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THE EFFECT OF USING WASTE WATER FOR TOMATO

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Abstract

Field experiment near Palosi drain was conducted to study the effect of tube well (TW) and waste water (WW) with or without basal dose of NP and K on the yield and heavy metal uptake of tomato during 2008. The soil of the experimental site was sandy loam, slightly alkaline, moderately calcareous with phytotoxically high concentration of Cu, Fe and Mn while Cd, Cr, Ni, Pb and Zn were less than the levels considered toxic to the plants. The tomato biomass was significantly ($p<0.05$) affected by different treatments. Taller plants and higher biomass was produced in plots receiving WW with or without NP and K and TW water receiving basal dose of NP and K while lower biomass and shorter plants were produced in plots receiving only TW water indicating the nutritive value of WW application. The results of metal concentration in leaves and fruit showed that with exception of Cd, there were significant variation ($p<0.05$) in the plant uptake of metals when irrigated with different supply of irrigation water. The overall results showed that leaves accumulated higher concentration (with exception of Cu) of heavy metals studied compared to fruit. The concentration of Cr, Fe, Mn Pb and Zn in leaves was above the permissible limits when irrigated with waste water while waste water supplemented with fertilizers showed reduction in heavy metals uptake. The concentration of Fe and Pb was above the permissible limits in fruits indicating toxicity. It was also noted that plants receiving sole application of WW accumulated more heavy metals compared to WW plus half dose of NP and K while the TW irrigated plots accumulated less heavy metals indicating that their was no build up of heavy metals in the river bed soils because of its coarse texture. It can be concluded that tomato can be irrigated with effluents containing moderate supply of heavy metals on coarse textured soil.

Introduction

Human activities such as industrial production, mining, agriculture and transportation release high amounts of heavy metals into surface and ground water, soils and ultimately to the biosphere. Accumulation of heavy metals in crop plants is of great concern due to the probability of food contamination through the soil root interface. Though the heavy metal viz. Cd, Pb and Ni are not essential for plant growth, they are readily taken up and accumulated by plants in toxic levels (Mussarat & Bhatti; 2005; Qadir *et al*., 1999; Bhatti & Perveen, 2005). Ingestion of vegetables irrigated with waste water and grown in soils contaminated with heavy metals poses a possible risk to human health and wildlife (Otero *et al*., 2000; Mussarat *et al*., 2007; Rattan *et al*., 2005; Bhatti & Mussarat, 2006).

Heavy metal concentration in the soil solution plays a critical role in controlling metal bioavailability to plants. Most of the studies show that the use of waste water contaminated with heavy metals for irrigation over long period of time increases the heavy metal contents of soils above safe limits Mapanda *et al*., 2005, Sharma *et al*., 2006). Ultimately, increasing the heavy metal content in soil also increases the uptake of heavy metals by plants depending upon the soil type, plant growth stages and plant species (Ismail *et al*., 2005, Farooq *et al*., 2008).

In the big cities of Pakistan, untreated sewage water and the industrial effluents are discharged directly into water channels or canals and the polluted water is used for growing crops particularly vegetables and fodder in the vicinity of big cities (Khan *et al*., 2003. City effluents (sewage and industrial) are one of the potential sources of metal pollution which is used for growing crops (mostly vegetables and fodder) in the pre-urban areas of Pakistan (Mussarat *et al*., 2007).

Due to industrialization in Pakistan, many different industries have also been established in Peshawar city of Pakistan. Tanning is one of the oldest industries in Pakistan and is one of the potential sources of heavy metals contamination of water, soils and plant growing on these soils. Wet process of tanning is the main source of generating waste water. Water consumption per kg of raw hides varies from tannery to tannery which should not go beyond 50 L kg^{-1}. However, the tanneries are generally consuming more water than required. Moreover, sugar industry is also main source of pollutants to surface water bodies. It is alarming that most of the cities and industries in Pakistan are without waste water treatment facilities. Large quantities of untreated municipal sewage and industrial effluents are discharged directly to surface water resulting in severe pollution particularly with heavy metals.

Keeping in view the heavy metals hazards of use of untreated waste water, a study was carried out to investigate the effect of waste water on crops and soils with respect to heavy metal accumulation.

