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Improvement of Economic Water Productivity of Cucumber by using Soil Water Retention Technology under Subsurface Trickle Irrigation System

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Abstract— Subsurface soil water retention (SWRT) is a recent technology for increasing the crop yield, water use efficiency and then the water productivity with less amount of applied water. The goal of this research was to evaluate the existing of SWRT with the influence of surface and subsurface trickle irrigation on economic water productivity of cucumber crop. Field study was carried out at the Hawr Rajab district of Baghdad governorate from October 1st, to December 31st, 2017. Three experimental treatments were used, treatment plot T1 using SWRT with subsurface trickle irrigation, plot T2 using SWRT with surface trickle irrigation, while plot T3 without using SWRT and using surface tickle irrigation system. The obtained results showed that the economic water productivity in plot T1 was greater than plots T2 and T3. The increasing value was about 65 % and 124 %, respectively. The benefit of the installing SWRT along with subsurface trickle irrigation in the crop root zone assisted to keep 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 system, subsurface water retention technology, yield, economic water productivity.

1. Introduction

As the population increases and increases the use of water in urban areas, irrigated cultivation is being called to output more nourishment utilizing least water, and implementing it without deterioration the soil and the water resources, **[8]**. Irrigated cultivation has been a substantial involved to the development of domestic and universal food requirements since the 1960s and is predictable to play a main part in feeding the increasing earth inhabitance. With increasing irrigation processes requirement and rising contest in sectors that use water, the world presently facing a confrontation to output more food with least water. This aim will be factual only if suitable methods are set for water keeping and for much more water productivity (WP) in cultivation, **[1]**. One substantial method is to raise the output of water, **[4]**. The term of WP in agricultural production is concentrates on produce a lot of food with the same amount of water or is to produce the same amount of food with less water. WP is a way of showing how the system transforms water consumed into goods and services. It is criterion for profitable output for water actually depleted. As this profitable product could be crops, livestock, forests, fish and other mixed farming systems. WP can also be expressed from a particular product or service through a concept called (water foot point), which is water accounting by product, **[2]**. As the lack of water, resources and their scarcity at the present time prevent access to more food production required to meet the need for increase in the population. Therefore, it is necessary to improve food production by improving water productivity, which aims at produce more food with less water. Practices is utilized to obtain this contain water gathering, additional irrigation, deficit irrigation, accuracy irrigation methods and soil - water maintenance processes, **[5]**. One of the modern techniques for developing water productivity is the use of soil water retention technology (SWRT) with trickle irrigation system (surface or subsurface). SWRT is a new technology to increase plant productivity by applying as little irrigation water as possible and thus improving water productivity, **[10]**. It is an organized way to improve food production and cellulose biomass and retaining soil water near the root zone. It is a water-saving membrane made of low-density polyethylene (PE). It is designed to double the soil's ability to retain water in plant root areas in a way that increases the efficiency of water use substantial for the massive expansion of food and cellulosic biomass production wanted by the sharply growing global populations, **[9]**. Installing SWRT below the root zone resulted in increased water-holding capacity when applied in sandy soil by 23 % to 95 % depending on the amount of water processed, **[7]**. Additionally, SWRT in sandy soil is applied to improve and reduce the water deficit of the plants during the different stages of growth in the dry seasons. As for the subsurface trickle irrigation is more efficient than surface trickle irrigation as it reduces evaporation from the surface, where the sub-pipes and the emitters are buried beneath the surface of the soil at a certain depth depending on crop's root zone. As for the effect of subsurface trickle irrigation on efficiency of water use, the University of Kansas state in 1989 has conducted a study to develop the use of subsurface trickle irrigation to produce corn on loam soil of the central Great Plains, USA. Where they reduced the use of irrigation water for maize crop by 35 to 55% compared with the use of other irrigation systems. The effect of using the membrane sheet on water use efficiency (WUE), saving in irrigation water and on economic water productivity (EWP) on okra crop evaluated by **[3]**. The experimental work was conducted inside the greenhouse planted with okra (Abelmoschus esculentus L.) through the spring growing season 2017. The field study was located in Babylon Governorate south of Baghdad/Iraq of soil texture loam. Two treatment plots were used; T1 with SWRT (where the membrane sheet was installed at aspect ratio 2:1, at depth 45 cm below the soil surface) and T2 without SWRT. The results showed that saving in water in plot T1 by 77 %. Additionally, the increasing values in WUE and in EWP were; 148 % and 170 %, respectively.

