Journal of Engineering
journal homepage: www.joe.uobaghdad.edu.iq
Number 3 Volume 26 March 2020

Chemical, Petroleum and Environmental Engineering

Assessment Improving of Rainwater Retention on Crop Yield and Crop Water Use Efficiency for Winter Wheat

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ABSTRACT

Storage of rainwater within the root depth zone is one of the modern ways to increase plant production. Subsurface water retention technology was applied to assess improving values of crop yield and crop water use efficiency, applying a membrane made of low-density polyethylene trough installed below the crop root zone. The goal of this paper is to assess that the retention of rainwater above the membrane can improve the crop yield and crop water use efficiency values for winter wheat. The experiment was conducted in open field, within Joeybeh Township, located in east of the Ramadi City, in Anbar Province, in winter growing season 2018-2019. Two plots T1 (with membrane trough) and T2 (without membrane) were used for the comparison and cultivated with winter wheat, where the rainwater was only the source of irrigation. At the end of the harvest stage the obtained results of crop yield and crop water use efficiency for plots T1 and T2 were; 0.35 kg/m^2 and 1.66 kg/m^3, and 0.28 kg/m^2 and 1.28 kg/m^3, respectively. The increasing value of crop yield and crop water use efficiency in plot T1 was about 25 % and 30 %, respectively more than plot T2. Benefits of the installation of membrane trough are to keep soil moisture for longer times, prevent the cracks of the soil surface and reduce the deep percolation losses.

Key words: subsurface water retention technology, crop yield, crop water use efficiency and wheat.

تقييم تحسين حجز مياه الامطار على غلة النبات وكفاءة استخدام المياه لنبات للحنطة الشتوية

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الخلاصة

يعد تخزين مياه الأمطار داخل منطقة عمق الجذر أحد الطرق الحديثة لزيادة الإنتاج النباتي. تم استخدام تكنولوجيا الاحتفاظ بالمياه تحت السطحية لتقييم تحسين قيم غلة النبات وكفاءة استخدام مياه النبات، بإضافة اغشية مصنوعة من البولي إيثلين واطىء الكثافة تحت المنطقة الجذرية للنبات. ان الهدف من هذا البحث هو تقييم حجز مياه الامطار فوق الغشاء على تحسين قيم غلة النبات و كفاءة استخدام مياه النبات لمحصول الحنطة الشتوية. أجريت التجربة في حقل مفتوح، في بلدة جويبة، الواقعة في شرق مدينة الرمادي، في محافظة الأنبار، في الموسم الزراعي لفصل الشتاء 2018-2019. تم استخدام الواح زراعية لغرض المقارنة، اللوح الأول كان متضمنا تثبيت حوض الغشاء واللوح الثاني بدون وضع الغشاء، زرعت بنبات الحنطة الشتوية وكان المصدر الوحيد للسقي هو مياه الامطار. بعد نهاية مرحلة الحصاد تضمنت النتائج المتحصلة من التجربة: ان غلة النبات وكفاءة استخدام

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Peer review under the responsibility of University of Baghdad.
https://doi.org/10.31026/j.eng.2020.03.04

Article received:2/9/2019
Article accepted:26/6/2019
Article published:1/3/2020

مياه النبات في اللوح الأول واللوح الثاني كانت 0.35 كغم/م2 و1.66 كغم/م3 و0.28 كغم/م2 و1.28 كغم/م3، على التوالي. ان قيمة الزيادة لغلة النبات وكفاءة استخدام مياه النبات في اللوح الاول حوالي 25 ٪ و30 ٪، على التوالي أكثر من اللوح الثاني. من فوائد تكنولوجيا الاحتفاظ بالمياه تحت السطحية هي زيادة غلة المحصول والحفاظ على رطوبة التربة لفترات أطول ومنع تشققات التربة السطحية والتقليل من فقدان المياه نتيجة التغلغل العميق.

