

Research Article



Effect of Sewage Water Irrigation Frequency on Growth, Yield and Heavy Metals Accumulation of Tomato and Okra

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Abstract | The current study was aimed to inspect the efficiency of different sewage water irrigation frequency treatments on growth, yield and heavy metals accumulation of tomato and okra during 2012 and 2013. A statistical randomized complete block design was applied in the field to perform experiments having three replicates while 03 sewage water irrigation frequency treatments i.e., 5, 10 and 15-days interval. The tomato yield, their growth along with the production of the plant biomass were increased considerably with more repetitive (interval of five days) application of the sewage water. While reasonably less repetitive application (interval of fifteen days) of sewage water cause the less production of biomass, yield and growth. Moderately less repetitive applications (interval of ten days) of sewage water showed a significant increase in the addressed attributes of production in okra. The yield, as well as growth aspects of the okra, were reduced noticeably by using the reasonably less repetitive application. Frequent sewage water application resulted in an increased amount of Fe, Cu, Pb, Cr, Ni and Cd in okra pods and tomato fruits than moderately and less repetitive irrigation. The leaves and root of okra and tomato displayed the higher contents of metal when these crops were cultivated with a repetitive application of the sewage water. The final result revealed that the metal concentration high in tomato and okra plant parts with decreasing irrigation intervals of sewage water.

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Introduction

Water is necessary for the physiological activity of crop plants. Too much irrigation at any stage can delay maturity and harvesting and promote vegetative growth, whereas inadequate and less irrigation cause water stress and reduce quality

and yield (Yazgan *et al.*, 2008). Proper irrigation time and interval is necessary for production of good quality vegetables. Water shortage at the early stage of growth and development usually results in reduced yield. If the water shortages occur later in the growing season, it may not only adversely affect the quality of vegetables but also reduce the total yield.

Large sized fruits and greater yields were obtained when tomato plants were irrigated at 10 days interval compared with other irrigated intervals (Mani *et al.*, 2007). However, Gudugi *et al.* (2012) recorded a higher number of tomato fruits and greater yield when plants were irrigated at 4 days interval than with 8 days interval. Okra is a warm-season crop and has considerable resistance to drought. Water shortage affects the morphological and physiological processes of the plants, which are associated with growth and development (Moniruzzaman *et al.*, 2007; Yadav and Dhankhar, 1999). Drought stress affects photosynthesis, respiration, nutrient metabolism, and membrane stability index, which ultimately reduces plant growth and productivity of plants (Naveed *et al.*, 2009). Maturity and harvesting of crop were delayed due to the excessive irrigations or shorter irrigation intervals, whereas the yield and quality of crop were also reduced due to insufficient irrigation (Ramalan and Nwokeocha, 2000; Sankar *et al.*, 2008). Greater pod length, pod weight and yield of okra genotypes were recorded under 10 days irrigation interval (Khalil, 2004).

Use of sewage water has positive effects on plant biomass, plant height and yield of tomatoes enriched with vital plants macro and micronutrients (Khan *et al.*, 2011). Similar results have been reported in okra by Khalil (2004) and Rehman (2007). Keeping in view of these facts, the present study was envisaged to determine the effect of frequency of irrigation with sewage water on growth, yield and heavy metals concentration in tomato and okra.

Materials and Methods

Six weeks old tomato seedlings were transplanted on both sides of 1 m wide beds with a plant to plant distance of 20 cm on 10th February 2012 (1st year crop) and 10th February 2013 (2nd year crop). By using both margins/border of ridges, okra seeds were sown at 60 cm distance, having PXP distance 20 cm on 5th March 2012 (1st year crop) and 5th March 2013 (2nd year crop). All the cultural practices were carried out according to the requirements of crops and experiments.

The crops were irrigated with sewage water at different intervals/ frequencies. By using these 03 treatments of application (frequencies of sewage water application) via more repetitive application i.e. 5 days interval,

moderately less repetitive i.e. 10 days interval and less repetitive i.e. 15 days interval, which were replicated thrice in a randomized complete block design (RCBD). The data were collected on different growth and yield parameters and heavy metals accumulation in different parts of these vegetables.

Determination of heavy metals

Pre-treatment and chemicals: The vegetable samples were washed with distilled water to remove any dirt or soil particles and air-dried at room temperature for sixty minutes. After that, sliced the samples into small pieces and incubated in the oven for 72 hours at 70 °C. Crushed the samples into chilled mortar and pestle until the fine powdered is prepared. The prepared fine powder filter through a muslin cloth and preserved in disinfected polythene bags. Required chemicals and heavy metals standards (1ml) viz., Cr Pb, Ni, Cu, Cd, and Fe were graciously achieved from the Merck.

