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Response of Some Field Crops to Irrigation with Municipal Wastewater

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ABSTRACT

Using of agricultural irrigation water is increasing greatly, and domestic consumption has reached a ceiling value. Therefore, alternative water resources are needed to satisfy further increases in demand in many parts of the world. The main objective of the present study is to evaluate the response of *Oryza sativa* L. (Poaceae) and *Abelmoschus esculentus* L. (Malvaceae) to irrigation with municipal Wastewater. Additionally, exploring the effect of municipal wastewater on soil and plants components compared to irrigation with freshwater. Results showed that the concentrations of elements attained their maxima in soil irrigated with Type I (soil irrigated with municipal wastewater) for rice and okra crop except for Cd in the later compared to Type II (soil irrigated with freshwater). There was a variation in the length and ratios of length of rice roots and shoots as well as number of tillers in rice for the two Types. Variation in the length and ratios of length (cm) of okra roots and branches as well as number of nodes in okra for the two types was appeared. Results indicated the effect of the type of irrigation water on its performance and morphological behavior. In conclusions, wastewater irrigation can affect rice and okra plants in terms of yields and crop quality such as appearance and flavor moreover, the type of irrigation water can effect of the performance and morphological behavior.

Key words: Municipal wastewater, Freshwater, *Oryza sativa L*, *Abelmoschus esculentus L*, El-keblia Drain and EL-Englizia Drain.

1. Introduction

Water is a major factor for the existence of human life and crop production. The major challenge faced by developing countries is the inability to produce adequate food for the growing human population and their domestic animals due to the shortage of freshwater for irrigating agricultural fields **(Gassama *et al.*, 2014)**. Therefore, alternative water resources are needed to satisfy further increases in demand in many parts of the world **(Jiménez, 2006).** The reuse of municipal wastewater for irrigation in agriculture is one of the oldest forms of water reclamation **(Paliwal *et al*., 1998).** One of the most positive effects of municipal wastewater irrigation is a rise of yield due to nutrients in municipal wastewater as well as soil texture improved by organic matters in municipal wastewater **(Jiménez, 2006).** On the other hand, it has negative effects that it causes accumulation of heavy metals, which are toxic to plants beyond a certain Limit (**Singh *et al.*, 2011**) and can affect seriously on soil quality and performance (**Chung *et al*., 2011**). Crops irrigated with municipal wastewater have potential to be contaminated with microbes, heavy Metals (**Park *et al.*, 2011).** Continuous monitoring and pollution control of hazardous materials are needed in order to ensure food safety and sustainable crop production **(Gassama *et al.*, 2014).**

Oryza sativa L. (Rice) which is one of the main crops feeding global population and requires large amount of water for its growth. Reuse of municipal wastewater for rice cultivation has a great potential to contribute to sustainable wastewater management (**Pham and Watanabe, 2017**). That is why heavy metals contamination in agricultural soils and their transfer into plants have been of increasing concern **(Zhao *et al.*, 2010).** As a result, heavy metals have a potential to cause side effect on human health and the environment (**Pham and Watanabe, 2017**). Rice may be the best indicator for the environment monitoring of Cadmium especially in rice eating countries (**Zazoli *et al*., 2006**).

It is highly recommended that municipal wastewater should be reused for irrigation; growth and yield of *Abelmoschus esculentus* L. (Okra) with different mix-proportion of partially treated municipal wastewater may be effect on soil by positive or negative way. It is usually difficult to expect which effect appears in municipal wastewater irrigation because soil is a very complicated structure involving inorganic and organic matters **(Gassama *et al*., 2014).**

The current study was carried out to evaluate the response of *Oryza sativa* L. (Poaceae) and *Abelmoschus esculentus* L. (Malvaceae) to irrigation with municipal Wastewater. Additionally, the aim extends to explore the effect of municipal wastewater on soil and plants components compared to irrigation with freshwater.

2. Materials and Methods

Two locations for the two study crops were selected in Antoniadis -Kafr Eldawar, El-Behera governorate to carry out the present study depending on the applied irrigation water. The municipal wastewater was from El-keblia Drain. While the control; freshwater sample was delivered from EL-Englizia

2.1. Soil sample collection

Twelve soil samples were collected from the two locations divided into 2 groups. The first group are consisting of 6 samples (3 soil samples for *Oryza sativa* and 3 soil samples for *Abelmoschus esculentus*) which are irrigated by municipal waste water whereas the second group are consist of 6 relevant samples which are irrigated by freshwater (EL-Englzia).