الكلمات الرئيسية: تكنولوجيا الاحتفاظ بالمياه تحت السطحية، غلة المحاصيل، كفاءة استخدام مياه النبات والحنطة.

1. INTRODUCTION

The drought, limited water supply, few agricultural lands, high fertilizer prices, and erosion of the soil are a major obstacle crop production. In addition, the world's population is about 9 billion in 2050, Require more water to produce approximately 60 % to 70 % of food. All of these problems require the search for new water conservation techniques within the root depth zone, with the lowest water losses and the highest water use efficiency (**Miller and Smucker, 2015**). SWRT is a new method to double water storage in sandy soils within the root depth zone and it reduces water losses. By new technology is improved crop yield and water use efficiency (**Guber et al., 2015**). SWRT was a polyethylene membrane trough installed under the surface of the soil and designed as U-shaped which put certain distances between one and the other to allow the discharge of excessive rain and the freedom of growth of roots without suffocation (**Smucker and Basso, 2014**). In Iraq, sandy soils make up about 19 % of agriculture lands, making them unsuitable for agriculture due to the high hydraulic conductivity and the permeability that do not have the ability to conserve water and nutrients within the root zone. By SWRT، sandy soils were transformed into soil of sustainable production due to the double conservation of moisture within the root depth zone (**AL-Rawi et al., 2017**). **Almasraf and Salim (2018)** examined the applying of SWRT below the ground surface on yield and water use efficiency of eggplant cultivated inside the greenhouse. The obtained results showed that yield and water use efficiency were improved by 6 % and 52 % in plot with applying the membrane trough comparing with plot without installing the membrane trough. Moreover, saving in the total of applied water was 44 %. Additionally, **Hommadi and Almasraf (2018)** evaluate the SWRT on water use efficiency and economic water productivity for hot pepper cultivated inside the greenhouse in the growing season 2016-2017. Three plots were used T1 (with SWRT), T2 (organic material) and T3 (tillage) in City of Babylon. The obtained results showed that the increasing value of yield and water use efficiency in plot T1 was more than T2 and T3 by 19.42 %, 26.87 % and 50 % and 59 %, respectively. Accordingly, economic water productivity in plot T1 was more than plots T2 and T3 by 81.7 % and 97.1 %, respectively. Moreover, water use efficiency and water productivity for okra crop cultivated inside the greenhouse was also improved when membrane trough was installed within the root zone. The obtained results showed that the water use efficiency and water productivity was increased well in plot with installing the membrane trough by 148 % and 170 %, respectively comparing with plot without applying the SWRT. Values of field water use efficiency and economic water productivity were also enhanced for zucchini by study carried out by **Hommadi and Almasraf (2019)**. The work was conducted to study the effect of installing the membrane trough below the crop's root zone on field water use efficiency and economic water productivity of zucchini during summer season 2017 in open field. Two plots were used for the comparison T1 (with the membrane) and T2 (without the membrane). The obtained results showed that an increasing value of FWUE in plot T1 was 30.2 % comparing with plot T2. Additionally, increasing value in economic water productivity in plot T1 was 36.5 % comparing with plot T2. The goal of this paper is to evaluate the installing of the membrane trough blow the crop root zone of winter wheat on crop yield and crop water use efficiency when rain water was only the source of irrigation. The objective of this study is to evaluate the improvement of the crop yield and crop water use efficiency values by retaining the rainfall water above the membrane trough which installed below winter wheat root zone. The novel matter in this work study comparing with others local studies (**Almasraf and Hommadi, 2018**), (**Almasraf and Salim, 2018**) and (**Hommadi and Almasraf, 2019**) is how efficient in installing the membrane trough below the winter wheat root profile to capture and hold the rainfall water and then improving values of crop yield and crop water use efficiency.

