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Full Length Research Paper

Effect of marginal quality water on Okra, *Abelmoschus Esculentus* l. Yield under drip irrigation system

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The research study was conducted at Coastal Agricultural Research Station of PARC, Karachi. In order to see the effects of marginal quality ground water in comparison to good quality water (tap water) on crop yield and water use efficiency. Okra was grown under drip system of irrigation during the year, 2011. The soil characteristics, soil samples at depth of 0-15, 15-30 and 30-60 cm were drawn and analyzed in laboratory for various parameters. The results indicated that the soil under study was sandy loam in texture, having the DBD 1.59 gm/cm^3, infiltration rate 1.56 cm/hr, F.C, W.P and A.M was 14.8, 6.2 and 8.6%, respectively. Before crop sowing, drip irrigation system was installed to assess for its performance through Uniformity Co-efficient which ranged from 93 to 96% and indicated that the system was working satisfactorily. The quantity of tap and ground water applied through drip system to okra crop was of equal volume i.e., 6989.7m3/ha. However, higher crop yield and higher water use efficiency i.e., 18.93 t/ha and 2.7kg/m3 were recorded under T1 over T2 (yield 17.0t/ha and water use efficiency 2.4kg/m3) respectively. The increase of yield and WUE in T1 over T2 was about 10% in each case. Thus, it was inferred that okra crop can be grown successfully on sandy loam using saline (Marginal quality) ground water for irrigation. Keeping in view the above results obtained under this study, the farming community of the coastal area should be made well aware of the use of saline ground water for vegetable cultivation. However, more research should also be conducted on the use of saline ground water for the cultivation of winter and summer vegetable crops and fruit orchards in the coastal belts of Sindh and Balochistan so that the local people of these area could get benefits from such research.

Keywords: Drip irrigation, Okra yield and Net profit.

INTRODUCTION

The length of Pakistan coast is about 1100 kms which ranges from Gwadar in Balochistan province to Badin in Sindh province. The Malir and other adjacent districts of Karachi come under coastal area. The climate of the area is continental with high relative humidity due to sea. The summers and winters are mild. The last 30 years climatic data of Karachi area revealed that mean minimum temperature was 20.3^{o}C whereas the mean maximum temperature was 31.7^{o}C. However, in the last decade, the minimum temperature fell to 10^{o}C whereas, the maximum temperature rose to 40^{o}C occasionally. The average annual rainfall is 217 mm, whereas the relative humidity ranged from 52 to 78% (Metrological

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Department of Pakistan, Karachi). The soils of the area are not the alluvial but are the outwash of the adjacent hilly tracts which are called piedmont soils. The texture of the soils ranged from loam to sandy loam mixed with small pebbles and gravels. Thus, the drain ability of these soils is high whereas, the water holding capacity is very low thereby, the irrigation frequency was of short duration. The underground water was saline in nature (ECw > 1.5dS/m). However, its quality ranges from marginal (ECw between 1.5 to 3.0 dS/m) to hazardous (ECw > 3.0 dS/m).The agricultural and horticultural activities in the area are limited and on small commercial basis. Vegetables like okra, gourds, spinach, cauliflower, green chillies, raddish and turnips etc. are grown on small scale. Whereas fruit orchards like guava, papaya, chiku, custered apple etc. are also grown on limited area. Besides ground waters, sewerage water is also used for irrigation in the area. Babar, *et al*., (2008) worked over the assessment of water use efficiency, soil salinity and system performance of Drip irrigation and got the fruitful results.

Water is a unique commodity created by Almighty Allah on the earth. In Holy Quran, Allah quotes that, he has created every living body with water. It is, therefore, crystal clear that life can not exist without water. Thus, agriculture activities can not be considered to be carried out without water. Pakistan is located in arid and semi-arid climatically zones. In such conditions, the rainfall is scanty and unevenly distributed whereas, evapotranspiration exceeds over rainfall due to hot and dry weather. Therefore, artificial irrigation was considered essential for the development of agriculture. For this purpose, a surface irrigation network has been constructed in the Indus Basin. This irrigation network is consisted of three super dams, 19 barrages, 12 inter-river link canals, 45 huge canal commands, more than 7,50,000 tube wells and more than 1,07,000 watercourses. This irrigation system thus irrigates more than 18.78 M ha. Chandio, *et al*., (1986) studied over the evaporation under furrow and drip irrigation. Due to increasing population of the country, water demand in agriculture, industrial and domestic sectors are increased. There fore, the water availability is decreased. According to an estimate, at the time of the existence of the country, in 1947, per capita / year availability of fresh water was about $5000m^3$ which currently decreased to about $1200m^3$ and is projected to go down to $800m^3$ in the year 2025. Thus, in the year 2025 a shortfall of 150 MAF would occur (Chandio and Afzal, 2001). International Water Management Institute (2007) has declared Pakistan as a physical water scarce country. Thus, a water effluent country has become a water deficit country at present. Therefore, water availability for sustainable agriculture is a big problem of the day. The total ground water potential in Pakistan is of the order of 55 MAF. Total water resources of the country are 193.7 MAF averagely which is sufficient to meet the present demand of water if it is managed on scientific lines. The main causes of water shortage included, seepage from earthen canals and watercourses, increasing in cropping intensity to grow more food and fiber for growing population, cultivation of high delta crops like rice, sugarcane and banana, over irrigation to crops beyond water requirement. Agriculture is the main water user which uses about 97% water. Whereas, the industrial and domestic sectors use only 3% of fresh water (WMI, 2000). By following the traditional methods, hardly 40 to 45% irrigation efficiency is achieved. Thus, a considerable quantity of water is lost. Besides overcoming the above causes of water losses, water conservation is must for the sustenance of agriculture and thereby ensured the food security for the growing population of the country. For water conservation in agriculture, we have to adopt the micro irrigation systems sooner or later as under these systems of irrigation, high water use efficiency is achieved which is around about 90 to 95%.