2.1.1. Analyzed parameters

Samples were chemically analyzed for the Iron (Fe), manganese (Mn), magnesium (Mg), Zinc (Zn), Copper (Cu), Nickel (Ni), chromium (Cr), Lead (Pb), Cobalt (Co), Cadmium (Cd), Aluminum (Al), Phosphorus (P), Nitrogen (N), Potassium (K)**,** bicarbonate (HCO3) and carbonate (CO3).

2.2. Water sample collection

Accordingly, 6 surface water samples representing the two sites of the study area were collected from the two canals; the samples were collected during summer season. Sampling procedures and protocols for chemical analyses were carried out according to the Standard Methods for the Examination of Water and municipal wastewater

2.2.1. Parameter's analysis

The collected water samples were chemically analyzed for the major **cations**; Calcium ($Ca^{2+),}$ Magnesium ($Mg^{2+),}$ Sodium (Na^+) and Potassium (K^+), major **anions**; Bicarbonate ($HCO3^-$), Sulfate (SO_4^-) and Nitrate (NO_3^-) and trace **metals**; Iron (Fe), Manganese (Mn), Magnesium (Mg), Zinc (Zn), Copper (Cu), Nickel (Ni), Chromium (Cr), Lead (Pb), Cobalt (CO), Cadmium (Cd) and Aluminum (Al).

2.3. Plant sampling

Samples from roots, shoots, leaves, and grains of rice as well as fruits of okra were collected from the two study sites in summer during year of 2020. Samples nearly of the same age and girth size were collected. Samples were washed thoroughly with running distilled water to remove dust particles from leaf surfaces. All samples were dried in an oven at 45 °C for 5 days then crushed and milled in grinder (**Celik *et al.,* 2005**). Each plant samples were stored in a clean plastic bag. Grinder was cleaned after each use to avoid sample contamination.

2.3.1. Analyzed parameters

Iron (Fe), manganese (Mn), magnesium (Mg), Zinc (Zn), Copper (Cu), Nickel (Ni), chromium (Cr), Lead (Pb), Cobalt (Co), Cadmium (Cd), Aluminum (Al), Phosphorus (P), Nitrogen (N) and Potassium K) has been determined in root, shoot and grains of rice and root, leaves, branches and legumes of okra. All elements analyzed by atomic absorption Atomic Absorption Spectrophotometer (3300 ASS spectrometers (**Celik *et al.,* 2005**).

2.3.2. Determination of phytomass and yield

The variation in phytomass of rice between the two locations was determined by harvesting the total plants in one meter square. The economic yield was evaluated according to the following equation:

Yield of rice (ton/ha) = (10,000 X No. of panicle/m^2 X No. of grains/panicle X Test weight) / (1000 X 1000 X 100 X 10) ……………………… (1)

Furthermore, the harvest index was calculated according the following equation:

Harvest Index = Grain yield (g)/ Grain yield (g) + Straw yield (g)……. (2)

Equations (1) and (2) were according to **Mboyerwa *et al.* (2021).**

3. Results

3.1 Soil Analysis

The variation in nutrient concentrations and ratios of soil underneath rice and okra irrigated with municipal **(Type I from El-keblia Drain)** and freshwater **(Type II from EL-Englizia Drain)** are presented in **Table 1**. Commonly, nutrient concentration attained their maxima in

Type I compared to Type II for rice and okra crops except for Cd in the later. Regarding nutrient ratio in the two study species, Al attained its maximum (83.4 and 83.8 **mg/g** respectively). Similarly, the highest values of 44 and 61.6 **mg/g** were attained for P in the soil underneath the two crops. On other side, the lowest values were registered by Co$_3$ and Mn (9.20 and 9.80 mg/g respectively) in the soil underneath rice. Also, in the okra the Co$_3$ was registered as lowest value in addition to Mg (4.4 and 4.5 mg/g respectively).

Table 1: Average concentration of different elements in soil samples collected underneath rice and okra plants from two locations (Type I: irrigated with municipal wastewater and Type II irrigated by freshwater).