2. MATERIALS AND METHODS

2.1 Experimental Layout 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 were taken, the depth for each soil sample was: 0-300 mm and 300-600 mm. The test of soil texture and apparent specific gravity was conducted at Laboratory of Anbar Agriculture Directorate. 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 classified silty clay loam for both depths. Apparent specific gravity, water content at field capacity and at permanent wilting point were addressed to 1.23, 35.5 (% by volume), and 12.5 (% by volume) for depth 0-300 mm and 1.27, 39 (% by volume), and 14 (% by volume) for depth 300-600 mm, respectively.

2.2 Experimental Plots and Crop Material

The total area of the field study was selected as 80 m^2. It was divided into two plots named as: T1 and T2. Polyethylene membrane trough was installed in plot T1, while plot T2 was prepared without installing the membrane. The area for each plot was 40 m^2 (10 m length and 4 m width). In this experiment, the 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.

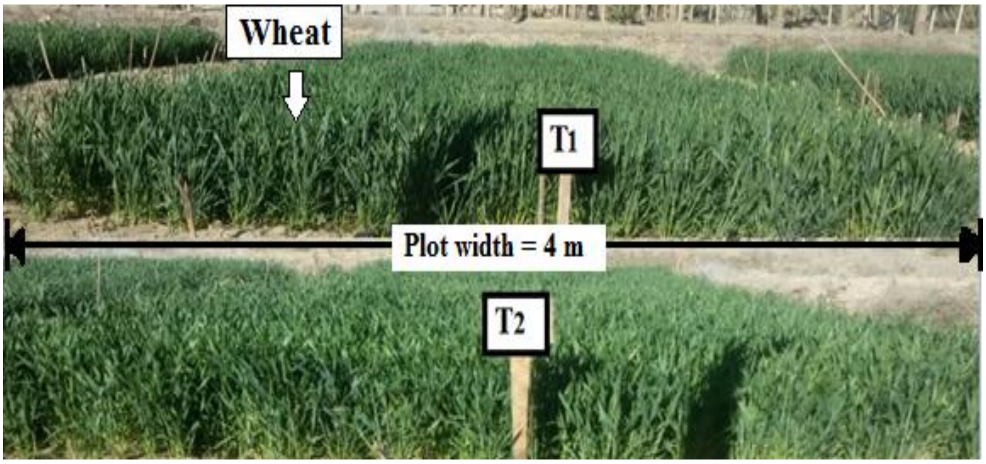

Figure 1. Growth of winter wheat plant in age of three months.

2.3 Subsurface Water Retention Technology (SWRT)

SWRT is a new technique for keeping the soil moisture under the soil surface and within the root zone. This technique is expressed as membranes made of low-density polyethylene sheet (LDPE) installed under or within the soil profiles as a trough shape. In this study the membranes trough 180-µm was installed in plots T1 under the soil surface by 2:1 aspect ratio according to the analyze

Guber et al., (2015). The proposed dimensions were 500 mm width and 250 mm depth at depth 400 mm (from 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** show the layout and the installation process of the membranes trough below the soil surface. In this study, the membranes were installed by hand tools.

