

Chemical, Petroleum and Environmental Engineering

Subsurface Water Retention a Technology for Increasing the Field Use Efficiency and Water Saving Values of Cucumber Plant

Fatima Sadoon Mushab*

Graduate student
College of Engineering
University of Baghdad
E-mail: fatimasadon@yahoo.com

Assist. Prof. Sabah Anwer Almasaf

Department of Water Resources Engineering
College of Engineering
University of Baghdad
E-mail: sabah_dawood@yahoo.com

ABSTRACT

The technology of subsurface soil water retention (SWRT) uses a polyethylene trough that is fixed under the root zone of the plant. It is a modern technology to increase the values of water use efficiency, plant productivity and saving irrigation water by applying as little irrigation water as possible. This study work aims at improving the crop yield and water use efficiency of a cucumber plant with less applied irrigation water by installing membrane trough below the soil surface. The field experiment was conducted in the Hawr Rajab District of Baghdad Governorate in Winter 2018 for testing various trickle irrigation systems. Two agricultural treatment plots were utilized in a greenhouse for the comparison. Plot T1 has used a subsurface trickle irrigation together with membrane trough. Plot T2 has used only surface trickle irrigation system without using SWRT. The total area of the plots T1 and T2 was 13.2 m² and 6.66 m², respectively. The obtained results of the study confirmed that the plot T1 satisfies values greater than plot T2 in terms of crop yield, field water use efficiency and in saving the applied irrigation water. The increase rate of field water use efficiency and crop yield in plot T1 compared with plot T2 was 103 %, and 24 %, respectively. Additionally, the increase rate in saving the applied irrigation water in plot T1 comparing with plot T2 was 64 %. The installation of the membrane trough below the plant's root zone together with subsurface trickle irrigation system assisted in keeping the water, nutrients, and fertilizers during the root zone profile, improving the field water use efficiency and then the parameter of water productivity.

Keywords: Subsurface trickle irrigation, subsurface water retention technology, yield, water use efficiency.

احتباس المياه تحت السطحية تقنية لزيادة قيم كفاءة الاستخدام الحقلية وخرن المياه لنبات الخيار

أم صباح أنور المصرف
قسم هندسة الموارد المائية

فاطمة سعدون مصحب
طالبة ماجستير/ قسم هندسة الموارد المائية

الخلاصة

ان تقنية احتباس المياه تحت السطح هو غشاء مصنوع من مادة البولي ايثيلين مثبتة تحت المنطقة الجذرية للنبات. وهي تقنية حديثة لزيادة قيم كفاءة استخدام المياه وإنتاجية النبات وادخار مياه الري المضافة عن طريق تطبيق أقل قدر ممكن من مياه الري المضافة. يهدف هذا البحث الى تحسين انتاجية النبات و كفاءة استخدام المياه لنبات الخيار مع كميات اقل لمياه الري المضافة من خلال تثبيت غشاء تحت سطح التربة. أجريت التجربة الميدانية في حقل يقع في منطقة هور رجب بمحافظة بغداد في شتاء 2018 لاختبار مختلف طرق الري بالتنقيط. استخدمت معالجتين زراعية داخل البيت الاخضر (البيت المحمي)

*Corresponding author

Peer review under the responsibility of University of Baghdad.

<https://doi.org/10.31026/j.eng.2019.09.5>

2520-3339 © 2019 University of Baghdad. Production and hosting by Journal of Engineering.

This is an open access article under the CC BY-NC license <http://creativecommons.org/licenses/by-nc/4.0/>.

