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Research Article

Saline Water Impact on Water Use Efficiency of Bitter Melon (*Momordica charantia* L) Using Drip Irrigation

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Water shortage is a real problem in many parts of the world and finding alternative solutions such as the application of saline water in cropping systems is highly appreciated. Research on drip irrigation and soil salinity is still inadequate, and their effect on crop yield and water use efficiency (WUE) is a huge challenge for small farmers. The present study was conducted in Malir, a semiarid region in the Sindh province of Pakistan. The purpose was to estimate the effects of two different qualities of irrigation water including fresh quality water (IT_1 0.56 dS m^{-1}) and saline groundwater (IT_2 2.89 dS m^{-1}) on WUE using drip irrigation technology in 2018–19. The experimental design was complete randomized block design (RCBD) with two treatments of irrigation: (1) freshwater (IT_1) with 0.56 dS m^{-1} electrical conductivity and (2) saline water (IT_2) with 2.89 dS m^{-1} electrical conductivity. The average biomass and crop yield under IT_1 were 10.2 t.ha^{-1} and 7.4 t.ha^{-1}, respectively, and were found higher than those under IT_2 (7.3 t^{-1} and 4.2 t.ha^{-1}, respectively). Hence, both the treatments remained equally effective in season 1 as compared to season 2 ($p \leq 0.05$). The WUE of bitter melon under IT_1 was 1.60 and 1.56 kg.m^{-3} in seasons 1 and 2, respectively, and was higher than those under IT_2 which were observed 1.21 and 1.07 kg.m^{-3} in seasons 1 and 2, respectively.

1. Introduction

The unavailability of freshwater is a serious worldwide threat, especially in dry climatic conditions [1] as the global population is facing an extreme shortage of freshwater [2]. Close to 92% freshwater of the world is linked to agriculture [3]; thus, there is a growing concern about declining freshwater supplies, which may endanger meeting the growing demand of several goods and services [4]. The water shortage limits sustainable agricultural development around the world [5]. The groundwater abstraction rate is growing by 2% per year globally [6]. In the year 2000, approximately 75% of all water withdrawals accounted for agricultural purposes in developing countries with a probable increase requirement of 14% by 2030 in order to meet food demands [7]. Therefore, the world is expected to face a 40% water deficit globally under the present situation [8]. Irrigation water comprising large amounts of sodium is of special concern due to sodium's effects on the soil and posing sodium hazard [9]. Salt intrusion is the most significant hazard causing crop reduction and unsuitable environmental and hydrological conditions that limit the normal crop development [10]. Nevertheless, the effects of each component of salinity such as anions and cations are quite different on plant growth and production, ranging from beneficial to very toxic [11, 12]. Salinity problems occurred in arid and semiarid regions due to the hot and dry weather, thus leading to a high evapotranspiration rate and may cause the salt concentration to increase in the soil [13].

For several years, the drip irrigation system has witnessed global promotion [14]. Besides, farmers have adapted this system according to their specific conditions, and its performance has remained dynamic [15]. A drip irrigation system attached with fertigation could increase yield up to 60% over surface irrigation [16]. For enhancing water use efficiency (WUE), this system was used in studies in South Asia [17]. In many parts of the Middle East including Iran, drip irrigation is the major method of irrigation of cropping lands due to limited water availability [18, 19].

Bitter gourd (*Momordica charantia* L), also identified as bitter melon, is cultivated in the Northern Territory, Queensland and New South Wales, and a slight quantity in Western Australia [20]. This crop is grown in Pakistan with a yearly production of 57190 t [21].

2. Material and Methods

2.1. Experimental Site. The experimental site was situated in Malir, Karachi-the southern Sindh, Pakistan (Figure 1). The texture of the experimental soil was sandy loam, whereas the climate of this area is warm and humid; the maximum temperature in summer surpasses 40°C. The evaporation rate in the southern zone of Sindh is comparatively higher than that in elsewhere in Pakistan [22]. The average yearly precipitation has been 217 mm, while due to the vicinity to the sea, the relative humidity ranges between 52% and 78% [23].