Source of water	**Element (mg/g)**														**Chemical group**	
	Fe	**Mn**	**N**	**P**	**K**	**Mg**	**Zn**	**Cu**	**Ni**	**Cr**	**Pb**	**Co**	**Cd**	**Al**	**Co3**	**Hco$_3$**
Rice																
Type I	**0.429**	**0.234**	81.26	40.13	86.16	7.90	0.723	0.049	0.058	0.610	1.79	1.85	0.004	0.43	1.62	9.76
Type II	**0.333**	**0.211**	51.80	22.16	60.13	6.56	0.613	0.040	0.042	0.480	1.41	1.49	0.003	0.071	1.47	7.93
Ratio of I: II (%)	**22.30**	**9.80**	**36.00**	**44.70**	**30.00**	**16.90**	**15.20**	**18.30**	**27.50**	**21.30**	**21.20**	**19.40**	**25.00**	**83.40**	**9.20**	**18.50**
Okra																
Type I	0.395	0.252	74.16	32.23	70.10	7.61	0.693	0.045	0.047	0.06	1.65	1.66	0.004	0.49	1.58	9.70
Type II	0.319	0.198	31.10	12.36	45.30	7.26	0.613	0.038	0.042	0.05	1.42	1.44	0.004	0.074	1.51	8.90
Ratio of I: II (%)	19.20	21.40	58.0	61.60	35.30	4.50	11.50	15.50	10.60	16.60	13.90	13.20	0.00	83.80	4.400	8.20

3.2. Water Analysis

The variation in element concentrations and ratios of municipal water sample (Type I) and freshwater (Type II) was presented in **Table 2**. Commonly, concentrations attained their maxima in Type I compared to Type II. Regarding concentration ratio, N and P attained its maxima (57.10 and 53.50 mg/g respectively). On the other side, the lowest values were registered by Ca, Na (6.20 and 9.00 mg/g respectively).

Table 2: Average concentration of different elements in water sampled collected from two water sources (Type I: Elkeblia (wastewater) and Type II: Elenglizia (freshwater) canals. The data are means of three replicas.

Source of water	**Element (mg/l)**													**Chemical group**			
	Ca	**Mg**	**Na**	**N**	**P**	**K**	**Fe**	**Mn**	**Cr**	**Zn**	**Cu**	**Ni**	**Pb**	**Hco_3**	**Co_3**	**So_4**	**No_3**
Type I	10.45	7.49	13.87	24.16	6.11	4.16	0.35	0.189	0.077	0.52	0.049	0.044	1.370	13.42	1.45	15.69	0.23
Type II	9.80	6.35	12.61	10.36	2.84	2.60	0.22	0.127	0.043	0.37	0.034	0.037	1.10	10.55	1.26	11.34	0.17
Ratio of I: II (%)	6.20	15.20	9.00	57.10	53.50	37.50	37.00	32.80	44.00	28.80	30.60	15.90	19.70	21.30	13.00	27.70	26.00

3.3. Plants analysis

Economic yield of rice (irrigated by municipal wastewater)

Yield of rice (ton/ha) = (10,000 X No. of panicle/m2 X No. of grains/panicle X Test weight) ÷ (1000 X 1000 X 100 X 10).
= (10,000 X 270 X 132 X 38.5) ÷ (1000 X 1000 X 100 X 10).
= 13.7 ton/ha.

Economic yield of rice (irrigated by freshwater)

Yield of rice (ton/ha) = (10,000 X No. of panicle/m2 X No. of grains/panicle X Test weight) ÷ (1000 X 1000 X 100 X 10).
= (10,000 X 250 X 128 X 27.1) ÷ (1000 X 1000 X 100 X 10).
= 8.672 ton/ha.

Harvest Index (municipal wastewater) = Grain yield (g)/ Grain yield (g) + Straw yield (g)
38.5/ (38.5+70) =0.36 g

Harvest Index (freshwater) = Grain yield (g)/ Grain yield (g) + Straw yield (g)
27.1/ (27.1+50) =0.34 g

Pearson coefficient value for matrix correlation between the roots of rice samples collected from the two studied locations are presented in **Figure 1** .In the roots irrigated by municipal water positive correlation coefficient was achieved between all elements except Zn with (Cu, Ni, Pb, Co, Cd, Al, N, P, K, Mn). Also Pb, K, Mn with (Fe, Mg respectively) attained negative correlation. It is worth mention that Cr has no correlation. On the other hand, **Figure 2** exhibited intense correlations between different pairs of elements.