Materials and Methods

Field experiment on tomato was conducted near the vicinity of Palosi drain, used for carriage of industrial and municipal effluents. Industrial effluents drain from Hayatabad Industrial Estate (HIE) Peshawar whereas domestic waste water comes from residential areas along the drain, thus making it difficult to locate a major discharge point for domestic wastes. The field is located on the western side of the Khyber Pakhtunkhwa Agricultural University, Peshawar that is grown with wheat and seasonal vegetables. The crops grown by the farmer are irrigated with the wastewater flowing through the drain. The experiment was laid out in RCB design with four treatments viz., irrigation with tube well (TW) water (T1), tube well irrigation plus NP and K at the rate of 120, 90 and 60 kg K2O ha^{-1} (T2), wastewater plus half dose of NP and K (i.e., 60, 45 and 30 kg ha^{-1}respectively) (T3) and wastewater (WW) without fertilizers (T4). The treatments were replicated three times. The plot size was kept at 3 m x 3 m (9 m^2). Strong demarcation between the treatments was made to avoid the mixing of tube well irrigated plots with waste water plots. The randomization was confounded i.e. waste water treated plots were made toward the waste water channel while tube well irrigated plots were kept away from the drain water. The N P and K were applied as urea, DAP and

Soil analysis: A composite soil sample from a depth of 30 cm was collected from the site before sowing the crop and analyzed for physico-chemical properties according to the standard procedures. Particle size was determined using the hydrometer method (Gee & Bauder, 1986). The soil pH and electrical conductivity (EC) were determined in 1:1 (w/v) soil-to-water extracts (Smith & Doran, 1996). Soil samples were analyzed for various heavy metals using AB-DTPA extractant Soil samples were analyzed for various heavy metals using AB-DTPA extractant according to the method given by Havlin & Soltanpour (1981).

Plant analysis: Plant leaves and fruit samples were collected for heavy metal analysis using wet digestion procedure (Richard, 1954) and the metal concentration in the digest was determined by using atomic absorption spectroscopy.

Statistical analysis: Replicated data were analyzed using MSTATC package (Russell, 1989). Means were compared by using least significant difference (LSD) test (Steel & Torrie, 1980).

Results and Discussion

Physico-chemical properties of soil: The soil of the experimental site was sandy loam (Table 1) with pH slightly alkaline (7.62) and the low EC (0.53 dS m-1) indicating no salinity problem. The lime content showed that the soil is moderately calcareous. The AB-DTPA extractable heavy metals content indicate that Cd, Cr, Ni, Pb and Zn concentration in soils of the study area are not toxic to plants (Linzon, 1978) while Cu, Fe and Mn were above the Anon., (1996) standard (permissible limit) and the crop growing on these soil may accumulate high Cu and Fe concentration.

Plant height and biological yield: The results of plant height as affected by different irrigation water treatment (Table 2) showed that there were significant ($p<0.05$) variations in plant height. The shortest plants (53 cm) were noted in plots irrigated with fresh tube well water. The significantly higher value was recorded when waste water was supplied along with half dose of NP and K (T3). The variation between the three treatments i.e. wastes water irrigation with or with out fertilizer (T3 and T4) and tube well water along with basal dose of fertilizer (T2) was not significant. Similar trend of higher fresh and dry biomass (Table 2) was noted as was for plant height being lowest in plots irrigated with tubewell water and significantly ($p<0.05$) higher in the waste water treated plots and tubewell water supplemented with basal NPK dose. The higher biomass yield and plant height in the waste water treated plots may be associated with its enrichment with the essential plants nutrient (both macro and micronutrients). Khan *et al.*, (2008) also reported the economic benefits of irrigating maize with treated effluent of waste stabilization ponds. This can also be explained from the results obtained in T2 where the yield increase apparently stems from the addition of basal application of NP and K. Segura *et al.*, (2004) reported advocated the re-use of waste water in arid and semiarid region of the world. They reported that significantly higher yield of melon and tomato were obtained when the crops were irrigated with effluents in the greenhouse crops. The positive effect of the effluents (ozone treated waste water) was due to its significantly higher amount of N, P and K. In another study by Akitaka *et al.*, (2002) reported that tomato growth, yield and quality was not effected by the addition of treated wastewater compared to tape water.

Heavy metal concentration of tomato: The results of metal concentration in leaves (Table 3) and fruit (Table 4) showed that with exception of Cd, there were significant variations ($p < 0.5$) in the plant uptake of metals when irrigated with different supply of irrigation water with or without application of basal dose of fertilizers. The Cd concentration in both leaves and fruit was not significantly affected by either treatment. This non significant variation may be due to the low level of Cd present in the soil as well as in the effluents. By comparing Cd concentration in leaves and fruit (Fig. 1) it can be seen that leaves accumulated more Cd than fruit indicating that tomato grown with effluents containing low level of Cd may be of little concern with regards to human consumptions (Khan & Jones, 2008).

Table 1. Physico-chemical properties of the experimental site.

Parameters	Unit	Value
Sand	%	60.58
Silt	%	28.57
Clay	%	10.88
Soil texture	-	Sandy loam
pH	-	7.62
EC	dS m^{-1}	0.53
OM	%	1.6
CaCO3	%	13.5
Cd	mg L^{-1}	0.09
Cr	mg L^{-1}	6.44
Cu	mg L^{-1}	7.83
Fe	mg L^{-1}	90.62
Mn	mg L^{-1}	11.79
Ni	mg L^{-1}	0.30
Pb	mg L^{-1}	3.61
Zn	mg L^{-1}	1.30

Table 2. Yield and yield component of tomato.

