IOP Conference Series: Earth and Environmental Science

The Role of Sewage Irrigation Management in Water Productivity, Growth and Yield Parameters of Broccoli in Al-Sulaimani government/Kurdistan region

IOP Conf. Series: Earth and Environmental Science **388** (2019) 012086 doi:10.1088/1755-1315/388/1/012086

The Role of Sewage Irrigation Management in Water Productivity, Growth and Yield Parameters of Broccoli in Al-Sulaimani government/Kurdistan region

A S Ati [1] , B R Rahim [2] , H A Neima[3] and R H Muhamad[4]

[1]Department Soil and water resourcesCollege of Agriculture Engineering Sciences / University of Baghdad ,Iraq

[2] Department Plant Protection, University of Sulaimani / College of Agricultural Sciences , Iraq

[3]Department Soil and water resources, University of Sulaimani / College of Agricultural Sciences , Iraq

[4]Department Soil and water resources, University of Sulaimani / College of Agricultural Sciences , Iraq

Email alaa.salih@coagri.uobaghdad.edu.iq [1]

Abstract. The objective of the present work was to estimate water requirements and water use efficiency for Broccoli under normal irrigation conditions and sewage irrigation. Field experiment was carried out during the season 2018 at station/Sulaimni agricultural station/ Bakrajo –College of Agricultural Sciences. The experiment included three treatments: River water irrigation in all season growth (I_1), Sewage water irrigation in all season growth (I_2), Alternate irrigation (one river irrigation followed by two sewage water irrigation) in all season growth (I_3). The experimental Design was Randomized Complete Block Design (RCBD) with three replications. Broccoli planted under surface irrigation system. Mean irrigation requirement for irrigation management scheduling gave water consumptive use values 442, 432 and 427 mm for river water, sewage water and alternate irrigation, respectively. Average yield Broccoli plant was 32.67, 40.25 and 46.73 Ton ha^{-1} for river water irrigation, sewage water irrigation and alternate irrigation, respectively. High performance of Alternate irrigation application was mentioned by plant height which record 39, 42 and 46 cm; head diameter 21, 25 and 28 cm; leaf area 306, 329 and 349 cm^2 and number of leaves 18, 21 and 22 for river water irrigation, sewage water irrigation and alternate irrigation, respectively. WUEc were 7.39, 9.32 and 10.94 kg m^{-3} for river, sewage and alternate treatments, respectively. The results showed that the concentrations of these elements did not reach the critical limits in the fruits for all irrigation treatments. This is a positive and good result due to the increase in rainfall rates in this season led to weak accumulation of heavy metals in the soil and poor absorption by the plant.

1. Introduction

Increasing frequencies of drought coupled with increasing populations require more water for irrigated agriculture. As global populations approach 9 billion by 2050, even more water will be required to produce an estimated 60% to 70% more food. In other words, the adequate food and water cannot be guaranteed for the current and next generations, due to the water shortage and uncertain maintenance of the natural resources [1 and 2]. Production of these greater quantities of food requires, at current water use efficiency rates, 50% more water [3]. The world loses 691 km^2 of agricultural land as a result of desertification, this increases the pressure on the most important water resources of the world. 97% of water is located in the seas and oceans and it is limited in use, 2% in the poles and 0.6% of water for Human, animal and plant as estimated 12,500 km^3 [4]. Iraq is located in arid and semiarid region. Consequently, sufficient water is not available to irrigate the cultivated crop farms. Kurdistan region part of Iraq area, therefore, today more of crop and vegetable extensively cultivated in large area of Kurdistan under the effect of water scarcity. To live with this crisis (water scarcity) must find alternatives to help raise the water productivity and yield, including the use of wastewater but in a scientific and rational quantity that does not affect the quality crops especially the crops (are eaten leaves or vegetative part of them) through the rational management of the process of irrigation.

