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GROWTH, YIELD AND HEAVY METAL CONTENTS OF MAIZE (*ZEA MAYS* L.) UNDER SEWAGE WASTEWATER IRRIGATION

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Canal water, heavy metals, maize growth, wastewater, yield, maize

ABSTRACT

Background Fresh water supply is becoming insufficient to meet the water requirements of agriculture sector due to higher population growth rate and rapid urbanization. In this scenario, use of wastewater for agricultural activities not only provides additional water source but also reduces the fertilizer expenditure.

Methodology A pot experiment was conducted to evaluate the effect of sewage wastewater irrigation on growth, yield and heavy metal contents of maize (*Zea mays* L.). Experimental treatments consisted of 5 treatments including T_1 = control (canal water), T_2 = wastewater, T_3 = canal water: wastewater (0.5: 0.5 ratio on volume basis, v/v), T_4 = canal water: wastewater (0.25: 0.75 ratio), T_5 = canal water: wastewater (0.75: 0.25 ratio), and T_6 = alternate irrigation with canal and wastewater. The experiment was laid out in completely randomize design with four replications. Four seeds of maize hybrid DK-919 were sown in each pot.

Results Sewage wastewater in different ratios with canal water and alternate use of wastewater and canal water markedly affected the growth and yield components as well as heavy metal contents of maize plants. Significantly the highest plant height, cob weight, biological yield and grain yield of maize were observed in treatment where canal and wastewater were applied in the ratio of 0.75: 0.25 (v/v). There was no significant increase in the concentration of heavy metals including lead (Pb), cadmium (Cd) and nickel (Ni) in this treatment. However, root dry weight of maize remained higher in pots irrigated with mixture of canal and wastewater in 0.25: 0.75 ratio.

Conclusion Sewage wastewater when diluted three times with canal water (0.75: 0.25 canal water: wastewater ratio, v/v) could be used efficiently for maize production without any deleterious effect in terms of heavy metal accumulation in plants.

INTRODUCTION

Fresh water supply for agricultural activities is shrinking rapidly due to increasing population and urbanization (Ashraf et al. 2017). According to an estimate, the maximum consumption of fresh water is being made in agriculture sector. However, it is not sufficient to fulfill crop requirements of water for food security (Fakayode 2005). The reuse of wastewater in agriculture sector is aimed to achieve additional water source for crops and also reduces the fertilizer expenditure as wastewater is rich in plant nutrients. It has been reported that wastewater is rich in nitrogen (N), phosphorous (P) and organic matter. Reuse of wastewater has developed as the necessity of time as fresh water deliveries cannot meet crop requirements. The role of wastewater in irrigation is fundamental. Large number of farmers living in urban or peri-urban areas is using wastewater for irrigation without considering its effects on soil, crop and environment. In the scenario of fresh water shortage, judicious use of wastewater in crop production seems rationale (Ashraf et al. 2013). Wastewater influences the growth of microbial population in soil which is further responsible for improving the soil health and crop yield (Libutti et al. 2018). The mixture of fresh water

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and wastewater in nutrient rich soil is a key strategy for increasing agriculture production (Ashraf et al. 2017). In semi-arid and arid regions, wastewater reuse has great importance where 70-90% water resources are used for the irrigation purposes (Bahri 1988). However, long term irrigation by the use of wastewater may pose significant effects on physicochemical properties of soil and crops. The large usage of wastewater in crops for irrigation may result in accumulation of heavy metals beyond the permissible limit for human and animal health standards specified by World Health Organization (Papaioannou et al. 2019). Another possible source of heavy metals discharge is by municipal solid waste stream. Wastewater use is limited to peri-urban and municipal farms in different countries (Nyamangara and Mzezewa 1999). In Zimbabwe, the study was carried out on heavy metals concentrate in maize, and found a significant increase in the concentration of copper (Cu), zinc (Zn), Cd and Pb (Muchaweti et al. 2006). Maize is main source of food in all over the world. It stands at 3rd position in the world with an area of 118 million hectares with production of 600 million metric tons. In Pakistan, after wheat and rice, maize is an important cereal. In Pakistan cultivated area of maize is 1.33 million hectares with production of 6.1 million tons (GOP 2016). Hybrid maize has gained popularity among farmers due to its higher yield potential. Maize growers in the peri-urban areas are using wastewater for irrigation with sewage wastewater because canal water has become scarce and the quality of underground water is mostly unfit for irrigation purpose. There is a great concern of people regarding hazards of irrigation with sewage wastewater as it is presumed to cause heavy metals deposition in soils and plants. The accumulation of heavy metals in plants beyond permissible limits may be toxic for public health (Handa et al. 2019). There is a need that wastewater must be used judiciously with appropriate management strategy to avoid the ill effects of wastewater. So, the present study was designed to formulate a viable strategy for using sewage wastewater in agriculture. For this, a pot study was designed for determining growth and yield components of maize as well as contents of heavy metals (Pb, Cd and Ni) in different plant parts irrigated with cyclic and blended use of sewage wastewater with canal water.

