

***Water Resources and Surveying Engineering***

**Improvement of the Water Use Efficiency and Yield of Eggplant by Using Subsurface Water Retention Technology**

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**ABSTRACT**

Sustainable crop production in a coarse soil texture is challenging due to high water permeability and low soil water holding capacity. In this paper, subsurface water retention technology (SWRT) through impermeable polyethylene membranes was placed at depth 35 cm below ground surface and within the root zone to evaluate and compare the impact of these membranes and control treatment (without using the membranes) on yield and water use efficiency of eggplant inside the greenhouse. The study was conducted in Al-Fahamah Township, Baghdad, Iraq during spring growing season 2017. Results demonstrated the yield and water use efficiencies were 3.483 kg/m<sup>2</sup> and 5.653 kg/m<sup>3</sup>, respectively for SWRT treatment plot and 3.286 kg/m<sup>2</sup> and 3.709 kg/m<sup>3</sup>, respectively for treatment without using SWRT. The increasing percentages for yield and water use efficiency were 6% and 52%, respectively. Additionally, saving in irrigation water in the SWRT membrane was about 44% of the total applied depth comparing with the control treatment.

**Keywords:** subsurface water retention technology, water use efficiency, yield, eggplant.

**تحسن كفاءة استخدام المياه والانتاجية لنبات الباذنجان باستخدام تقنية الأغشية الحافظة للماء تحت السطح**

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**الخلاصة**

استدامة انتاج المحاصيل في التربة ذات النسجة الخشنة يشكل تحديا بسبب النفاذية العالية وانخفاض قدرة التربة على مسك الماء. لهذا الغرض، فإن تقنية الاحتفاظ بالماء تحت السطح باستخدام اغشية البولي ايثيلين وضعت عند العمق 35 سم تحت سطح الارض لتقييم ومقارنة تأثير هذا الاغشية والالواح الزراعية المسيطر عليها (بدون استخدام الأغشية) على انتاجية و كفاءة الماء المستخدم للباذنجان داخل البيوت الخضراء. تمت الدراسة ضمن منطقة الفحامة، مدينة بغداد- العراق للموسم الزراعي الربيعي 2017. النتائج اظهرت ان الإنتاجية وكفاءة استخدام الماء لتقنية الاحتفاظ بالماء تحت السطح وبدون استخدام الاغشية كانت 3.484 كغم /م<sup>2</sup> و 5.653 كغم/م<sup>3</sup> على التوالي، و 3.287 كغم /م<sup>2</sup> و 3.709 كغم/م<sup>3</sup> على التوالي، و بزيادة مقدارها 6 % و 53 % على التوالي. بالإضافة الى ان نسبة ادخار مياه الري المضافة في تقنية استخدام الاغشية كانت 44 % من المجموع الكلي للعمق المضاف مقارنة بالالواح الزراعية المسيطر عليها.

