



Nutrients and heavy metals accumulation in spike and bulb of tuberose (*Polianthes tuberosa*) under varied wastewater-groundwater irrigation regimes

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ABSTRACT

An experiment was conducted to assess the nutrients and heavy metals accumulation in spike and bulb of tuberose (*Polianthes tuberosa* L. cv. Prajwal) under varied wastewater-groundwater irrigations regimes at WTC farm of ICAR-Indian Agricultural Research Institute, New Delhi during three consecutive seasons in the years 2013-16. The treatments comprised wastewater irrigation schedules (0.6, 0.8, 1.0, 1.2 and 1.4 ID: CPE), conjunctive use of groundwater and municipal wastewater (at 1.0 ID: CPE) and only groundwater irrigations (at 1.0 ID: CPE) were laid-out in randomized block design with three replication. Major nutrients (N, P and K), micronutrients (Zn, Mn, Cu, Fe) and toxic heavy metals (Ni, Pb, Cd, Cr) concentration in spike and bulb parts of tuberose were analysed as per standard methods. Results indicated that significantly higher contents of macro nutrients (NPK), micronutrients (Zn, Mn, Cu, Fe) and toxic heavy metals (Ni, Pb, Cd, Cr) in both spike and bulb parts of tuberose were recorded under wastewater irrigations scheduled at 1.4 ID/CPE as compared to groundwater irrigation at 1.0 ID/CPE. Hence, irrigation with wastewater may enhanced uptake of nutrients and toxic heavy metals in tuberose due to their higher concentration in wastewater as compared to groundwater.

Key words: Heavy metals, ID/CPE, Irrigation, Nutrients, Tuberose, Wastewater

In urban and industrial areas, wastewater is deliberately being used by the farmers to irrigate high value crops (vegetables and cereals) as wastewater irrigation has been associated with a number of advantages such as having higher amount of nutrients such as nitrogen, phosphorous, potassium and other essential micronutrients as well as organic carbon content, adequate availability, less energy requirement and economical alternative source of irrigation water as compared to clean groundwater irrigation (Kaur *et al.* 2012, Lal *et al.* 2013). Despite several advantages associated with wastewater irrigation in one side on the another side it may lead to adverse effects on soil health and further may create toxic effects on irrigated plants due to accumulation of higher amount of nutrients and metals in soil and then plants. Heavy metals such as copper (Cu), cadmium (Cd), zinc (Zn), lead (Pb), nickel (Ni), and chromium (Cr) present in the wastewater, amount depends on wastewater generating source, and wastewater irrigation may lead to contamination of the food chain (Sharma *et al.* 2006). Long

term wastewater irrigation may buildup of these metals in the soil even at low concentration of metals in it (Rattan *et al.* 2005). Wastewater irrigation leads to accumulation of heavy metals in the soil (Singh *et al.* 2004). Long-term application of wastewater has increased the concentration of heavy metals and their availability in the soil and also enhanced the uptake of metals by the plants (Bohn *et al.* 1985) due to their persistent nature in the soil. Therefore, public awareness on the issue of metals contamination in food chain due to wastewater irrigation may be increased for the safety of human health and environment (Cui *et al.* 2005). Hence, it is very necessary to prevent the growing food crops with wastewater irrigation and promoted the growing of non-edible crops such flowers with wastewater irrigation to avoid the food chain contamination. Therefore, feasibility of flower crop cultivation under wastewater irrigation needs to be evaluated and accumulation level of nutrients and metals in different parts of flower crops also needs to be assessed. Tuberose (*Polianthes tuberosa* L. cv. Prajwal) was chosen as test crop for this study. Further, tuberose is an important commercial flower crop which is being cultivated over an area of 30000 ha in India (Singh *et al.* 2010). Irrigation with nutrients and metals rich wastewater created the problem of toxicity in tuberose due to accumulation of higher quantities of nutrients and heavy metals in the spike and bulb parts of tuberose. Keeping this in view, the tuberose was selected for the test flower crop to

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assess the nutrients and heavy metals accumulation level in spike and bulb parts of tuberose under varied wastewater-groundwater irrigation regimes.