Broccoli requires adequate soil moisture to maximize yield and quality, especially during flower head formation. Overwatering can cause loose heads or hollow stems to develop and can promote root diseases. Broccoli is mostly irrigated with furrows and overhead sprinklers, and Total water requirement is approximately 440mm. As a general guideline apply 10 to 15 mm per week for the first third to half of the growing season, and about 25 mm per week thereafter for winter production. Corresponding figures during summer would be 20 to 25 mm and 40 to 50 mm, respectively [5]. Broccoli (*Brassica oleracea*) is a cool-season crop that requires moderate temperatures for optimum growth and quality; it performs poorly in hot weather. As a member of the crucifer family, broccoli is closely related to other well-known cole crops, such as cabbage, cauliflower and Brussels sprouts. Therefore our current study is the first study in Iraq and the Kurdistan region to estimate the water requirement of Broccoli under irrigation management with different water quality.

2. Materials and Methods

A field experiment was conducted on silt clay soil, to cultivate the Broccoli (*Brassica oleracea*) (Shaspa varieties) crop during the 2018-2019 season, located in the research area of field station/Sulaimni agricultural station/ Bakrajo –College of Agricultural Sciences. The prevailing soil was a silt clay texture. The basic characteristics of the soil were determined by taking samples from three sites and the depths 0-0.10, 0.10-0.20 and 0.20-0.40 m. Soil characteristics were estimated according to standard methods [6] (Table 1). The soil moisture release curve was estimated at 33 and 1500 kPa for samples taken from depths 0.10, 0.20, 0.30 and 0.40 m. Soil available water content was calculated from difference in moisture content at 33 and 1500 kPa. The soil plowed two orthogonal plows with the plow-bearing plow and softening with the disk plough. The experimental layout consisted of complete randomize block design with three replicates. The plots were isolated by ditches of 1.5 m in width to avoid lateral movement of water.

The experiment included three treatments: River water irrigation in all season growth (I_1), Sewage water irrigation in all season growth (I_2), Alternate irrigation (one river irrigation followed by two sewage water irrigation) in all season growth (I_3). The experiment Design was Randomized Complete Block Design (RCBD) with three replications. Broccoli planted under surface irrigation system. Seedlings were planted on trench and plants spaced were 0.50 m × 0.35 m on 20/9/2018 and harvest was on 1/2/2019. Compound fertilizer (N-P_2O_5-K_2O 18-18-18) was applied to all treatments according to recommendation of Agriculture Ministry in Sulaimani government/Kurdistan region. All required management practices were done as they are required.

Irrigation water was applied through a plastic pipe network connected to an electric pump and water meter to measure the quantities of water applied to each experimental plot, when 35% of the available water was depleted based on gravimetric method according to the following equation:

$$d = (\theta_{fc} - \theta_w)D \ldots\ldots (1)$$

Where d = depth of water applied (mm), θ_{fc} =Volumetric water content at field capacity (cm^3 cm^{-3}), θ_w = Volumetric water content before irrigation (cm^3 cm^{-3}), D = Soil depth to be wetted at irrigation (0-0.30 m).

Water consumptive use (evaporation) of the crop was measured using the following water balance equation:

$$(I + P + C) - (ET_a + D + R) = \mp \Delta s \ldots\ldots (2)$$

I=irrigation (mm), P=precipitation (mm), C= capillaries (mm), ET_a= actual evapotranspiration (mm), D= deep percolation (mm), R=rune off (mm), ΔS= changes in the water storage during soil profile, R=0 (plain soil), C=0

Table1. Some physical and chemical properties of soil

Property	Unit	value
Sand	gm kg^{-1}	66.06
Silt		511.93
Clay		422.02
Texture	Silt Clay	
Bulk density	Mg kg^{-3}	1.26
Particle density	Mg kg^{-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
Volumetric moisture content at tensions		
Water Content at KPa 33	%	30.03
Water Content at KPa 1500		19.34
Available Water		10.69

limited contribution , water table depth= 3m) and D=0 (because irrigation is limited to depletion at field capacity) Equation (2) becomes:

$$I + P - ET_a = \pm\Delta s \ldots\ldots (3)$$

In this study, the soil water content at the beginning of the study was found to be close to its content at the end of the experiment, ie, D ≈ 0