Treatment	Plant height (cm)	Fresh biomass (g)	Dry biomass (g)
T1	53.0	66.9	13.1
T2	81.3	143.9	39.5
T3	87.0	156.3	43.3
T4	83.3	148.1	42.3
LSD	14.6	16.8	12.9

T1 = Tube well water, T2 = Tub well + NP & K fertilizers, T3, Wastewater + half dose of NP and K fertilizer, T4 = wastewater.

Table 3. Heavy metal content in tomato leaves.

Leaves	Cd (0.02)*	Cr (1.3)	Cu (10)	Fe (150)	Mn (6.16)	Ni (10)	Pb (2)	Zn (5)
T1	0.13	1.03	2.19	400.8	14.10	6.50	8.67	7.15
T2	0.12	0.91	4.33	423.52	11.83	5.90	7.73	6.32
T3	0.14	1.97	6.94	554.88	18.27	9.73	18.00	12.36
T4	0.13	1.90	7.09	855.68	23.87	17.00	29.47	15.59
LSD	NS	0.71	2.80	77.6	10.90	5.58	13.57	6.98

*****Values in the parenthesis are the WHO permissible limits of metals in plants

Table 4. Heavy metal content in tomato fruits.

	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
T1	0.03	0.33	3.68	118.40	4.50	4.67	4.40	4.97
T2	0.03	0.21	2.36	140.91	4.83	5.30	3.33	4.05
T3	0.06	0.67	7.25	134.77	5.60	6.67	6.27	5.31
T4	0.04	0.70	9.33	220.85	5.87	8.33	9.60	8.60
LSD	NS	0.52	7.25	61.26	5.63	NS	4.94	3.98

The Cr concentration of both leaves (Table 3) and fruit (Table 4) was significantly affected by the application of different treatments. Leaves accumulated higher concentration (above the permissible limits as set by Anon., (1996) and the treatment receiving effluents accumulated significantly higher values of Cr. Similarly, the fruit concentration of Cr was also significantly affected by different treatments but the fruit Cr concentration was lower than the permissible limits (Anon., 1996). By comparing the leaves and fruit Cr concentration (Fig. 2) it can be seen that leaves accumulated higher concentration of Cr than fruits. The higher accumulation of Cr in leaves may be associated with elevated levels of Cr in effluents as well as in the soil. The elevated level of Cr in treatments plots receiving tape water may be the results of soil accumulated Cr as these plots were receiving effluents since long. Khan *et al*., (2007) observed elevated levels of Cr in tomato leaves and fruits receiving effluents but unlike the present study, there were high concentration in both leaves and fruit in their study. The reason of variations in the Cr concentration in plants may be the different physico-chemical properties of the soil.

The concentration of Cu was also significantly affected by irrigation treatments. Significantly ($p<0.05$) higher values were recorded in both leaves and fruit (Tables 3 & 4) when irrigated with effluents. It was also observed that irrigation treatment receiving half dose of fertilizers (T3) accumulated comparatively less Cu than sole irrigation with waste water and this may be due to dilution effect as the biomass was higher in T3 than T4. By comparing the leaves and fruit concentration of Cu (Fig. 1), it is clear that fruit accumulated more Cu than leaves with exception of T2 where the reverse was true. The over all Cu concentration shows that the levels in both leaves and fruits were below the permissible levels (10 mg kg^{-1}) of Anon., (1996). These findings indicate that waste water with moderate concentration of Cu can be used for irrigating tomato while elevated levels in waste water may not be good as the comparatively higher concentration of Cu in fruits (compared to leaves) indicates it mobility within the plant that may not be good for human consumptions.

The Fe concentration in tomato leaves (Table 3) was beyond the permissible limits (150 mg kg^{-1} Anon., 1996) regardless of the irrigation water supply. Significantly higher value in leaves was recorded in waste water (WW) supplied plots followed by T3. The reduction in T3 (WW + fertilizers) compared to T4 may be due to dilution effect i.e., higher biomass production while the elevated levels in the tubewell irrigated water indicates the presence of elevated levels of Fe in the soil. By comparing the fruit Fe concentration with leaves (Fig. 4), it can be seen that Fe concentration was much lower in fruit than leaves. With exception of T4 (WW), the Fe concentration was lower than permissible limits in tomato fruits. These results also indicates that the addition of fertilizer helps in reducing the Fe concentration due to it phytostabilizing effect mainly from DAP (Khan & Jones, 2008).

The Mn concentration was higher in the leaves (Tables 3 & 4) compared to fruits (Fig. 5). Plots irrigated with tube well water (T1 and T2) accumulated less Mn than T3 and T4 (WW irrigated plots). The addition of fertilizers to both the water supply i.e. tube well water and waste water reduced the plant uptake of Mn although the reduction was not significant.

