J. of Plant Production, Mansoura Univ.,Vol 11 (6): 591-594, 2020

Journal of Plant Production

Journal homepage: www.jpp.mans.edu.eg
Available online at: www. jpp.journals.ekb.eg

Cauliflower Water Productivity, Growth, and Yield in Response to Irrigation Management Using Different Water Sources

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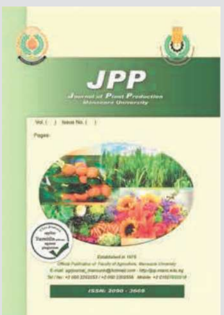

ABSTRACT

The present study aimed to estimate water use efficiency for cauliflower crop production using different irrigation water sources. This research was carried out during the seasons of 2018-2019 in the Research Field Station of the College of Agricultural Engineering Sciences, University of Sulaimani. The experiment was laid out in randomized complete block design with three treatments and three replicants. The cauliflower plants were grown under a surface irrigation system. The three treatments were: (I_1) River water irrigation and (I_2) Sewage water irrigation during the entire growing seasons from planting to harvest, and (I_3) alternate irrigation which meant one river irrigation water followed by two sewage irrigation water, alternatively. The results showed that the means of irrigation water requirements were 441, 457, and 427 mm for river water, sewage water, and alternate irrigation, respectively. It is observed that I_3 had significantly higher WUEc (6.33kg m^{-3}) and compared with other treatments I_1 and I_2 (5.13 and 4.27 kg m^{-3}), respectively.

Keywords: Water use efficiency, Water Productivity, Sewage water, Cauliflower

INTRODUCTION

Currently, the demand for more food and water has increased significantly and there will be more demands which are estimated by many folds by 2050 due to the increase of the global human population. To fulfill these demands, agricultural production growth will deepen the compete on utilizing more land, water, and energy (Islam and Karim, 2019). Consequently, it is getting difficult to maintain and guarantee the adequate amount of food and water supply for the current and future generations' demands, due to climate change, the water shortage and uncertain maintenance of the natural resources (Mckenna, 2012 and Asuquo and Etim, 2012). It is expected that guaranteeing these greater quantities of food production will require 50% more water within the use of current water use efficiency rates for agricultural production regardless the climate change and environmental pollution (Clay, 2004).

The Kurdistan region is located in northern Iraq with a semi-arid climate that hot dry summer and cold rainy winter. About half of the water sources in this region come from neighboring countries. Some of the vegetable crops are cultivated near the urbanized areas in this region. The sources of irrigation waters nearby the major cities are mixed with wastewaters from municipality and factory wastewater. To adapt to the water scarcity crisis and mitigate contamination, farmers need alternatives to improve the water use efficiency, and safe use of wastewater. it is previously studied that the frequent and continuous use of wastewater for irrigation may lead to soil and groundwater contamination, and health risks through heavy metal bioaccumulation (Hicks and Hird, 2000).

Cauliflower (*Brassica oleracea L.*) (Family: Brassicas) is of the cultivated and consumed vegetables for its high nutrition (Jahangir et al., 2009; Ahmed and Ali, 2013) and consumption (Serrano and Rolle, 2018). Cauliflower growth and yield are highly influenced by irrigation water quantity and regularity and sensitive to water shortage (Kochler and Kage, 2007).

The present study aimed to estimate the impact of sewage water management on the yield of cauliflower and water productivity in the Sulaymaniyah Governorate, Kurdistan Region of Iraq.

MATERIALS AND METHODS

A field experiment was carried out in the research field station of the College of Agricultural Engineering Sciences, University of Sulaimani, Bakrajo district, the Sulaymaniyah governorate, Kurdistan Region of Iraq (35°32'40.9"N 45°21'55.2"E) during the growing seasons 2018-2019. Soil samples were collected from the

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experimental site at the depths 0-10, 10-20 and 20-40 cm, and analyzed according to standard methods (Black et al., 1965) for some physicochemical properties (See Table 1)