The water consumptive use equation becomes as follows:

$$I + P = ETa \ldots\ldots (4)$$

Water productivity (Crop water use efficiency) was measured as well according [7]:

$$water\ productivity = \frac{yield}{ETa} \ldots\ldots (5)$$

At maturity stage 6 plants from middle line in each treatment were selected for calculations of plant height in cm, head diameter in cm, number of leaves, leaf area and total yield (ton ha^{-1}). Samples of Broccoli fruit for different water treatment has been taken, and put in plastic bags to a avoid contamination then taken to laboratory for analysis. The edible parts of the vegetables used for human consumption were washed with distilled water, dried in air oven at 80ºC for 2 days until reached constant weight. Concentrations of heavy metals Pb, Cd, Fe, Cu and Zn according to methods of [8] using atomic absorption spectrophotometer. Data were statistically analyzed using the [9] software, and the least significant difference (LSD) ($p \leq 0.05$) was used.

3. Results and Discussions

The results showed (Table 2) the irrigation water management scheduling gave not varying averages for actual water consumptive use values 442, 432 and 427 mm for river water, sewage water and alternate irrigation, respectively. The results indicate that the values of water consumptive use are close because the high rainfall rates in the season, which led to not significant clear differences, and the equal variation in the water consumption rates is due to the fact that the quantities of irrigation water added to the treatment were equal and close to the field capacity. This makes Broccoli suitable for growth in this regions where farmers can rely on monsoon rains. This can be attributed to improvement in total porosity and aggregate stability in the sewage-irrigated soils due to addition of organic matter which plays an important role in improving soil physical environment [10]. Therefore the result of this study is the first of its kind to know the water requirement of Broccoli and its suitability for agriculture in Iraqi and Kurdistan region under the conditions of rainfed agriculture in that year or in this agricultural season.

The results of Broccoli growth and yields parameters are plotted in Table (3). Average yield Broccoli plant was 32.67, 40.25 and 46.73 Ton ha^{-1} for river water irrigation, sewage water irrigation and alternate irrigation, respectively. From them value and value of LSD 0.05 it is obvious that Alternate irrigation produced a significantly higher than all other treatments. Same trends were found for Broccoli growth. High performance of Alternate irrigation application was mentioned by plant height record 39, 42 and 46 cm; head diameter 21, 25 and 28 cm; leaf area 306, 329 and 349 cm^2 and number of leaves 18, 21 and 22 for river water irrigation, sewage water irrigation and alternate irrigation, respectively. The alternate irrigation treatment (one river irrigation followed by two sewage water irrigation) in all season growth has produced higher significant Broccoli yields and growth parameters than river water and sewage water irrigation treatments. The reason could be related to the high ability of organic matter to absorb water and hence nutrients. The sewage water irrigation treatment has produced higher and significant yield than the river water irrigation treatments. This is probably due to the fact that sewage water irrigation resulted in large pores therefore water holding capacity and nutrient are lower the river water irrigation, also the use of sewage water for irrigating agricultural crops in the vicinity of big cities because of its plant essential nutrient content which serves as a low analysis fertilizer. Research has shown beneficial effects of sewage irrigation on soil fertility.

Table 2. Actual water consumption (ETa) and added irrigation quantities for Broccoli as influenced by irrigation management

Treatments	Actual evapotranspiration and irrigation water applied(mm)					
	ETa (irrigation water + precipitation)					
	September	October	November	December	January	Total
River water irrigation	27	60	100	45	210	442
Sewage water irrigation	30	55	100	37	210	432
Alternate irrigation	20	60	100	37	210	427
average	26	59	100	40	210	435
	irrigation water					
River water irrigation	27	11	---	16	---	54
Sewage water irrigation	30	16	---	8	---	54
Alternate irrigation	20	11	---	8	---	39
Average	26	13	---	11	---	49

Table 3. Plant height (cm), Head diameter (cm), Leaf area (cm^2), Number of leaves and Total yield (Ton ha^{-1}) of Broccoli as influenced by irrigation management