Drip irrigation is a system that applies water and fertilizers directly to the root zone of individual plant instead of irrigating the entire area with flood or sprinkler irrigation. The system is consisted of pipeline network as main, sub main, lateral lines and emitters or tricklers which are fitted on laterals from which water is delivered to the plant at a low pressure. Under proper management, drip irrigation system is capable to save water, since only the plant's root zone is supplied with water and the entire area remains dry, therefore under drip irrigation system, high water application efficiency, high water use efficiency, higher crop yields and appreciable water saving in comparison to traditional methods of irrigation are achieved. In a FAO report (1997), it has been stated that major benefit of drip irrigation is its high water application efficiency which can reach values of 90%, although 80% is practicable. This can be compared with surface irrigation schemes which normally have an efficiency of 50%. Yaseen, *et al*., 1992; Chandio, *et al*., 1995; Babar, *et al*., 2008 have reported that higher water use efficiency, higher vegetable yields along with an appreciable quantity of water saving i.e., 50-60% have been saved under drip irrigation over furrow mode. Topcu, *et al*., (2002) conducted the partial root drying practice for increasing water use efficiency of furrow and drip irrigated cotton. Verkade, *et al*., (1986) suggested about the trickle irrigation methods mostly used in nursery farms. Urban agriculture is the typical requirement of coastal areas of Sindh and Balochistan but irrigation water (canal) is the main constraint to develop the agricultural activities in these areas. Sabah and Safa, (1983) stated that overall efficiency of the trickle system was 45% more than that of furrow irrigation system. Majumdar, (2002) described about the irrigation water management, principles and practices applied in the agriculture crops. However, as the underground water is saline which ranges from marginal to hazardous quality

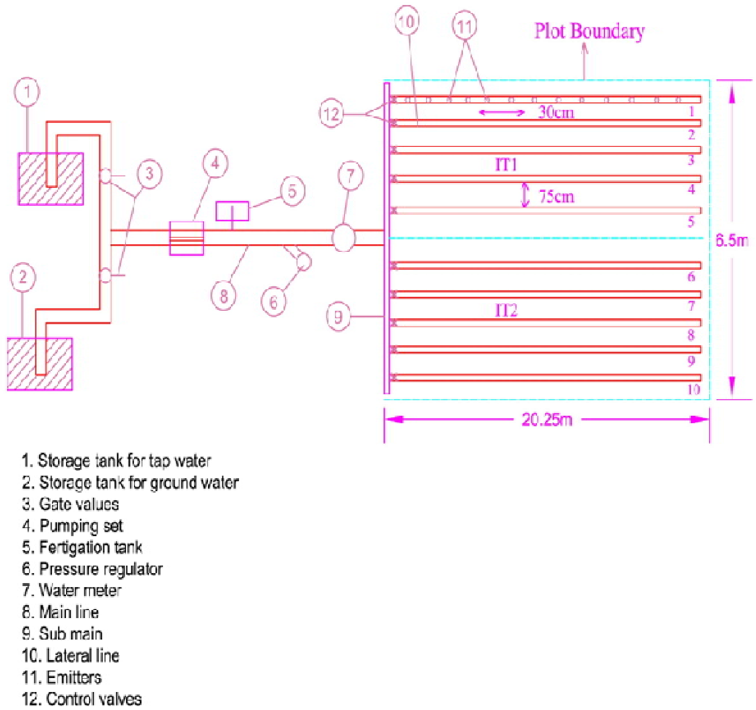

Figure 1. Drip irrigation system and field layout

should be used for cultivation of vegetable crops and fruit orchards through conducting research. Thus, keeping in view the importance and benefits of drip irrigation and to use marginal quality ground water for growing okra in the coastal area at Karachi, this research study was formulated and conducted to achieve the objectives.