The concentration of Ni in both leaves and fruit as shown in Table 3 and 4 indicate that leaves accumulated more Ni than fruit (Fig. 6). The level of Ni in fruit was below the permissible levels in all the treated plots while leaves accumulated more Ni when irrigated with waste water supply. The variation in Ni content (leaves) between the two water supply were significant and non significant in fruits.

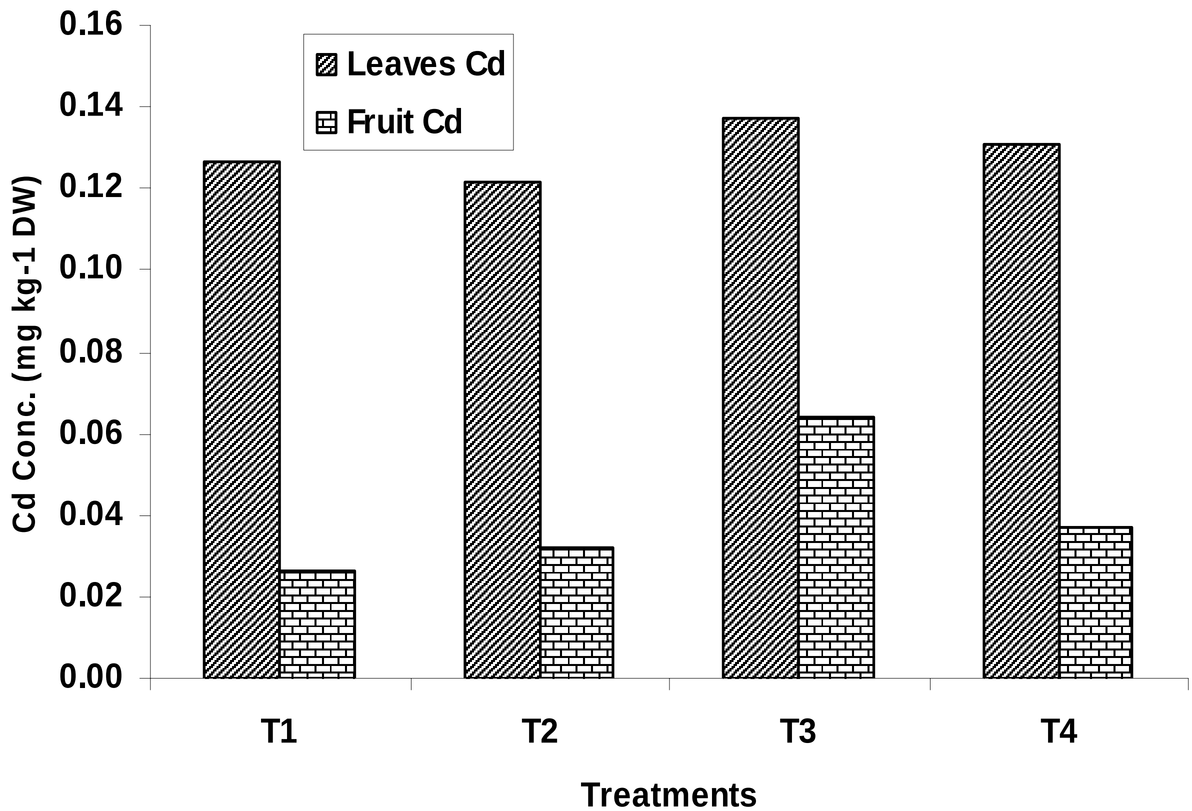

Fig. 1. Concentration of Cd in tomato leaves and fruit.