Acid digestion and statistical analysis

Heavy metals were extracted by digesting 500mg dehydrated sample from recommended treatments in 15 mL HNO₃ along with 5 ml HClO₄ mixture (3:1) by using a hot plate (Velp, Italy) with the temperature at 80°C until the clear solutions were achieved. The Whatman No. 42 filter paper was used to filter the obtained solution in 25 mL DEPC water (Farooq *et al.*, 2008). These heavy metals contents (Pb, Cu, Ni, Cd, Cr and Fe) were determined in the obtained solution by utilizing the atomic absorption spectrophotometer (Thermo Scientific 3000 series, USA). The data collected were subjected to analysis of variance (ANOVA). Least significant difference test was employed to determine significant differences among the treatment means at 5% level of probability. The data were analyzed using statistical software statistix 8.1.

Results and Discussion

Effect of sewage water irrigation frequency on plant growth

Significantly greater height, relative leaf chlorophyll content and leaf area of tomato were recorded when plants were grown with frequent irrigation with the sewage water. Whereas, significantly lower values of these parameters were recorded under less frequent irrigation treatment (Table 1). The mean values for the interaction between various irrigation frequency treatments and years exhibited a statistically

significant effect on plant height and leaf area. The taller plants were obtained with the interactive effect of frequent irrigation × year 2012, followed by the interaction of frequent irrigation × year 2013. These two treatments were statistically at par. The combined effect of less frequent irrigation × year 2013 resulted in significantly shorter plants. The combined effect of the frequent × year 2012, the frequent × year 2013 and moderately frequent irrigation × year 2013 resulted in greater leaf area. These three treatment combinations stood statistically at par with each other. Leaf area was significantly lower in the plants grown under less frequent × year 2013 (Table 1).

The maximum plant height and leaf area were produced in okra grown with moderately frequent irrigation treatment, which was followed by frequent irrigation treatment. The minimum values for these parameters were obtained when plants were irrigated with less frequent irrigation treatment. All the treatments were significantly different from each other. Frequent and moderately frequent irrigation treatments were statistically similar with greater relative leaf chlorophyll content. Whereas, significantly lesser content was recorded with less frequent irrigation treatment (Table 1). Significantly higher relative leaf chlorophyll content was recorded when okra plants were grown under the frequent irrigation treatment during the year 2013 and moderately frequent irrigation treatment during the year 2012, which were statistically alike. Whereas relative leaf chlorophyll content was significantly decreased when the plants were grown under less frequent irrigation treatment during year 2013.

Effect of sewage water irrigation frequency on fruiting

The maximum number of tomato fruits, fruit length and fruit diameter were recorded in the plants which received frequent irrigation, while the minimum values for these parameters were recorded with less frequent irrigation with the sewage water. All these three irrigation frequency treatments were statistically different from each other (Table 2). The significantly higher number of tomato fruits was obtained with the interactive effect of frequent irrigation × year 2012, followed by the interaction of frequent irrigation × year 2013. These two treatment combinations were statistically similar. The combined effect of less frequent irrigation × year 2013 and less frequent irrigation × year 2012 produced the minimum number of fruits. These two treatment combinations also behaved

statistically alike. However, the combined effect of irrigation frequency treatments and years for fruit length and fruit diameter indicated non-significant differences among the treatment combinations.

Pod number, pod length and diameter in okra were significantly affected by various irrigation frequency treatments with the sewage water. Significantly greater number of pods and pod diameter were recorded with moderately frequent irrigation treatment when compared with frequent and less frequent irrigation treatments. However, latter two treatments were statistically similar. The maximum pod length was observed in the plants under moderately frequent irrigation treatment, followed by in those grown with frequent irrigation treatment. Whereas less frequent irrigation treatment produced the shortest pods. All these three treatments were statistically different from each other.

Effect of sewage water irrigation frequency on yield

Significantly higher fresh and dry weights of fruit and yield per hectare of tomato were recorded with frequent irrigation treatment. The minimum fresh and dry weights of fruit and yield were observed in less frequent irrigation treatment. All these three treatments were statistically different (Table 2).