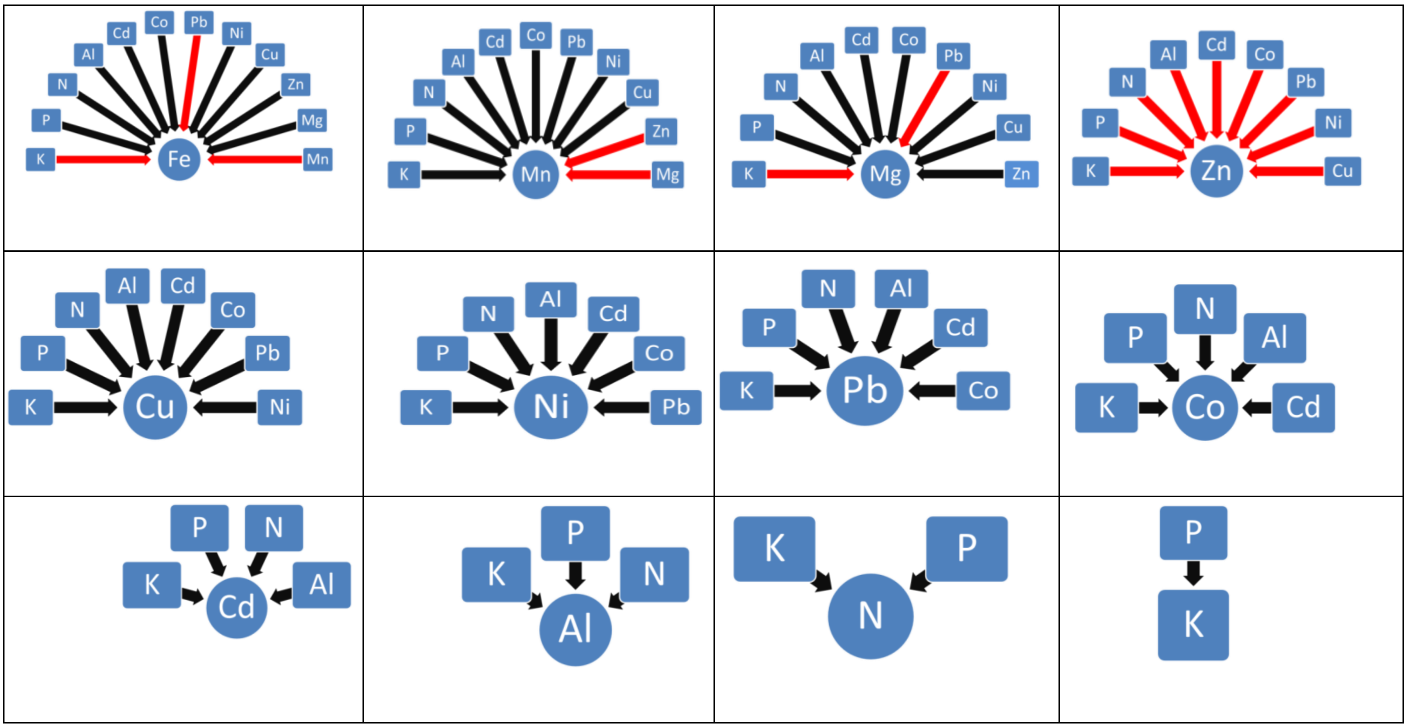

Figure 1: Probable positive or negative correlation coefficients among the elements in roots irrigated with municipal waste water (Type I).