The target of this search was to improve the economic water productivity of cucumber crop by utilizing soil water retention technology together with subsurface trickle irrigation system.

2. Materials and Methods

Experiential site for the field study, agricultural treatment plots, experiential layout and crop type and water productivity were discussed in details.

2.1 *Experiential Site for the Field Study*

This research was carried out in a greenhouse within the town of AL Yusufiyah, in the Governorate of Baghdad in Iraq for cucumber crop during the autumn time. The to December growing season was started from October1, 31, 2017. The experimental field was situated at latitude: 33°09' N, longitude: 44°24' E, and altitude: 34m. The applied water was from a well. Four soil samples were taken from the fieldwork at depths 15 cm and 30 cm. Laboratory analyzes of soil samples were carried out at the Graduate Laboratory of the Faculty of Agriculture, University of Baghdad. A physical property of the soil was conducted to identify the soil type and texture, field capacity, permanent wilting point, and apparent specific gravity. The average analysis of the soil texture for the four specimens of the greenhouse farm site was categorized as medium loam soil. The apparent specific gravity was equal to 1.54. Moreover, the field capacity and permanent wilting point values were tested and equal to 22.65 and 9.73 % (by volume), respectively.

2.2 *Agricultural Treatment Plots, Experiential Layout and Crop Type*

Surface and subsurface trickle irrigation system was used for irrigation through the growing season of the crop inside the greenhouse. The internal dimensions of the greenhouse are 9 m width and 10 m length and the cultivated area of 20 m2. Surface trickle system was used with double lateral pipes of diameter 13 mm and 10 m length, and each lateral pipe contains 25 emitters spaced at 0.4 m. The average flow rate from the emitter was $4.2*10^{\wedge -4}$ l / sec. Subsurface trickle system was used with double lateral pipes of diameter 16 mm and of length 10 m, and each lateral pipe contains 32 emitters spaced at 0.31 m. It was placed at a depth of 10 cm beneath the surface of the soil**. Fig. 1** presents the layout of the experimental plots of the greenhouse. Cucumber (Cucumis sativus) was planted next to each emitter of both sides for surface and subsurface trickle irrigation system. Three plots were used In plot T1, the membrane sheet for the study fieldwork. was placed beneath the soil surface with subsurface trickle irrigation system. At plot T2, the membrane sheet was also installed below the soil surface with surface trickle irrigation system. While in plot T3, surface trickle irrigation system was used only without installing the membrane sheet. The membrane sheet was a technique of installing a membrane made of 200µm low-density polyethylene sheet placed at depth equal to 25 cm beneath the ground with 2:1 (width to depth) aspect ratio. The membrane was manually installed and hands executed all the digging operations, no particular machine was utilized in the process. The width of membrane was 30 cm with both sides of the height 15 cm. **Fig. 2** presents the arrangement of the membrane sheet beneath the soil surface.