Moderately frequent irrigation treatment produced the maximum fresh weight per pod of okra, followed by frequent irrigation treatment and it was significantly reduced with less frequent irrigation treatment. However, behavior of all these three treatments was statistically different. Moderately frequent irrigation produced higher dry weight per pod, followed by frequent irrigation treatment and these two treatments were statistically similar. Significantly higher pod yield was achieved in the plants under moderately frequent irrigation treatment. The frequent and less frequent irrigation treatments behaved statistically alike with lower yields (Table 3). Fresh weight per pod was not affected by the interactive effect of irrigation frequency treatments and years. However, greater dry weight of pod was observed with the interactive effect of moderately frequent irrigation treatment × year 2013, moderately frequent irrigation treatment × year 2012, frequent irrigation treatment × year 2013 and frequent irrigation treatment × year 2012. All these four treatment combinations were statistically at par with each other. While the lowest values for a dry weight of pod was observed with the interactive

Table 1: *Effect of sewage water irrigation frequency on growth of tomato and okra.*

Frequency of irrigation water	Tomato			Okra		
	Year 2012	Year 2013	Mean	Year 2012	Year 2013	Mean
Plant height (cm)						
Frequent	90.70a	89.80a	90.25a	85.23a	84.93a	85.08b
Moderately frequent	83.60b	83.23b	83.41b	91.76a	92.13a	91.95a
Less frequent	80.06c	77.16d	78.61c	68.40a	69.36a	68.88c
Mean	84.78a	83.40a		81.80a	82.14a	
Relative leaf chlorophyll content						
Frequent	63.50a	61.93a	62.71a	62.70b	72.0a	67.55a
Moderately frequent	56.53a	55.86a	56.20b	69.03a	62.03b	65.53a
Less frequent	49.73a	49.96a	49.85c	56.96c	52.50d	54.73b
Mean	56.58a	55.92a		62.90a	62.31a	
Leaf area (cm²)						
Frequent	24.50a	24.46a	24.48a	198.67a	197.80a	198.23b
Moderately frequent	23.50b	23.86ab	23.68b	204.77a	203.77a	204.27a
Less frequent	21.40c	20.63d	21.01c	185.77a	184.33a	185.03c
Mean	23.13a	22.98a		196.40a	195.29a	

Treatment means sharing the different letter(s) in a group are significantly different at p ≥ 0.05

Table 2: *Effect of sewage water irrigation frequency on fruiting of tomato and okra.*

Frequency of irrigation water	Tomato			Okra		
	Year 2012	Year 2013	Mean	Year 2012	Year 2013	Mean
Number of fruit/pods per plant						
Frequent	26.16a	26.03a	26.10a	22.33a	22.50a	22.41b
Moderately frequent	24.26b	23.90b	24.08b	26.33a	25.66a	26.00a
Less frequent	22.53c	22.00c	22.26c	21.66a	21.33a	21.50b
Mean	24.32a	23.97a		23.44a	23.16a	
Fruit/pod length (cm)						
Frequent	6.87a	6.88a	6.87a	10.06a	10.26a	10.16b
Moderately frequent	5.91a	5.86a	5.89b	12.23a	12.70a	12.46a
Less frequent	5.81a	5.76a	5.79c	9.76a	9.60a	9.68c
Mean	6.20a	6.17a		10.68a	10.85a	
Fruit/pod diameter (cm)						
Frequent	6.10a	6.23a	6.16a	1.45a	1.44a	1.45b
Moderately frequent	5.80a	5.73a	5.76b	1.56a	1.54a	1.55a
Less frequent	5.36a	5.43a	5.40c	1.40a	1.33a	1.36b
Mean	5.75a	5.80a		1.47a	1.43a	

Treatment means sharing the different letter(s) in a group are significantly different at p ≥ 0.05

effect less frequent irrigation treatment × year 2013. The highest yield was obtained with the combined effect of moderately frequent irrigation treatment × year 2012, which was statistically different from all other treatment combinations. The treatment combinations, less frequent irrigation treatment × year 2012, less frequent irrigation treatment × year 2013, frequent irrigation treatment × year 2013

and frequent irrigation treatment × year 2012 were statistically at par with each other with significantly lower pod yield.

Effect of sewage water irrigation frequency on biomass production (on fresh and dry weight basis)

Total biomass (fresh and dry) of tomato was significantly affected by different irrigation frequency

treatments. Greater values for these parameters were recorded in the plants which were grown with frequent irrigation application. Whereas the minimum fresh and dry biomass was observed with less frequent irrigation treatment. All three irrigation treatments were statistically different from each other. Significantly greater biomass (on fresh weight basis) was recorded with frequent irrigation treatment × year 2012, followed by frequent irrigation treatment × year 2013. These two treatment combinations were statistically alike. Whereas the minimum fresh total biomass was recorded with the interactive effect of less frequent treatments × year 2013, followed by less frequent irrigation treatment × year 2012. These two treatment combinations also behaved statistically alike (Table 4).