Treatments	Plant height (cm)	Head diameter (cm)	Average of Leaf Area (cm^2)	Number of leaves	Total yield (Ton ha^{-1})
River water irrigation	39	21	306	18	32.67
Sewage water irrigation	42	25	329	21	40.25
Alternate irrigation	46	28	349	22	46.73
LSD 0.05	0.126	0.562	2.765	0.223	3.191

The results showed that the fruit yield ranged from 40.25 to 46.73 for the sewage and alternate irrigation treatments, respectively compared with 32.67 ton ha^{-1} for normal irrigation treatments, noting that alternate treatment gave the highest fruit yield and significantly different from other treatments (Table 3). The results also indicate that sewage and alternate irrigation treatments caused a significant increase in fruit yield from 23.21 and 43.04%, respectively compared to normal irrigation treatment. The increase is due to the fact that sewage irrigation has affected one or more of

IOP Conf. Series: Earth and Environmental Science **388** (2019) 012086 doi:10.1088/1755-1315/388/1/012086

the components of the crop, depending on the stage of growth. The sewage irrigation increased the all the expansion of the total vegetative, which led to the light exposure, increase the rate of photosynthesis and the amount of accumulated dry matter.

The results indicated a significant difference between irrigation treatment and crop water use efficiency (WUEc). WUEc were 7.39, 9.32 and 10.94 kg m^{-3} for river, sewage and alternate treatments, respectively (Figure 1). The difference in the efficiency of the irrigation treatment in water use efficiency is due to differences in the duration of growth, amount of water used by the plants, amount of dry matter produced and the transfer of part of the total dry matter in plants towards fruit, which is directly associated with water use efficiency. These result indicted the role of rainfall, increased wetted soil volume inside root zone and this mean increasing in water volume which was stored in root zone.

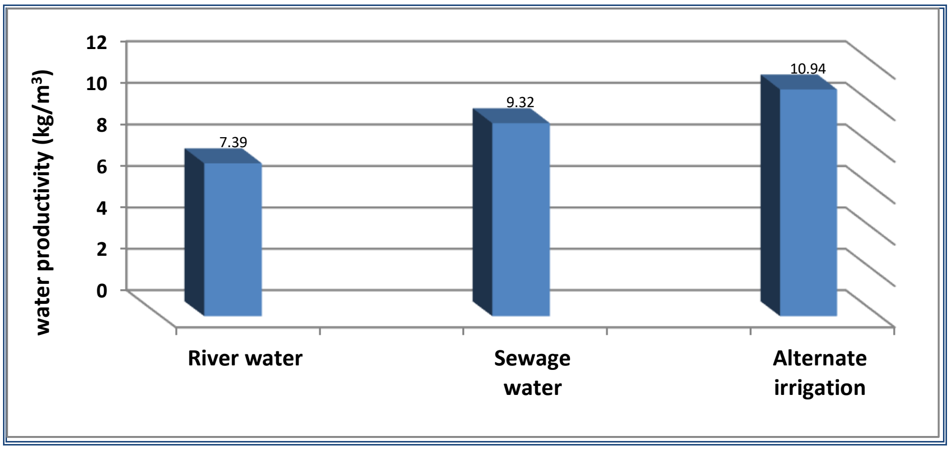

Figure 1. Water use efficiency crop of Broccoli as affected by the irrigation treatments.

Figure 2 clearly list the concentration of lead, cadmium, iron and copper in fruit of Broccoli (ppm). The results showed that the concentrations of these elements did not reach the critical limits in the fruits for all irrigation treatments. This is a positive and good result due to the increase in rainfall rates in this season led to weak accumulation of heavy metals in the soil and poor absorption by the plant.

That most vegetable farmers in this region of Kurdistan region (Sulaimani government) using sewage to irrigate to irrigate vegetables frequently. Through the results of our current study, we can say, that farmers can use two or more irrigation (sewage or/and alternative irrigation) in the event of ensuring good rainfall rates, which result in lack of fear of the use of these fruits by human, and we should attention in the long-term use this may **contaminate** the soil with heavy metals which may pose serious human and animal health risk, this result according with [11 and 12].

