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Effect of wastewater irrigation with zinc application on okra crop

■ **Govind Kumar Maurya**

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Author for Correspondence :
Govind Kumar Maurya
Department of Soil and Water Engineering, Rajendra Agricultural University, Pusa, **Samastipur (Bihar) India**
Email : govindmaurya548@gmail.com

■ **ABSTRACT :** An investigation was carried out to evaluate the effect of wastewater irrigation and zinc combination on growth and yield of okra (*Abelmoschus esculentus*). The pot experiment was conducted for okra crop var. INDAM-9821 during *Kharif* season of the year 2011. The experiment was designed as per Factorial Completely Randomized Design (FCRD) with four irrigation treatments, four zinc treatments and three replications. The irrigation treatments consisted of all fresh water irrigation, two fresh and one sewage water irrigation, alternate fresh and sewage water irrigation and all sewage water irrigation. The zinc treatments consisted of application of Zn @ 0.0, 2.5, 5.0 and 7.5 kg Zn/ha. The study revealed that alternate irrigation with fresh water and wastewater along with the application of Zn @ 5.0 kg/ha resulted in better crop growth, early flowering and highest yield of okra. The maximum concentration of Zn (51.50 mg/kg), Mn (37.84 mg/kg) were found in fruits under treatment alternate irrigation with application of Zn @ 5.0 kg/ha. The concentration of Fe in okra fruits maximum (871.67 mg/kg) in treatment all waste water irrigation with no application of zinc. Similarly, regarding the plant residue (dry matter) the highest concentrations of Zn (88.54 mg/kg), Mn (59.56 mg/kg) were also seen for treatment alternate irrigation with application of Zn @ 5.0 kg/ha, while maximum concentration of Fe (1531.34 mg/kg) was showed in alternate irrigation with no application of Zn.

■ **KEY WORDS :** Okra, Wastewater, Irrigation, Zinc

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Water is important to all living organism, as water shows their existence upto 50-97 per cent in plant and in animals and about 70 per cent of human body weight, but it is unfortunate to say that this abounded resource is not managed or we can say most poorly managed by world. The agriculture sector alone consumes about 80 per cent of ground water, but ground water resource is depleted day by day and to fulfil the agriculture/irrigation requirement farmers searching the alternate water resources as results, an urban /semi urban farmer is re-utilizing the wastewater to irrigate their crops.Treatment of wastewater, as a segment of water management, usually produces a liquid effluent of suitable quality that can be used for irrigation purposes with minimum impacts on human health or the environment (Hussain *et al.*, 2001). Estimates on wastewater use worldwide indicate that about 20 million hectares of agricultural land is irrigated with (treated and untreated) wastewater (Scott *et al.*, 2004). Wastewater when used in low concentrations or in combination with canal and tube well water may have a good effect on crop growth and yield (Ranwa,1999). The direct use of wastewater in high concentrations should be avoided for its reuse in agriculture.

Zinc is one of the most essential micro nutrients for the vegetative growth of the crop. It activates enzymes in protein synthesis and is involved in the regulation and consumption of sugars. It is necessary for starch formation and proper root development in crops.It is well documented that the crop growth and yield are greatly influenced by a wide range of nutrients. Zinc is regarded as the third most important limiting nutrient in crop production after nitrogen and phosphorus (Takkar and Randhawa, 1980). According to Katyal and Rattan (1991) nearly half of the Indian soils and crops suffered from zinc deficiency of varying magnitude. Zinc deficiency is wide spread at the high pH, low organic matter and calcareous soil (Sakal, 2001; Ratan and Sharma, 2004). The purpose of present work is to study extensively the essential plant nutrient, under varying levels of micro nutrient application (Zn) under the influence of wastewater for the irrigation. Further, the study analyses the response of okra under various wastewater application strategies. Keeping in view of the ever increasing irrigation water requirement, the ultimate goal of the present work is to assess the possibilities of safe disposal of wastewater through irrigation in vegetable crops.