Different irrigation frequency treatments affected the total biomass (fresh and dry) of okra. Moderately frequent irrigation treatment resulted in significantly greater total fresh and dry biomass. Whereas, the minimum values for the parameters under study were recorded with less frequent irrigation treatment. These three treatments significantly differed from each other.

Heavy metals contents in tomato fruits and okra pod

Frequent irrigation application with sewage water resulted in greater Pb, Ni and Cr contents in tomato fruits, followed by with moderately frequent irrigation treatment. These two irrigation frequency treatments were statistically at par. Significantly lower contents (Pb, Ni and Cr) were recorded in fruits when plants were grown with less frequent irrigation treatment. This irrigation frequency was statistically similar with moderately frequent irrigation application. Significantly greater Cu content was recorded in fruits when plants were grown with frequent irrigation application compared with moderately or less frequent irrigation application, which was statistically alike with lower Cu contents. Tomato fruits contained significantly greater Cd and Fe contents when the plants were grown with frequent irrigation application. Whereas significantly lower Cd and Fe accumulation in the fruits were recorded with less frequent irrigation application (Table 5).

Significantly higher Pb and Cr contents were noticed in okra pods of the plants grown with frequent irrigation application. Moderately and less frequent irrigation application resulted in lower Pb and Cr

contents in okra pods. Okra pods contained higher Ni and Cd contents with frequent irrigation application, followed by moderately frequent irrigation. These two irrigation frequencies were statistically similar. Less frequent irrigation application resulted in lower Ni and Cd contents, which was also statistically at par with moderately frequent irrigation. Frequent irrigation application resulted in greater Cu content in okra pods, followed by those with moderately frequent irrigation application. These two irrigation frequency treatments were statistically alike. While significantly lesser Cu content was detected in pods when less frequent irrigation was applied to okra plants. Significantly greater Fe content was recorded in okra pods with frequent irrigation treatment. Less frequent irrigation application resulted in significantly lower Fe contents in okra pods.

Heavy metals contents in tomato and okra leaves

Among irrigation frequency treatments with sewage water, significantly higher Pb and Fe contents were recorded in leaves when tomato plants were irrigated frequently. Whereas less frequent irrigation resulted in significantly lower Pb and Fe contents. Greater Ni and Cd contents were recorded in leaves of the plants grown with frequent and moderately frequent irrigation treatment. Whereas less frequent irrigation application resulted in the minimum Ni and Cd contents in leaves. Cu and Cr substances were considerably higher in leaves of the plants grown with frequent irrigation application compared with moderately or less frequent irrigation application. The latter two irrigation treatments were statistically similar with lower Cu and Cr contents (Table 6).

Significantly higher heavy metals (Pb, Ni, Cu and Cr) contents were recorded in okra leaves grown with frequent irrigation, followed by moderately frequent irrigation. These two irrigation frequencies were statistically at par. Whereas, less frequent irrigation treatment resulted in a lower value for Pb, Ni, Cu and Cr contents. This treatment was also statistically alike with moderately frequent irrigation treatment. Significantly greater Cd content was recorded with frequent irrigation compared, while moderately and less frequent irrigation treatments were statistically similar with lower Cd contents. Frequent and moderately frequent irrigation applications were statistically similar with greater Fe contents. Whereas significantly lower Fe content was recorded in okra leaves when plants were irrigated with less frequent sewage water.

Table 3: Effect of sewage water irrigation frequency on yield of tomato and okra.

Frequency of irrigation water	Tomato			Okra		
	Year 2012	Year 2013	Mean	Year 2012	Year 2013	Mean
Fresh weight of individual fruit (g)						
Frequent	95.46a	95.83a	95.65a	8.96a	9.00a	8.98b
Moderately frequent	92.36a	92.00a	92.18b	9.23a	9.26a	9.25a
Less frequent	88.36a	88.16a	88.26c	8.11a	8.10a	8.10c
Mean	92.06a	92.00a		8.76a	8.78a	
Dry weight of individual fruit (g)						
Frequent	7.83a	7.90a	7.86a	1.79a	1.80a	1.79a
Moderately frequent	6.80a	6.63a	6.71b	1.84a	1.85a	1.85a
Less frequent	6.16a	6.13a	6.15c	1.62b	1.42c	1.52b
Mean	6.93a	6.88a		1.75a	1.69a	
Fruit yield per hectare (tons)						
Frequent	48.96a	48.47a	48.71a	10.79c	10.58c	10.69b
Moderately frequent	42.65a	42.10a	42.37b	17.99a	15.60b	16.80a
Less frequent	35.75a	35.45a	33.60c	10.14c	10.29c	10.21b
Mean	41.79a	41.34a		12.97a	12.16a	

Treatment means sharing the different letter(s) in a group are significantly different at $p \geq 0.05$

Table 4: Effect of sewage water irrigation frequency on biomass production (on fresh and dry weight basis) of tomato and okra.