MATERIALS AND METHODS

The study was conducted at Coastal Agricultural Research Station of the Pakistan Agriculture Research Council (PARC), situated at Saleh Muhammad Goath, Landhi, Karachi during, 2011. A field plot measuring 20.25m x 6.5m = 131.6m^2 was selected in the study area. It was ploughed thoroughly with tractor using a disc plough and leveled partially. It was divided in two equal parts, each plot meant for using ground water and tap water for irrigation. cm/hr. After preparation of the land / seedbed, drip irrigation system was installed. Since the plot size were small, i.e. each 20m x 3 m = 60m^2. Therefore, for each water quality to be used for irrigation i.e. underground (marginal) and tap water (good quality), two plastic drums about 300 lit. capacity each were used as water storage tanks. For water pumping to the system through the main, an electric pump of ½ H.P. was used in the system. The main line in the system installed was made of PVC having 32 mm I.D. on this main line, a pressure regulator, fertigation tank, filter and water meter were installed. The sub-main was also PVC made having 25 mm I.D. The length of the sub-main on each plot was 3.25 m. The main line was connected with a reduced "T" 32/25 mm. The lateral lines used were also PVC made and flexible, having 3 mm I.D. On each plot, five laterals each 20m long were used. The distance between two lateral kept was 75 cm (recommended distance for okra between two rows)

Plastic made turbo type emitters were used in the system. The water delivering orifices of these emitters was 0.5 mm I.D., and was flow adjustable. 65 emitters were inserted on each lateral keeping a distance of 30 cm from c/c (based on the distance between two plants of okra). Thus, on five lateral lines, the total numbers of emitters used were, 65 x 5 = 325 in each plot. The pressure regulator was fitted on the main line for regulating the water pressure as per requirement. Likewise pressure regulation, a filter was also fitted on the main line for passing clean water to the emitters to avoid choking of the emitters which is one of the drawbacks of drip irrigation system. Since the quantity of fertilizers used were small from time to time, therefore a plastic made fertigation tank (10 lit. capacity) was also fitted on the main line with a control valve so that the fertilizer solution / liquid fertilizer could be mixed in the water running in main line during irrigation. For the measurement of irrigation water applied to crop, a water meter 32 mm I.D. was fitted on the main line also. This water meter indicated the volume of water used in m^{3}On each lateral line, a control valve was used for control of water pressure and to ensure water delivery uniform up to last emitter. The layout and drip irrigation system used is presented in under given Fig. 1.

Components of drip irrigation system:

The components of trickle irrigation system are described as under:

Storage tank	Two Nos. 2000 liter capacity each.
Pump (Diesel)	12 H.P
Maximum flow rate	150 lit/min
Main line (PVC)	32 mm I.D.
Sub main (PVC)	25 mm I.D
Lateral Lines (PVC flexible)	13 mm I.D.
Emitters	Turbo type 0.5 mm I.D.
Water meter	32 mm. I.D.
Filter	Fitted on main line
Fertigation Tank Capacity	80 lit.
Length of each lateral	20 m
Total number of laterals under study	06

The distance between two laterals was 75cm (row to row). The emitters were inserted at 30 cm c/c along the laterals (distance between plant to plant). Thus total number of emitters was 390. The total area under drip system of irrigation was 6m x 20m = 120 m^2.

Performance of drip irrigation system

For the assessment of the performance of drip irrigation system used to irrigate okra crop, discharge (flow rate) of emitters of selected laterals and their uniformity coefficient was computed as under:

Discharge of Emitters

The total numbers of laterals used were 6, out of which, four lateral lines 1, 3, 4, and 6 were randomly selected. Since there were 65 numbers of emitters on each lateral line, therefore 65 numbers of plastic bowls each one-liter capacity were kept under each emitter and the system was run for five minutes using a stop watch. The same procedure was repeated for each selected lateral line. A graduated cylinder was used for measuring the water collected in each bowls and calculations were made as discharge in liters per hour.

For the assessment of the drip irrigation system installed on the field plot under study, discharge rate of emitters and their uniformity co-efficient were determined. The total numbers of laterals on each plot were five and on each lateral, 65 emitters were inserted. Therefore, two lateral lines were selected from each plot. Thus, in all, four lateral lines were selected randomly for discharge measurement of the emitters. For this purpose, 65 plastic bowls each one lit. capacity was obtained. Each bowl was placed under each emitter after its flow adjustment. The system was then run for five minutes. The water received by each bowl was measured with a graduated cylinder and recorded after number by number starting with the beginning to the end of the laterals. The calculations then made for finding the discharge rate of each emitter as lit. /hr. After the determination of discharge rate of the emitters, the uniformity co-efficient of selected laterals i.e., No. 2, 4 in plot 1 and No. 7 and 9 in plot 2 was determined using the following formula as given by Keller and Karmeli, (1975).

$$Ue = 100\,[1.0-(c/n)\,CV]\,qm$$

Where,

Ue = Uniformity co-efficient.

