**Anbar Journal of Engineering Science (AJES )** **Vol. 11 , No. 1 (2020) , pp.** 60 ~ 65
P-ISSN: 1997-9428; E-ISSN: 2705-7440 DOI:10.37649/aengs.2020.171289

Unviersty of Anbar

**Anbar Journal of Engineering Science©**

**journal homepage: http://www.uoanbar.edu.iq/Evaluate/**

# Evaluating the Effect of Supplementary Irrigation on Improvement of Economic Water Productivity for Winter Wheat

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**PAPER INFO**

***Paper history:***
Received … … …
Received in revised form … … …
Accepted … … …

***Keywords:***
Supplementary irrigation system, subsurface water retention technology, economic water productivity.

**ABSTRACT**

Utilizing of subsurface water retention technology is a modern technique to retain and save the application water for sustainability of agricultural production through scheduling and management the irrigation processes. The goal of this paper is to evaluate the effect of the supplementary irrigation and rainfed water on improvement of economic water productivity for winter wheat. The experiment was conducted in open field, within Joeybeh Township, located in east of the Ramadi City, in Anbar Province, for the growing season 2018-2019. Two plots were used for comparison process, the first plot where membrane trough below the root depth was installed and supplementary irrigation system was conducted beside the rainfed water and according to scheduling the irrigation process as checkbook method. While in second plot, the membrane trough was installed and only rainfed water was depend on. Cultivated date of winter wheat was December, 20$^{th}$, 2018, and the harvest date was May, 10$^{th}$, 2019. The obtained result was showed that the crop yield and economic water productivity from the first plot and the second plot were equaled to 0.52 kg/m$^2$ and 0.35 kg/m$^2$, and 930 ID/m$^3$ and 800 ID/m$^3$, respectively. The increasing value of crop yield and economic water productivity in the first plot was more than that in the second plot by 49 % and 16 %, respectively. The benefits of applying supplementary irrigation system with installing the new techniques of retaining the applied water were sufficient in improvement the crop yield and accordingly improved value of the economic water productivity.



## 1. Introduction

Agriculture consumes about 70 of the world's fresh water, which is larger than the consumption of municipal, industrial water and multi-purpose [1]. The losses of irrigation water as a result of deep percolation is a problem facing the agricultural sector to product food and it is necessary to look for new techniques to conserve water in the root depth zone [2]. Rainwater is a natural source needs by plants, animals and humans. It is considered to be freshwater that is suitable for plant growth and is purer than other water sources such as seas and rivers. It is necessary to harvest rainwater and use it as another source of irrigation water. Fields, which depend on rain-fed systems, hold about 80 % of the world's agricultural field area and represent more

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than 67 % of the global food production [3]. To retain the applied water and reduce the deep percolation water, subsurface water retention technology (SWRT) is a new method to hold the soil moisture, nutrient and fertilizer materials within the root plant for longer time and then increase plant production. SWRT consists of a polyethylene membrane trough that is instillated within the root depth zone by a specific aspect ratio fit the plant root depth to prevent water losses and deep percolation [4]. Water productivity (WP) describes the relationship between crop yield divided by the volume of water consumed or applied (irrigation water and effective rain). The definition of water productivity differs from region to region and from farm to farm depending on several factors as crop type, irrigation system, climate factors, and inputs including: fertilizers‹ labor and equipment. World water productivity will increase from 0.67 kg/m$^3$ to 1.01 kg/m$^3$ for cereals and from 0.39 kg/m$^3$ to 0.52 kg/m$^3$ for rice in 2025. Water productivity of irrigated crops was higher than water productivity of crops dependent on rain [5]. The term of water productivity is link to the relationship between the quantity of food obtained and the amount of water used for irrigation [6]. Quantity of water is add for irrigation should give the best amount of production, from this principle, the term "water productivity" [7]. The production of any crop must provide a financial return and it must cover all costs paid for agriculture and production of these costs that include: purchase of grains, fertilizers and pesticides, manpower and machinery wages, costs of irrigation systems and profits of farmers. These factors are assesse by the term economic water productivity (EWP) [8]. The reaserchers were conducted an experiment to study the effect of installing the membrane trough below the crop's root zone on economic water productivity of zucchini during summer season of 2017. Two plots were used for the comparison plot T1 where the membrane was applied and plot T2 without installing the membrane. The obtained results showed that an increasing value of economic water productivity in plot T1 was 36.5 % higher than in plot T2 [9].

The goal of this paper is to evaluate the effect of applying of the supplementary irrigation on improvement of economic water productivity for winter wheat.