Table 1. The Physicochemical Properties of the experimental site's soil

Parameters	Unit	Soil Test Values
Bulk Density	mg cm^{-3}	1.26
Particle Density	mg cm^{-3}	2.53
Organic Matter	gm kg^{-1}	22.40
Electrical Conductivity	dSm^{-1}	0.45
pH	---	7.28
$CaCO_3$	gm kg^{-1}	270
The Volumetric Moisture Content and Tensions		
Water Content at KPa 33		30.03
Water Content at KPa 1500	%	19.34
Available Water		10.69
Soil Texture		
Sand		66.06
Silt	gm kg^{-1}	511.93
Clay		422.02
Textural Class	---	Silty Clay

The experiment was laid out in Randomized Complete Block Design (RCBD) with three treatments, and three replications. The treatments were the use of river water for irrigation (I_1), sewage water (I_2), and the use of both sewage and river water sources alternatively (one river water irrigation followed by two sewage water irrigation) (I_3) during all growing season. The land was plowed with the share-plough and softened with rotary-plough. Furrow with 1.5 m width was ditched between the plots to avoid lateral movement of water.

The cauliflower (*Brassica oleracea*) seedlings were transplanted to the plots in the open field on 20th September 2018 under a surface irrigation system. The spacing was 45 cm between the plants and 100 cm between the rows. A Compound fertilizer (N-P-K 18-18-18 + micro-nutrients) was applied to all the treatments. All the required Agricultural practices were done as they are required. Surface irrigation water was flown through a pipe network. The quantity of applied irrigation water for each experimental plot was estimated by a meter based on the gravimetric. Actual Evapotranspiration (Eta) was estimated according to the equation below (Ati, et al., 2019):

$$I + P = ETa \dots\dots (1)$$

Where:

P=Precipitation (mm)
ET_a= Actual Evapotranspiration (mm).
I= Irrigation water

Water productivity was estimated according to the following equation (Allen et al., 1998):

$$Water\ Productivity = \frac{Yield}{ETa} \dots\dots (2)$$

The cauliflower crops were harvested on 1st February 2019. Six plants from each experimental unit were taken for the measurement of growth and yield parameters, including; head diameter (cm), the number of leaves, leaf area (cm^2), and total yield (ton ha^{-1}). The plant samples were taken to a laboratory for analysis. The edible parts of the plant samples were washed with distilled water, air dried, and then oven-dried at 80ºC for 48 hours. Concentrations of some heavy metals (namely; Pb, Cd, Fe, Cu, and Zn) were determined with atomic absorption spectrophotometer according to Reilly (1991). The recorded data of all parameters and measurements were statistically analyzed using SAS. 2012 software and the means were compared according to the least significant difference (LSD) ($p \leq 0.05$).

RESULTS AND DISCUSSION

As shown in Table (2) the data recorded on the cauliflower growth and yield parameters showed no significant differences. The cauliflower crop yield was 22.63, 19.50, and 27.02 tons ha^{-1} for I_1, I_2, and I_3, respectively. It is observed that I_3 had given smaller heads (16.48 cm) in comparison to I_1 (17.65 cm) but a relatively higher yield (27.02 ton ha^{-1}), and a smaller number of leaves (24.07) compared to I_1 (27.20) but a bigger leaf area (290.83cm^2) than other treatments while wastewater considered to be rich in useful nutrients for plant growth and yield (Khurana and Singh, 2012; Kharche, et al., 2011).

Table 2. Cauliflower Growth and Yield Parameters as influenced by irrigation water treatments

Experimental Treatment	Head diameter (cm)	Leaf Area Average (cm^2)	Number of leaves	Weight of Head & Leaves (kg)	Total yield (ton ha^{-1})
I_1	17.65	238.05	27.20	4.64	22.63
I_2	13.70	218.10	22.87	4.03	19.5
I_3	16.48	290.83	24.07	4.97	27.02
p-Value	0.588 n.s	0.601 n.s	0.140 n.s	0.757 n.s	0.790 n.s

*** p-Value significant at 0.05 Level.**

It is observed from results in Table (3) that the actual water consumptive (ETa), and irrigation water (IR) was significantly varied ($P \leq 0.05$) between the treatments with the means 441, 457 and 427 mm for river water (I_1), sewage water (I_2), and alternate (I_3) irrigation, respectively. The results indicate that the values of water consumptive use for alternate treatment (I_3) was significantly lower in comparison to other treatments, even though, the rainfall rate was relatively high during the growing season, and the quantities of added irrigation water were equal or close to the field capacity.