MATERIALS AND METHODS

The pot experiment was conducted in the research area, College of Agriculture, University of Sargodha, Sargodha, Pakistan to evaluate the effect of blended and cyclic use of sewage wastewater and canal water on plant growth, yield and heavy metal accumulation in maize. Experimental site lies at 31.32°N latitude and 71.18°E longitude and 190 m height from sea. The soil was clay loam in texture and had pH 8.0.

Experimentation

Experiment was laid out in Completely Randomized Design (CRD) with six treatments and four replications. Experimental treatments comprised of following treatments; T_1 = control (canal water), T_2 = wastewater, T_3 = canal water: wastewater (0.5: 0.5 ratio on volume basis, v/v), T_4 = canal water: wastewater (0.25: 0.75 ratio), T_5 = canal water: wastewater (0.75: 0.25 ratio), and T_6 = alternate irrigation with canal and wastewater. Total number of pots was 24, filled with 20 kg soil in each. Irrigation was done @ 3 liter/pot with the regular interval of three days. Urea, diammonium phosphate and sulphate of potash used as source of N, P and K @ 3.1, 2.5 and 1.5 g per pot, respectively. Nitrogen was applied in 3 different doses while P and K were applied at the time of sowing. After sprouting, seedlings were thinned to two plants per pot which further thinned to one plant per pot after 3 to 4 leaves stage.

Observations and data recording

Data about yield and yield components including plant height, number of leaves plant^{-1}, dry weight plant^{-1}, root dry weight plant^{-1}, cobs plant^{-1}, cobs weight plant^{-1} and grain yield plant^{-1} of maize grown with wastewater were recorded. Heavy metal contents including Pb, Cd and Ni in maize roots and shoots were also determined.

Statistical analysis

Data were statistically analyzed using Fisher's analysis of variance (ANOVA) technique and means were compared by least significant difference (LSD) test at 5% probability (Steel et al. 1997) through software Statistix 8.1 (Analytical Software 2005)

RESULTS AND DISCUSSION

Growth and yield contributing attributes of maize

Data regarding growth and yield attributes of maize including plant height showed significant variation in response to different irrigation treatments (Table 1). Maize achieved maximum plant height (66.2 cm) when mixture of canal and wastewater was applied at 0.75: 0.25 ratio that did not vary significantly from canal and wastewater ratio of 0.25: 0.75 as well as alternate canal and wastewater irrigation treatments. However, the minimum plant height (51 cm) was recorded from maize plants harvested from pots irrigated with canal water only. Results were in line to the findings of Malik et al. (2013) who reported that blended use of wastewater effluents and canal water

Table 1 Effect of irrigation treatments on yield and yield components of maize

Treatments	**Plant height (cm)**	**Leaves plant^{-1}**	**Cob weight (g plant^{-1})**	**Biological yield (g plant^{-1})**	**Root dry weight (g plant^{-1})**	**Grain yield (g plant^{-1})**
Control (CW)	51.0c	14.7	10.12d	89.8 c	12.4 e	21.61c
WW	55.5bc	12.7	5.60d	63.5 d	23.9 d	6.32d
CW:WW (0.5:0.5)	53.0c	14.7	8.01d	104.2 c	25.3 d	11.63cd
CW:WW (0.5:1.5)	66.0ab	13.0	33.92b	141.5 b	47.5 a	64.62b
CW:WW (1.5:0.5)	66.2a	14.0	41.72a	169.3 a	40.4 b	77.7a
Alternate irrigation	56.7abc	15.2	23.34c	133.8 b	31.9 c	11.9cd
LSD value	10.60	NS	6.39	19.04	4.75	12.83

CW = Canal Water, WW= Wastewater, Means sharing the same letter in a column did not significantly differ at 5% probability level, NS = Non-significant, NS and **indicate non-significant and significant at $p \leq 0.01$ level of probability, respectively.

significantly increased the plant height of tomato. However, in contrary to our results, Kaushik et al. (2005) reported that there was a reduction in plant height of wheat by the application of untreated wastewater and this reduction of plant height was due to toxicity caused by heavy metals present in wastewater.