■ METHODOLOGY

In the present investigation, pot experiments were conducted in the College of Agricultural engineering, RAU, Pusa during *Kharif* season of 2011. Experimental soils were alluvial, calcareous in nature and medium to light in texture having low available micronutrients (Zn) (Table A). The pot experiment was conducted for okra crop var. INDAM-9821. The experiment was designed as per Factorial Completely Randomized Design (FCRD) with four irrigation treatments, four zinc treatments and three replications. The irrigation treatments consisted of all fresh water irrigation (I_1), two fresh and one sewage water irrigation (I_2), alternate fresh and sewage water (I_3), (chemical properties of water is given in Table B) irrigation and all sewage water irrigation (I_4). The zinc treatments consisted of application of Zn @ 0.0 ($Zn_{0.0}$), 2.5 ($Zn_{2.5}$), 5.0 ($Zn_{5.0}$) and 7.5 ($Zn_{7.5}$) kg Zn/ha.The obtained data from the pot experiment is shown in Table A and laboratory analysis were analyzed statistically by

Table A : Observation during investigation

Sr. No.	Group	Parameter	Remarks
1.	Growth parameters	Plant height	Recorded at 33, 61 and 82 DAS
		Flowering time	Days after sowing
2.	Yields attributes	Fresh fruits yield	Weekly
		Dry fruits yield	On harvest
		Dry matter yield	On harvest
3.	Nutrients uptake	Concentration of Zn, Fe, Mn, Cu in fruits	After harvest

Table B : Initial physico-chemical characteristics of experimental soils

Parameters	Contents	Method used
Sand,%	57.28	International pipette method (Piper,1950)
Silt,%	30.34	
Clay,%	12.38	
Texture class	Sandy loam	
Bulk density (g/cm^3)	1.76	Core method (Blake and Hartge, 1986)
Hydraulic conductivity (cm/h)	1.68	Falling head method
Porosity, %	33.58	Porosity = $100 - \frac{B.D.}{P.D.} x100$
pH	8.21	Glass electrodes (Jackson, 1973)
Available Zn (ppm)	0.53	Atomic Absorption spectrophotometer (Parkin Elmer A Analyst, 200).
Available Cu (ppm)	1.45	
Available Fe (ppm)	16.6	
Available Mn (ppm)	5.40	

Source: Anonymous, 2010-2011

Table C : Chemical characteristics of sewage water

Parameters	Contents	Method used
pH	7.56	Glass electrodes (Jackson, 1973)
EC (dsm^{-1})	1.42	Conductivity Bridge (Jackson, 1973)
Na (me/L)	5.28	Flame photometer
Ca + mg (me/L)	7.66	Vercenate (EDTA) Titration method (Cheng and Bray, 1951)
CO^3 +HCO_3^- (me/L)	2.24	Acidimetric titration method
Cl (me/L)	5.2	Mohr' titration method
Zn (ppm)	0.16	Atomic absorption spectrophotometer (Parkin Elmer A Analyst, 200)
Cu (ppm)	0.039	
Fe (ppm)	0.255	
Mn (ppm)	0.157	
Cd (ppm)	0.003	

FCRD to assess the treatments having significant bearing on the plant growth characters and yields attributes.

Plant nutrients analysis:

The fruits were sun dried for 15 days then plant samples were dried in oven at 65^{0}C and dry matter were recorded for each sample from each pot. The samples were grinded and kept in polythene bags for their chemicals analysis. The 0.5g powdered fruits were transferred to a clean and dried flask and 15 ml tri-acid nitric acid, perchloric acid and sulphuric acid in the ratio 10:4:1 was added into the flask. The solution was kept overnight then primary digestion was done on hot plate until few drops of white residue were left. The residues were dissolved in double glass distilled water and final volume was made to 50 ml in volumetric flask. The concentration of Fe, Zn, Cu and Mn was determined with the help of atomic absorption spectrophotometer.