Article received: 9/10/2018

Article accepted: 3/12/2018



لأغراض المقارنة. المعالجة الأولى تم استخدام الري بالتنقيط تحت السطح مع تثبيت غشاء من البولي اثيلين. المعالجة الثانية تم استخدام نظام الري بالتنقيط السطحي فقط بدون استخدام تقنية احتفاظ المياه للتربة. كانت المساحة الزراعية المستخدمة للمعالجة الأولى والثانية هي 13.2 م² و 6.66 م² على التوالي. أكدت نتائج الدراسة المستحصلة بان المعالجة الأولى أكدت بقناعة ان القيم كانت اكبر من المعالجة الثانية من حيث إنتاجية المحصول وكفاءة استخدام المياه في الحقل وقيمة الادخار في مياه الري المضافة. بلغ معدل الزيادة لكفاءة استخدام المياه وانتاجية النبات في المعالجة الأولى مقارنة مع المعالجة الثانية: 24 % و 103 % على التوالي. بالإضافة الى ذلك، كان معدل الزيادة في ادخار مياه الري المضافة في المعالجة الأولى مقارنة مع المعالجة الثانية كانت: 64 %.

الكلمات الرئيسية: الري بالتنقيط تحت السطح، تقنية احتفاظ المياه تحت السطح، الانتاجية، كفاءة استخدام المياه.

1. INTRODUCTION

The issue of water shortage and its scarcity is one of the most serious problems and challenges that threaten the future of the earth. The huge population growth and the variable climate lead to a change in the availability of water resources. Immoderate demand for food is predictable to increase, and it is important to evolve our ability to produce food with less water. There are a few basic processes of utilizing water resources in the land to meet rising food demands, **Descheemaeker, et al., 2013**. One of the utilizing method and saving the applied irrigation water is the use of soil water retention technology (SWRT) along with the surface and subsurface trickle irrigation system. SWRT can keep water and nutrients, and it saves up to 50 % of the water and fertilizers added in agricultural land, **Cameron, et al., 2013**. SWRT is a water-saving membrane made of low-density polyethylene (LDPE), and that is installed as U-shaped beneath the root area of the plant with a particular aspect ratio (the ratio of width to height), leaving a proper space for root growth and ease of movement with internal drainage through excessive rainfall. **Guber, et al., 2015**, emphasized that the preferable aspect ratio to place a membrane under the surface of the soil is 2:1 through an experiment conducted in a greenhouse. They used the HYDRUS-2D model to simulate the lowest water losses in the various aspect ratios, using different aspect ratios for comparison 3:1 and 5:1 at a depth of 20 cm and 40 cm. The results showed that the lowest water losses are achieved utilizing a membrane of 2:1 and a depth of 20 cm. It is a modern technology to increase plant productivity by applying as little irrigation water as possible. Installation of the membrane trough in the top 50 to 75 cm of sandy soils augment both top soils land biomass and food output by 40 % to 400 % with essential decrease of irrigation water, **Smucker, 2016**. **Al-Rawi, 2016**, explained a significant increase in water use efficiency and the overall yield of cultivating tomato plants. The work was conducted in Diyala Governorate when comparing using SWRT with subsurface trickle irrigation and using subsurface trickle irrigation only where the increase was 88.78 % and 15.35 %, respectively. The global use of surface and subsurface trickle irrigation system has increased dramatically in recent decades. The major advantage of these systems is the possibility of increasing crop yields while reducing water use and fertilizer and agriculture costs. Subsurface trickle irrigation is a suitable system for irrigation the desert lands and arid lands because it gives the best control over irrigation water and works on processing water near the root area if used well. As for the effect of subsurface trickle irrigation on the efficiency of water use, **Lamm and Trooien, 2002** reported that subsurface trickle irrigation water provision of 35 % to 55 % were probable compared to conventional irrigation forms like sprinkler and furrow irrigation systems. The aim of this study is to improve crop yield, field water use efficiency of cucumber plant and the value of saving in applied of irrigation water with subsurface trickle irrigation system together with the soil water retention technology (SWRT).