Leaf is the basic factory to assimilate food through photosynthesis. More the number of leaves produced by plant, more will be the efficiency of photosynthetic machinery to synthesize food. Data in Table 1 showed that number of leaves per plant of maize did not differ significantly under wastewater irrigation in cyclic and blended form. Malik et al. (2013) reported that dilution of waste effluents with canal water significantly increased the number of leaves per plants of tomato. Kaushik et al. (2005) also reported that there was reduction in number of leaves per plant of wheat crop by the application of untreated wastewater. Wastewater-induced accumulation of heavy metals in plant might be the main cause of reduction in number of leaves per plant.

The cob weight of maize is an important trait that showed assimilate portioning pattern of plant during cob development. The data presented in Table 1 showed that treatment means of cob weight per plant of maize significantly differed with cyclic and blended use of wastewater and canal water. Significantly the highest cob weight (41.7 g) per plant of maize was observed in treatment receiving canal and wastewater in 0.25: 0.75 ratio. This treatment was followed by those where canal and wastewater (WW) were applied in the ratio of 0.75: 0.25 ratio, and the cyclic use of canal and wastewater. Below all, minimum cob weight (5.6 g) per plant was noted in wastewater treatment. This enhancement in cob weight due to wastewater application was probably due to increased nutrients supply by wastewater that resulted in better reproductive growth of maize plant.

Grain yield per plant is the ultimate goal of all management practices carried out by farmer. The higher grain yield per plant would result in higher grain yield per unit area. Data given in Table 1 showed that significantly the highest grain yield (77.7 g) per plant of maize was achieved by treatment where canal and wastewater was applied at 0.75: 0.25 ratio. This treatment was followed by canal and wastewater application at 0.25: 0.75 ratio, and the cyclic use of canal and wastewater, respectively. However, the lowest grain yield (6.3 g plant^{-1}) was resulted from sole application of wastewater. The grain yield enhancement in response to Wastewater application in mixture with canal water was probably the result of improved growth of maize plants by better supply of nutrients present in Wastewater. However, sole application of wastewater without diluting with canal water caused inhibitory effect on reproductive growth of plant. Hayyat et al. (2013) showed similar improvement in sorghum yield by irrigating with mixture of canal water with wastewater. Malik et al. (2013) also noted the increase in fruit yield of tomato by blending wastewater effluents with canal water. Kaushik et al. (2007) also concluded that grain yield of wheat suffered from reduction up to 50% by the application of untreated wastewater.

Data of biological yield per plant of maize (Table 1) showed that it was markedly affected by cyclic and blended use of canal and wastewater. The results showed that in comparison to canal water, there was decrease in biological yield of maize by the application of untreated sewage WW as this treatment gave the lowest biological yield (63.5 g plant^{-1}). However, blending of wastewater with canal water showed improvement in biological yield. Maximum biological yield (169.3 g plant^{-1}) of maize was observed at canal and WW ratio of 0.75: 0.25. This treatment was followed by canal and wastewater ratio of 0.25: 0.75, and the cyclic use of canal water and WW, respectively. Malik et al. (2013) also reported the similar results where dilution of waste effluents with canal water significantly decreased the total dry matter of tomato plants. Hayyat et al. (2013) also reported similar results that the highest dry weight of sorghum was observed in plants which were irrigated with