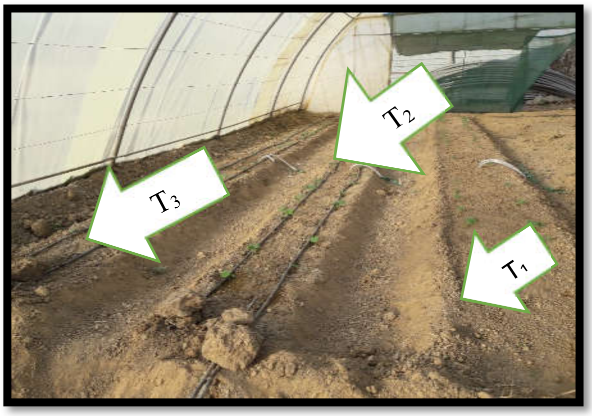

Figure 1: Layout of the experimental plots

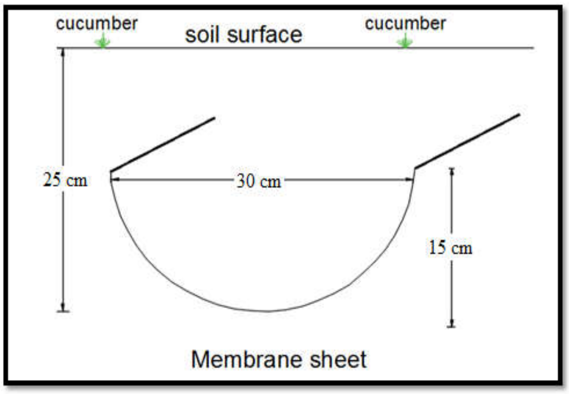

Figure 2: Arrangement of the membrane sheet beneath the soil surface.

2.3 *Water Productivity*

Water productivity is defined as "crop production" per unit "quantity of water consumed". In this research, the economic water productivity (EWP) will be calculated according to the following equation as stated by **[6]**:

$$\text{EWP (ID/m}^3\text{)} = \frac{\text{Yield (kg/m}^2\text{)} \times \text{Market selling price (ID/kg))}}{\text{Gross depth of applied water (m)}} \quad (1)$$

And

$$\text{Yield (kg/m}^2\text{)} = \frac{\text{Crop production}}{\text{m}^2} \quad (2)$$

3. Results and Discussions

Applied depth of water, crop yield and economic water productivity were discussed in details.

3.1 *Applied Depth of Water*

The irrigation process for the suggested plots was carried out by using the irrigation scheduling. The irrigation was started when the soil water content reached 50 % of the available water. Soil moisture content was measured daily by utilizing watermark sensors installed at different depths through the root profiles. The total depths of applied water during the growth season for plots T1, T2 and T3 were: 104, 147 and 203 mm, respectively. Saving of the applied water in plot T1 comparing with plots T2 and T3 was 41 and 95 %, respectively. Additionally, number of irrigation processes in plot T1 was recorded to be less than that in plots T2 and T3 by 3.22 times and 4.11times, respectively.

3.2 *Crop Yield*

The crop yield of cucumber was estimated for the three treatment plots, T_1, T_2 and T_3 according to equation (2). The average crop yields for plots T_1, T_2 and T_3 were 3.97, 3.4 and 3.5 Kg/m^2, respectively. The increasing value of the crop yield in plot T_1 was more than plots T_2 and T_3 by 16.8 and 13.4 %, respectively. This increase due to installing the membrane sheet especially together with subsurface trickle irrigation system. **Fig.3** presented the impact of SWRT and subsurface trickle irrigation system on cucumber harvest. There was a considerable variance between the plots.

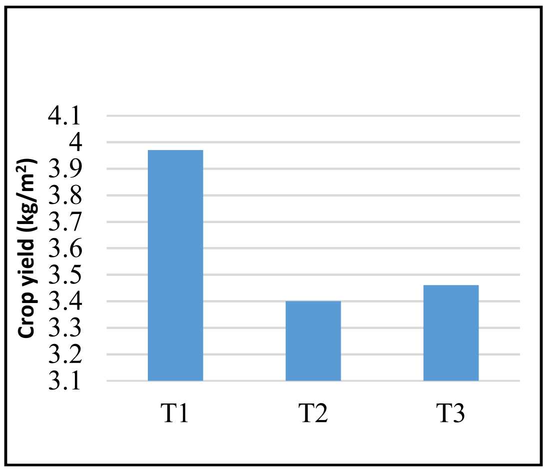

Figure 3: Comparison of the crop yield (kg/m^2) for cucumber for the growing season in plots T_1, T_2 and T_3.

3.3 *Economic Water Productivity*

The economic water productivity (EWP) for cucumber was evaluated via utilizing equation (1). The return's value was computed by multiplying the amount of crop yield by the market-selling price. EWP for plots T_1, T_2 and T_3 were 26719, 16191and 11928 ID/m^3, respectively. The EWP of cucumber in the growing season for treatment plot T_1 was more than in plots T_2 and T_3 by 65 % and 124 %, respectively. This increase value in T_1 was due to installing the membrane sheet especially together with subsurface trickle irrigation system, saving more irrigation water and more crop yield. The water productivity was mainly depending on crop yield and applied water, and as long the crop yield in plot T_1 was more than other plots and with less applied water.