Statistical analysis:

The obtained data from the pot experiment and laboratory analysis were analyzed statistically by factorial CRD in order to find out to which treatments had significant bearing on the plant growth characters, yields attributes and nutrients uptake.

■ RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Plant height (at 33 DAS):

Maximum plant height of 25.69 cm was recorded in treatment I_3 which was significantly superior to I_1 *i.e.* 23.30 cm but found at par with I_2 *i.e.* 24.25 cm and I_4 *i.e.* 25.54 cm.

Plant height of 26.09 cm in treatment $Z_{7.5}$ was found

Table 1 : Composite effects of sewage water irrigation and zinc application on plant height (cm) at 33 DAS of okra

Irrigation treatments	Zinc treatments					
	$Z_{0.0}$	$Z_{2.5}$	$Z_{5.0}$	$Z_{7.5}$	Mean	Per cent increase over control
I_1 (control)	20.84	23.80	24.40	24.14	23.30	-
I_2	20.50	24.37	25.84	26.30	24.25	4.07
I_3	22.73	25.77	27.10	27.17	25.69	10.25
I_4	22.94	26.25	26.25	26.73	25.54	9.61
Mean	21.75	25.05	25.90	26.09	-	-

Treatments	S.E.±	C.D. (P=0.05)	CV
Irrigation treatment (I) Zinc treatment (Z)	0.86	2.38	12.08
I x Z	-	NS	-

NS= Non-significant

significantly superior over control treatment $Z_{0.0}$ and at par with $Z_{2.5}$ (25.05 cm) and $Z_{5.0}$ (25.90 cm). Also treatment $Z_{2.5}$ (25.05 cm) and $Z_{5.0}$ (25.90 cm) were statistically at par to each other (Table 1).

Plant height (at 61 DAS):

From Table 2 it was found that the plant height at 61 DAS (*i.e.* 50.27 cm) in treatment I_3 was significantly superior over control treatment I_1 (43.47 cm) and I_2 (45.85 cm) and at par with treatment I_4 (48.54 cm). The maximum plant height (50.27 cm) of okra was observed in treatment I_3.

Data presented in Table 2 indicate that plant height at 61 DAS (49.29 cm) in treatment $Z_{5.0}$ was significantly superior over control $Z_{0.0}$ (43.35 cm) and statistically at par with treatments $Z_{2.5}$ (48.10 cm) and $Z_{7.5}$ (47.69 cm). The interaction effect of irrigation and zinc treatments was found non-significant whereas the per cent increase in plant height over control varied from 5.47 to 15.64.

Plant height (at 82 DAS):

From the experimental data shown in Table 3, it was found that the plant height in treatment I_3 was significantly higher (77.23 cm) than all other irrigation treatments I_1, I_2 and I_4 which have the plant height 65.96 cm, 71.14 cm and 75.04 cm, respectively at 82 DAS. The per cent increase in plant height was found higher with alternate irrigation of sewage and fresh water. This might be due to optimum translocation of zinc with irrigation treatment.

Table 3 reveals that the average plant height varied from 68.68 cm to 77.19 cm at various levels of zinc treatments at 82 DAS. The maximum plant height was observed in $Z_{5.0}$ treatment (77.19 cm) which was significantly superior over all the other zinc treatments. Also $Z_{7.5}$ (72.50 cm) was superior over treatments $Z_{0.0}$ (68.68 cm) and was statistically at par with $Z_{2.5}$ (70.99 cm). The interaction effect between irrigation treatments and levels of zinc was found non- significant.