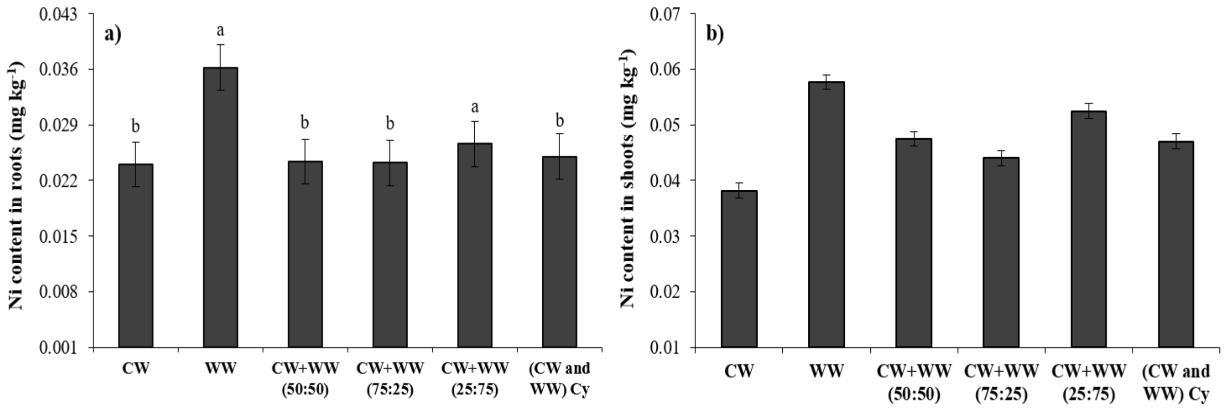

Figure 1: Lead (Pb) concentration in maize (a) shoot and (b) root as affected by different irrigation treatments. CW: Canal water, WW: Wastewater, Cy: Cyclic use

cyclic application of canal water and wastewater.

The data showed that root dry weight plant^{-1} of maize was significantly different among wastewater irrigation treatments (Table 1). The results showed that from canal water (control) treatment, significant increase in root dry weight plant^{-1} of maize was observed by blending the WW with canal water in different ratios. The highest root dry weight (47.5 g plant^{-1}) of maize was observed in treatment where canal and wastewaters were applied at 0.25: 0.75 ratio. This treatment was followed by treatment receiving blended application of canal and WW (0.5: 0.5 ratio), and cyclic application of canal and WW, respectively. Minimum root dry weight (12.4 g plant^{-1}) of maize was obtained by treatment receiving sole CW. Malik et al. (2013) reported the similar results of increased root fresh and dry weights in tomato by use of sewage water. Kaushik et al. (2007) reported that increase in sewage effluent application caused more deteriorative effect in shoots compared to roots. However, reduction in root dry weight of tomato occurred when plants were irrigated with 40% sewage waste at post-flowering stage (Marwari and Khan 2012).

Heavy metal uptake by maize plant

The data showed significant differences among the treatment means regarding Pb concentration in maize shoot under WW irrigation strategies (Figure 1). Maximum Pb contents (0.0159 meq L^{-1}) in shoots of maize plants were observed in case of 100% WW irrigation followed by blending at 0.5: 0.5 and 0.75: 0.25 CW: WW ratio. Minimum Pb content (0.0141 meq L^{-1}) in maize shoots were found in case of canal water. Singh et al. (2012) also reported heavy metals accumulation slightly higher in treatments where sewage water was applied as compared to canal water. The continuous use of wastewater for long period resulted in many environmental problems such as deterioration of soil, groundwater contamination and toxicity to plants. Ghafoor et al. (2004) showed that heavy metals accumulated above the permissible limits in the soils, vegetables and crops irrigated with wastewater effluents. Furedy et al. (1999) reported that crops irrigated with untreated sewage effluent may contain heavy metals up to toxic level, particularly for human and animals.

The data showed that irrigation with sewage wastewater resulted in significant increase in Pb content in maize roots (Figure 1). It is evident from data that in comparison with control (canal water), significantly the higher values of Pb (0.0199-0.0206 meq L^{-1}) in maize roots were detected in case of sole WW irrigation, and irrigation with mixture of canal and wastewater at 0.5: 0.5 and 0.75: 0.25 ratios. Singh et al. (2012) also reported heavy metals accumulation in plant at higher levels by the use of wastewater. Ghafoor et al. (2004) showed similar results that heavy metals accumulated above the permissible limits in the soils and plants under WW irrigation.