2. MATERIALS AND METHODS

2.1 Experimental Works

The research was carried out in a greenhouse within the town of Yusufiyah, in Baghdad Governorate, Iraq during Winter of cucumber plant from January 1st, to May 8th, 2018. The work was conducted in a field belonging to a farmer cultivated a cucumber plant and except to did the experiment work in his field. Therefore the cucumber plant was used. The experiential field was situated at Latitude: 33°09' N, Longitude: 44°24' E, and altitude: 34 m. The major source of applied water was from the well near the greenhouse. Four soil samples were taken from the fieldwork at depths 15 cm and 30 cm. Lab analyses of soil specimens were carried out at the Graduate Laboratory of the Faculty of Agriculture, University of Baghdad. The target of the analyses was to determine the type and soil texture, field capacity, permanent wilting point, and bulk density. The analysis of the soil texture showed that the soil texture was classified as medium loam soil. Also, bulk density, field capacity, and permanent wilting point were measured and was equal to 1.54, 22.65 (% by volume) and 9.73 (% by volume), respectively.

2.2 Agricultural Treatment Plots, Experiential Layout, and Crop Type

The greenhouse used in this study was extending in an N-E trend; it was 10 meters in length, 9 m in width, and 3 m in height with a whole cultivated area of about 20 m². It was enveloped by 200- μ m polyethylene membrane. It was not equipped with ventilation or heating systems. A system of trickle irrigation surface and sub-surface trickle irrigation system was used to irrigate the cucumber plant. Surface trickle system was used with double lateral pipes of diameter 13 mm and of length 10 m, and each lateral pipe contains built-in 25 emitters placed at 0.4 m. The average flow rate from the emitter was 25 ml/ min. Subsurface trickle system was used with three lateral pipes of diameter 16 mm and of length 10 m, and each lateral pipe contains built-in 32 emitters spaced at 0.31 m. It was placed at a depth of 10 cm below the surface of the soil. **Fig. 1** presents the layout of the systems inside the greenhouse. Cucumber plant (*Cucumis sativus*) was cultivated on 0.4 m and 0.31 m distance among plants on both sides for surface and subsurface trickle irrigation system, respectively. The water content of the soil before irrigation, date and irrigation time and the flow rate of the emitter were recorded when possible in each irrigation process. Two plots were used for the study fieldwork, plot T1 where the membrane sheet was installed beneath the soil surface with subsurface trickle irrigation system and plot T2 where surface trickle irrigation system was used only without installing the membrane sheet. The area of the plots T1 and T2 was 13.2 m² and 6.66 m², respectively. The difference in the selected area was due to the equalization of the number of emitters per square meter and because it was the available area.