C = Constant = 1.27

n = No. of emitters on lateral line.

CV = Co-efficient of variation = $(\partial/qn) \times 100$

qm = Minimum discharge of the emitters.

qn = Mean or average discharge of emitters

∂ = Standard deviation = $\sqrt{\dfrac{\sum (q-qn^2}{n}}$

q = discharge of the emitters.

Under this study, two kinds of irrigation water were also used i.e., ground water and tap water (canal water). As irrigation water to be used for irrigation, plays an important role in producing crop yields and plant growth and secondary salinization of the soil. Therefore, to know the water quality of these two irrigation waters, samples were collected periodically and analyzed for ECw, pH, SAR and RSC parameters.

Under drip system of irrigation okra, *Abelmoschus esculentus* crop was cultivated. For this purpose, a soaking dose to both the plots (one irrigated with tap water and another irrigated with ground water) was applied through the system. When the soil came in workable condition, DAP and urea fertilizers @ 1 bag and ½ bags per acre respectively were applied and mixed with soil in each plot (recommended by ARI, Tando Jam). Pre-soaked seeds of okra then were dibbled under the emitters. After four days of sowing, the germination appeared. All the cultural practices like interculturing, fertilization, plant protection measures etc. were carried out as per recommendations.

Since the soil of the study area was light textured (sandy loam), therefore, light irrigation to okra crop keeping one to two days interval was applied to keep the soil at field capacity level to avoid stress to the plants. The irrigation waters applied at each time was noted from the water meter installed in the system and recorded.

The rainfall occurs during a crop growing period is very important from total water used and water use efficiency point of view. All the rainfall receives at one spell may not be effective to crop but a part of it could be effective which is stored in the root zone, or a light rain could be cent per cent effective to the crop as it is intercepted by the foliage of the crop or is stored in the root zone.

The table showing the rainfall and its effectiveness:

Rainfall (mm)	25	50	75	100	125	150	>150
Effectiveness (%)	90	85	75	50	30	10	0

Source: Irrigation and Drainage Paper No. 24, FAO, Rome (1975).

Table-1. Soil Characteristics

S. No.	Parameters	Characteristics
1.	Texture	Sandy loam
2.	Dry bulk density	1.59 gm/cm^3
3.	Infiltration rate	1.56 cm/hr
4.	Field capacity	14.8%
5.	Wilting point	06.2%
6.	Available moisture	08.6%

Table- 2. Computation of uniformity co-efficient of emitters in lateral No. 2, 4, 7 and 9.

Lateral No.	Minimum Discharge of Emitters (q_m)	Mean or Average Discharge of Emitters (q_n)	$\Sigma (q-q_n)^2$	Standard Deviation $\sigma = \sqrt{\Sigma(q-q_n)^2 / n}$	Co-efficient of Variation CV=(σ/q_n) x 100 (%)	Uniformity Co-efficient (%) =100 [1.0–(c / n) CV] q_m/q_n
2	5.7	6.03	2.44	0.02	0.33	93%
4	5.7	5.98	2.26	0.02	0.33	94%
7	5.6	5.93	1.55	0.01	0.16	94%
9	5.7	5.86	1.62	0.01	0.33	96%

n= 65, C = 1.27

Keeping in view these facts, effective rainfall was considered to be taken into account. Thus, the rain-fall received during crop growing period was recorded using a rain gauge already installed at the research station of the PARC beside the study area. The effective rainfall was computed using the following table.

The following two parameters of agronomic data were recorded.

Plant height and,

Girth of the plant.

The effective rainfall was computed and added to total water used for irrigating the okra crop. For this purpose, three plants in each plot at random were selected and labeled. The plant height and their girth were recorded fortnightly. The mature okra pods (vegetable) were picked from time to time from both the plots and the yield was recorded accordingly. The water use efficiency (WUE) of okra was computed as per formula given by Majumdar, (2000) which is as under:

WUE = Y/W

Where,

WUE = Water use efficiency (Kg/m^3)

Y = Total crop yield (Kg/ha)

W = Total water used (m^3/ha).

RESULTS

The characteristics of the soil as per laboratory analysis of the soil samples and field determinations are presented in table- 1.

To assess the performance of drip irrigation system, the uniformity co-efficient of the system was determined. The computation of uniformity co-efficient of drip irrigation system based on the discharge rate of the emitters on the selected laterals is presented in table-2.