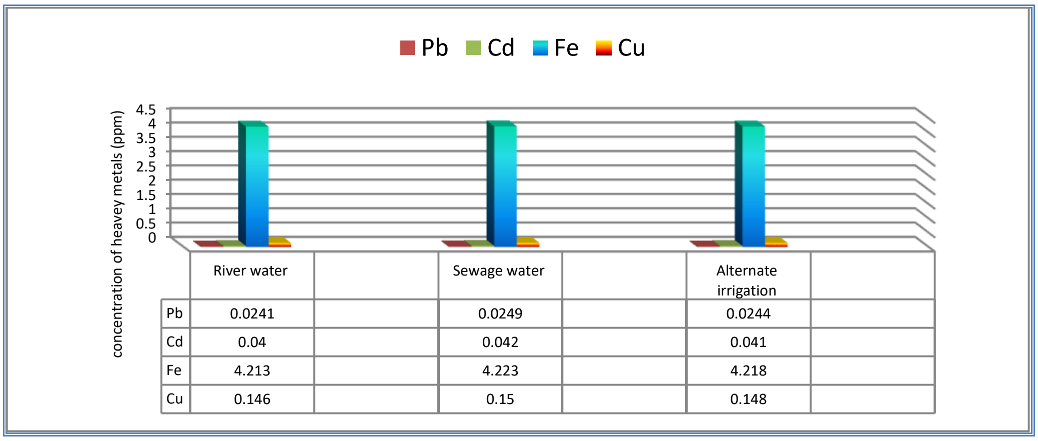

Figure 2. The concentration of Pb, Cd, Fe and Cu in fruit Broccoli as affected by the irrigation treatments

IOP Conf. Series: Earth and Environmental Science **388** (2019) 012086 doi:10.1088/1755-1315/388/1/012086

References

[1] Mckenna, T. 2012.“*Feed the future deputy coordinator for development*'', Report before the senate foreign relations international development subcommittee. November 28, 2012. http://www.usaid.gov/news-information/congressional-testimony/testimony-tjada-mckenna-feed-future-deputy-coordinator.

[2] Asuquo, J. and E. Etim. 2012. Physicochemical and bacteriological studies of selected borehole water in Uyo Metropolis in Akwa Ibom State. International Journal of Modern Chemistry. **1(2):**7-14.

[3] Clay, J. 2004. “*World Agriculture and the Environment*'': A Commodity-by-Commodity Guide to Impacts and Practices. Chicago: Island Press.

[4] Arab Organization for Agriculture Development. 2000. Effect of drought on agriculture yield. **2: 24**-35. In Arabic.

[5] Michelle, S. **2015**. Broccoli Production in California. Vegetable Production Series. Uc Vegetable research and Information Center.

[6] Black,C.A.1965 Methods of soil analysis. Physical & mineralogical properties. ASA. Medison. Wisc. USA.

[7] Allen, R.G., Pereira, L.S., Raes, D., Smith, M. 1998. *Crop Evapotranspiration*. FAO Irrigation and Drainage, **Paper 56**, Rome.

[8] Reilly, C. 1991. Metal contamination of food. 2 Edn., London. Applied Sciences Published

[9] SAS. 2012. Statistical Analysis System, User's Guide. Statistical. Version 9.1th ed. SAS. Inst. Inc. Cary. N.C. USA.

[10] Kharche V., V. Desai and A. Pharande. 2011. Effect of Sewage Irrigation on Soil Properties, Essential Nutrient and Pollutant Element Status of Soils and Plants in a Vegetable Growing Area around Ahmednagar City in Maharashtra. Journal of the Indian Society of Soil Science. **59 (2):** 117-184.

[11] Isam, M. The level of heavy metals in selected vegetables crops collected from Baghdad city markets. Pakistan Journal of Nutrition. **9(7)** 683-685.

[12] Afshin, M., and M. Zarasvand. 2008. Heavy metals in selected vegetables and estimation of their daily intake in sanadaj. Iran, Southeast. Asiar Journal Trop. Med. Health. **39:336**-340.