Table 2 : Composite effects of sewage water irrigation and zinc application on plant height (cm) at 61 DAS of okra

Irrigation treatments	Zinc treatments					
	$Z_{0.0}$	$Z_{2.5}$	$Z_{5.0}$	$Z_{7.5}$	Mean	Per cent increase over control
I_1 (control)	39.53	45.83	45.63	42.90	43.47	-
I_2	42.97	46.43	46.97	47.03	45.85	5.47
I_3	45.03	51.70	52.90	51.43	50.27	15.64
I_4	45.87	47.20	51.67	49.40	48.54	11.66
Mean	43.35	47.79	49.29	47.69	-	
Treatments	S.E.±		C.D. (P=0.05)			CV
Irrigation treatment (I) Zinc treatment (Z)	1.12		3.12			8.29
I x Z	-		NS			-

NS= Non-significant

Table 3 : Composite effects of sewage water irrigation and zinc application on plant height (cm) at 82 DAS of okra

Irrigation treatments	Zinc treatments					
	$Z_{0.0}$	$Z_{2.5}$	$Z_{5.0}$	$Z_{7.5}$	Mean	Per cent increase over control
I_1 (control)	62.03	62.70	69.83	69.27	65.96	-
I_2	69.70	69.57	74.90	70.37	71.14	7.85
I_3	72.07	75.90	84.17	76.77	77.23	17.08
I_4	70.93	75.77	79.87	73.60	75.04	13.76
Mean	68.68	70.99	77.19	72.50	-	
Treatments	S.E.±		C.D. (P=0.05)			CV
Irrigation treatment (I) Zinc treatment (Z)	1.14		3.16			5.46
I x Z	-		NS			-

NS= Non-significant

Addition of sewage and fresh water with different doses of zinc had significant effect on the plant height and was found maximum at 33 DAS, 61 DAS and 82 DAS which was 25.69 cm, 50.27 cm and 77.23 cm, respectively and minimum in control treatment I_1 at various growth stages.

Flowering time:

Table 4 representing the flowering time varied from 40.17 to 44.83 DAS and was found maximum in control treatment. The earliest flowering time was observed in treatment I_3 *i.e.* 40.17 DAS which was at par with I_4 (41.67 DAS) and significantly superior over I_1 (44.83 DAS) and I_2 (43.00 DAS).

The flowering time in all the zinc treatments $Z_{0.0}$, $Z_{2.5}$, $Z_{5.0}$ and $Z_{7.5}$ *i.e.* 45.83 DAS, 44.25 DAS, 37.50 and 42.09 DAS, respectively. Amongst the treatments, earliest flowering time was observed in treatment $Z_{5.0}$ (37.50 DAS)

The treatment (I_3) led to early flowering (40.17 DAS) which is significantly superior to I_1 (44.83 DAS) and I_2 (43.00 DAS) but at par with I_4 (41.67 DAS).

While application of zinc @ $Z_{5.0}$ (37.50 DAS) showed its superiority over all other treatments, significantly. This might be due to the appropriate accumulation of nutrients by the plant with the help of zinc.

Crop yield :

It was observed that the average fruits yield varied from 33.50 g/pot to 55.32 g/pot at various levels of sewage water irrigation (Table 5). The maximum fruits yield (55.32 g/pot) was recorded in treatment I_3 which was significantly superior over I_1, I_2 and I_4 *i.e.* 33.50 g/pot, 39.24 g/pot and 47.26 g/pot, respectively. The per cent increase in fruits yield over control varied from 17.13 to 65.13.

As per Table 5 it was also revealed that the

Table 4: Composite effects of sewage water irrigation and zinc application on flowering time (DAS) of okra

Irrigation treatments	Zinc treatments					
	$Z_{0.0}$	$Z_{2.5}$	$Z_{5.0}$	$Z_{7.5}$	Mean	Per cent time reduction over control
I_1(control)	48.33	46.00	40.00	45.00	44.83	-
I_2	46.33	45.00	38.00	42.67	43.00	4.08
I_3	44.67	42.00	35.00	39.00	40.17	10.39
I_4	44.00	44.00	37.00	41.67	41.67	7.04
Mean	45.83	44.25	37.50	42.09	-	

Treatments	S.E.±	C.D. (P=0.05)	CV
Irrigation treatment (I) Zinc treatment (Z)	0.66	1.85	5.45
I x Z	-	NS	-

NS= Non-significant

Table 5 : Composite effects of sewage water irrigation and zinc application on fresh fruits yield (g/pot) of okra