**الكلمات الرئيسية:** تقنية الاغشية الحافظة للماء تحت السطح، كفاءة استخدام المياه، الانتاج، الباذنجان.



## 1. INTRODUCTION

Water shortage presents a serious problem nowadays. This problem will certainly worsen in the future, and so, improving the irrigation water efficiency by various methods is one of the economically viable alternatives in overcoming the water scarcity. It considers a good solution to overcome the fight against famine especially in the developing countries, **Ismail and Ozawa, 2007**. Development new technologies to conserve water are becoming important for achieving a sustainable economic growth, **Shahid, et al., 2012**. **Andrey, et al., 2015**, stated that subsurface water retention technology (SWRT) is a new, long-term approach to improve water storage capacities especially in coarse soil texture for sustainable crop production, increasing in yield and water use efficiency. They found that the SWRT controls the soil water content in sandy soils at optimal levels for corn growth, diminish water loss through deep drainage and minimize total irrigation depths. SWRT consists of subsurface polyethylene membrane installed within the crop's root zone with a specific aspect ratio that prevents the loss of irrigation water via deep percolation. **Ahmed, et al., 2012**, mentioned in their research work that SWRT is not only crucial for the sustainable agricultural yield but also to meet the financial problems, physical barriers and the challenges of current environmental issues and justice in the developing countries, SWRT impermeable membranes hold nutrient and agricultural chemicals reducing deep leaching losses into groundwater. SWRT solve worldwide famine and poverty and reduce global food shortages by increasing the viability of existing crops which will increase production per unit area; SWRT can also convert the previously inhospitable land into viable growing condition for food, feed, and biomass. **Demirel and Kavdir, 2013**, investigated that SWRT retains optimal soil water content in plant root zones and saved 35–74 % of irrigation water compared with control (without membrane). So, **Amirpour, et al., 2016**, concluded in a study work that the frequency of irrigation will reduce after installing water-saving membranes and consequently the number of irrigation times decreased. The effect of SWRT on the yield differed for different crops. For example, **Elawady, et al., 2003**, observed an increasing value of 18 % in spinach (*Spinacia oleracea* L.) yield. **El-Nesr, et al., 2014**, obtained 119 and 131% increases in tomato and artichoke (*Cynara cardunculus* L.) yields, respectively, while **Kavdir, et al., 2014**, evaluated the performance of using membranes below the soil surface in sandy soil planted with corn. The result indicates an increase in corn production of about 238%. The objectives of this study were to evaluate and compare the effects of subsurface water-saving membranes, installed at depth 35 cm below ground surface in a sandy loam soil, on yield (Y) and water use efficiency (WUE) of eggplant inside the greenhouse.

## 2. MATERIALS AND METHODS

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

The experiment was conducted in Al-Fahamah Township, Baghdad, Iraq for the spring season of eggplant from January 10<sup>th</sup> to May 31<sup>st</sup>, 2017. The experimental work was carried out in the greenhouse located at Latitude: 33°25' N, Longitude: 44°20' E, and altitude: 36 m. The main source of water is from a farm reservoir charged continuously from Tigris River. Two soil samples from the greenhouse of eggplant were taken at depth (0-50 cm). Analysis of soil sample were conducted at the laboratories of the Agricultural Research Directorate of Ministry of Science and Technology. The goal of the analysis was to identify the physical characteristics of the soil in order to determine soil texture and physical properties of the soil which included bulk density, soil texture, field capacity (FC), and permanent wilting point (PWP). The average analysis of the soil texture for the two samples of the greenhouse field is classified as sandy loam soil. Also, FC and PWP were measured and equal to 16.4 and 6.9 % (by volume), respectively.



## 2.2 Treatments, Experimental Design and Crop Material

The greenhouse stretching in an N-S trend; it was 8 m long, 3 m wide, and 1.8 m in high (a total area of about 24 m<sup>2</sup>). It was covered by 90 µm transparent polyethylene film treated with ultraviolet radiation. The greenhouse was without heating and air ventilation; it was classified as low technology greenhouse. Trickle irrigation system has been used in the greenhouse, the system consists of two double irrigation lines each was 8 m long of diameter 15 mm, and each trickle line contains 16 emitters along its total length. The emitters were spaced at 0.5 m apart. The average flow rate of each emitter was 20 ml/min. **Fig. 1** shows the internal layout of the greenhouse. Eggplant crop (*Solanum Melongena L.*) was planted at 0.5 m distance between plants on both sides. In each irrigation process, soil water content before irrigation, date, the flow rate from the emitter, and time of the irrigation was recorded when possible. Two treatment plots were selected for the research work, treatment no.1 (T1) SWRT was installed below the soil surface and treatment no.2 (T2) was control plot (without using SWRT).

## 2.3 Description of the Subsurface Water Retention Technology (SWRT)

Subsurface water retention technology (SWRT) consists of subsurface low-density polyethylene membrane of thickness 175µm installed for a half area of the experiment at depth 35 cm below ground surface with 3:1 (length to height) aspect ratio. The installation of the membrane was done manually and all the excavation work was done by hands, no special machine was used in this process. The width of the membrane was 36 cm with both side heights was 12 cm. **Fig. 2** shows the layout of the polyethylene membrane under the soil profile.