2.2. Experimental Design. The experimental flow chart is shown in Figure 2. An experimental block of 20.25 m × 24 m was selected, tilled thoroughly, and levelled partially. This block was further separated into two equal sub-blocks by complete randomized block design (RCBD), replicated thrice with a separate block of 20.25 m in 12 m (243 m^2) (Figure 3). Two irrigation treatments, one in each block, applied were IT_1 (EC 0.56 dS m^{-1}) and IT_2 (EC 2.89 dS m^{-1}).

2.3. Soil and Water Analysis. To determine the soil physical and chemical properties including soil salinity, texture, field capacity (FC), dry bulk density (DBD), and wilting point (WP), 18 soil samples (9 from each block) were drawn from the experimental block at the soil depth of 0–15, 15–30, and 30–60 cm before sowing the crop. Moisture content (MC) of the soil was determined using the equation given in [24]. For chemical analysis including EC, pH, SAR, and ESP, these soil samples were mixed to obtain a composite sample in plastic bags. The composite soil samples were analyzed. The electrical conductivity (EC) was determined by using a digital EC meter (model HI-8333), while the pH was determined by using a digital pH meter (model SP-34 sunteor [25].

2.4. Installation of Drip Irrigation System and Its Performance. A drip system of irrigation was installed at the experimental site with a distance of 70 cm between the two laterals. A total of 65 drippers were fixed on a single lateral with a space of 30 cm between each plant. To observe the discharge rate of the drippers, out of 10 laterals, six lateral lines with three in each treatment, lateral 1, 3, and 5 under IT_1 (EC_{iw} 0.56 dS.m^{-1}) and lateral 6, 8, and 10 under IT_2 (EC_{iw} 2.89 dS.m^{-1}), were selected. There were five laterals in each sub-block, with 65 drippers on each lateral. For this purpose, 65 plastic bowls with I L volume were used, and the discharge rate of each dripper, in terms of lit.hr^{-1}, was calculated.

2.4.1. Computation of Uniformity Coefficient. The uniformity coefficient of the drip system of irrigation was calculated on the release rate of the drippers. The uniformity coefficient of the selected laterals 1, 3, and 5 as well as 6, 8, and 10 under IT_1 and IT_2, respectively, were determined according to prior research [26].

2.5. Crop Sowing and Fertilizer Application. Under the drip system of irrigation, the crop was cultivated in two consecutive seasons of May 2017 and Nov 2017. With drip irrigation, under feasible soil conditions, di-ammonium phosphate (DAP) and nitrogen fertilizer (227 gm and 115 gm per acre, respectively) were applied in the soil in each sub-block [27].

2.6. Irrigation Application and Soil Moisture Measurement. A tensiometer including a vacuum gauge was inserted at 0.2 m depth under the drippers of each site to observe soil moisture for irrigation scheduling. The tensiometers were examined two times daily (i.e., at 08 : 00 and 17 : 00), and the time of irrigation was recorded through a water meter connected to the drip irrigation system.

2.7. Agronomic Observations. Agronomic data recorded comprised fruit weight (gm) and length and diameter in cm. For calculating biomass in 10–30 days interval, six *M. charantia* plants from each block were selected randomly and oven-dried for 24 hours at 70°C to constant weights [28].

Overall, 12 plants, six from each treatment, were selected and harvested for agronomic observations. The harvested fruit was weighed by using a digital balance. The fruit length and diameter were measured by a tape and a Vernier calliper, respectively. The agronomic observations for season 1 were recorded fortnightly from the end of July 2018 to September 2019. Nevertheless, for season 2, the same observations were recorded from December 2019 to March 2020.

2.8. Crop Yield and Water Use Efficiency. The mature bitter gourd fruits were harvested from both experimental sub-blocks frequently, and the yields were recorded. Eventually, the water use efficiency (WUE) was calculated by using the formula described in [29].

$$\mathrm{WUE} = \frac{Y}{W}, \tag{1}$$

where WUE is the water use efficiency in kg.m^{-3}, Y is the crop yield in kg.ha^{-1}, and W is the total water used n m^3.ha^{-1}.