## 2. MATERIALS AND METHODS

### 2.1 Experimental Conditions and Location of the Field Study

The experiment was conducted in open field, within Joeybeh Township, located in east of the Ramadi City, in Anbar Province, Iraq (latitude: 33°26' 5.6" N, longitude: 43°24'40" E). Two samples of the soil from the experimental field of plots were taken, the depth for each soil sample was: 0-300 mm and 300-600 mm. The physical test of soil was conducted at Laboratory of Anbar Agriculture Directorate, while the test of water content at field capacity (% by volume) and water content at permanent wilting point (% by volume) was conducted at the Baghdad University, faculty of Agriculture, College Laboratory. Texture of the soil was classified as silty clay loam for both depths, the apparent specific gravity, water content at field capacity and water content at permanent wilting point for depths from 0-300 mm and from 300-600 mm were equaled to: 1.23, 35.5 and 12.5 (all % by volume) and 1.27, 39 and 14 (all % by volume), respectively.

### 2.2 Experimental Plots and Crop Material

The total area of the field plots was selected as 80 m$^2$. It was divided into two plots (each 40 m$^2$, 10 m length and 4 m width) named as: T1 and T2. Polyethylene trough was installed in both plots, supplementary irrigation system was applied for plot T1 beside the rainfed water, while plot T2 was depends only on rainfed water for irrigation process. Winter wheat (*Triticum aestivum L.*) was cultivated during the winter growing season 2018-2019. **Fig. 1** shows growth of the plant in age of three months.


**Figure 1.** Growth of plant in age of three months.

### 2.3 Subsurface Water Retention Technology (SWRT)

Membrane trough made of low-density polyethylene (LDPE) of thickness installed under or within the soil profiles as a trough shape of thickness 180-μm was installed by hand tools under the soil surface by 2:1 aspect ratio (length to height) according to [10]. The proposed dimensions were 500 mm in width and 250 mm in depth, 400 mm below the soil surface. Multi units of the membrane was distributed using 375 mm space between one and other membrane to allow the extra of rainfall water to be drained out and to permit the growth of roots to be grown freely without suffocation. **Fig. 2** shows the layout and the installation process of the membranes trough below the soil surface.

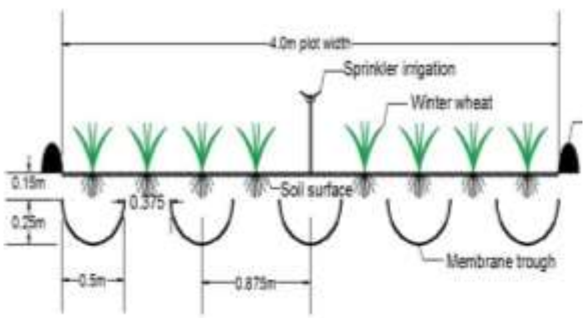


**Figure 2.** Layout of the membrane trough below the soil surface.

### 2.4 Crop Yield

Crop yield is the relationship between the amount of crop production divided by the total area of agriculture in (kg/m²) [11].

$$\textbf{Crop yield} = \frac{\textbf{Total weight of the crop (kg)}}{\textbf{Total area of the crop } (m^2)} \quad \textbf{(1)}$$

### 2.5 Economic Water Productivity

Economic water productivity (EWP) is a term that refers to the conversion of water applied for irrigation as return into biomass, animal production, fish, feed, and financial returns [12].

$$\textbf{EWP} = \frac{\textbf{Gross return}}{\textbf{Unit of water applied}} \quad \textbf{(2)}$$

Where:

Gross return: production (kg)* market selling price (kg/ID), and

ID: Iraqi Dinars (local currency).

### 2.6 Measuring Rainfall

Rainfall depth through the growing season was recorded in the field study by using the suitable apparatus installed in the field plots. Effective rainfall (which represents half of the recorded rainfall depth) was only used as a depth of applied water.

**Fig. 3** shows rain gauge. The simulation of rainfall was conducted by 150 mm through the growing season to continue the experiment study in some critical drying days. **Table. 1** shows the value of effective rainfall through growning season 2018-2019.