Irrigation treatments	Zinc treatments					
	$Z_{0.0}$	$Z_{2.5}$	$Z_{5.0}$	$Z_{7.5}$	Mean	Per cent increase over control
I_1 (control)	27.66	36.67	37.24	32.44	33.50	-
I_2	33.43	41.25	43.84	38.43	39.24	17.13
I_3	45.84	59.78	61.01	54.64	55.32	65.13
I_4	40.04	48.38	53.98	46.65	47.26	41.07
Mean	36.74	46.52	49.02	43.04	-	

Treatments	S.E. ±	C.D. (P=0.05)	CV
Irrigation treatment (I) Zinc treatment (Z)	0.53	1.47	4.22
I x Z	-	2.96	-

maximum fresh fruits yield of okra crop varied from 36.74 to 49.02 g/pot over control with maximum yield at $Z_{5.0}$ (49.02 g/pot). It was also observed that there were considerable decreases in fresh fruits yield (43.04 g/pot) beyond this level in treatment $Z_{7.5}$. The interaction effects between irrigation and zinc level was found significant.

The fresh fruits yield increased with increase in magnitude of sewage water application upto I_3 but there after it decreased might be due to increase in availability of micronutrients with application of sewage water and beyond this level yield was found decreased when it reached to toxicity level in treatment I_4, regard with zinc application yield is increased upto $Z_{5.0}$ after that it decreased might be due to toxicity of zinc at higher level.

Dry matter production:

The dry matter yield varied from 9.83 to 19.14 g/pot (Table 6). The maximum dry weight of okra was recorded in treatment I_3 *i.e.* 19.14 g/pot which was significantly superior to all other treatments.

It can also be observed that the dry matter yield *i.e.* 18.38 g/pot in treatment $Z_{5.0}$ is significantly superior to other zinc treatments.

The dry matter yield in irrigation treatments varied from 9.83 g/pot to 19.14 g/pot. The yield was observed maximum in treatment I_3 and minimum in control (I_1). However, alternate irrigation with sewage water (I_3) showed better response at $Z_{5.0}$ might be due to the fact that the maximum translocation of zinc and other essential nutrients in plant and fruits. The level of micronutrient due to application of I_3 and $Z_{5.0}$ may be optimum for plant growth which is reflected in highest dry matter yield. The interactions effect of irrigation and zinc was found statistically significant.

Zinc concentration in fruits:

The overall zinc concentration in fruits of okra varied from 32.50 mg/kg to 51.50 mg/kg (Table 7). Zinc concentration was maximum (42.34 mg/kg) in treatment I_3 which was significantly superior to other treatments

Table 6: Composite effect of sewage water irrigation and zinc application on dry matter yield (g/pot) of okra

Irrigation treatments	Zinc treatments					
	$Z_{0.0}$	$Z_{2.5}$	$Z_{5.0}$	$Z_{7.5}$	Mean	Per cent increase over control
I_1(control)	8.54	9.89	11.26	9.64	9.83	-
I_2	12.13	13.41	20.98	18.05	16.14	64.19
I_3	14.38	19.18	23.11	19.89	19.14	94.71
I_4	12.24	12.55	18.15	13.16	14.03	42.72
Mean	11.82	13.76	18.38	15.19	-	-
Treatments	S.E.±		C.D. (P=0.05)		CV	
Irrigation treatment (I) Zinc treatment (Z)	0.47		1.32		11.23	
I x Z	-		2.65		-	

Table 7 : Composite effects of sewage water and zinc application on zinc concentration (mg/kg) in fruits of okra

Irrigation treatments	Zinc treatments					
	$Z_{0.0}$	$Z_{2.5}$	$Z_{5.0}$	$Z_{7.5}$	Mean	Per cent increase over control
I_1(control)	32.80	40.00	48.34	35.80	39.24	-
I_2	32.50	44.94	46.90	37.56	40.48	3.16
I_3	34.06	45.34	51.50	38.44	42.34	7.90
I_4	35.70	41.50	44.30	35.34	39.21	-0.07
Mean	33.77	42.95	47.76	36.79	-	-
Treatments	S.E.±		C.D. (P=0.05)		CV	
Irrigation treatment (I) Zinc treatment (Z)	0.57		1.59		4.93	
I x Z	-		3.18		-	