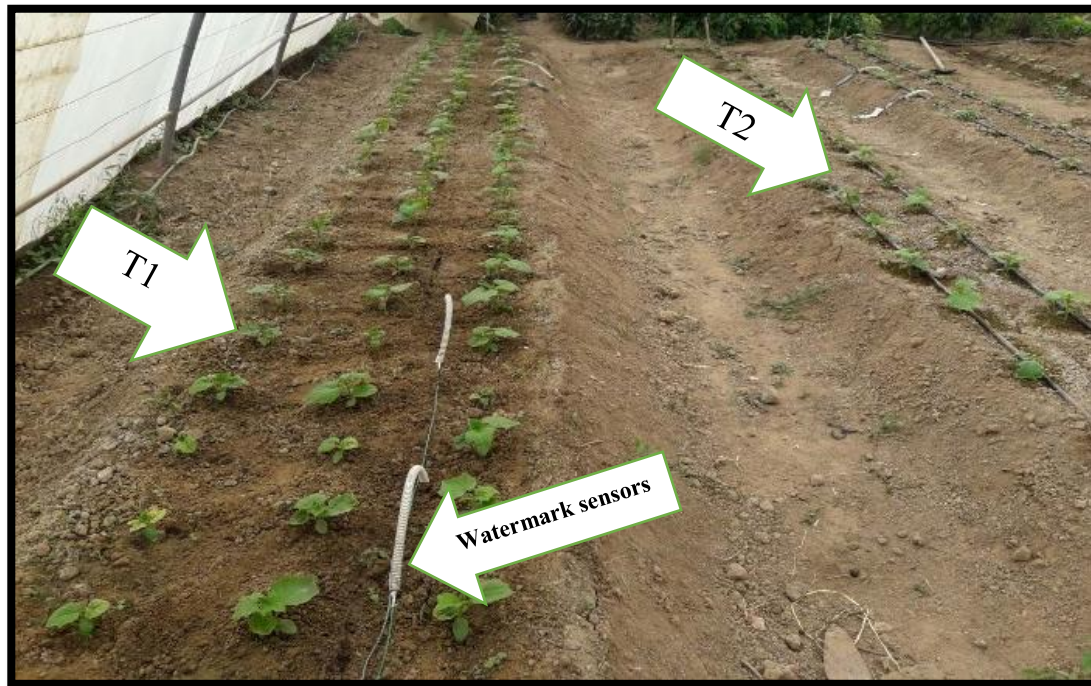


Figure 1. The layout of the systems inside the greenhouse.

2.3 Soil Water Retention Technology

Soil water retention was a technique of installing a membrane made of low-density polyethylene sheet of thickness $200\mu\text{m}$ fixed at depth 35 cm beneath the ground surface with aspect ratio 3:1 (width to depth). The membrane trough was manually installed, and the digging operations were done by hands. The membrane width was 75 cm with both sides of the height 25 cm. **Fig. 2** presents the location and dimensions of the membrane trough.

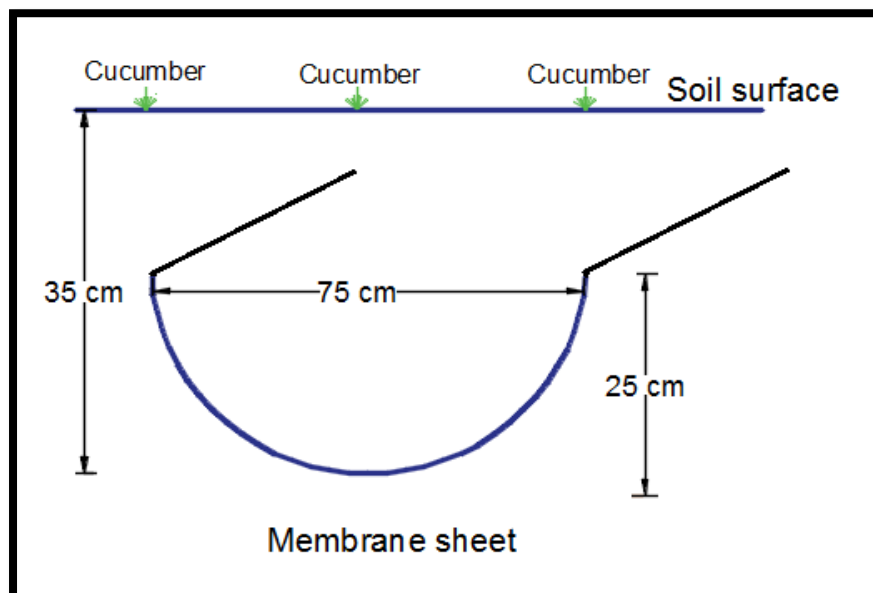


Figure 2. Location and dimensions of the membrane trough.



2.4 Crop Yield

The total of the pickings crop’s output was expressed as a gross vegetable crop yield. The crop yield in kg/ m² was expressed as substantive by **Mady and Derees, 2007**:

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

2.5 Field Water Use Efficiency

The field water use efficiency (FWUE) was the result of a complete position of the plant and ecological processes operating along the life of a crop to determine both the water applied and the yield. The following equation was utilized to calculate the FWUE in (kg/ m²) by **FAO, 1982**:

$$FWUE = \frac{Yield\ (kg/m^2)}{Gross\ depth\ of\ applied\ water\ (m)} \tag{2}$$

3. RESULTS AND DISCUSSIONS

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

In this work, irrigation water was added when 80 % of readily available water (RAW) was exhausted and equal to 50% of the available water during the growing season. The irrigation scheduling was applied from January 1st to May 8th, 2018 for a total growing season equal to 128 days. **Table 1** presents the number of irrigations, gross depth of applied water, plot and crop yield for each month during the growing season of cucumber. The overall numbers of irrigation process during the growing season for plots T1 and T2 were: 11 and 34, respectively; the frequency of irrigation in plot T2 was increased by 209 % compared with plot T1. Additionally, the gross depth of applied water for plots T1 and T2 were 133 and 218 mm, respectively with 64 % expected value in water saving in plot T1.