Furthermore, the results have also shown a significant difference between irrigation treatment and crop water use efficiency (WUEc), 5.13, 4.27, and 6.33 kg m^{-3} for I_1, I_2, and I_3 treatments, respectively. Though significant differences were seen for the quantities of actual water consumption (ETa), added irrigation water (IR), and crop water use efficiency (WUEc) between the treatments, no significant differences were found in growth and yield parameters of the experimental cauliflower plants in this study.

Table 3. Actual water consumption (ETa), added irrigation water (IR) and crop water use efficiency (WUEc) influenced by irrigation water treatments

Experimental Treatment	Precipitation (mm)	IR (mm)	Eta (mm)	WUEc (kg m^{-3})
I_1	388	53	441	5.13
I_2	388	69	457	4.27
I_3	388	39	427	6.33
p-Value	---	0.000**	0.000**	0.000**

* p-Value significant at 0.05 Level.

Some of the farmers nearby Sulaymaniyah city, frequently use untreated sewage water that flows into the rivers and other irrigation water sources to irrigate their vegetable farms and orchards. From the results of this study, it can be recommended that these farmers might use alternate irrigation (I_3), which may help in the reduction of the soil and bio-contamination with heavy metals which might cause a serious health risk for human and animals (Wuana and Okieimen, 2011; Isam, 2008).

Table 4. shows the analysis results of some heavy metal concentrations in the sewage water samples collected and used in this experiment. It is observed that from the results, all the determined heavy metals (Pb=0.17, Zn=0.02, Mn=0.02, and Cu=0.03 mg L^{-1}) were lower than the recommended maximum concentrations, at that time, except cobalt (Co =0.07 mg L^{-1}) which tends to be inactivated by neutral and alkaline soil (Ayer and Westcot, 1985). The pH of experimental soil (see table 1) and mostly in the Sulaymaniyah governorate is neutral to slightly alkaline (Azeez and Rahimi, 2017).

Table 4. The concentration of some heavy metal in the sewage irrigation waters

Heavy metals	Concentration (mg L^{-1})	Recommended Maximum Concentration (mg L^{-1}) *
Pb	0.17	5.00
Zn	0.02	2.00
Mn	0.02	0.20
Cu	0.03	0.20
Co	0.07	0.05

* adopted from Ayer and Westcot (1985)

CONCLUSION

Some farmers often depend on untreated sewage water for irrigation due to having no access to enough clean water for crop production. It is clear that the absence of sewage water treatment plant in the Sulaymaniyah governorate may cause a high risk of contamination of the irrigation water sources around Sulaymaniyah city. As an alternative for these farmers, it is recommended from this study that the use of sewage and clean water in alternation is more efficient in terms of water use efficiency and productivity and has less health risk compared to the use of untreated sewage water.

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إنتاجية المياه ، نمو وحاصل نبات القرنبيط تحت ادارة نظام الري باستخدام مصادر مختلفة للري

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الهدف من إجراء هذه الدراسة هو تقدير كفاءة استخدام المياه لإنتاج محصول القرنبيط باستخدام مصادر مياه ري مختلفة. نفذ البحث لخريف موسم 2018- 2019 في محطة البحوث بكلية علوم الهندسة الزراعية ، جامعة السليمانية. وباستخدام تصميم القطاعات العشوائية الكاملة لثلاثة (مصادر) معالجات للمياه وهي: (I1) الري بمياه النهر و (I2) الري بمياه الصرف الصحي بدون معالجة و (I3) الري البديل والذي استخدم فيه نظام التناوب برية واحدة لمياه النهر تليها ريتين متتاليتين بمياه الصرف الصحي لنبات القرنبيط طيلة موسم النمو تحت نظام الري السطحي. أوضحت النتائج أن متوسط مياه الري كان 441 و 457 و 427 مم لمياه النهر ومياه الصرف الصحي والري البديل على التوالي. لوحظ أن كفاءة استخدام المياه WUEc لI3 كان أعلى بكثير من (6.33 كجم م -3) مقارنة بالمعالجات الأخرى I1 و I2 (5.13 و 4.27 كجم م -3) ، على التوالي.