The results are given in table- 2 indicated that uniformity coefficient of the drip system of irrigation in laterals 2, 4, 7 and 9 was computed as 93, 94, 94 and 96% respectively. Thus, it was inferred that the system was performing satisfactorily. Waters to be used for irrigation play an important role in obtaining the optimum crop yields besides producing adverse effects on the soil. Research studies revealed that marginal and hazardous quality water's applied for irrigation that can pose a serious problem not only in crop yield production but led the good soils to saline or saline-sodic. Even good quality waters which are usually used for crop cultivation, if are applied under poor drainage, soil and poor water management conditions, the good soils are also likely to

Table- 3. Analytical results of Tap and ground water samples used for irrigation

S. No.	Sampling Date	Kind of Water	Parameters ECw (dS/m)	pH	SAR	RSC	Water quality
1.	07-06-11	Tap Water	0.50	7.2	1.9	Nil	Good
		Ground Water	2.91	7.5	4.8	Nil	Marginal (saline)
2.	18-07-11	Tap Water	0.45	7.1	1.8	Nil	Good
		Ground Water	2.75	7.6	6.1	Nil	Marginal (saline)
3.	09-08-11	Tap Water	0.51	7.1	1.9	Nil	Good
		Ground Water	2.94	7.4	5.8	Nil	Marginal (saline)
4.	30-08-11	Tap Water	0.48	7.2	1.9	Nil	Good
		Ground Water	2.89	7.5	4.6	Nil	Marginal (saline)

Table- 4. Water applied to okra crop under the treatments

Date of application	Water applied (m^3)		Date of application	Water applied (m^3)		Date of application	Water applied (m^3)	
	T_1	T_2		T_1	T_2		T_1	T_2
06-06-11	2.03(S.D)	2.03(S.D)	13-07	1.39	1.39	24-08	1.64	1.64
09-06	0.69	0.69	16-07	1.43	1.43	25-08	1.59	1.59
11-06	0.70	0.70	17-07	1.46	1.46	27-08	1.63	1.63
13-06	0.73	0.73	20-07	1.49	1.49	29-08	1.67	1.67
15-06	0.77	0.77	21-07	1.52	1.52	01-09-11	1.68	1.68
17-06	0.81	0.81	22-07	1.53	1.53	03-09	1.67	1.67
19-06	0.84	0.84	23-07	1.54	1.54	05-09	1.68	1.68
21-06	0.89	0.89	24-07	1.56	1.56	07-09	1.69	1.69
23-06	0.91	0.91	08-08-11	1.67	1.67	09-09	1.70	1.70
25-06	0.96	0.96	10-08	1.58	1.58	11-09	1.66	1.66
27-06	1.03	1.03	11-08	1.57	1.57	13-09	1.70	1.70
29-06	1.09	1.09	12-08	1.56	1.56	15-09	1.63	1.63
01-07-11	1.14	1.14	13-08	1.58	1.58	17-09	1.65	1.65
03-07	1.21	1.21	15-08	1.59	1.59	19-09	1.67	1.67
05-07	1.26	1.26	17-08	1.61	1.61	21-09	1.67	1.67
07-07	1.29	1.29	19-08	1.63	1.63	23-09	1.65	1.65
09-07	1.33	1.33	21-08	1.62	1.62	25-09	1.64	1.64
11-07	1.36	1.36	23-08	1.63	1.63	**Total**	**76.46**	**76.46**
-	-	-	-	-	-	**Rainfall**	**9.38**	**9.38**
-	-	-	-	-	-	**Total**	**85.84**	**85.84**
-	-	-	-	-	-	**Per ha**	**6989.7**	**6989.7**

become saline/saline sodic due to salts which the irrigation waters contain themselves, thereby deposited in the soil profile.

Since, under this study, tap water and ground waters were used for crop cultivation, therefore it was thought necessary to know the quality of these two waters. Thus, periodically water samples were collected and analyzed for ECw, pH, SAR and RSC parameters. The analytical results of these irrigation water samples are given in table- 3.

Above given table- 3 explained that ECw, pH and SAR of all the four tap water samples ranged from 0.48 to 0.51, 7.1 to 7.2 and 1.8 to 1.9 respectively. Thus, the analytical parameter of these samples indicated that tap water used under okra crop was non-saline and non-sodic i.e. E.Cw < 1.5dS/m, pH up to 8.0 and SAR<10.0. Where as the ECw of all the ground water samples ranged from 2.75 to 2.94 dS/m, pH 7.4 to 7.6 and SAR 4.6 to 6.1. Therefore, these values indicated that the ground water was saline and non-sodic i.e. of marginal quality (E.Cw 1.5 to 3.0 dS/m, pH <8.0 and SAR <10.0).

Date wise irrigations applied to okra crop including soaking dose up to the end of crop season under each treatment are presented in table- 4.