Table 1. Number of irrigations, gross depth of applied water, plot and crop yield of the cucumber.

Month	Number of irrigations		Gross depth of applied water (mm)		Plot and crop yield (kg /m ²)	
	T1	T2	T1	T2	T1	T2
January	1	8	51	39	0	0
February	0	5	0	23	0	0
March	4	10	31	65	1.33	1.11
April	5	9	42	73	3.1	2.52
May	1	2	9	18	1.27	0.97
Total	11	34	133	218	5.7	4.6

Fertilizer and insecticides were added to the plant for the two plots during the growing season in proper amounts and time when required as recommended by an agricultural specialist. The picking production of the crop was starting from mid of March to the early days of May. The crop yield for the two plots T1 and T2 was equal to 5.7 and 4.6 kg/ m², respectively with major increasing value of 24 % in T1 compared with T2. **Fig. 3** presents the accelerated cucumber growth with SWRT under subsurface trickle irrigation.



Figure 3. Accelerated cucumber growth with SWRT in plot T1 under subsurface trickle irrigation comparing with plot T2.

3.2 Influence of SWRT on Field Water Use Efficiency

The value of the field water use efficiency index which was calculated based on **Eq. (2)**, for the plots, T1 and T2 were 42.9 and 21.1 kg /m³, respectively. The increasing value in plot T1 was greater than plot T2 by 103 %. This was due to the increase in the crop yield, and the reduction in the applied water. Savings more water for the same crop yield will promptly raise the field efficiency of water use.

The reduction in the applied depth of water and numbers of irrigation process in plot T1 was due to the soil moisture that was still existing over the membrane trough, and the plant root zone absorbed the water by capillary rise. The membrane trough was acting as a barrier holding the soil moisture. Furthermore, the subsurface trickle irrigation system prevents evaporation and works to transfer water directly to the root area, so saving the greatest amount of soil moisture. Additionally, the increase in the field water use efficiency was due to the trough was worked to save agricultural chemical elements and nutrients as well as limited the deep filtration of water and thus maintain the appropriate water and moisture as long as possible saving more water. Also, subsurface trickle irrigation distributed moisture appropriately near the root zone and thus access nutrient-rich water directly to the root area and reduced the number of irrigation processes.



4. SUMMARY and CONCLUSIONS

The installation of the membrane trough beneath the soil surface combined with the subsurface trickle irrigation system in plot T1 has significantly affected the following factors:

- 1- The total depth of applied water was reduced by 64% and accordingly the number of irrigation processes was reduced by 209 %.
- 2- The crop yield in plot T1 was greater than that in plot T2 by 24%.
- 3- The field water use efficiency in plot T1 was greater than in plot T2 by 103%.

For the time being the water resources in our country was reduced and it was clear that there was a shortage in holding enough water for irrigating the agricultural lands. Moreover, the change in the global world also affects the limited and quantities of water resources. Therefore, looking for modern technologies was the main goal. These modern irrigation technologies were beneficial in keeping the invaluable gift of nature (water). The saving in applied water, saving in several irrigations processes and to the increasing values of the crop yield and field, water use efficiency was improved due to installing the membrane trough below the soil surface together with the applied of the new technology of subsurface trickle irrigation. The membrane trough works as soil's retention of the moisture and reducing the losses of applied water, fertilizer and pesticides materials. While the subsurface trickle irrigation system regularly distributes the moisture, reduces surface evaporation loss and directs water supply to the root area. Moreover, the impression of saving more water and high obtained yield with less applied water was led and encouraged the farmer(s) to use the modern irrigation technologies as well as with simple information data in the sandy soil and desert area with or without a complementary irrigation system. At the same time, raising the economic level of the farmers as long the farmer looking for more return and profits and then influenced the community.