Frequency of irrigation water	Tomato			Okra		
	Year 2012	Year 2013	Mean	Year 2012	Year 2013	Mean
Total plant biomass on fresh weight basis (g)						
Frequent	2885.8a	2877.6a	2881.7a	514.92a	521.39a	518.15b
Moderately frequent	2599.7b	2556.4b	2578.0b	646.93a	637.73a	642.33a
Less frequent	2297.5c	2241.6c	2269.6c	440.27a	443.03a	441.65c
Mean	2594.3a	2558.5a		534.05a	534.46a	
Total plant biomass on dry weight basis (g)						
Frequent	318.76a	319.14a	318.95a	90.27a	90.91a	90.59b
Moderately frequent	271.39a	264.83a	268.11b	125.71a	123.31a	124.51a
Less frequent	230.35a	224.96a	227.66c	76.42a	72.98a	74.70c
Mean	273.50a	269.64a		97.46a	95.73a	

Treatment means sharing the different letter(s) in a group are significantly different at $p \geq 0.05$

Heavy metals contents in tomato and okra roots

Significantly greater metals contents (Pb, Ni, Cu, Cd and Cr) were recorded in tomato roots grown with frequent irrigation, followed by moderately frequent irrigation treatment. These two treatments were statistically at par. While, less frequent irrigation resulted in lower Pb, Ni, Cu, Cd and Cr contents in roots, which was statistically similar to moderately frequent irrigation. Significantly higher Fe content was recorded in the roots of tomato plants under frequent irrigation treatment, while significantly lower Fe contents were observed with less frequent

irrigation application (Table 7).

Significantly higher Pb and Fe contents were recorded in roots of okra plants grown with frequent and moderately frequent irrigation treatments. These two irrigation frequencies were statistically similar. Significantly lower Pb and Fe contents were noticed with less frequent irrigation application. Significantly greater Ni content was recorded in roots when plants were grown with frequent irrigation treatment, significantly lesser Ni content was recorded with less frequent irrigation treatment. Higher Cu, Cd and

Cr contents were recorded with frequent irrigation application, which was statistically at par with moderately frequent irrigation application. Lower Cu, Cd and Cr contents were recorded with less frequent irrigation, which was also statistically similar with moderately frequent irrigation application.

Water shortage results in drought stress and poor growth and yields in crop plants. In the present study, significantly greater growth of tomato in terms plant height, relative leaf chlorophyll content and leaf area was recorded with frequent irrigation treatment (5 days interval), followed by moderately frequent (10 days interval) and less frequent irrigation treatment (15 days interval). The interaction between irrigation frequency treatments and years indicated that increased tomato growth (plant height and leaf area) was observed when plants were irrigated frequently

during 2012 and 2013, while reduced growth was found with less frequent irrigation interval during both the years. The differences in growth parameters due to various irrigation frequency treatments during the years were possibly due to the availability of more water in frequent irrigation treatment and prevailing weather conditions of the area during the growing season. The current findings are also related with those of [Abdel Mouty and Ali \(2008\)](#), who found increased plant growth of eggplant when irrigated at 10 days irrigation interval than those irrigated with 21 days interval. [Kirnak et al. \(2001\)](#) also found that water shortage reduced plant height, leaf chlorophyll content and vegetative growth of eggplant when grown with different irrigation regimes (100, 80, 60 and 40%). The number of eggplant leaves increased with increasing irrigation frequency ([Byari and Al-Rabighi, 1996](#)), being higher at shorter irrigation interval i.e., 6 days.

Table 5: Effect of sewage water irrigation frequency on heavy metals contents in tomato fruits and okra pods.