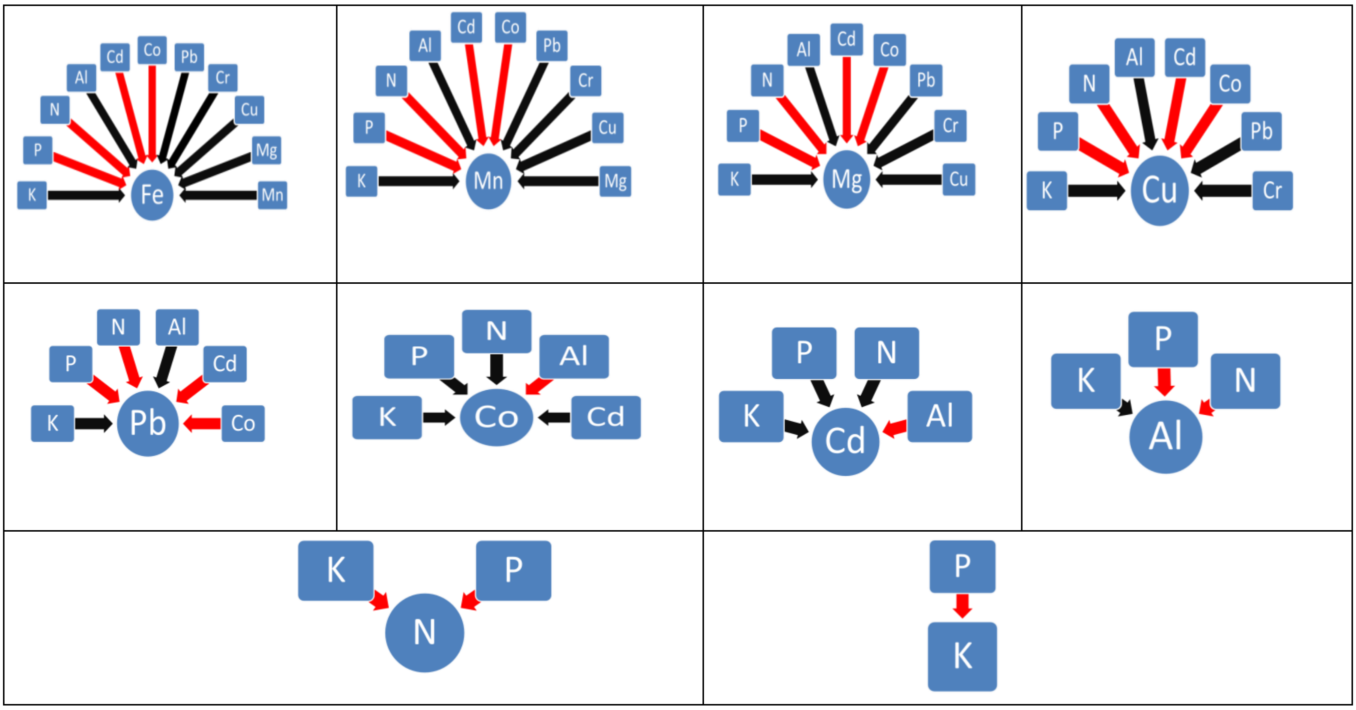

Figure 2: Probable positive or negative correlation coefficients among elements in roots irrigated with fresh water (Type II).

T-test applied to compare among the concentrations of different elements in okra roots sampled from two locations (Type I and Type II) (**Table 3**) showed significant variations for all elements.

Table 3. T-test for comparison among the concentrations of different elements in okra roots sampled from two locations (Type I: irrigated with municipal wastewater and Type II: irrigated with freshwater).

	Type I (n = 3)		Type II (n = 3)		t-value	p
	Mean	SD.	Mean	SD.		
Fe	0.08	0.0	0.08	0.0	3.920*	0.017*
Mn	0.17	0.0	0.16	0.0	5.209*	0.006*
Mg	1.33	0.01	1.15	0.0	26.899*	0.001*
Zn	0.06	0.0	0.05	0.0	2.885*	0.045*
Cu	0.01	0.0	0.01	0.0	13.0*	0.006*
Ni	0.02	0.0	0.01	0.0	5.970*	0.004*
Cr	0.02	0.0	0.01	0.0	6.332*	0.003*
Pb	0.17	0.0	0.11	0.0	19.645*	<0.001*
Co	0.21	0.02	0.13	0.0	7.513*	0.016*
Cd	0.01	0.0	0.0	0.0	2.824*	0.048*
Al	0.01	0.0	0.0	0.0	6.500*	0.003*
N	0.73	0.03	0.59	0.01	8.758*	0.001*
P	0.87	0.05	0.59	0.02	9.997*	0.001*
K	2.02	0.04	1.42	0.01	23.175*	<0.001*