It is obvious from table- 4 that total irrigations including soaking dose applied to okra crop since sowing up to the end of the crop season were 53 in number. The total water used/applied under each treatment was 76.46m^3. The rainfall received during crop growing period (from July 25 to August 4, 2011) was computed for its effectiveness, which came to 9.38m^3. Thus the total water including effective rainfall (E.R.) used under each treatment was 85.84m^3. This quantity of water was further computed on hectare basis, which came to 6989.7 m^3/ha.

Table 5. Rainfall received during crop growing season its effectives and effective rainfall

Month / Date	Rainfall Received (mm)	Effectiveness (%)	Effective Rainfall (mm)
25-07-11	17.8	100	17.8
26-07-11	19.5	100	19.5
27-07-11	21.8	100	21.8
28-07-11	2.5	100	2.5
29-07-11	2.0	100	2.0
01-08-11	36.3	87.5	31.76
03-08-11	21.0	100	21.0
04-08-11	46.5	86	40
Total	**167.4**	**-**	**156.36**

Table 6. Okra yield obtained under T_1 and T_2

Date of Picking	Yield (Kg)		Date of Picking	Yield (Kg)	
	T1	T2		T1	T2
24-08-11	2.5	1.9	15-09	12.4	8.4
26-08	4.1	3.3	17-09	13.2	12.0
28-08	4.6	4.0	19-09	6.5	6.0
30-08	4.9	4.3	21-09	7.1	5.6
02-09-11	6.1	5.2	23-09	5.9	4.3
04-09	6.9	7.2	25-09	4.7	4.8
07-09	7.0	6.3	27-09	4.2	4.5
09-09	7.7	7.5	29-09	3.7	4.3
12-09	9.2	8.5	01-10-11	2.9	3.7
			Total	**113.6**	**101.8**
			Per hectare	**18933.0**	**16,967.0**

Effective rainfall is the actual portion of total rainfall. Part of the rain may be lost by surface run off, deep percolation below the root zone or by evaporation intercepted by the plant foliage. In regions with heavy and high intensity rains only a portion of rain water can be stored in the root zone and the effectiveness of rain is consequently low or zero. In case of light rains, interception by the plant foliage can be important. Wet plants tend to transpire less, which is an off-set by increased evaporation of the rain water interception by the plant foliage. Thus, intercepted light rainfall is close to 100% effective. Based on the table given, the effective rainfall (E.R.) has been computed. The date wise rainfall received during study period, was recorded with the help of a rain gauge installed already at the study site, thereby effective rainfall was computed accordingly. The total effective rainfall (E.R.) was added in the total water used for irrigation under each treatment. The rainfall received in different days, its effectiveness and effective rainfall is presented in table- 5.

Table- 5 indicated that from July 25 to August 4, 2011, 167.4mm rainfall was received in 8 different days. Accordingly, the effectiveness of the rainfall received in each day, was seen from the table given. Thus, the total effective rainfall in 8 days was computed as 156.4mm. This was added in total water used for irrigating the okra crop under both the treatments. The mature okra pods were picked from time to time from both the treatments / plots. The yield obtained on different dates was weighed and recorded. The crop yield was further computed as total yield / ha. These are presented in table- 6.

Table- 6 showed that picking of okra pods started on August 24 and ended on October 1^{st} 2011. The total numbers of pickings were 18, and the total yield obtained under T_1 and T_2 was 113.6 Kg and 101.8 Kg respectively. The yield was further computed on hectare basis which came to 18933 Kg (18.9 t) and 16967 Kg (17.0 t) / ha under the respective treatments. The yield obtained under T_1 was higher (10.4%) in comparison to T_2. The highest yield under T_1 attributed to the fact that, under this treatment, tap water (good quality) was used, which did not affect the crop yield. Whereas, under T_2, the yield decreased some what as compared to T_1 however, the decrease in yield was non significant statistically.

The water use efficiency (WUE) is determined to evaluate the benefit of applied water through crop production. It is one of the important parameters in crop production and irrigation water management. It indicates that, how much crop yield is produced per unit volume of irrigation water. The yield, water used and water use efficiency (WUE) of okra computed for T_1 and T_2 are presented in table- 7.