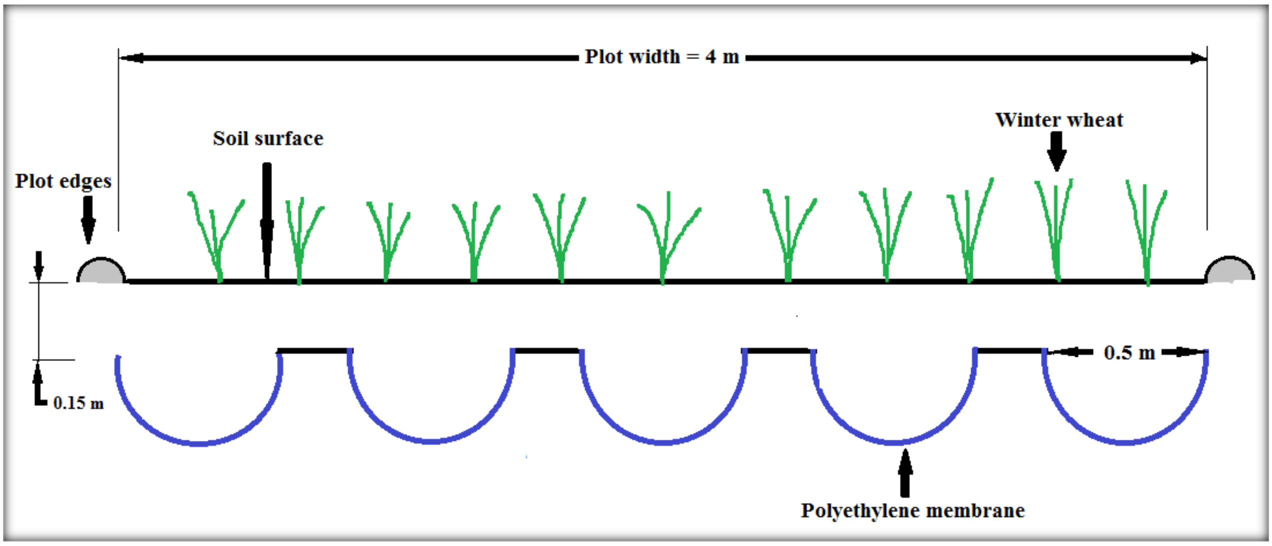

Figure 2. Layout of the membrane trough below the soil surface.

2.4 Computation of Crop Evapotranspiration

Daily soil moisture content was measured daily by using the water mark sensors installed at depths 150 mm and 300 mm and at different plots. Crop evapotranspiration (ET_c) in mm for winter wheat was calculated daily as much as possible and during the growing season based on the following general water balance model:

$$ET_c = (\theta_p - \theta_n) - (R+I) \quad (1)$$

Where:

θ_p: soil water content in the day before (mm),

θ_n: soil water content in the next day (mm),

R: rainfall water (mm), and

I: irrigation depth (mm).

In the above equation, rainfall was considered and irrigation depth was equal to zero (where rainfall was only the irrigation source).

2.5 Crop Yield

Crop yield is the relationship between the amount of crop production divided by the total area of agriculture in ($\frac{kg}{m^2}$) as described by **Mady and Derees (2007)**.

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

2.6 Corp Water Use Efficiency (CWUE)

The relationship between crop yield ($\frac{kg}{m^2}$) divided by crop evapotranspiration (mm) resulted crop water use efficiency according to **Tennakoon and Milroy (2003)**:

$$CWUE = \frac{Yield\ (\frac{kg}{m^2})}{crop\ evapotranspiration\ (mm)} \qquad (3)$$

2.7 Recording 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.

2.8 Root Depth

Crop's root depth through the growing season was measured weekly as much as possible by hand excavation in the soil and measured the root length by tape.

3. RESULTS AND DISCUSSIONS

3.1 Influence of SWRT on rain-fed retention and crop evapotranspiration

The growing season of winter wheat was started from 20th, December 2018 and harvest time was ended on 10th, May 2019. For both plots, daily soil water content was measured through the growing season, where effective rainwater was also recorded and equaled to 220 mm. Accordingly the crop evapotranspiration was measured daily by applying Eq. (1). The accumulated values of crop evapotranspiration (ET_c) during the growing season for plots T1 and T2 were estimated to be: 210.4 and 218.9 mm, respectively, which is almost similar with 4 % difference. The value of crop yield in plots T1 and T2 was estimated by applying Eq. (2) and were equal to 0.35 kg/m^2 and 0.28 kg/m^2 (875 and 700 kg/donum), respectively. The increasing value in plot T1 was more than T2 by 25 %. The low value of the crop yield in plot T2 was due to the crop was effected by soil water stress in some days when no rain water was occurred and the soil surface was effected by cracks and more deep percolation was taken place. While, in plot T1 the existing of the membrane trough within the root zone was worked as a barrier and retained the rain water for long time. The crop was used this water even if no rain was occurred. **Fig. 3** presents daily-accumulated ETc values of winter wheat in the three plots for the growing season, also **Fig. 4** showed comparison between plots T1 and T2 on basis of the crop yield of the winter wheat.