**Table 1.** Effective rainfall through growning season 2018-2019.

| Date | Effective rainfall (mm) |
|---|---|
| 26-Dec. | 2.00 |
| 27-Dec. | 2.20 |
| 13-Jan. | 0.20 |
| 16-Jan. | 0.35 |
| 26-Jan. | 0.80 |
| 27-Jan. | 8.60 |
| 28-Jan. | 0.85 |
| 07-Feb. | 0.65 |
| 08-Feb. | 2.40 |
| 21-Feb. | 0.05 |
| 28-Feb. | 2.10 |
| 07-Mar. | 0.03 |
| 14-Mar. | 14.80 |
| 16-Mar. | 1.55 |
| 23-Mar. | 0.40 |
| 24-Mar. | 5.60 |
| 25-Mar. | 0.20 |
| 30-Mar. | 6.60 |
| 01-Apr. | 1.35 |
| 04-Apr. | 0.30 |
| 05-Apr. | 0.30 |
| 07-Apr. | 0.25 |
| 09-Apr. | 0.90 |
| 10-Apr. | 2.05 |
| 16-Apr. | 0.15 |
| 18-Apr. | 1.10 |
| 29-Apr. | 2.30 |
| 30-Apr. | 4.00 |
| 01-May. | 4.00 |
| 04-May. | 4.00 |

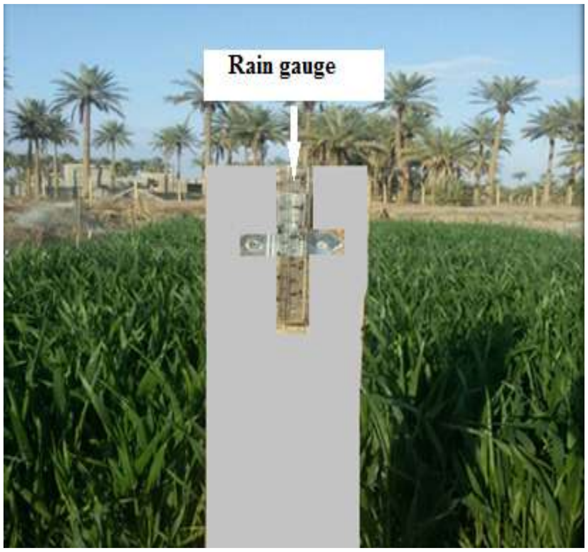


**Figure 3.** Rain Gauge.

## 3. RESULTS AND DISCUSSIONS

### 3.1 Influence of SWRT on Applied Water Depth and Crop Yield

In this experiment, rain water was used as a source of irrigation, where the supplementary irrigation system was applied in plot T1 to keep the moisture content in the root profile within the acceptable limit of readily available water and without any soil water stress. Water was added when 55 % of readily available water (RAW) was depleted and the scheduling of irrigation was started from January 4$^{st}$ until April 28$^{th}$, 2019. Sprinkler irrigation system was conducted for plot T1. The calculated total applied depth of irrigation water (irrigation and rainfed) in plot T1 was 280 mm, while in plot T2 (rainfed only) was equaled to 220 mm. **Fig. 4** showed the accelerated winter wheat growth with supplementary irrigation system in plot T1 comparing with plot T2. The crop yield was calculated by applying **Eq. (1)**. The obtained results showed that crop yield values in plots T1 and T2 were: 0.52 kg/m$^2$ and 0.35 kg/m$^2$, respectively. The increasing value in plot T1 was greater than plot T2 by 49 %. **Fig. 5** shows comparison of the crop yield of winter wheat among plots T1 and T2. The total rainfed water occurred on the area in the season was not enough to keep the moisture content within the acceptable limit and the plant was under soil stress in plot T2 for some days through the growing season. The membrane trough was saved and hold the soil moisture within the root zone as longer as much. The length of the spike at this age was measured in plots T1 and T2 and equaled to: 120 mm and 100 mm, respectively, and width of leaves of the plants at this age in plots T1 and T2 were; 24 mm and 15 mm, respectively. The plant in plot T1 was healthier than in plot T2. Moreover, wilting of the plants was started earlier in plot T2 and before few days compared with plot T1 as showed in **Fig. 4.**