It can be seen from table- 7 that total yield obtained under T_1 and T_2 was 18933.0 and 16967.0 Kg/ha respectively whereas, the total water used under each treatment was equal as 6989.7 m^3/ha. Thus, the WUE computed for T_1 and T_2 were 2.70 and 2.43 Kg/m^3 respectively. Likewise yield, under T_1, about 10% higher

Table 7. Yield, water used and WUE of okra

S. No.	Treatment	Total Yield (Kg / ha)	Total water used (m^3/ha)	WUE (Kg/m^3)
1.	T_1	18933.0	6989.7	2.70
2.	T_2	16967.0	6989.7	2.43

Table- 8. Plant height and girth of selected plants under T_1 and T_2

Date of observations	T1 (good quality water)						T2 (marginal quality water)					
	Plant 1		Plant 2		Plant 3		Plant 1		Plant 2		Plant 3	
	Height (cm)	Girth (cm)	Height (cm)	Girth (cm)	Height (cm)	Girth (cm)	Height (cm)	Girth (cm)	Height (cm)	Girth (cm)	Height (cm)	Girth (cm)
28-06-11	12.5	-	11.0	-	10.8	-	11.6	-	11.0	-	10.2	-
13-07-11	27.3	1.0	26.2	1.1	28.0	1.1	26.2	1.0	24.3	1.1	25.2	1.0
28-07-11	39.1	1.2	37.3	1.2	38.0	1.2	37.8	1.2	38.1	1.2	37.0	1.2
15-08-11	61.3	2.3	60.2	2.0	61.0	2.2	60.2	2.2	58.8	2.1	60.1	2.2
30-08-11	77.5	3.1	76.0	3.0	78.0	3.2	75.2	3.0	73.5	3.0	73.2	3.1
16-09-11	91.3	4.8	90.2	4.6	92.2	4.9	89.2	4.2	90.1	3.9	90.3	4.5
Avg. of 3 plants			**-**	**-**	**91.2**	**4.8**	**-**	**-**	**-**	**-**	**89.9**	**4.2**

WUE was achieved as compared to T_2. The reason for obtaining higher WUE in T_1 was the use of good quality water where as, under T_2 marginal quality ground water was used which decrease the yield and WUE too.

In order to assess the health of the okra plants grown under good and marginal quality waters i.e. T_1 and T_2 respectively, three plants in each plot at randomly were selected and their height and girth were measured fortnightly, which are presented in table- 8.

Table- 8 indicated that average height and girth of okra plants under T_1 and T_2 were recorded as 91.2 and 89.9 cm and 4.8 and 4.2 cm, respectively. The data indicates that okra plants under T_1 were somewhat healthier as compared to the plants under T_2. This condition is attributed to the fact that marginal quality waters more or less affect the plant growth and yield also, though the difference was non significant.

DISCUSSION:

The soil of the study area was non-saline (ECe < 4.0 dS/m) and non-sodic (SAR < 7.0) having sandy loam texture in nature. The bulk density and infiltration rate of the soil was determined as 1.59 gm/cm^3 and 1.56 cm/hr respectively. Whereas, the field capacity and wilting point were 14.8% and 6.2% of these respective parameters. Thus, the available moisture was 8.6% only. Based on these findings, it was inferred that the drain ability of the soil under study was very high and water holding capacity was low. The results are in agreement with of Kahloon, *et al*., (2004) who observed that under drip irrigation, maximum moisture content prevailed in the surface of soil layer (0-15 cm) and minimum in the bottom layer (45-60 cm). Moisture level fluctuated around field capacity under drip irrigation throughout the crop growing period due to frequent irrigation (on alternate days). The literature reviewed also revealed that marginal quality waters if are used for crop cultivation under good soil and water management conditions, the growth of the plants and crop yields are not effected significantly as West, *et al*., (1979) conducted the studies over the soil salinity gradients and growth of tomato plants under drip irrigation. Mofoke, *et al*., (2006), conducted experiment on tomato under four kinds of continuous flow rate of drip system. Babar, *et al*. (2008) concluded a research study conducted on slightly saline sandy loam soil having field capacity of 10.35%, wilting point 5.56% and available moisture 4.79%, by sowing winter vegetables i.e., spinach, radish, turnip and carrot under drip irrigation system using canal water for irrigation. They recommended that various studies under drip irrigation system on vegetables, orchards, and field forage crops and forest plant species may be conducted using different quality saline water under different soil and climatically conditions. Raad, (1985) assessed the comparative studies of drip irrigation in Iraq recommended that drip irrigation system could be introduced with the intention of increasing the yield of crop along with considerable quantity of water saving. FAO, (1997), in a report, stated that major benefit of drip irrigation is its high water application efficiency, which can reach a value of 90% although 80% are practicable.

Before crop sowing, drip irrigation system was installed, also assessed for its performance in okra crop. Like our study in the vegetable crop, others studies were also reported on different crops which were irrigated by the drip irrigation methods from different countries of the world which are as agreed with Al-Jamal, *et al*., (2000) who conducted experiment on comparison of sprinkler trickle and furrow irrigation efficiencies for production. They found that maximum irrigation water use efficiency 0.084 t/ha mm^{-1} of water applied was obtained using the sprinkler system followed by drip 0.059 t/ha mm^{-1} and furrow 0.046 t/ ha mm^{-1} of onion. Aujla, *et al*., (2007) experimented on eggplant as influence by different quantities of nitrogen and water applied through drip and furrow irrigation. They further exploited the beneficial effect of drip irrigation and to obtain maximum yield accompanied by highest WUE and crop yields. Asgari, *et al*., (2007) researched on sunflower with drip and furrow irrigation system found that yield was higher with drip irrigation in comparison with furrow irrigation. Erdem, (2006) stated that potato yield and water use efficiency were higher under drip method of irrigation as compared to furrow irrigation system. Shalhevet, *et al*., (1983) suggested that the potato irrigation requirement in a hot climate using sprinkler and drip methods.