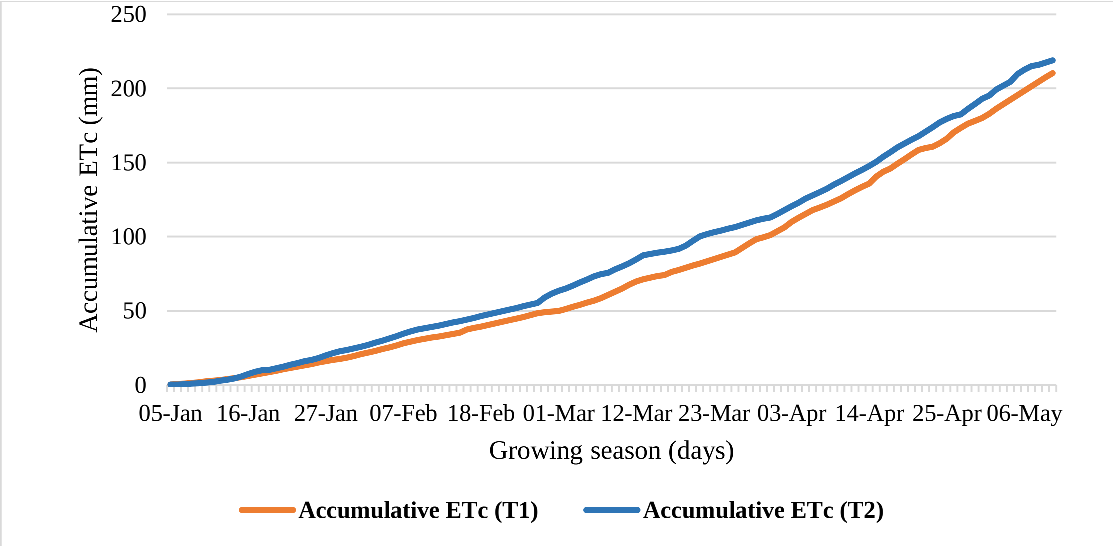

Figure 3. Accumulated ET_c values of winter wheat during growing season for plots T1 and T2.