*SD: **Standard deviation**

- **t: Student t-test**
- p: p value for comparing between the studied groups
- *: Statistically significant at $p \leq 0.05$
- **Type I: soil irrigated with municipal wastewater**
- **Type II: soil irrigated with freshwater**

The variation in the element concentrations and ratios in shoots of rice and branches of okra irrigated with municipal Type (I) and fresh water Type (II) are presented in **Table 4**. Commonly, element concentrations attained their maxima in shoots (Type I) compared to (Type II) for rice as well as branches of okra crop. Regarding element ratio in rice and okra, Mn in okra, and Zn in rice attained its maximum (83.4 and 50.60 mg/g respectively). On the other side, the lowest values were registered by Zn in okra and Pb in rice (11.40 and 7.60 mg/g respectively).

Table 4: Average concentration of different elements in shoots of rice and branches of okra sampled from two locations (Type I: irrigated with municipal wastewater and Type II: irrigated with freshwater). The data are means of three replicas.

Source of water	**Element (mg/g)**													
	Fe	**Mn**	**N**	**P**	**K**	**Mg**	**Zn**	**Cu**	**Ni**	**Cr**	**Pb**	**Co**	**Cd**	**Al**
Rice														
Type I	0.093	0.325	0.55	0.74	1.75	1.76	0.083	0.011	0.013	0.018	0.13	0.21	0.001	0.009
Type II	0.072	0.213	0.42	0.54	1.10	1.21	0.041	0.008	0.007	0.013	0.12	0.18	0.0008	0.005
Ratio of I: II (%)	**22.50**	**34.40**	**23.60**	**27.00**	**37.10**	**31.25**	**50.60**	**27.20**	**46.10**	**27.70**	**7.60**	**14.20**	**20.00**	**44.40**
Okra														
Type I	0.083	0.713	1.036	1.096	1.993	1.386	0.061	0.022	0.023	0.016	0.188	0.192	0.005	0.007
Type II	0.071	0.115	0.683	0.833	1.613	1.163	0.054	0.005	0.016	0.006	0.111	0.153	0.002	0.004
Ratio of I: II (%)	14.40	83.30	34.00	23.90	19.00	14.90	11.40	77.20	30.40	62.50	40.90	20.30	60.00	42.80

Pearson coefficient value for matrix correlation between the shoots of rice samples collected from the two studied locations are presented in **Figure 3** in shoots irrigated by municipal water (Type I). Positive correlation coefficient was achieved between all elements except Pb with Fe, Mn, Zn, Mg, Cr, Co, Al, N, P and K. Also, Mg with Zn and Ni and N with P and K attained negative correlation. It is worth mention that Cd has no correlation. Additionally, shoots irrigated by freshwater (Type II) attained different and intensive correlations **(Figure 4).**

