizers were added to the two treatments, in addition to pesticides in a certain period in ideal quantities was also applied.

2.1.3 Subsurface water retention technology installation and description

A subsurface water retention technique made of a 200μm low-density polyethylene trough was placed at a depth equal to 30 cm beneath the soil surface with an aspect ratio of 2.66:1 (width to depth). The root depth of the hot pepper was about 30 cm. Figure 1 presents a cross-sectional view of the trough membrane through the soil deck. The element ratio was hard to establish at 2:1 because of the hand-setting procedure. The set-up procedure on the membrane was done by hand, as revealed in Figures 2 and 3. The width of the membrane was 40 cm and 15 cm on each side in height. Plants were grown on both sides of the furrow, with a distance of 20 cm between each plant.

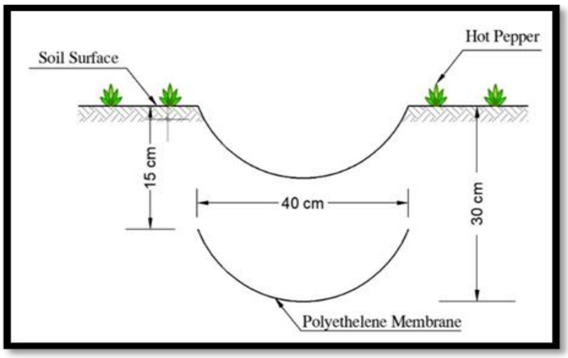

Figure 1: Polyethylene trough location and cross-section through soil deck.

Figure 2: Installation of the membrane beneath the soil surface.

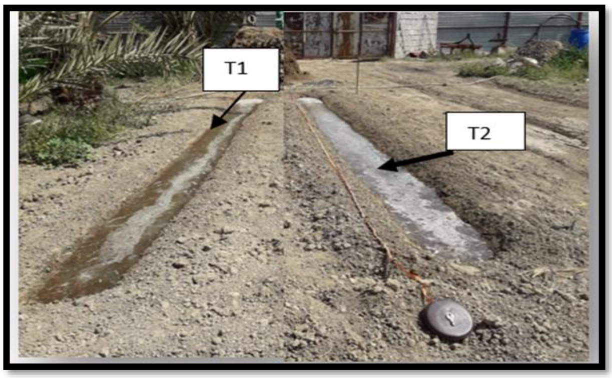

Figure 3: The experiential plots' layout.

2.1.4 Yield, water use efficiency (WUE)

The total of pickings crop 's output was stated as a complete fruit yield. Eq. (1) was used to compute the crop yield (kg/m²) [14]

$$Yield = \frac{total\ weight\ of\ crop(kg)}{total\ area\ of\ crop\ in\ (m^2)} \quad (1)$$

Water use efficiency is definitely the consequence of a whole range of environmental activities during the life cycle of a plant to define both yield water and utilization. WUE (kg/m³) was calculated based on Eq. (2) below [15]

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$$WUE = \frac{Yield\ (\frac{kg}{m^2})}{total\ depth\ of\ applied\ water(m)} \tag{2}$$

3. RESULT AND DISCUSSION

3.1 Irrigation Frequency and Depth of Applied Water

Number of days of utilized frequency and depth of added water for hot pepper in growth time of year 2020 as well as 2021 for treatments T1, T2, presented in Table 1. The temperature ranged from 30°C to 50°C with a 35–65% relative humidity. The frequency of irrigation procedures required for hot pepper in treatment T1 was reduced by 22% compared to treatment plot T2. The depth of added water for treatment T1 was 433 mm, while the depth of water added for treatment T2 was 549 mm, which shows that the depth of water added for treatment T1 is 26.8% less than T2.

Table 1: Month, water depth, and irrigation frequency for hot pepper in 2020-2021.

Month – Year	**Depth of applied water in T1 (mm)**	**Frequency of irrigation in T1 (days)**	**Depth of applied water in T2 (mm)**	**Frequency of irrigation in T2 (day)**
Oct-2020	16	2	20	2
Nov-2020	22	2	25	2
Dec-2020	45	2	45	2
Jan-2021	46	2	55	3
Feb-2021	79	3	143	5
Mar-2021	121	4	123	4
Apr-2021	104	3	138	4
Total	433	18	549	22

3.2 Crop Yield and Water Use Efficiency

The crop yield of hot pepper was estimated according to Eq. (1) for treatment plots T1 and T2, which were 4.071 kg/m² and 3.54 kg/m², respectively. The value of crop yield for plot T1 was much higher than in plot T2 by 15%. The composition of the membrane plate, which retained water, nutrients, and chemical additives during the period of plant growth, was the reason for this increase. Table 2 presents the yield of each month's crop of hot pepper for treatments T1 and T2 for the period of plant growth from 2020 to 2021. Figure 4 presents the accelerated hot pepper growth in T1 compared with plot T2. The water use efficiency for hot pepper was evaluated by applying Eq. (2). WUE for plots T1 and T2 were 9.35 kg/m3 and 6.45 kg/m3, respectively.

Table 2: Monthly crop production for treatment plots T1 and T2 of hot pepper in 2020–2021.

Month	**Yield for T1 (kg/m²)**	**Yield for T2 (kg/m²)**
Dec.2020	0.39	0.35
Jan.2021	0.54	0.50
Feb.2021	0.73	0.58
Mar.2021	0.59	0.50
Apr.2021	1.82	1.61
Total sum	4.07	3.54

Figure 4: Accelerated hot pepper growth in T1 compared with plot T2.

Treatment plot T1 had a 44.9% higher water efficiency than treatment T2. This increase was due to the use of less water as a result of the use of SWRT in T1, which saved large amounts of water and nutrients in addition to increasing crop output. Figure 5 showed the values of WUE for treatments plots T1and T2.

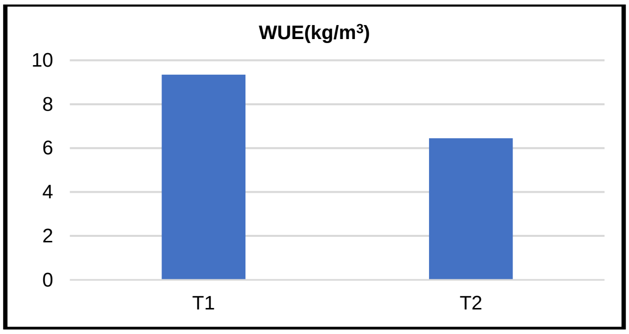

Figure 5: WUE for treatment plots T1 and T2 of hot pepper in 2020–2021.

4. CONCLUSION

Based on the results obtained from the field experiments conducted on the plots T1 and T2, it can be concluded that the number of irrigations were decreased in plot T1 compared with plot T2. This is can be attributed to the usage of SWRT in plot 1. The function of the SWRT is to mainly to maintained soil moisture and reduces water losses in the root zone. Consequently, the calculated field water consumption efficiency for the hot pepper cultivated in plot T1 was greater than that cultivated in plot T2. In addition, the usage of SWRT helps maintaining nutrients in the root zone. This finally increases crop production and reduces the volume of irrigation water.

5. RECOMMENDATIONS

Depending on the results of the study, here are several recommendations to consider

- To study the influence of SWRT along with furrow system irrigation on develop the grain crops to be able to enhance the national support and agricultural product existing in Iraq.

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- Study the potential for utilizing SWRT to implant strategic crops like wheat, rice, and barley, particularly in coarse-textured soils and in areas with heavy rainfall.

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