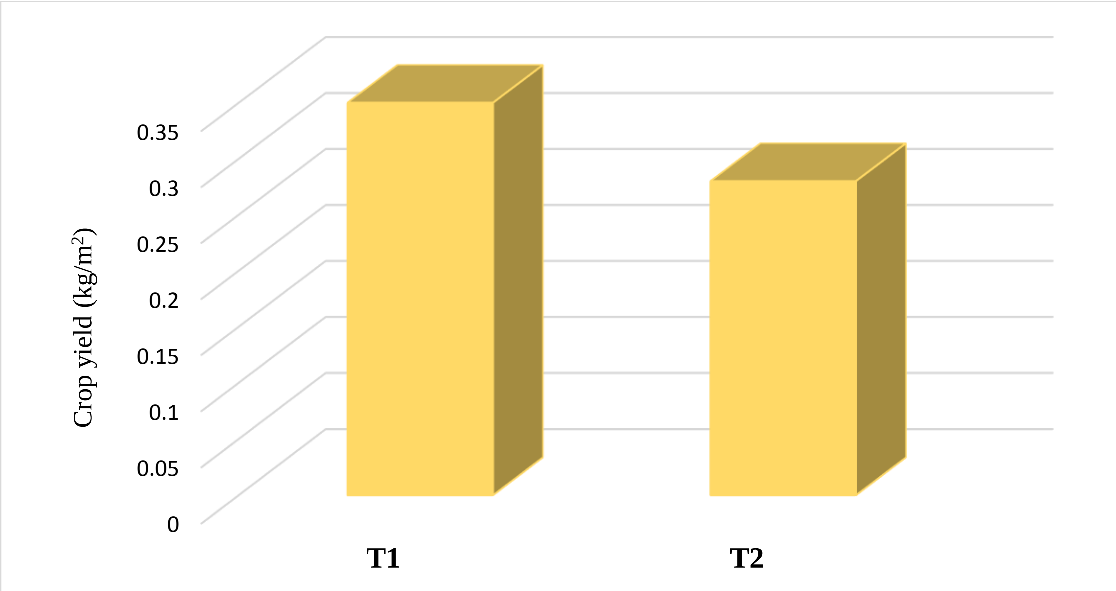

Figure 4. Comparison between plots T1 and T2 on basis of the crop yield of the winter wheat.

3.2 Influence of SWRT on Crop Water Use Efficiency

CWUE was calculated by applying Eq. (3). The effective total amount of the rain water occurred in the field plots were 220 mm. The value of CWUE for plots T1 and T2 were: 1.66 kg/m^3 and 1.28 kg/m^3, respectively. The increasing value of CWUE in plot T1 was more than plot T2 by 30 %. Membrane trough saved the water for longer time, reduced soil water stress, reduced deep percolation, increased crop yield and accordingly increased the value of the CWUE. **Fig. 5** showed the accelerated growth of winter wheat in plot T1 comparing with plot T2. The length of the spike at this age was measured in plots T1 and T2 and equaled to: 100 mm and 80 mm, respectively, and width of leaves of the plants at this age in plots T1 and T2 were; 15 mm and 10 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. 5**.

Fig. 6 showed comparison between plots T1 and T2 on basis of the crop water use efficiency of the winter wheat.

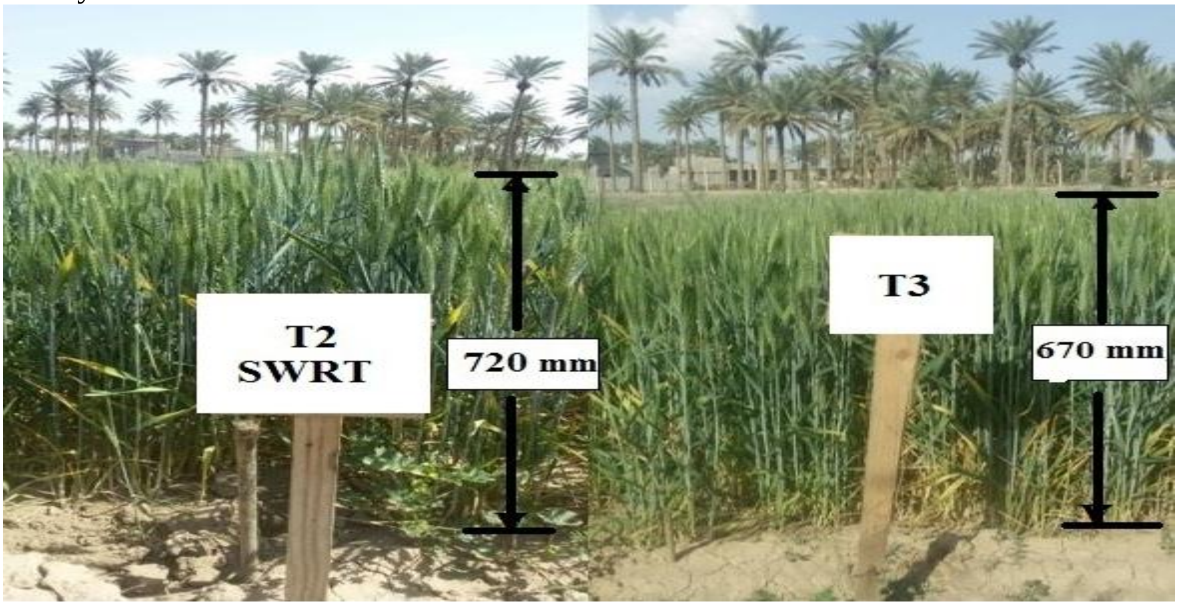

Figure 5. Accelerated winter wheat growth in plot T1 comparing with plot T2.