The yield of okra and WUE increased to about 10% under T_1 as compared to T_2. However, the increase was non-significant. Thus, marginal quality ground water could be used for growing okra crop on a non-saline and non-sodic sandy loam soil in the coastal areas of Sindh and Balochistan (Pakistan). The results of the conducted studies are satisfactory with Batchelor, *et al*., (1996) conducted research on micro irrigation techniques such as low head drip irrigation, pitcher irrigation and sub surface irrigation using clay pipes. Clarck, (1979) compared relative efficiencies of trickle, sprinkler and furrow methods with an Irrigation Runoff Recovery System (IRRS). Gomez, *et al*., (2006) concluded that highest yield of forage, maize (46200 kg/ha) was obtained in drip irrigation against the yield (43800 kg/ha) recorded in furrow irrigation system. Yohannes and Tadesse, (1998) got higher yields from tomato crop under drip and furrow irrigation system. Kahloon, *et al*., (2004) observed salt and moisture distribution in Rhizosphere under drip and furrow methods of irrigation. Under furrow irrigation, however, maximum salt concentration was observed near the plant base and it decreased as the distance increased.

The farming community of the coastal area should be made aware regarding the use of marginal quality (saline) ground water for cultivation of okra and other vegetable crops through field demonstrations, conducting workshops and by providing print material in local language. That will provide better and fruitful results in net income support with applying these methods not only in okra crop but also in other crops as Swietlik, (1992) assessed the yield, growth and mineral nutrition of young ‘Ray Ruby’ grape fruit under trickle and flood irrigation and various nitrogen rates. Goel, *et al*., (2005) conducted on feasibility of drip irrigation in sugarcane in Haryana indicated that drip irrigation was capable of saving water, but had high capital costs. Goldberg and Shamuli, (1970) studied over the drip irrigation a method used under arid and desert condition of high water and soil salinity. Ibragimov, *et al*., (2007) conducted an experiment on water use efficiency of irrigated cotton in Uzbekistan under drip and furrow irrigation on a deep silt loam soil (Calcic xerosol). Seed-lint cotton yield was increased 10-19% relative to that for furrow-irrigated cotton. Soomro, *et al*., (1983) conducted research on apple tree found that drip irrigation system can de used successfully where soil texture and slope conditions made the conventional methods difficult. Singh, *et al*., (2006) explained that the drip irrigation produced maximum potato production. The yield of maize and bottle gourd were found maximum compared to other crops raised under different irrigation methods. Uriel, (1985) conducted research in Jordan Valley; the results revealed that under trickle irrigation, yield of tomatoes, egg plant, cucumber and onion were 75%,72%,79% and 75%, respectively higher than furrow irrigation method. Nightingale, *et al*., (2003) conducted an experiment on managing of soil salinity in the root zone of cotton under drip irrigation system. The trickle irrigation treatments were 20, 40, 60, 80 and 100% of the previous days pan evaporation. Montemayor, *et al*., (2006) conducted research on effect of three drip tape installation depths on water use efficiency and yield parameters in forage maize cultivation. Maisiri, *et al*., (2005) conducted research at Zholube. It was concluded that low cost drip systems achieved water saving of more than 50% compared to surface irrigation system that influenced the yield of vegetables significantly but instead it was the type of fertilizer application method that contribute to the increase in the yield of vegetables. Nisar, *et al*., (1995) determined the effect of trickle and furrow irrigation methods on growth and water use efficiency of mango orchard. As a result, 49% water was saved in trickle irrigation as compared to furrow irrigation. Veeraputhiran and Chinnusamy, (2005) conducted research on American cotton grown under drip and furrow method of irrigation found out that average plant height was higher in drip system. The benefit cost ratio was lower in drip fertigation and drip band application mainly due to higher initial investment cost for drip irrigation along with fertigation unit. Punam, *et al*., (2003) conducted research on okra crop under drip irrigation system and compared it to the conventional irrigation method. They concluded that drip irrigation increased okra yield by 30.34%, and brought about water saving of 41.23% compared to the conventional method. More research should be conducted on different kinds of winter and summer vegetables and fruit orchards to grow under drip system of irrigation at various locations in the coastal areas of Sindh and Balochistan using different quality underground waters on sustainable basis, so that the people of coastal areas could benefit from those.

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