The data for Cd concentration in shoot of maize showed significant differences among treatment means (Figure 2). The highest Cd concentration (0.0131 meq L^{-1}) in maize shoot was observed in treatment receiving 100% wastewater that did not differ significantly from other treatments in which wastewater was applied in mixture with canal water or applied in cyclic form. Minimum Cd concentration (0.0108 meq L^{-1}) in maize shoot was noted in case of canal water treatment (control). The data showed significant differences among treatment means regarding Cd concentration in maize roots (Figure 2). Maximum root Cd concentration (0.001 meq L^{-1}) in maize plant was observed in treatment of 100% wastewater which remained statistically at par with mixture of canal water and wastewater (0.25: 0.75 ratio). Singh et al. (2012) also reported the similar results. The data showed non-significant differences among treatment means of various WW irrigation

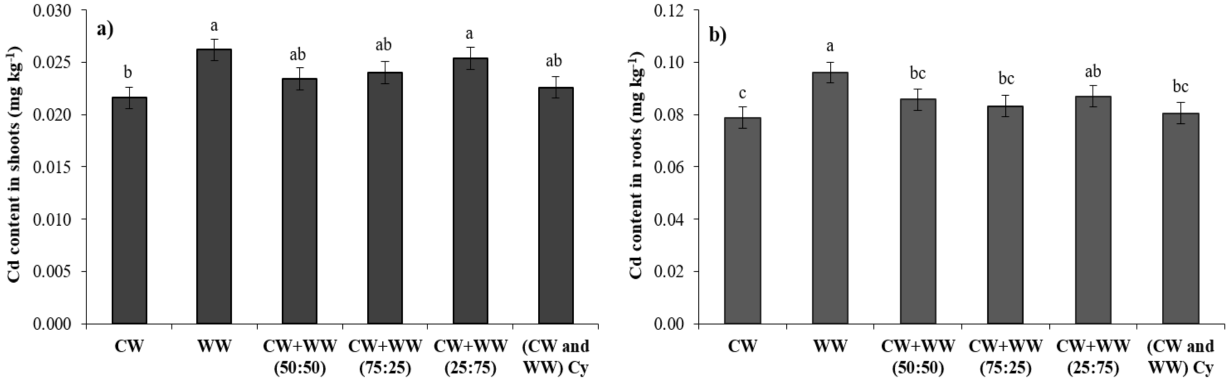

Figure 2: Cadmium (Cd) concentration in maize (a) shoot and (b) root as affected by different irrigation treatments. CW: Canal water, WW: Wastewater, Cy: Cyclic use

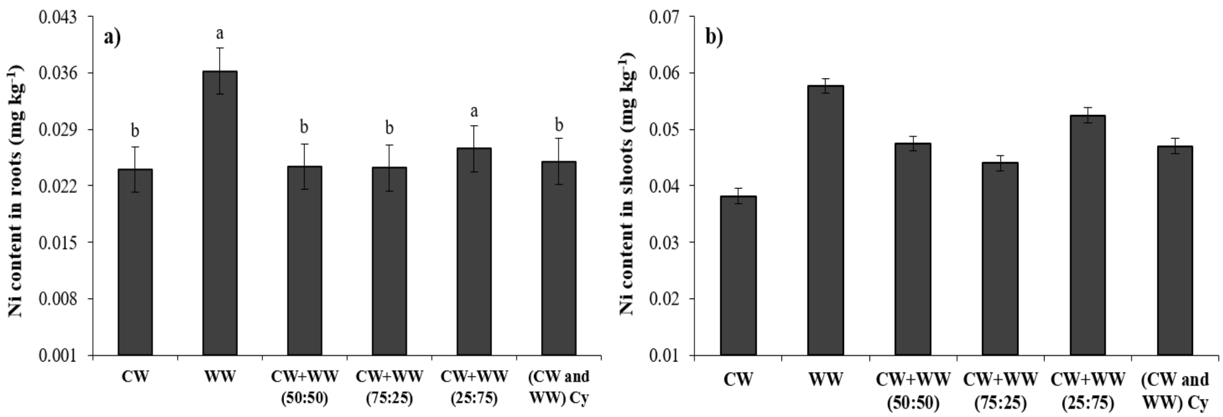

Figure 3 Nickel concentration in maize (a) shoot and (b) root as affected by different irrigation treatments. CW: Canal water, WW: Wastewater, Cy: Cyclic use

treatments pertaining to Ni concentration in maize shoot (Figure 3). However, significant difference among means of Ni concentration in maize roots under wastewater irrigation (Figure 3). Significantly the highest Ni concentration (0.036 ppm) in roots of maize was noted with 100% wastewater.

CONCLUSION

Sewage wastewater if diluted three times with canal water (0.75: 0.25 canal water: wastewater ratio) could be the best strategy of using wastewater in maize crop. It resulted in significant improvement in maize growth and yield without increasing heavy metals (Pb, Cd and Ni) contents in roots and shoots of maize.

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