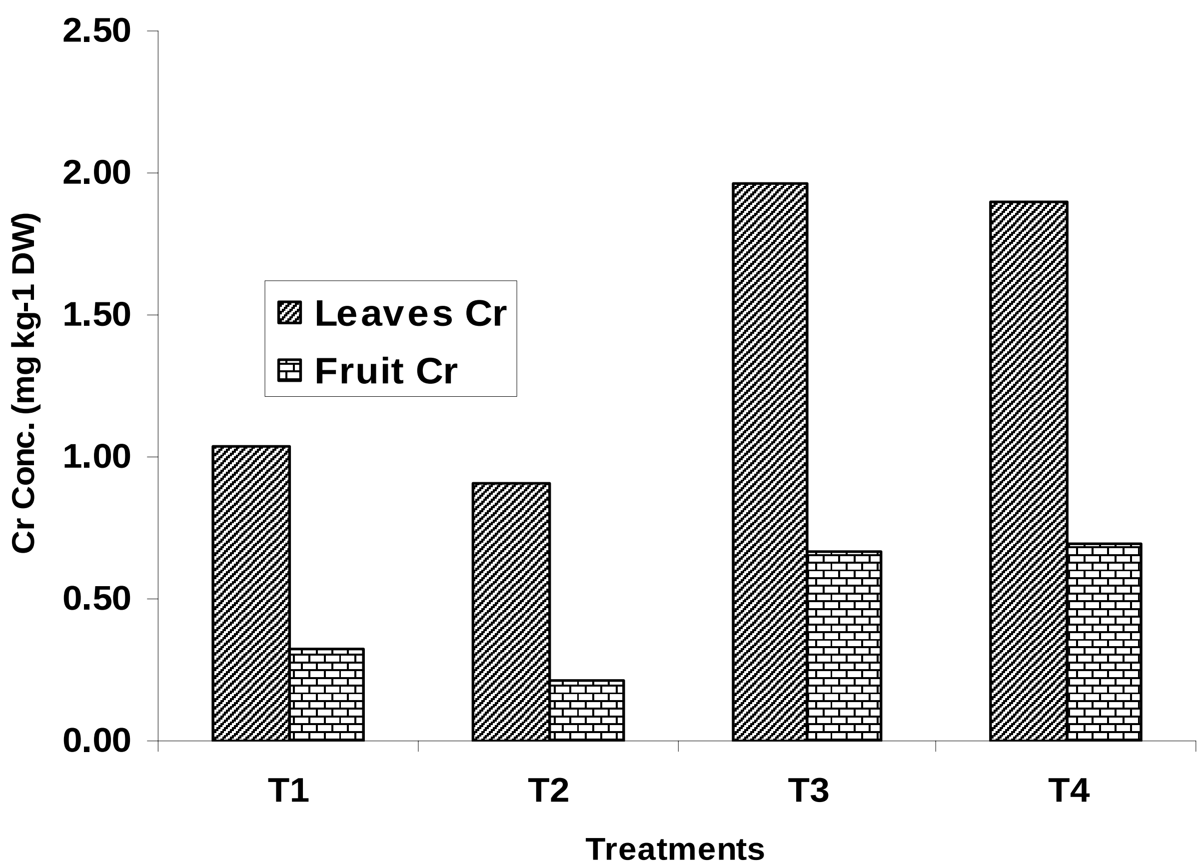

Fig. 2. Concentration of Cd in tomato leaves and fruit.