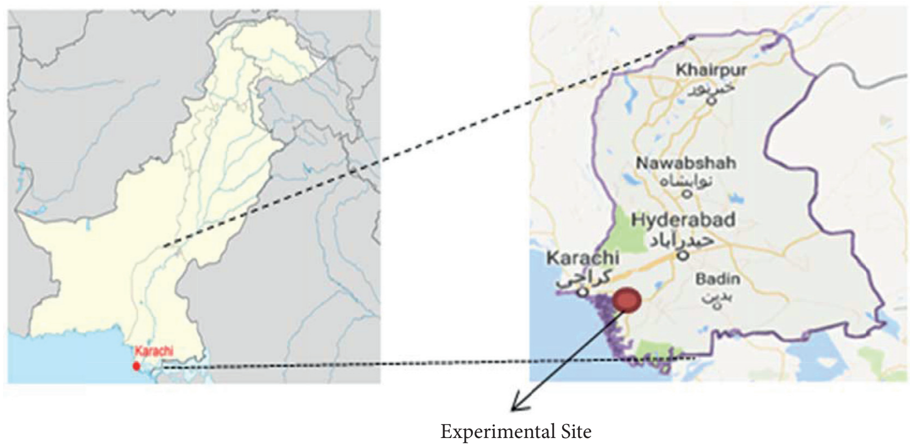

Figure 1: Location map of the experimental site.

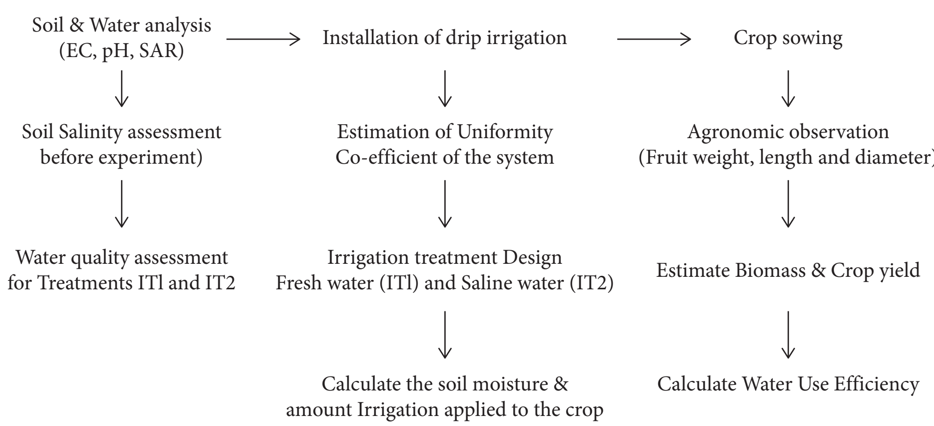

Figure 2: Flow chart of the experiment.

2.9. Statistical Analysis. Using SPSS version 25.0, a two-way analysis of variance (ANOVA) was run to analyze the significance of the agronomic data including fruit length (L), weight (W), and diameter (D), recorded using IT_1 and IT_2 in season 1 and 2.

3. Results and Discussion

3.1. Irrigation Application and Uniformity Coefficient. The experimental soil was sandy loam in nature; hence, light irrigation, at a steady interval of two days, was applied to retain the soil moisture and avoid plant stress. A total of 53 applications of irrigation were given to bitter gourd from planting till the end of the crop. Overall, 81.8 m^3 of water was applied under each treatment, in season 1, in summer (May 2017–September 2017). Besides, 48 irrigations, in season 2, in winter (Nov 2017–Mar 2018), were applied where 47.04 m^3 of water was used for each treatment as the requirement of water is less in winters. In the drip irrigation system, the uniformity coefficient of drippers in selected laterals, i.e., 1, 3, and 5 in block 1, whereas 6, 8, and 10 in block 2 were figured as 93, 94, 94, 96, 94, and 96%, respectively. The average uniformity coefficient was 94%.