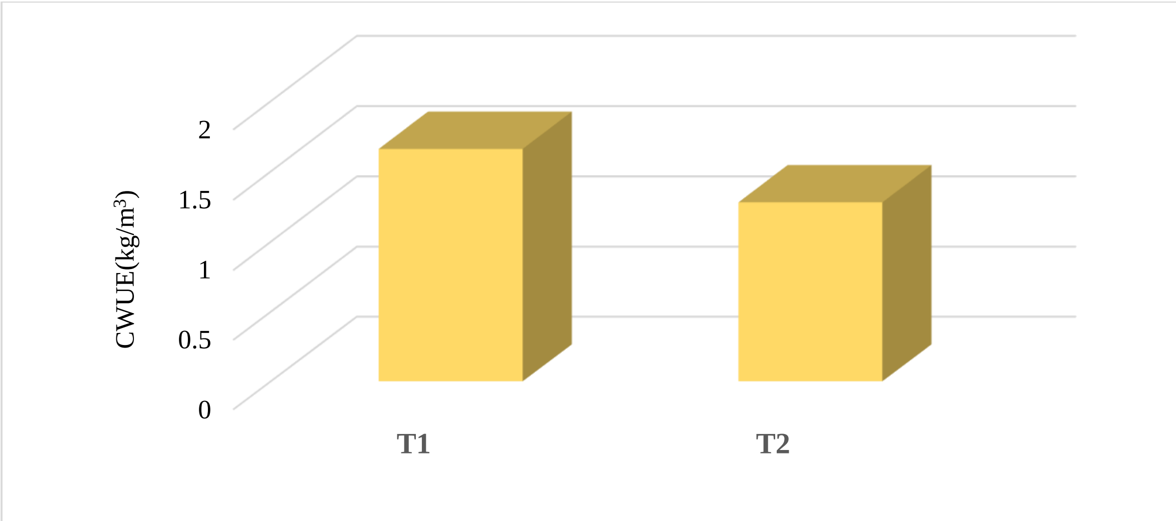

Figure 6. Comparison between plots T1 and T2 on basis of the crop water use efficiency of the winter wheat.

4. CONCLUSIONS

In this study, installing the membrane trough below the root zone of winter wheat has many benefits such as:

1. The membrane trough kept and saved the rain water, fertilizers and nutrient materials for longer time and the crop was depleted the moisture by capillary rise.

2. The available moisture content above the membrane trough was reduced the soil water stress on the plant.

3. Improved the crop yield and CWUE values by 25 % and 30 %, respectively.

4. The membrane was reduced soil surface from cracks after drying period and finally reducing the deep percolation losses.

5.The obtained results indicate that the membrane trough has the same effects on improving the irrigation parameters when vegetables plants were used in open fields and inside greenhouses (**Almasraf and Salim, 2018**), (**Hommadi and Almasraf, 2018**) and (**Hommadi and Almasraf, 2019**).

Installing the membrane trough in the desert area with the absent of irrigation source is recommended and could improve the crop yield even if the accumulated rain water is less than the required value. Another value will be improved is the return benefit to the farmer. The more plant production with high efficiency of the applied water, the result will be the higher return value.

5. NOMENCLATURE

SWRT=subsurface water retention technology.
T1, T2=agriculture plots.
CWUE = crop water use efficiency (kg/m^3).
ET_c= crop evapotranspiration.
θ_p= soil water content in the day before (mm).
θ_n= soil water content in the next day (mm).
R= rainfall water (mm).
I: irrigation depth (mm).

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