Table 1 presented summary of the depth of applied water, crop yield and economic water productivity for the plots T_1, T_2 and T_3. The selling price in the market was also playing a substantial factor affecting the value of EWP as long as the farmer is looking for an economic issue as the first considered in the cultivated the plant and before beginning the project. Installing the membrane sheet in the crop root zone in treatment plots T_1 and T_2 assisted to keep the water, nutrients and fertilizers during the root zone profile, improving the field efficiency of the water use and then the parameters of water productivity.

Table 1: The depth of applied water, crop yield and economic water productivity of cucumber for plots T_1, T_2 and T_3.

Present study	Depth of applied water (mm)	Crop yield (kg/m^2)	EWP (ID/m^3)
T_1	104	3.97	26719
T_2	147	3.4	16191
T_3	203	3.5	11928

4. Conclusions

The followings conclusions were listed from this study work regarding the installation of the membrane sheet below the soil surface combined with the subsurface trickle irrigation system in plot T_1:

1- The crop yield was significantly affected by installing the membrane sheet especially together with subsurface trickle irrigation system. The crop production was increased per square meter of the field comparing with plots T_2 and T_3 by 16.8 % and 13.4 %, respectively.

2- The membrane sheet together with subsurface trickle irrigation was retained the applied water within the root zone. The saving in applied water comparing with plots T_2 and T_3 was 41 % and 95 %, respectively. Moreover, saving nutrient, pesticides and fertilizers materials.

3- The increasing value of the crop yield with less amount of the applied water in T1 resulting high value of economic water productivity comparing with plots T2 and T3 by 65 % and 124 %, respectively.

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تحسين إنتاجية المياه الاقتصادية لمحصول الخيارباستخدام تقنية احتباس المياه تحت سطح التربة تحت نظام الري بالتنقيط تحت السطحي

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الخلاصة – ان تقنية استخدام اغشية الاحتفاظ المياه تحت سطح الترب تعتبر تقنية جديدة لزيادة انتاجية المحصول و كفاءة استخدام المياه وايضا زيادة انتاجية المياه مع اضافة قليلة للماء المضاف. ان الهدف من هذه البحث هو تقدير تأثير استخدام الري بالتنقيط السطحي وتحت السطحي مع وبدون تقنية الاحتفاظ بمياه التربة على إنتاجية المياه الاقتصادية لمحصول الخيار. أجريت الدراسة الميدانية في منطقة هور رجب بمحافظة بغداد من تشرين الأول / أكتوبر إلى كانون الأول / ديسمبر2017. تم استخدام ثلاث معالجات زراعية تجريبية، كانت المعالجة الاولى باستخدام الاغشية مع نظام الري بالتنقيط تحت السطحي والثانية باستخدام الاغشية مع نظام الري بالتنقيط السطحي و الثالثة بدون استخدام الاغشية مع استخدام نظام الري بالتنقيط السطحي. أظهرت النتائج أن إنتاجية المياه الاقتصادية كانت الأعلى في المعالجة الزراعية الاولى مقارنة مع المعالجات الثانية والثالثة حيث كانت الزيادة بحدود 65٪ و124٪ على التوالي. أظهرت نتائج هذه الدراسة أن تثبيت تقنية الاحتفاظ بالمياه تحت سطح التربة مع استخدام منظومة الري بالتنقيط تحت السطحي في المنطقة الجذرية يساعد في الحفاظ على الماء المضاف والمغذيات والأسمدة في منطقة الجذر، وتحسين الكفاءة الحقلية لاستخدام المياه ومن ثم معيار إنتاجية المياه.

الكلمات الرئيسية – : نظام الري بالتنقيط تحت السطح,تقنية احتفاظ المياه تحت السطح , الإنتاجية , إنتاجية المياه الاقتصادية .