MATERIALS AND METHODS

A field experiment was conducted for three consecutive seasons during 2013 to 2016 at the research farm of the Water Technology Centre (WTC Field No. 1) of ICAR-Indian Agricultural Research Institute (IARI), New Delhi, India. The WTC experimental farm is located between 28° 37' 22" to 28° 39' 00" N latitude and 77° 8' 45" to 77° 10' 24" E longitudes with an average elevation of 230 m above mean sea level. The average annual rainfall of the site was 710 mm. Soil of the experimental site was sandy loam. Soil pH₂ (7.69) and EC₂ (0.27 dS/m) were optimum. Mean soil organic carbon (0.32 %), available nitrogen (N: 128 kg/ha) as low, available phosphorous (P: 26 kg/ha) and available potassium (K: 284 kg/ha) were medium. bulk density of soil was 1.52 Mg/m³ at a depth of 0-30 cm. The groundwater had 7.55 pH, 2.12 dS/m EC, 5.16 SAR and nil Residual Sodium Carbonate (RSC). Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Fecal Coliform were not present in groundwater. Nitrogen, phosphorous and potassium contents in groundwater were present as 6.24, 1.22, and 4.45 mg/L, respectively. Micronutrients (Zn, Mn, Cu, Fe) and toxic heavy metals (Ni, Pb, Cd, Cr) were present in traces. In contrast, wastewater were slightly alkaline (pH: 7.58, SAR: 4.73 and RSC: nil) and associated with 188 mg/L BOD, 356 mg/L COD, 5.4×10^5 MPN/100ml fecal coliforms, 26 mg/l nitrogen, 4.5 mg/l phosphorous, 12 mg/l potassium concentrations. Micronutrients (Zn, Mn, Cu, Fe) as 0.08, 0.04, 0.01, 2.6 mg/l, respectively and toxic heavy metals (Ni, Pb, Cd, Cr) as 0.005, 0.006, 0.0003, 0.05 mg/l were present in wastewater. The treatments comprised wastewater irrigation schedules (0.6, 0.8, 1.0, 1.2 and 1.4 ID: CPE), conjunctive use of groundwater and municipal wastewater (at 1.0 ID: CPE) and only groundwater irrigations (at 1.0 ID: CPE) were laid-out in randomized block design with three replications. Proper package and practices for cultivation of tuberose were followed during crop period. Irrigation treatments were based on different ID/CPE ratio, a climatological approach of irrigation scheduling. ID, depth of unit irrigation, was taken as 50mm. CPE, cumulative pan evaporation, were determined by adding daily data of pan evaporation. Daily pan evaporation data, based on open pan U.S.W.B. Class I Pan Evaporimeter, were received from IARI website and source of data was from a meteorological observatory located in research farm of Division of Agricultural Physics at IARI New Delhi. The effective rainfall was considered as irrigation water in each plot during rainfall and in rainy season. Effective rainfalls were determined using FAO CROPWAT 8.0 model. As per plot size (6 m²) and depth of unit irrigation (0.05 m), 300 l of water was required to irrigate each plot of tuberose. A digital handheld water velocity meter was used to ensure the accurate and same volume of water application in each treatment plot. Leaf and bulb samples were collected at the

time of digging of bulbs of tuberose in of March in each year of experimentation (2013-16). Plant samples (leaf and bulb) were oven dried and grinded for lab analysis. Digestion of plant sample was done as per method described by Singh *et al.* (2005). The nitrogen content in plant samples was determined by using nitrogen analyzer by following standard method (APHA 2005). Phosphorous content was determined by using same di-acid digested samples through Vanadomolybdate method (Jackson 1973) and potassium by Flame Photometer method. The concentration of micronutrients and toxic heavy metals (Fe, Cu, Mn, Zn, Cr, Ni, Pb and Cd) in digested and filtered plant samples (leaf and bulb of tuberose) were estimated on inductively coupled plasma spectrophotometer (ICP-MS) using standard solution of Fe, Cu, Mn, Zn, Cr, Ni, Pb and Cd against unknown samples of plants. In order to measure the concentration of metals in samples, the concentration range of standard metal solution were modified. Blank solution contained everything except plant sample material was prepared to set the initial reading zero so as to minimize the metal contamination in samples. Recorded values of metals in unknown samples solution (ppm) were multiplied by the dilution factor to find out the actual concentration of metals in dry plant sample (µg/g dry weight of sample). Standard procedure and methodology were followed during the process of metal analysis in plant samples. The mean values of all the recorded characters were subjected to analysis of variation (ANOVA) technique as applicable to randomized block design (Gomez and Gomez 1983). The significance of the difference between the means of the two treatments were estimated through least significant differences (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Data set on major nutrients (NPK) micronutrients (Zn, Mn, Cu, Fe) and toxic heavy metals (Ni, Pb, Cd, Cr) accumulation in spike and bulb parts of tuberose of three years seasons (2013-16) were statistically analyzed. It has been observed that the main effect of year, interaction effects of years and irrigations were not significant at $P < 0.05$ for all parameters. Thus, it has been established that the effect of years/seasons was rather negligible, and the pooled average data for three consecutive seasons are reported in this paper.