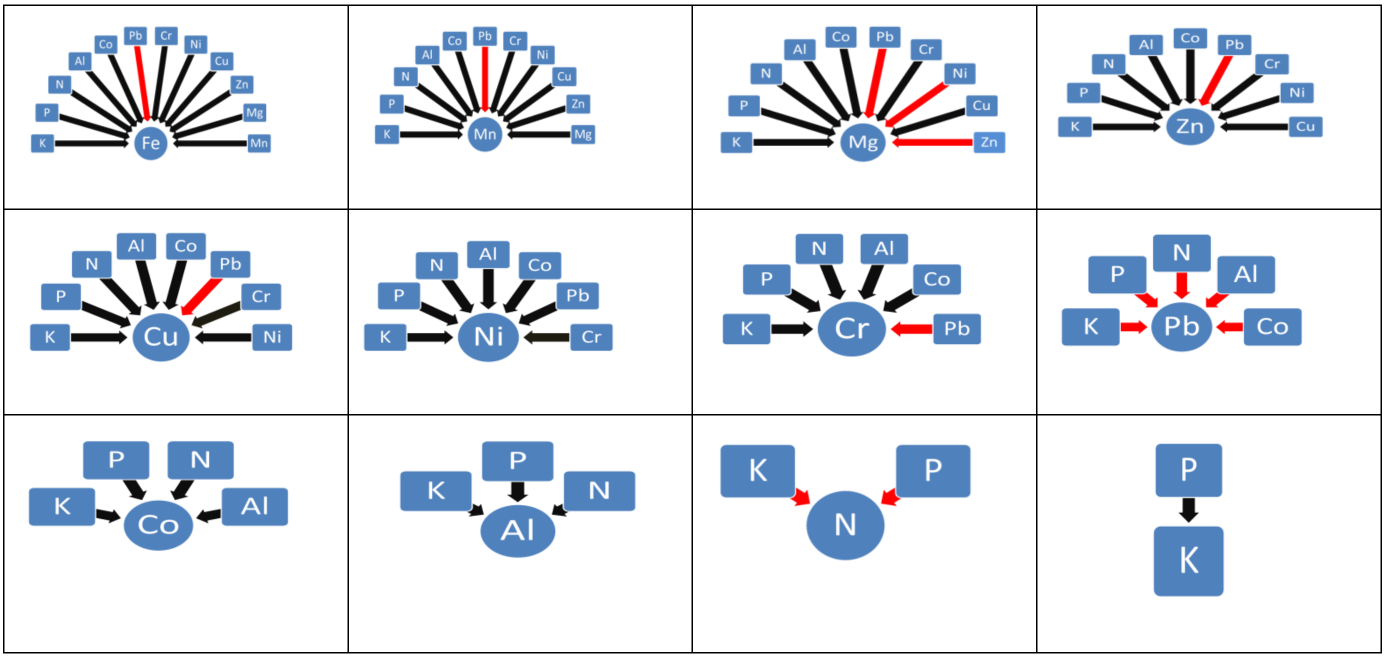

Figure 3. Probable positive or negative correlation coefficients among elements in shoots irrigated with waste water (Type I).