REFERENCES

- Almasraf, S. A. and Salim, A. H. ,2018, *Improvement of the Water Use Efficiency and Yield of Eggplant by using Subsurface Water Retention Technology*, Journal of Engineering. Vol. 24, Issue 3. March 2018, Baghdad/Iraq.
- AL-Rawi, S. S., 2016, *States of Temperature and Salinity in Coarse Textural Soil using Subsurface Water Retention Technology SWRT and Their Impact on Production of Tomato and Chill Pepper*, Ph.D. Thesis College of Agriculture, Baghdad University, Baghdad/Iraq.
- Aoda, M. I., and Mahdi, N. T., 2017, *Analysis of Soil Physical Properties*, Baghdad University, College of Agriculture, Iraqi Soc., Soil Sci. Publication.
- Cameron, L., Smucker A. and Walsh, K., 2013, *Revolutionary Technology Aids Thirsty Crops during Drought*. Michigan State University Today, Jan. 16, 2013.
- Demirel, K., and Kavdir, Y., 2013, *Effect of Soil Water Retention Barriers on Turfgrass Growth and Soil Water Content*, Journal Irrig. Sci., Vol. 31, No. 4, pp. 689-700.
- Descheemaeker, L., Bunting, S. W., Bindraban, P., Muthuri, C., Molden, D., Beveridge, M., Brakel, M. V., Herrero, M., Clement, F., Boelee, E., and Jarvis, D. I.,2013, *Managing Water*



and Agroecosystems for Food Security, Increasing Water Productivity in Agriculture, Chap 8.

- Douh, B., Mguidiche, A., Khila, S., Mansour, M., Rania, H., and Boujelben, A., 2013, *Yield and Water Use Efficiency of cucumber (Cucumis sativus L.) conducted under subsurface drip irrigation system in a Mediterranean Climate*, IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT), ISSN: 2319-2402, ISBN: 2319-2399, Vol. 2, No. 4, PP 46-51.
- FAO, 1982, *Crop Water Requirements Irrigation and Drainage*, Paper no. 24, FAO, Rome, Italy.
- Guber, A. K., Smucker, A. J. M., Berhanu, S., and Miller, J. M. L., 2015, *Subsurface Water Retention Technology Improves Root Zone Water Storage for Corn Production on Coarse-Textured Soils*, Vadose Zone Journal, Soil Science Society of America, Vol.14, No.7.
- Hartz, T., Miyao, G., Mickler, J., Lestrangle, M., Stoddard, S., Nunez, J., and Aegerter, B., 2008, *Processing tomato production in California*, <http://anrcatalog.ucdavis.edu/pdf/7228.pdf>.
- Hommadi, A. H. and Almasraf, S. A., 2018, *Improving Water Use Efficiency and Water Productivity for Okra Crop by using Subsurface Water Retention Technology*, Journal of Engineering. Vol. 24, Issue 7. July 2018, Baghdad/Iraq.
- Khan, Z., Shah, A. H., Gul, R., Majid, A., Khan, U., and Ahmad, H. 2015, *Morpho-agronomic characterization of cucumber germ plasm for yield and yield associated traits*. International Journal of Agronomy and Agricultural Research, Vol. 6, No. 1, pp. 1-6.
- Lamm, F. R., and Trooien T. P., 2002, *Subsurface Drip Irrigation for Corn Production: A Review of 10 Years of Research in Kansas*, Irrigation Science, Vol. 22, no. (3-4), pp. 195-200.
- Mady, A. A., and Derees, Abd. H., 2007, *Effect of Water Stress and Application of Compost on Water Use Efficiency and Productivity of Cucumber in Plastic House under Trickle Irrigation System*, Misr J. Ag. Eng. Irrigation and Drainage, Vol. 24, No. 1, pp. 182-197.
- Smucker, A. J., 2016, *A Transforming Soil Water Retention Technology that Eradicates Drought and Increases Crop Resilience to Changing Climates*, 5th International Conference on Agriculture & Horticulture June 27-29, 2016 Cape Town, South Africa.

NOMENCLATURE

FWUE = field water use efficiency.

SWRT = soil water retention technology.

T1 and T2 = treatment plots.

Y = crop yield.