3.2. Agronomic Observations. The analysis of fruit length, weight, and diameter under IT_1 and IT_2 for seasons 1 and 2 are given in Tables 1 and 2. It was found that fruit length, weight, and diameter under IT_1 and IT_2 were higher in season 1 than in season 2. This agronomic behaviour of the plant in season 1 is due to warm weather as bitter melon is a summer crop and produces better results in a warm climate. A similar field experiment, in Caspian seawater in Iran [30], showed that the yield decreased 10–14% for every 1 dS m^{-1} increase in soil salinity and showed that the salinity threshold value for oleic sunflower is about 1.6 dS m^{-1} in the Sari region.

The statistical analysis of biomass and crop yield under IT_1 and IT_2 for seasons 1 and 2 are shown in Tables 3 and 4. It was observed that the freshwater having EC less than 4.0 dS m^{-1} had the highest yield of 1.52 kg while the lowest yield was found 0.66 kg using water with EC 10 dS m^{-1} as the

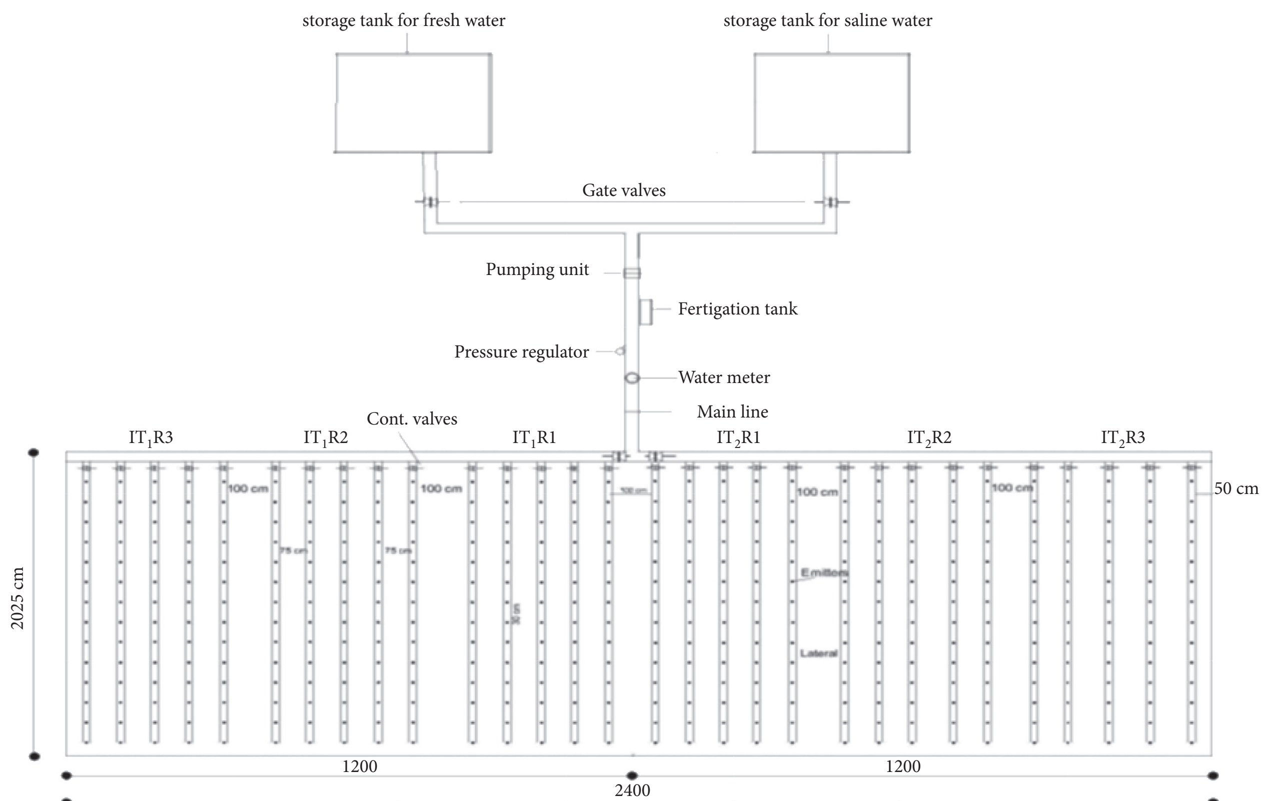

Figure 3: Design of drip irrigation in an experiment field.