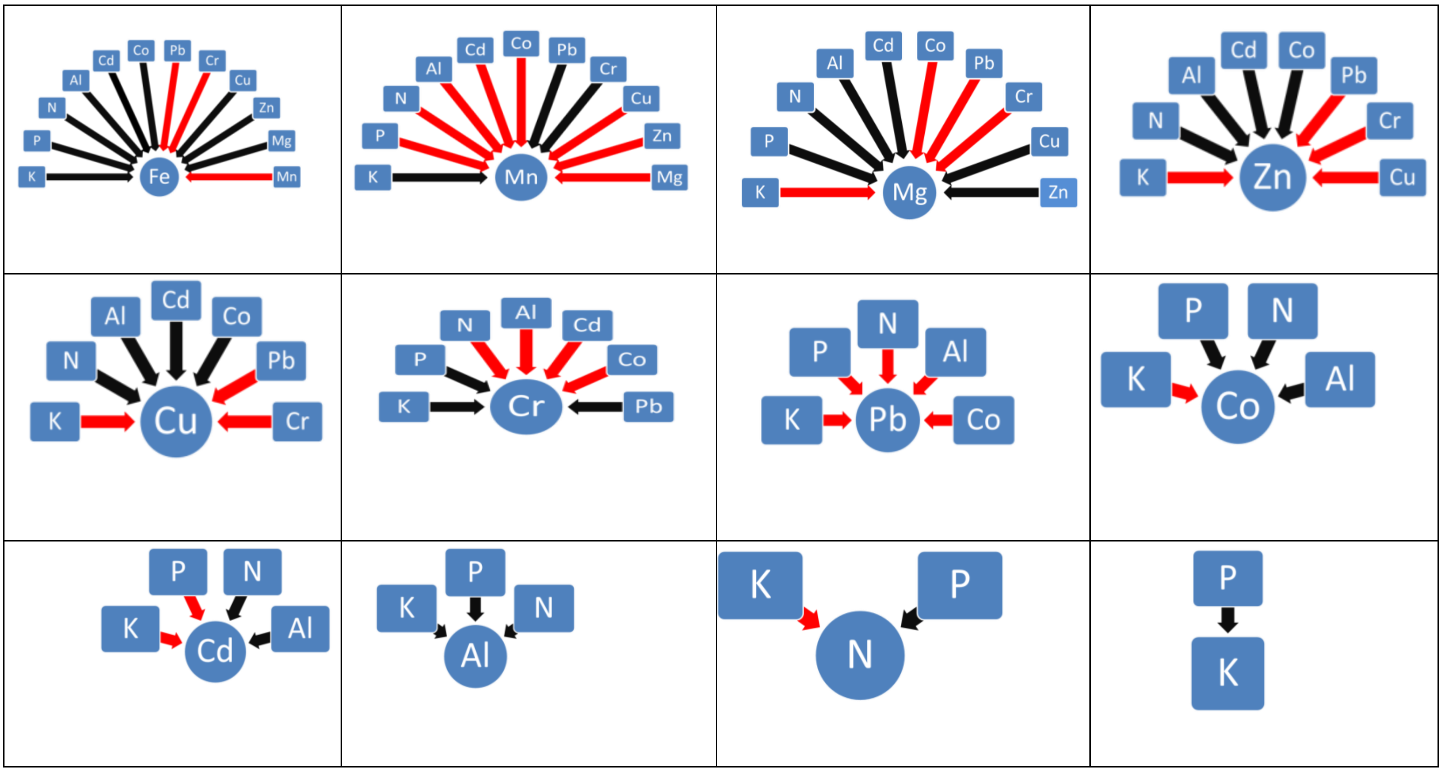

Figure 4. Probable positive or negative correlation coefficients among elements in shoots irrigated with fresh water (Type II).

T-test was applied to compare among the concentration different elements in the shoots of rice sampled from two locations (I: irrigated with municipal wastewater and II: irrigated with freshwater) **(Table 5)**. Data showed significant variations for all elements except (Cd, Pb).

Table 5. T-test for comparison among the concentrations of different elements in rice shoots sampled from two locations (Type I: irrigated with municipal wastewater and Type II: irrigated with freshwater).

	Type I (n = 3)		Type II (n = 3)		t-value	p
	Mean	SD.	Mean	SD.		
Fe	0.09	0.0	0.07	0.0	17.105*	<0.001*
Mn	0.33	0.0	0.21	0.0	65.895*	<0.001*
Mg	1.77	0.02	1.21	0.0	38.989*	<0.001*
Zn	0.08	0.0	0.04	0.0	51.439*	<0.001*
Cu	0.01	0.0	0.01	0.0	4.158*	0.014*
Ni	0.01	0.0	0.01	0.0	7.181*	0.019*
Cr	0.02	0.0	0.01	0.0	2.942*	0.042*
Pb	0.14	0.10	0.12	0.0	0.265	0.816
Co	0.22	0.0	0.19	0.0	13.565*	<0.001*
Cd	0.001	0.0	0.001	0.0	2.500	0.130
Al	0.01	0.0	0.01	0.0	3.464*	0.026*
N	0.55	0.03	0.43	0.02	6.718*	0.003*
P	0.75	0.03	0.54	0.01	10.783*	<0.001*
K	1.75	0.04	1.11	0.02	29.247*	<0.001*

Conclusions

Overall increase in fertility was observed in terms of major nutrients (N, P and K) along with increase in organic matter with wastewater irrigation. The accumulation of heavy metals due to wastewater addition was noticeable rice. The long-term irrigation of domestic wastewater farmland slightly increased levels of heavy metals. The contents of Cd and Pb in rice fields were lower than the permitted limits in grains. Continuous monitoring and pollution control of hazardous materials are needed in order to ensure food safety and sustainable crop production. To avoid negative effects on environment and human health, it is highly recommended that municipal wastewater should be reused for irrigation after being treated properly. Okra (lady’s fingers) was able to obtain its nutrient requirements from treated effluent which indicates a good establishment in enhancing the growth of plants. Hence, the recycling of treated effluent may indicate an alternative source for irrigation in plantations.

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الملخص

تعتبر مشكلة نقص المياه واحدة من اكبر المشكلات التي يواجها العالم في الوقت الحالي، لذلك فان البحث عن مصادر جديدة تلبي حاجات العالم من المياه هي احد التحديات التي تواجه العالم.تهدف هذه الرسالة الي المشاركة في ايجاد جزء من الحل من خلال دراسة ميدانية لاستخدام مياه الصرف الصحي في الري، وتوضح الرسالة تاثير استخدام مياه الصرف الصحي علي اجزاء النبات المختلفة لكل من (الارز-البامية).

الكلمات الدالة : مياه الصرف الصحي-مياه الري –الارز-البامية-مصرف القبلية-مصرف الانجليزية