## 2.4 Yield

The sum of all pickings crop's production was expressed as a total vegetable yield. The yield (in kg/m<sup>2</sup>) was expressed as described by, **Mady and Derees, 2007** as follows:

$$Yield = \frac{\text{Total wieght of the crop (kg)}}{\text{Total area of the crop (m}^2\text{)}} \quad (1)$$

## 2.5 Water Use Efficiency

The water use efficiency (WUE) is the outcome of an entire site of plant and environmental processes operating over the life of a crop to determine both yield and water use. The following equation was used for calculating the field WUE (in kg/m<sup>3</sup>), **FAO, 1982** as follows:

$$WUE = \frac{\text{Yield } (\frac{\text{kg}}{\text{m}^2})}{\text{Total depth of applied water (m)}} \quad (2)$$

# 3. RESULTS AND DISCUSSIONS

## 3.1 Effect of SWRT on Variation of Soil Moisture

In this work, irrigation water was applied when all readily available water was depleted with 45% of depletion value through the whole stages of the growing season (no deficit irrigation was allowed). The irrigation schedule was started from mid of January 2017 and ended on end of May 2017. **Table 1** and **Table 2** show the numbers of irrigation, applied depth, and yield for SWRT treatment plot and for without using SWRT, respectively for each month through the growing season of eggplant. Soil moisture content within the membrane was affected and the



water absorption by the plant root zone was conducted by capillary rise. Reduction of soil water was slower in treatment T1 compared with control treatment (T2) due to SWRT working as a barrier and to keep water within the soil profile. Additionally, daily observation showed that the top of the soil surface under SWRT plot was wetted. **Fig. 3** shows the effect of SWRT membrane on soil moisture changes and **Fig. 4** shows the soil surface of SWRT and without using SWRT after a day of irrigation. The total numbers of irrigation through the growing season for T1 and T2 were 49 and 71, respectively; frequency of irrigation in T1 was reduced by 45 %. Moreover, the total applied depth of water for treatments T1 and T2 were 617 and 887 mm, respectively, the saving in water in treatment T1 was 44 % of the total applied depth.

### 3.2 Effect of SWRT on Crop Yield

Fertilizer and pesticides were added to the crop for both treatments through the growing season in suitable quantities and time and as required. The crop yield value calculated based on equation 1 was stating after three months from time of planting and continuous for two months. The crop yield for both treatment T1 and T2 was 3.483 and 3.286 kg/m<sup>2</sup>, respectively with a minor increasing value of 6 % in treatment T1. Although the yield value was almost equal in both treatment, but observation of the crop's growth for treatment T1 was showed clearly an accelerated eggplant's growth through the growing season compared with control (T2), this was due to the membrane was capture nutrients and agricultural chemical and reduce deep leaching of rich water contains, minerals, fertilizer, and pesticides materials. **Fig. 5** shows the accelerated eggplant growth with SWRT.

### 3.3 Effect of SWRT on Water Use Efficiency

The results for water use efficiency indicator based on a calculation using equation 2 observed clearly that water use efficiency was improved in treatment T1. The water use efficiency for T1 and T2 were: 5.653 and 3.709 kg/m<sup>3</sup>, respectively. The increasing value in T1 was more than T2 by 52 %. This was explicit that the total applied depth in T1 was less than in T2 as long water use efficiency depends on total applied water. Saving more water with the same crop yield value will definitely increase the water use efficiency value. **Fig. 6** shows the of water use efficiency and the yield of eggplant among T1 and T2.