Table 1: Descriptive statistics for fruit length (L), weight (W), and diameter (D) under IT_1 and IT_2 for season 1.

Variables	Mean	*N*	Standard deviation	Standard error
$L\_S1\_T_1$	12.61	36	1.71	0.28
$L\_S1\_T_2$	11.22	36	1.06	0.17
$W\_S1\_T_1$	53.01	36	5.91	0.98
$W\_S1\_T_2$	45.98	36	4.91	0.81
$D\_S1\_T_1$	03.21	36	0.56	0.09
$D\_S1\_T_2$	02.44	36	0.40	0.06

Table 2: Descriptive statistics for fruit length (L), weight (W) and diameter (D) under IT_1 and IT_2 for season 2.

Variables	Mean	*N*	Standard deviation	Standard error
$L\_S2\_T_1$	08.43	36	1.47	0.24
$L\_S2\_T_2$	07.00	36	1.08	0.18
$W\_S2\_T_1$	44.56	36	5.73	0.95
$W\_S2\_T_2$	38.51	36	5.10	0.85
$D\_S2\_T_1$	02.71	36	0.48	0.08
$D\_S2\_T_2$	01.98	36	0.36	0.06

biomass and crop yield were higher in season 1 under IT_1 than in season 2. The results are in line with those of the study by Ahmed et al. [31] who conducted a field experiment on tomatoes using saline irrigation water in Bangladesh. The authors concluded that the tomatoes irrigated with freshwater with EC < 4.0 dS m^{-1} had the highest fruit yield of 1.52 kg while the lowest yield of 0.667 kg was found under higher salinity with EC 10 dS m^{-1}. These outcomes also in connection with the results of the study conducted by the authors in [32, 33] concluded that the yield of crop species grown in semiarid region could be improved if the salinity of irrigation water is decreased.

3.3. Crop Yield and Water Use Efficiency. The crop was harvested from both experimental sub-blocks, and the yield was weighed and recorded on different dates. It was further calculated as total yield per ton. For season 1, the WUE under IT_1 and IT_2 was 1.60 and 1.21 kg.m^{-3}, respectively. However, the WUE slightly decreased in the second season, recording 1.56 and 1.07 kg.m^{-3} under IT_1 and IT_2, respectively, as shown in Table 5.

The water quality values showed that the groundwater (IT_2) was saline (EC_{iw} 1.5 to 3.0 dS.m^{-1}, pH < 8.0, and SAR < 10.0). The uniformity of the drip irrigation system was satisfactory and in line with the past study [34] which reported the highest uniformity coefficient (99.2%). The distribution uniformity (97.4%) was found under the drip irrigation at a pressure of 1.5 kg cm^{-2} using a 25 m long lateral line in New Delhi, India. Moreover, this system was reported to reduce water usage by minimizing up to 75% runoff.

The fruit length, fruit weight, and fruit diameter were found to be higher in season 1 under IT_1 than those in season 2 under IT_2. These results supported the hypothesis that IT_1 is beneficial for plant characteristics (i.e., length, weight, and

Table 3: Descriptive statistics with confidence bounds for the biomass (bio) data for seasons 1 and 2 with IT_1 and IT_2.

Variables	*N*	Mean	Standard error	Standard deviation	95% confidence bounds	
					Lower	Upper
Bio_S1_T_1	22	6.91	0.71	3.35	5.40	8.42
Bio_S1_T_2	22	5.43	0.32	1.51	4.74	6.11
Bio_S2_T_1	18	4.77	0.49	2.12	3.73	6.85
Bio_S2_T_2	18	3.20	0.30	1.28	2.57	5.28

Table 4: Descriptive statistics with confidence bounds for the crop yield (cy) data for seasons 1 and 2 with IT_1 and IT_2.