Frequency of irrigation water	Tomato fruits			Okra pods		
	Year 2012	Year 2013	Mean	Year 2012	Year 2013	Mean
Pb (mg kg⁻¹)						
Frequent	8.200a	8.933a	8.566a	3.300a	3.500a	3.400a
Moderately frequent	7.200a	7.400a	7.300ab	2.766a	3.100a	2.933b
Less frequent	5.567a	6.100a	5.833b	2.433a	2.600a	2.516b
Mean	6.988a	7.477a		2.833a	3.066a	
Ni (mg kg⁻¹)						
Frequent	12.800a	13.167a	12.983a	8.800a	9.200a	9.000a
Moderately frequent	10.600a	11.13a	10.867ab	8.200a	8.500a	8.350ab
Less frequent	8.700a	9.900a	8.800b	7.400a	7.800a	7.600b
Mean	10.700a	11.067a		8.133a	8.500a	
Cu (mg kg⁻¹)						
Frequent	9.633a	9.966a	9.800a	10.800a	11.233a	11.017a
Moderately frequent	7.700a	7.666.a	7.683b	9.400a	10.500a	9.950a
Less frequent	6.500a	6.600a	6.550b	8.200a	9.033a	8.617b
Mean	7.944a	8.077a		9.467a	10.256a	
Cd (mg kg⁻¹)						
Frequent	2.566a	2.700a	2.633a	0.083a	0.333a	0.208a
Moderately frequent	2.166a	2.233a	2.200b	0.053a	0.059a	0.056ab
Less frequent	1.700a	1.800a	1.750c	0.033a	0.040a	0.036b
Mean	2.144a	2.244a		0.056a	0.144a	
Fe (mg kg⁻¹)						
Frequent	137.00a	139.57a	138.28a	203.93a	210.47a	207.20a
Moderately frequent	116.43a	117.67a	117.05b	143.60a	162.60a	153.10b
Less frequent	80.23a	92.80a	86.52c	128.07a	138.10a	133.08c
Mean	111.22a	116.68a		158.53a	170.39a	
Cr (mg kg⁻¹)						
Frequent	0.500a	0.603a	0.551a	0.900a	1.333a	1.116a
Moderately frequent	0.333a	0.366a	0.350ab	0.500a	0.633a	0.566b
Less frequent	0.166a	0.233a	0.200b	0.200a	0.366a	0.283b
Mean	0.333a	0.401a		0.533a	0.777a	

Treatment means sharing the different letter(s) in a group are significantly different at $p \geq 0.05$

Table 6: Effect of sewage water irrigation frequency on heavy metals contents in tomato and okra leaves.

Frequency of irrigation water	Tomato fruits			Okra pods		
	Year 2012	Year 2013	Mean	Year 2012	Year 2013	Mean
Pb (mg kg⁻¹)						
Frequent	9.400a	9.966a	9.683a	4.800a	5.300a	5.050a
Moderately frequent	7.800a	7.866a	7.833b	4.033a	4.200a	4.116ab
Less frequent	5.200a	6.133a	5.666c	3.601a	3.600a	3.600b
Mean	7.466	7.988a		4.200a	4.311a	
Ni (mg kg⁻¹)						
Frequent	16.600a	16.700a	16.650a	10.533a	11.500a	11.017a
Moderately frequent	15.300a	15.633a	15.467a	9.633a	9.700a	9.667ab
Less frequent	13.533a	13.633a	13.583b	8.833a	8.840a	8.833b
Mean	15.144a	15.322a		9.667a	10.011a	
Cu (mg kg⁻¹)						
Frequent	11.633a	12.267a	11.950a	13.933a	14.667a	14.050a
Moderately frequent	9.767a	9.967a	9.867b	12.433a	12.967a	12.700ab
Less frequent	9.200a	9.300a	9.250b	11.367a	11.267a	11.317b
Mean	10.200a	10.511a		12.578a	12.800a	
Cd (mg kg⁻¹)						
Frequent	2.866a	3.166a	3.016a	0.800a	0.966a	0.883a
Moderately frequent	2.466a	2.800a	2.633ab	0.433a	0.700a	0.566b
Less frequent	1.866a	2.333a	2.100b	0.300a	0.366a	0.333b
Mean	2.400a	2.766a		0.511a	0.677a	
Fe (mg kg⁻¹)						
Frequent	249.37a	261.70a	255.53a	259.63a	262.90a	261.27a
Moderately frequent	236.70a	240.20a	238.45b	244.57a	245.43a	245.00a
Less frequent	155.87a	157.13a	156.50c	214.00a	214.63a	214.32b
Mean	213.98a	219.68a		239.40a	240.99a	
Cr (mg kg⁻¹)						
Frequent	1.600a	1.900a	1.750a	2.200a	2.300a	2.250a
Moderately frequent	1.000a	1.166a	1.083b	1.800a	1.866a	1.833ab
Less frequent	0.701a	0.700a	0.700b	1.500a	1.400a	1.450b
Mean	1.100a	1.255a		1.833a	1.8553a	

Treatment means sharing the different letter(s) in a group are significantly different at $p \geq 0.05$

In the present study, moderately frequent irrigation (10 days interval) gave significantly greater plant height and leaf area of okra than frequent (5 days interval) and less frequent irrigation treatments (15 days interval). This study supports the previous findings of Khalil (2004), who found increased growth rate in terms of plant height and number of leaves per plant when the plants were grown with 10 days' irrigation interval. Abbas (2007) found that irrigation at every 8 days' interval gave significantly taller okra plants. The variations in the present and previous results could be due to soil type and environmental differences. The increased growth of summer vegetables by the application of frequent or moderately frequent irrigations with sewage water was possibly due to

that this water not only provides moisture but also contains nutrients required for proper growth and development.