Major nutrients accumulations in spike and bulb parts of tuberose

The application of wastewater irrigations at different irrigation scheduling from 0.6 to 1.4 ID/CPE significantly influenced the NPK contents in spike and bulb parts of tuberose (Table 1). Significantly higher nitrogen contents in spike (1.36%) and bulb (1.52%) were recorded under wastewater irrigations scheduled at 1.4 ID/CPE which were significantly higher over remaining treatments. P_{tot} contents significant higher in spike (0.31%) and bulb (0.29%) parts of tuberose were also recorded under wastewater irrigations scheduled at 1.4 ID/CPE which

were significantly at par at wastewater irrigation scheduled at 1.2 ID/CPE, whereas it was significantly higher over other remaining treatments. Significantly higher K contents in spike (0.36%) and bulb (0.43%) were observed in the treatment plots where wastewater irrigations applied at 1.2 ID/CPE which were at par with wastewater irrigations scheduled at 1.4, 1.0 and 0.8 ID/CPE, whereas significantly higher as compared to wastewater irrigation applied at 0.6 ID/CPE and groundwater irrigations applied at 1.0 ID/CPE. The higher contents of NPK in spike as well as bulb parts of tuberose under wastewater irrigations applied at 1.4 ID/CPE or higher ID/CPE as compared to lower ID/CPE might be due to frequent or more number of irrigations and higher volume of water were applied at higher ID/CPE as wastewater contains higher amount of nutrients as compared to groundwater. This is also might be due to adequate and frequent availability of moisture under irrigation at higher ID/CPE which increased the availability of nutrients and led to better vegetative growth that ultimately enhance the absorption of mineral nutrients or higher uptake of NPK. These results are in close conformity with the findings of Singh *et al.* (2001). It was reported that contents of nitrogen, phosphorous and potassium in plant parts are closely related to significantly enhanced yields of spike and bulb in tuberose (Roy 1992). Moreover, the several researchers reported that municipal wastewaters are rich in organic matter and also contain appreciable amounts of major and micronutrients (Gupta *et al.* 1998). Accordingly, nutrient levels of soils and plants are expected to improve considerably with continuous irrigation with sewage water or wastewater (Brar *et al.* 2000). Yadav *et al.* (2002) also monitored higher contents of N, P, K in plant parts when grown on soils irrigated with sewage water.

Micro-nutrients accumulation in spike and bulb parts of tuberose

It is evident from the data in Table 2 that application of wastewater irrigations at different ID/CPE showed statistically significant difference of the contents of total zinc (Zn), manganese (Mn), copper (Cu) and iron (Fe) in