Variables	*N*	Mean	Standard error	Standard deviation	95% confidence bounds	
					Lower	Upper
Cy_S1_T_1	22	6.61	0.64	3.01	4.50	7.96
Cy_S1_T_2	22	5.03	0.31	1.46	2.92	5.69
Cy_S2_T_1	18	4.14	0.46	1.95	2.06	5.10
Cy_S2_T_2	18	2.83	0.34	1.46	0.75	3.55

Table 5: Crop yield and water use efficiency.

Irrigation treatment	Crop yield ($t.ha^{-1}$) season 1	Crop yield ($t\ ha^{-1}$) season 2	WUE ($kg\ m^{-3}$) season 1	WUE ($kg\ m^{-3}$) season 2
IT_1 (EC 0.56 $dS.m^{-1}$)	45.5	22.6	1.60	1.56
IT_2 (EC 2.89 $dS.m^{-1}$)	33.4	14.5	1.21	1.07

diameter). Therefore, it can be concluded that IT_1 elicits a significant improvement in the length, weight, and diameter of bitter gourd fruit. The crop yield achieved under IT_1 was comparatively higher than that under IT_2 because, under IT_1 treatment, freshwater did not influence the crop yield. However, under IT_2, the yield somewhat decreased in comparison with IT_1. This reduction was attributable to the higher vegetative growth in the summer season when it was able to support a higher fruit plant. Overall, it was observed that the biomass and crop yield were higher in season 1 under IT_1 than those in season 2 under IT_2. A similar result was obtained where coriander biomass and chili pepper growth and fruit characteristics were increased by mild salinity induced by different salts [35, 36].

The authors reported that plants irrigated with freshwater with EC < 4.0 $dS.m^{-1}$ had the highest fruit yield of 1.52 kg while the lowest yield of 0.667 kg was found under higher salinity with EC 10 $dS.m^{-1}$. However, the growing salinity of irrigation water declined the safflower yield and reduced the saline water application (EC_{iw} 3.4 $dS.m^{-1}$). Nevertheless, this can be improved, during germination, by adopting an effective strategy and efficient saline irrigation [37]. Increased level of salinity decreased 50% yield of the crop, and it has been reported while investigating the response of *Capsicum annuum* L. to saline irrigation water in a greenhouse [38].

Compared to IT_2, the WUE was high under IT_1 as fresh quality irrigation water increases crop yield and water use efficiency. The results are in line with a recent study [39] which reported that a higher WUE was achieved by using low discharge drip irrigation with a discharge rate of 1.6 $L.h^{-1}$ in the first year and 0.6 $L.h^{-1}$ in the next year on potatoes in the Arava Desert, Israel.

The overall agronomic data indicated that the bitter gourd plants under IT_1 (EC of 0.56 $dS.m^{-1}$) were somewhat healthier than the plants under IT_2 (EC_{iw} 2.89 $dS.m^{-1}$). The outcomes were attributed to the saline quality of groundwater affecting the fruit weight, size, and yield although the change was not significant.

4. Conclusion

The bitter gourd yield under IT_1 (EC of 0.56 $dS.m^{-1}$) was 45.5 $t.ha^{-1}$ and 22.6 $t.ha^{-1}$ in season 1 and 2, respectively, and was found higher in than 33.4 $t.ha^{-1}$ and 14.5 $t.ha^{-1}$under IT_2 (EC_{iw} 2.89 $dS.m^{-1}$) in season 1 and 2, respectively. Overall, the outcome of the research revealed that when fresh and saline irrigation water were applied to bitter gourd through drip irrigation, the crop yield improved. Moreover, the crop yield and water use efficiency were slightly better for freshwater than for saline water. It is concluded that saline water is a viable option which can be used for bitter gourd by using drip technology in the semiarid region. More research should be conducted on moderate saline vegetables under drip irrigation systems by using different quality groundwater on a sustainable basis so that the obtained results can be promoted among farmers.

Data Availability

The data used to support the findings of this study are available from the corresponding author on request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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