In the present study, frequent irrigation application significantly increased the number of fruits per plant, fruit length, fruit diameter, fresh and dry weight of individual fruit and yield per hectare in tomato compared with moderately frequent and less frequent irrigation treatments. The larger size of tomato fruits was probably due to proper supply of water at particular development stage such as reproductive phase, which needs more supply of water and nutrients for the production of an appreciable size of fruits. The yield of tomato significantly increased with increasing

the frequency of sewage water (Phene *et al.*, 1986). Gudugi *et al.* (2012) reported that irrigation interval at 4 days resulted in a higher number of tomato fruits and greater yield than with 8 days interval during 2010-2011, possibly associated with conditions of low humidity and high temperature, which could quickly dry the soil. Less availability of irrigation water negatively affects the hormonal balance, plant growth, development, and nutrients translocation (Salisbury and Ross, 1992). Bafeel and Moftah (2008) concluded that reduced vegetative growth and negative effect on yield and its components in eggplants could be related to drought stress. Similar results were also achieved for tomato by Mahmood (2008).

The present study indicated that the irrigation

regimes used have a significant effect on yield and yield components of okra. This difference in yield was possibly due to excessive and low irrigation application to okra crop (Al-Harbi *et al.*, 2008). The decreased yield was also observed in water-stressed okra plants (Sankar *et al.*, 2008). The current findings are connected with the conclusions of Khalil (2004), who found significantly greater pod length, pod weight and yield of okra under 10 days irrigation interval. This difference in the results was due to different soil types and environmental conditions of the growing areas. The increased yield in the present study was also possibly due to the application of sewage water, as this water is enriched with macro and micronutrients and organic matter, which ultimately increased yields of the studied vegetables.

Table 7: Effect of sewage water irrigation frequency on heavy metal contents in tomato and okra roots.

Frequency of irrigation water	Tomato fruits			Okra pods		
	Year 2012	Year 2013	Mean	Year 2012	Year 2013	Mean
Pb (mg kg⁻¹)						
Frequent	12.966a	13.200a	13.083a	7.533a	8.100a	7.816a
Moderately frequent	9.500a	11.500a	10.500ab	6.700a	7.200a	6.950a
Less frequent	7.533a	9.600a	8.567b	5.400a	6.300a	5.850b
Mean	10.00a	11.43a		6.544a	7.200a	
Ni (mg kg⁻¹)						
Frequent	19.633a	23.167a	21.400a	13.500a	13.600a	13.550a
Moderately frequent	17.633a	19.400a	18.517ab	11.700a	12.500a	12.100b
Less frequent	15.700a	17.800a	16.750b	10.067a	10.200a	10.133c
Mean	17.656a	20.122a		11.756a	12.100a	
Cu (mg kg⁻¹)						
Frequent	16.600a	17.500a	17.050a	16.400 a	15.633a	16.017a
Moderately frequent	14.733a	15.567a	15.150ab	15.300a	15.533a	15.417ab
Less frequent	12.600a	13.700a	13.150b	13.500a	13.967a	13.733b
Mean	14.644a	15.589a		15.067a	15.044a	
Cd (mg kg⁻¹)						
Frequent	3.800a	4.200a	4.000a	1.333a	1.416a	1.375a
Moderately frequent	3.400a	3.700a	3.550ab	0.700a	1.100a	0.900ab
Less frequent	2.733a	3.200a	2.966b	0.300a	0.6300a	0.466b
Mean	3.311a	3.700a		0.744a	1.050a	
Fe (mg kg⁻¹)						
Frequent	289.27a	313.63a	301.45a	310.50a	327.53a	311.43a
Moderately frequent	252.47a	266.13a	259.30b	295.33	304.57a	307.53a
Less frequent	172.43a	196.00a	184.22c	271.77a	270.47a	71.12b
Mean	238.06a	258.59a		290.56a	302.83a	
Cr (mg kg⁻¹)						
Frequent	2.433a	2.700a	2.566a	2.600a	2.933a	2.766a
Moderately frequent	1.800a	2.200a	2.000ab	2.333a	2.533a	2.433ab
Less frequent	1.200a	1.900a	1.550b	1.866a	2.200a	2.033b
Mean	1.811a	2.266a		2.266a	2.555a	