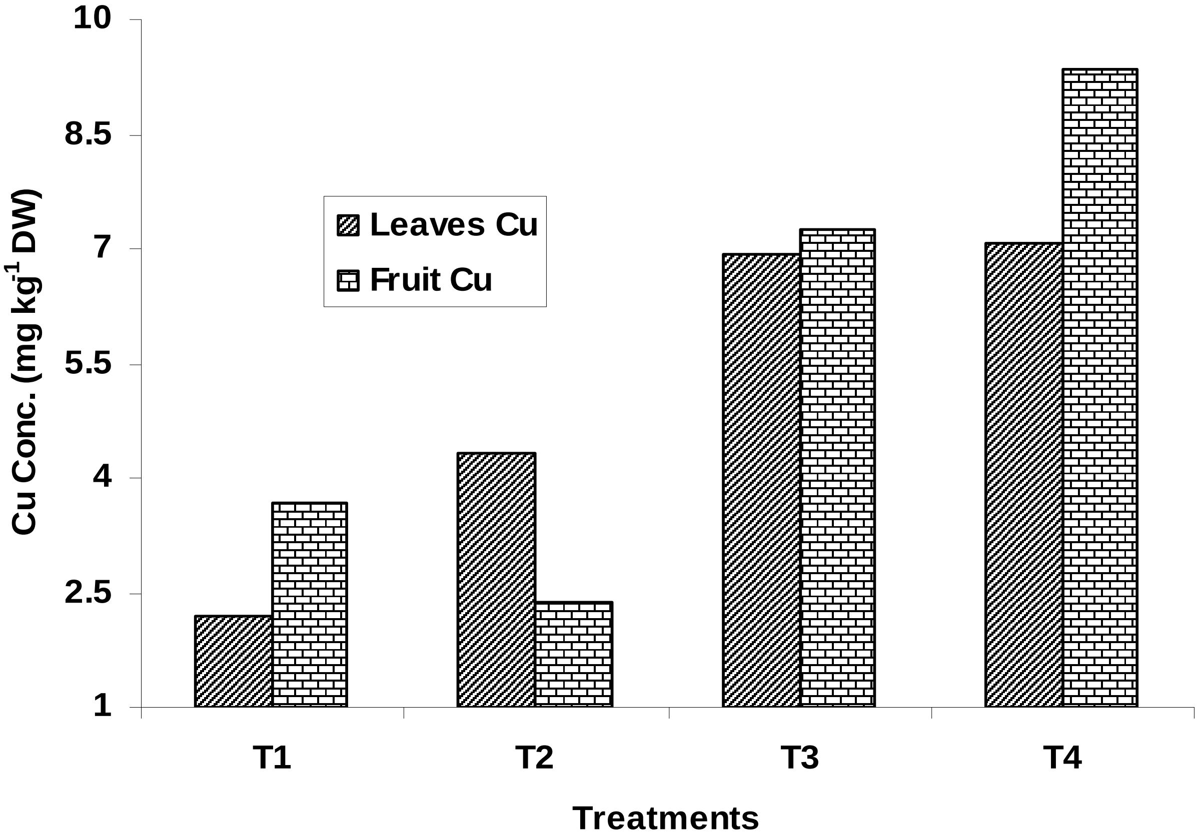

Fig. 3. Concentration of Cd in tomato leaves and fruit.

Fig. 4. Concentration of Fe in tomato leaves and fruit.

Fig. 5. Concentration of Mn in tomato leaves and fruit.

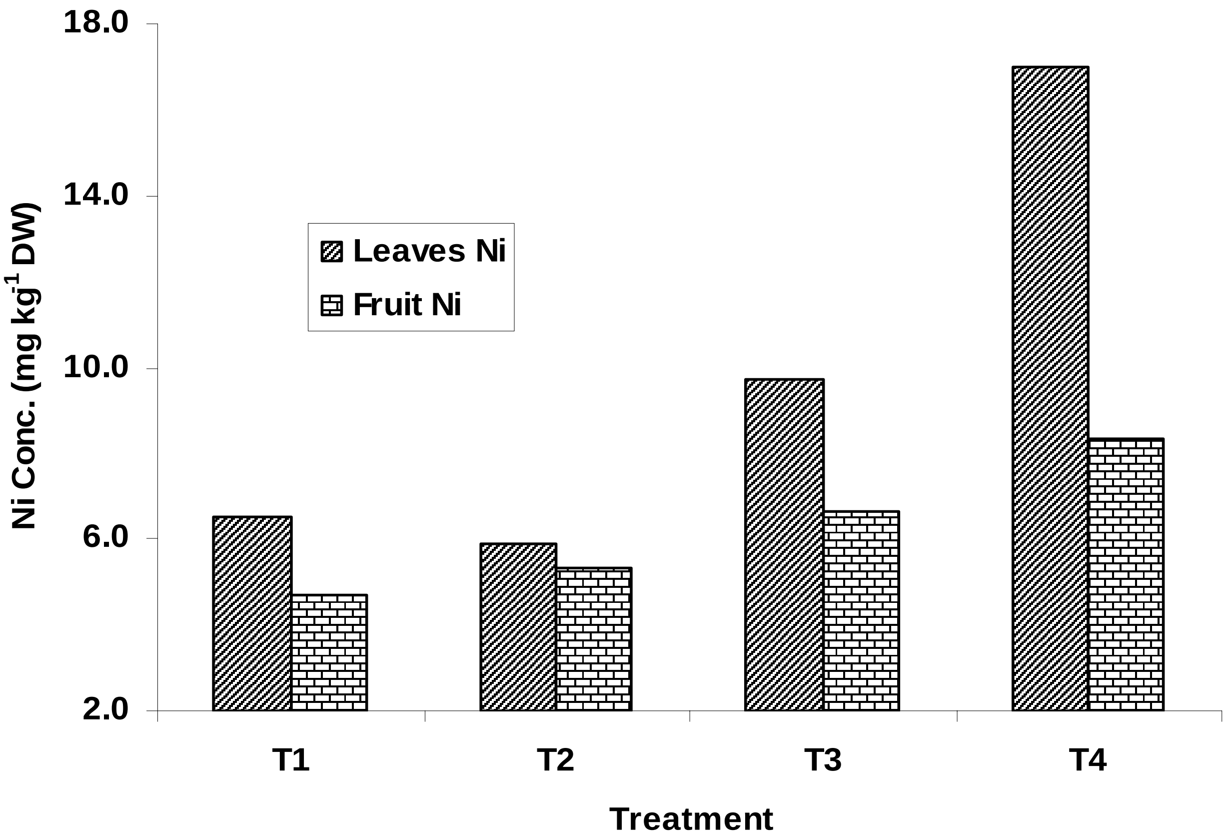

Fig. 6. Concentration of Ni in tomato leaves and fruit.

The results of Pb concentration in both leaves and fruit of tomato were beyond the permissible limits (Anon, 1996) regardless of the irrigation water supply. The higher concentration in tube well irrigated plots may be due to the soil accumulated Pb as these soils are irrigated since long with the effluents. By comparing the treatments mean (Table 3), it can be seen that low values were recorded when irrigated with tube well water compared to waste water (T3 and T4). It can be further observed that plants supplied with fertilizers (T2 and T3) accumulated comparatively less Pb than unfertilized plants (T1 and T4). The role of phosphorus as Pb stabilizing agents is documented by Hettiarachchi *et al*., (2000, 2001) and Khan & Jones (2008). By comparing the Pb content of leaves and fruit (Fig. 7), it was noted that Pb content in fruit was almost half of the concentration in leaves. These results are similar to the findings of Hooda & Alloway (1996), Khan & Jones (2008).