I_1, I_2 and I_4 *i.e.* 39.24 mg/kg, 40.48 mg/kg and 39.21 mg/kg. The irrigation treatments showed significant response In view of the effect of difference doses of zinc application, the concentration of zinc increased upto treatment $Z_{5.0}$ (47.76 mg/kg) and significant reduction observed in treatment $Z_{7.5}$. The concentration of zinc in fruits of okra was found maximum in treatment $Z_{5.0}$ (*i.e.* 47.76 mg/kg) which was significantly higher to other zinc treatments $Z_{0.0}$, $Z_{2.5}$ and $Z_{7.5}$ *i.e.* 33.77 mg/kg, 42.95 mg/kg and 36.79 mg/kg, respectively. Increasing level of zinc significantly increased the zinc concentration in respective order except treatment $Z_{7.5}$ (*i.e.*36.79 mg/kg).

Zinc application significantly increased zinc concentration in treatment $Z_{5.0}$ in fruits with fresh and sewage water (Table 7). This might be due to alternate irrigation with fresh and sewage water provides the optimum translocation of zinc to the okra plant due to the solubility of zinc.

Iron concentration in fruits:

Perusal of data presented in Table 8, reveals that the concentration of iron in fruits of okra due to various irrigation treatments was observed maximum (784.58 mg/kg) in treatment I_3, which was significantly superior among all irrigation treatments namely I_1 (688.08 mg/kg), I_2 (710.83 mg/kg) and I_4 (743.50 mg/kg). Per cent increase over control varied from 3.30 to 14.02.

The average iron concentration in fruits of okra varied from 647.84 mg/kg to 837.41 mg/kg. It is obvious from the data that iron concentration varied with level of zinc and it was significantly decreased with increasing levels of zinc. Concentration of zinc reduced the concentration of iron might be due to depressing effect to each other. Maximum Iron concentrations in zinc treatments was found maximum in treatment $Z_{0.0}$ (837.41 mg/kg) and continuously decreased to all other treatments.

The effect of different levels of sewage water irrigation and different levels of zinc application on iron concentration in fruits, while zinc decreased the iron concentration in fruits, which might due to antagonistic relationship between zinc and iron (Table 8). The sewage water load increased the iron concentration. The effect of zinc on iron concentration was significant. The various combinations of zinc and irrigation treatment resulted in iron concentration in the range of 619.34 mg/kg to 871.67 mg/kg in fruits. The interaction effect of irrigation and zinc treatments was significant for fruits.

Manganese concentration in fruits:

It is evident from Table 9, that the concentration of manganese in fruits of okra in irrigation treatments was observed maximum in treatment I_3 *i.e.* 34.38 mg/kg which was significantly superior to other irrigation treatments I_1 (*i.e.* 29.68 mg/kg), I_2 (*i.e.* 32.35 mg/kg) and at par with treatment I_4 (*i.e.* 30.67 mg/kg). The concentration of manganese was significantly increased due to application of wastewater load upto treatment I_3 (*i.e.* 34.38 mg/kg), but further increase in application of sewage water load decreased the concentration of manganese due to imbalance of nutrient.