## 4. CONCLUSIONS

The installation of SWRT membrane under soil surface significantly affected saving water applied and numbers of irrigation process by 44 and 45 %, respectively. Although the crop yield values for treatments T1 and T2 equal to 3.484 and 3.287 kg/m<sup>2</sup>, respectively with minor increasing, the water use efficiency for T1 and T2 were 5.653 and 3.709 kg/m<sup>3</sup>, respectively with increasing value in T1 by 52 %. In other words in spite of getting the same crop yield and using less amount of water, with a high value of water use efficiency, this called improvement in irrigation process and then will be in drainage collection systems. These results are encouraging the researchers to work using the same procedures for other vegetable crops and also for strategies crops on more coarse-textured soil and even by using only rainfall water and the irrigation water will be an only supplementary method in the open field. The saving in irrigation water not only by using less water from irrigation sources but from how to collect and stored and exploit the amount of rainfall water and use it at a certain time.



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## NOMENCLATURE

FC = field capacity.

PWP = permanent wilting point.

SWRT = subsurface water retention technology.

WUE = water use efficiency.

Y = yield.

T1 = Treatment no. 1

T2 = Treatment no. 2



Figure 1. Internal layout of the greenhouse.

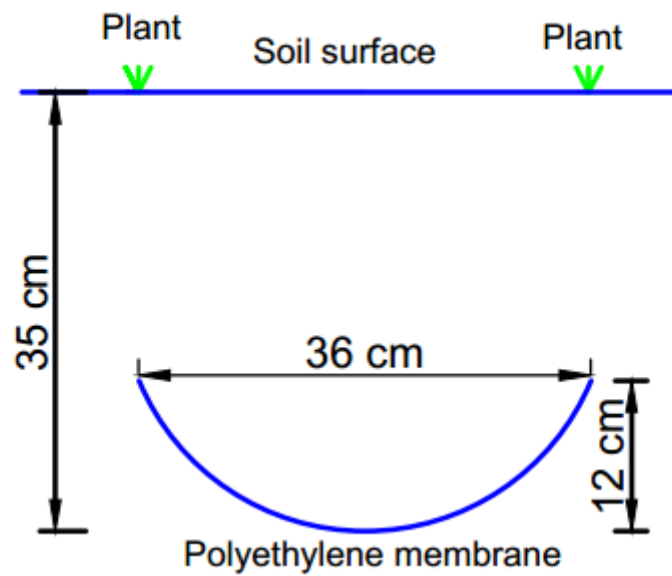
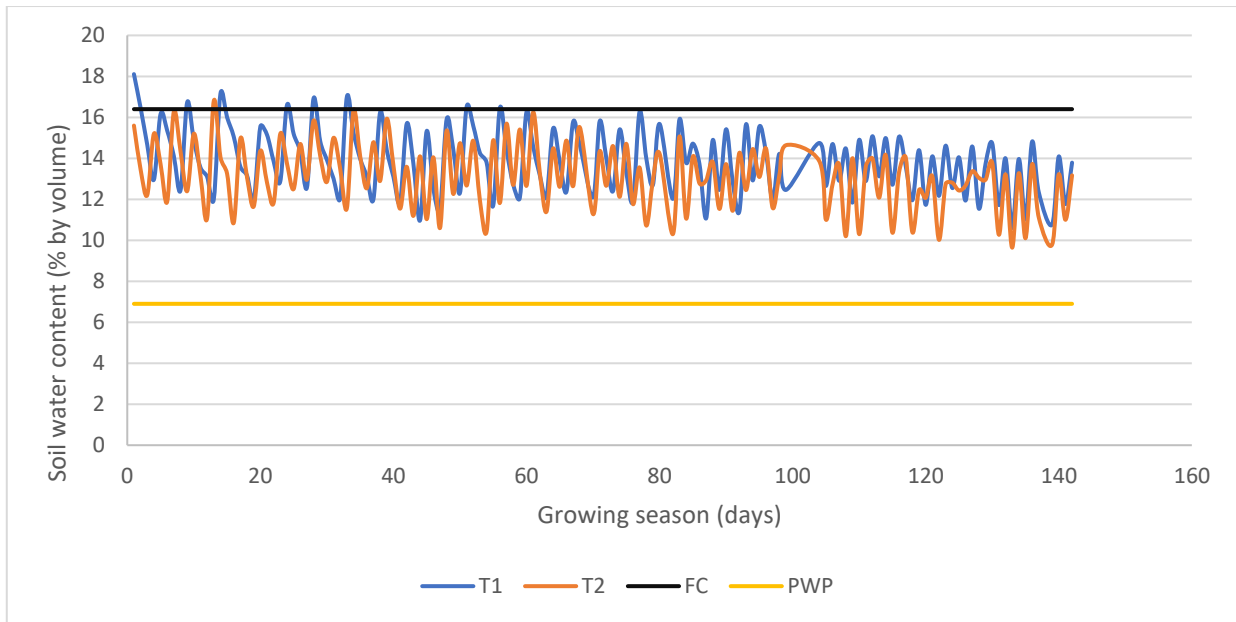