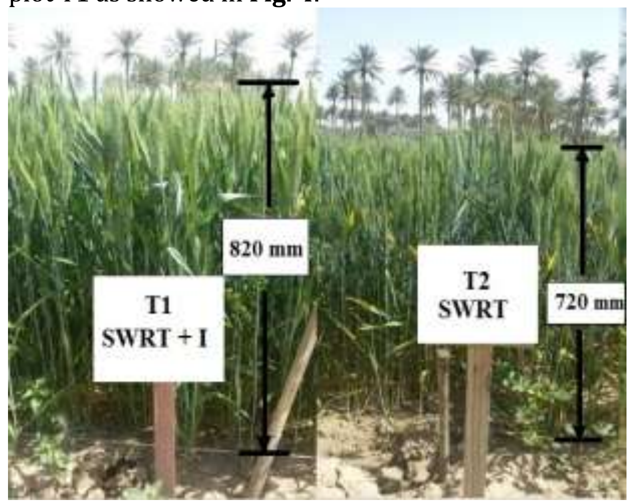


**Figure 4.** Accelerated winter wheat growth with supplementary irrigation system in plot T1 comparing with plot T2.

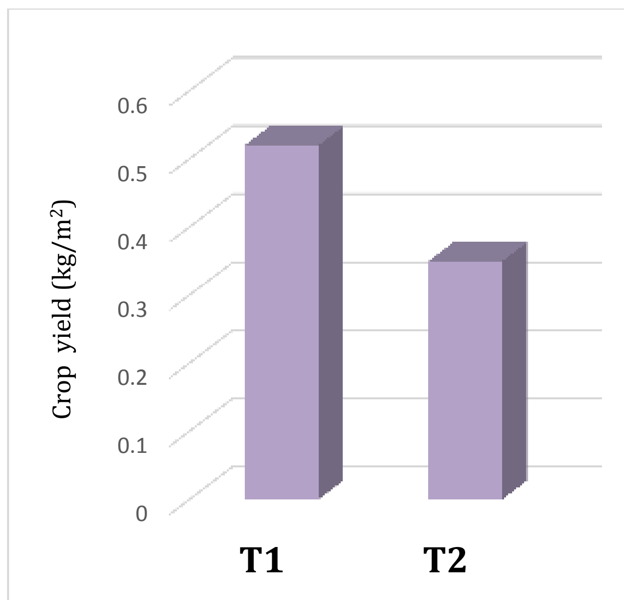


**Figure 5.** Comparison of crop yield of winter wheat among the plots.

### 3.2 Influence of SWRT on Economic Water Productivity

The value of economic water productivity (EWP) was calculat by applying **Eq. (2)**. The gross return was calculat by multiplying the crop production by the marketing price. EWP in T1 and T2 were 930 and 800, respectively.

Increasing value of EWP in plot T1 was greater than plot T2 by 16 %. **Fig. 6** shows comparison of the EWP of winter wheat among the plots. The more production value the more gross return was obtain. The membrane trough was assist in saving the applied water, reduced the percolation water through the soil layers, and accordingly reduced the difference in the value of the EWP. On the other hands, the supplementary irrigation was required to avoid the effect of the soil stress on the plants.
The obtained results in plot T1 were showe healthy growth of the plant, saving applied water, more production and higher profit. Additionally, when the amount of rainfall is limited and inefficient for healthy growth, supplementary irrigation is required especially when membrane trough is applied. Therefore, a membrane is recommended to be use when irrigation system is not available or not included in the water management system especially in the desert regime area. Retaining rainfall in the root profile should be considered.

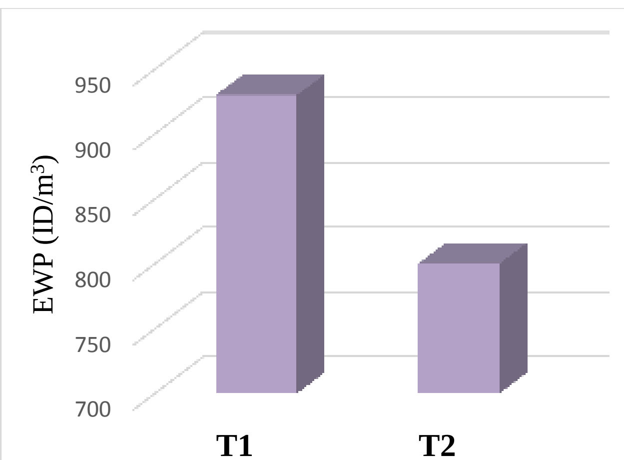


**Figure 6.** Comparison of economic water productivity of winter wheat among the plots.

**4. SUMMARY and CONCLUSIONS**

1. Installing the membrane trough below the root zone was improved the soil moisture, holding fertilizers and nutrient materials through the root profile and above the membrane trough. The results were healthy plant's growing as grain seeds and spike length.
2. Following checkbook scheduling irrigation was offered a sufficient management of applied water avoiding farm losses and reduced numbers of irrigation with less power was consumed.
3. Utilizing supplementary irrigation with efficient irrigation scheduling was improved the crop yield and EWP in plot T1 comparing with plot T2 by 49 % and 16 %, respectively.
4. The field that depends on rainfed water only is required to apply the membrane trough to improve the crop yield value.

## Nomenclature

EWP= economic water productivity.
RAW=Radially available water.
SWRT=subsurface water retention technology.
T1, T2=agriculture plots.
WP= water productivity.

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