Treatment means sharing the different letter(s) in a group are significantly different at $p \geq 0.05$

Total fresh and dry plant tomato plant biomass was significantly greater with 5 days sewage irrigation frequency, followed by 10 days interval and the minimum was recorded with 15 days irrigation interval. Reduced dry weight of shoot and leaves of tomato results usually due to insufficient soil moisture (Singandhupe *et al.*, 2003). Various plant physiological processes might be hampered due to inadequate availability of soil water. Water stress tends to decrease root growth of the tomato plant, which leads to reduced shoot dry weight because the development of roots and shoots are closely related (Ismail *et al.*, 2008). In another study, total tomato plant biomass was decreased with water stress (Birhanu and Tilahun, 2010).

In the present study, significantly increased fresh and dry total plant biomass were obtained in okra plants grown with moderately frequent irrigation (10 days interval) than frequent (5 days interval) and less frequent irrigation treatment (15 days interval). Reduction in biomass of okra plant due to water stress has already been reported by Sankar *et al.* (2008).

Significantly greater Pb, Cr, Ni, Fe, Cu and Cd substances were noted in the cultivated tomato fruits and okra pods when plants were irrigated frequently (5 days interval), while less frequent irrigation treatment (15 days interval) resulted in lesser accumulation of these heavy metals. All the fruit and pod samples of tomato and okra plants under all three irrigation frequency treatments exhibited Pb and Cd contents exceeding above the higher approved limits set by Asaolu (1995) and WHO (1996). Ni contents in fruits of tomato plants irrigated with frequent and moderately frequent irrigation treatments were above the maximum permissible limits, and these contents were below the permissible limits when less frequent irrigation was applied. Whereas Cu, Fe and Cr contents in fruits of tomato plants irrigated with all the three irrigation frequency treatments were below the maximum permissible limits. The Ni and Cr contents in okra pods were found below the safer limits when grown with all the three irrigation frequency treatments. The pods contained Cu contents above the permissible limits when sewage water was applied frequently, while moderately and less frequent irrigation treatments resulted in Cu contents below the recommended levels. Frequent and moderately frequent sewage water applications showed higher Fe contents in pods above the permissible limits, while

less frequent sewage water application showed lower content in pods lower the safe limits, recognized by Asaolu (1995) and WHO (1996).

Application of sewage water continuously pollutes the soils with heavy metals. Soils act as filters of poisonous compounds, possibly absorbing and retaining heavy metals from sewage water. When soils' capacity to retain heavy metals, contents is decreased due to loading of these contaminants continuously or soil pH changes, then soils can discharge these toxic metals into water or soil solution and make available for plants uptake. The results of the present study indicated that as the frequency of sewage irrigation application was increased, there was more accumulation of heavy metals in plant parts. It was possibly due to more buildup of heavy metals in soil because of indiscriminate use of sewage water which ultimately contaminated the crop plants grown on those soils. It was observed that as the duration of sewage irrigation interval increased, there was less accumulation of heavy metals in plant parts. It is because the heavy metals contents were increased with frequent irrigation treatment and decreased when grown with moderately and less frequent irrigation applications in the present investigation.

Tomato and okra leaves and roots showed all the heavy metals contents as affected by the frequency of irrigation treatments in order: frequent > moderately frequent > less frequent sewage water application. With the decrease in duration of sewage irrigation application, the metals tended to accumulate in the soil, and their availability in soil solution and uptake resulted in greater metal content in plant parts. Therefore, the frequent irrigation water increased the heavy metals contents in tomato and okra plant parts as compared to moderately frequent irrigation application, while less frequent irrigation application resulted in lower metals contents in plant parts. Thus, the frequent use of sewage water for irrigation has a greater ability to pollute the soil, which in turn results in uptake of metals by crops.

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Novelty Statement

Novelty of the current research highlights the malpractices performed in olericulture by farming community by the frequent use of sewage water application in an increased amount which results in the accumulation of Fe, Cu, Pb, Cr, Ni and Cd in higher amounts in okra and tomato in pods and fruits respectively. Resultantly these commodities are used as food and a serious hazard for human health.

Author's Contribution

The idea was conceived by Safina Naz and Muhammad Akbar Anjum. The experiments were performed by Safina Naz, Sajid Ali, Hassan Sardar and Sakeena Tul Ain Haider. Statistical analysis was performed by Syed Atif Hasan Naqvi and Zehri Khan. The overall management of the article was performed by Muhammad Asif Zulfiqar, Sibghat Ullah, Hajra Azeem and Shah Pasand.

Conflict of interest

The authors have declared no conflict of interest.

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