Figure 2. Layout of the polyethylene membrane under the soil profile.



**Figure 3.** Effect of SWRT membrane on soil moisture changes.



**Figure 4.** Comparison between soil surface of SWRT and without using SWRT after a day of irrigation.



**Figure 5.** Accelerated eggplant growth with SWRT.

**Table 1.** Number of irrigation, depth of applied water and yield of the eggplant (with SWRT)\*.

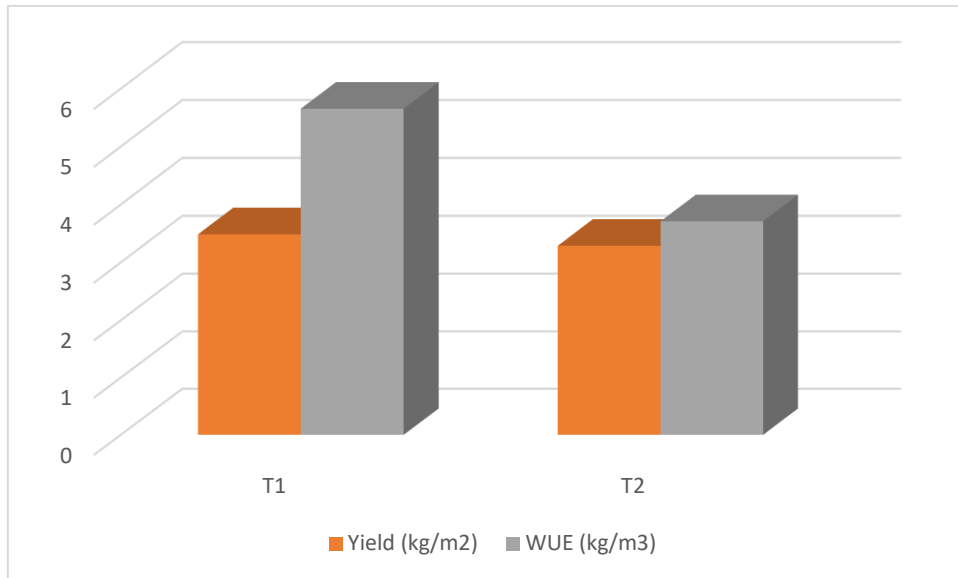
Month	Number of irrigation	Depth of applied water (mm)	Yield (kg/m <sup>2</sup> )
January	6	58	0
February	8	86	0
March	8	100	0
April	14	178	1.631
May	15	195	1.852
<b>Total</b>	<b>49</b>	<b>617</b>	<b>3.483</b>

**Table 2.** Number of irrigation, depth of applied water and yield of the eggplant (without SWRT)\*.

Month	Number of irrigation	Depth of applied water (mm)	Yield (kg/m <sup>2</sup> )
January	9	86	0
February	11	120	0
March	14	180	0
April	17	224	1.241
May	20	277	2.045
<b>Total</b>	<b>71</b>	<b>887</b>	<b>3.286</b>

\*for a period from January to May 2017.





**Figure 6.** Comparison of water use efficiency and the yield of eggplant among T1 and T2.