The Zn concentration followed the similar trend as was noted for other heavy metals. Higher Zn content was noted in leaves than in fruit (Fig. 8). By comparing the Zn concentration with the WHO permissible limits of plants, it can be seen that fruit accumulated less Zn than permissible limits (5 mg kg^{-1}) except in T4 where the concentration was beyond the permissible limits while leaves had values higher than the permissible limits. Plants irrigated with tube well water accumulated less Zn than waste water irrigated plants while T3 (WW plus fertilizer) was effective in reducing Zn uptake than the T4 (WW) probably due to phytostabilizing effect of fertilizer or dilution effect as there was more biomass produced in T3 compared to T4. These results are similar to the findings of Khan & Jones (2008).

Conclusions

Significantly taller plant with highest fresh and dry biomass yield was produced in waste water irrigated plots with or with out fertilizers and tube well water supplemented with basal dose of NP and K. The results of metal concentration in leaves and fruit shows that with exception of Cd, there were significant variation in the plant uptake of metals when irrigated with different supply of irrigation water. Leaves accumulated higher concentration of Cr (above the permissible limits) in plots receiving effluents. The fruit Cr concentration was lower than the permissible limits in all the treatments. The Cu concentration was more in fruit than leaves with exception of T2 where the reverse was true. The over all Cu concentration shows that the levels in both leaves and fruits were below the permissible levels. The Fe concentration in leaves was beyond the permissible limits regardless of the irrigation water supply while fruits accumulated Fe below the permissible limits (with exception of T4). The Mn concentration was higher (beyond the permissible limits) in leaves than fruits. Plots irrigated with tube well water (T1 and T2) accumulated less Mn than T3 and T4 (WW irrigated plots). The Ni concentration in leaves was above the permissible limits in T4 (WW) and below the permissible limits in fruit in all the treatments. The results of Pb concentration in both leaves and fruit of tomato were beyond the permissible limits regardless of the irrigation water supply. The Zn concentration in fruit was less than the permissible limits except in T4 where the concentration was beyond the permissible limits while leaves had values higher than the permissible limits regardless of the irrigation water supply.

Recommendations

Tomato can be grown with effluents without accumulation of toxic concentration of heavy metals (in fruits) under special management practice that includes addition of phytostabilizing heavy metal agents (like DAP especially for Pb and Zn) in coarse textured soils.