Data presented in Table 9, show that the mean concentration of manganese in fruits of okra varied from 25.85 mg/kg to 36.44 mg/kg. Manganese concentration in fruits varied with levels of zinc application. A significant increase in Mn content was obtained with increasing levels of zinc might be due to synergistic effect. Maximum manganese concentrations in okra among zinc

Table 8 : Composite effects of sewage water irrigation and zinc application on iron concentration (mg/kg) in fruits of okra

Irrigation treatments	Zinc treatments					
	$Z_{0.0}$	$Z_{2.5}$	$Z_{5.0}$	$Z_{7.5}$	Mean	Per cent increase over control
I_1 (control)	781.67	690.67	660.67	619.34	688.08	-
I_2	845.67	667.34	705.67	624.67	710.83	3.30
I_3	871.67	864.00	721.67	681.00	784.58	14.02
I_4	850.67	699.67	757.34	666.34	743.50	8.05
Mean	837.41	730.41	711.34	647.84	-	-

Treatments	S.E.±	C.D. (P=0.05)	CV
Irrigation treatment (I) Zinc treatment (Z)	9.74	27.01	4.61
I x Z	-	54.03	-

treatments was found in treatment $Z_{7.5}$ (*i.e.* 36.44 mg/kg) which was significantly superior to other treatments $Z_{0.0}$, $Z_{2.5}$ and $Z_{5.0}$ *i.e.* 25.85 mg/kg, 30.48 mg/kg, 34.31 mg/kg, respectively.

A perusal of the data in Table 9, showed the effect of sewage water application and various levels of zinc application on Mn concentration in fruits of crop. It was observed that sewage water increased manganese concentration in fruits; also application of zinc increased the manganese concentration in fruits. There are possibilities of synergistic relationship between zinc and manganese. The effect of various combinations of zinc and irrigation treatments on manganese concentration varied from 24.06 mg/kg to 37.23 mg/kg in fruits. The interaction effect of irrigation and zinc application was statistically significant.

Copper concentration in fruits:

The samples of okra fruits were analysed to evaluate the effect various sewage water irrigation and zinc treatments on uptake of copper. The sample were analysed on atomic absorption spectrophotometer and the results obtained showed the negative values of concentration in most of the replication for fruits, which is not acceptable. This may be due to either there was some technical error in the instrument or the concentration of copper was so thin that the instrument failed to detect concentration of copper in samples.

In a view of above mention reason the results obtained for copper were rejected and no further analysis was carried out. However, the results obtained are presented in Table 10.

Conclusion:

Based on the observations recorded, laboratory analysis of samples of fruits and statistical analysis of data, following conclusions can be drawn:

On the basis of facts stated and Table 1 to 10, it can be concluded that the alternate irrigation with sewage water and fresh water (treatment I_3) with the application of Zn @ 5.0 kg/ha results in best crop growth, earliest flowering and highest yield of okra. The study also revealed that the application of zinc influenced the uptake of other micronutrients like Fe and Mn. The optimum level of Zn application was found to be 5.0 kg/ha in combination of alternate irrigation with fresh and sewage water.

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Table 9 : Composite effects of sewage water irrigation and zinc application on concentration of manganese (mg/kg) in fruits of okra

Irrigation treatments	Zinc treatments					
	$Z_{0.0}$	$Z_{2.5}$	$Z_{5.0}$	$Z_{7.5}$	Mean	Per cent increase over control
I_1 (control)	24.06	25.66	32.50	36.50	29.68	-
I_2	24.34	33.84	34.50	36.74	32.35	8.99
I_3	28.06	34.40	37.84	37.23	34.38	15.83
I_4	26.96	28.03	32.44	35.26	30.67	3.33
Mean	25.85	30.48	34.31	36.44	-	
Treatments	S.E.±		C.D. (P=0.05)		CV	
Irrigation treatment (I) / Zinc treatment (Z)	0.67		1.86		7.33	
I x Z	-		3.72		-	

Table 10 : Composite effects of sewage water and zinc application on concentration of copper (mg/kg) in fruits of okra

Irrigation treatments	Zinc treatments			
	$Z_{0.0}$	$Z_{2.5}$	$Z_{5.0}$	$Z_{7.5}$
I_1 (control)	0.73	-2.06	-0.50	-0.80
I_2	-4.36	-5.46	-3.63	-5.74
I_3	-4.26	-3.03	-5.60	-7.03
I_4	-4.84	-4.26	-5.23	-5.27

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