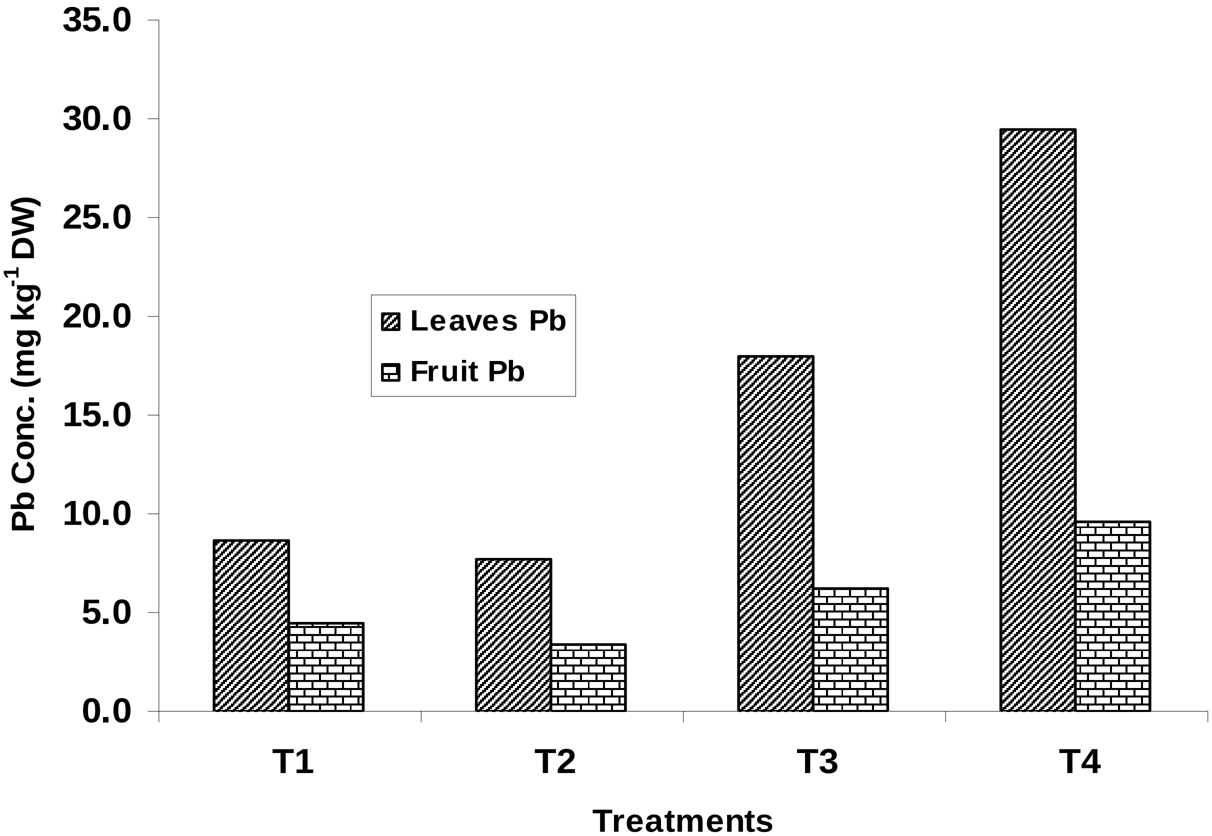

Fig. 7. Concentration of Pb in tomato leaves and fruit.

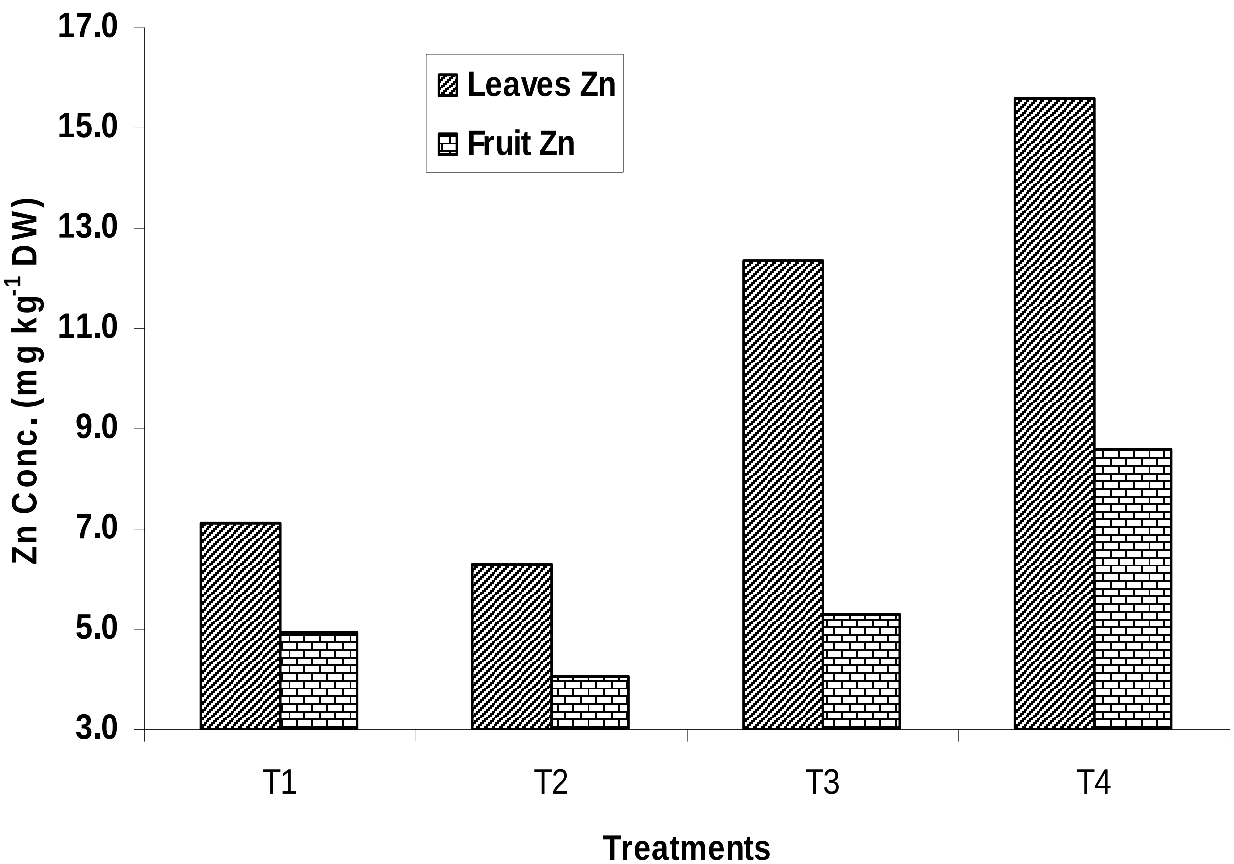

Fig. 8. Concentration of Zn in tomato leaves and fruit.

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