leaf and bulb parts of tuberose. Significantly higher zinc contents in spike (42.93 mg/kg) and bulb (23.85 mg/kg) were observed under wastewater irrigations scheduled at 1.4 ID/CPE which were at par with the treatments of wastewater irrigation scheduled at 1.2 and 1.0 ID/CPE and significantly higher over remaining treatments. Manganese contents were observed significantly higher in spike (42.99 mg/kg) and bulb (33.07 mg/kg) parts of tuberose at wastewater irrigations scheduled at 1.4 ID/CPE. Manganese contents in spike and bulb were at par in the treatments of wastewater irrigations scheduled at 1.2 and 1.0 ID/CPE with the treatments of wastewater irrigation applied at 1.4 ID/CPE, whereas it was significantly different over the remaining treatments. Significantly higher copper contents in spike (7.17 mg/kg) and bulb (4.57 mg/kg) were observed in the treatment plots where wastewater irrigations applied at 1.4 ID/CPE which were at par with wastewater irrigations scheduled at 1.2, 1.0 and 0.8 ID/CPE and significantly higher over the remaining treatments. Significantly higher iron contents in spike (4062.68 mg/kg) and bulb (1324.48 mg/kg) were observed under wastewater irrigations scheduled at 1.4 ID/CPE which were at par with the treatments of wastewater irrigation scheduled at 1.2 ID/CPE and significantly higher over remaining treatments. In comparison of all micronutrients (Zn, Mn, Cu, Fe) contents in spike and bulb parts of tuberose in the treatment plots where wastewater and groundwater was applied at 1.0 ID/CPE, it was found that the micronutrients content were higher in wastewater irrigated then groundwater irrigated plots in the both spike and bulb parts of tuberose. This might be due to presence of higher concentration of micronutrients in wastewater as compared to groundwater. The frequent or more numbers of irrigation and higher volume of water were applied at 1.4 ID/CPE may be the main reason for presence of higher amount of micronutrients (Zn, Mn, Cu, Fe) in spike as well as bulb parts of tuberose under wastewater irrigations applied at 1.4 ID/CPE or higher ID/CPE as compared to lower ID/CPE. Higher accumulation of micro-nutrients and heavy metals in plants was also observed in sewage water irrigated crops by Yadav *et al.* (2002).

Table 1 Nitrogen, phosphorous and potassium accumulation in spike and bulb of tuberose under varied wastewater-groundwater irrigation regimes (Pooled data of 3 years)

Treatment	N (%)		P (%)		K (%)	
	Spike	Bulb	Spike	Bulb	Spike	Bulb
Wastewater irrigation at 0.6 ID/CPE	1.30	1.45	0.26	0.24	0.31	0.38
Wastewater irrigation at 0.8 ID/CPE	1.32	1.48	0.28	0.26	0.33	0.39
Wastewater irrigation at 1.0 ID/CPE	1.35	1.50	0.29	0.27	0.34	0.41
Wastewater irrigation at 1.2 ID/CPE	1.34	1.49	0.30	0.28	0.36	0.43
Wastewater irrigation at 1.4 ID/CPE	1.36	1.52	0.31	0.29	0.35	0.42
Conjunctive irrigation at 1.0 ID/CPE	1.30	1.45	0.27	0.25	0.32	0.39
Groundwater irrigation at 1.0 ID/CPE	1.27	1.42	0.25	0.24	0.31	0.36
SE _m ±	0.02	0.02	0.01	0.01	0.01	0.02
LSD (P=0.05)	0.05	0.06	0.02	0.02	0.03	0.04

Table 2 Micronutrients (mg/kg) accumulation in spike and bulb parts of tuberose under varied wastewater-groundwater irrigation regimes (Pooled data of 3 years)

Treatment	Zn		Mn		Cu		Fe	
	Spike	Bulb	Spike	Bulb	Spike	Bulb	Spike	Bulb
Wastewater irrigation at 0.6 ID/CPE	36.33	20.18	36.39	27.99	6.06	3.51	3438.67	1118.56
Wastewater irrigation at 0.8 ID/CPE	39.01	21.67	39.07	30.05	6.51	3.96	3692.24	1202.24
Wastewater irrigation at 1.0 ID/CPE	40.25	22.36	40.31	31.01	6.72	4.17	3809.11	1240.80
Wastewater irrigation at 1.2 ID/CPE	42.26	23.48	42.31	32.55	7.05	4.50	3998.74	1303.38
Wastewater irrigation at 1.4 ID/CPE	42.93	23.85	42.99	33.07	7.17	4.57	4062.68	1324.48
Conjunctive irrigation at 1.0 ID/CPE	37.36	20.75	37.41	28.78	6.24	3.69	3535.69	1150.58
Groundwater irrigation at 1.0 ID/CPE	35.63	19.79	35.69	27.45	5.95	3.38	3372.52	1096.73
SEm±	0.92	0.51	0.92	0.71	0.15	0.15	86.74	28.60
LSD (P=0.05)	2.86	1.59	2.87	2.21	0.47	0.48	270.20	89.10

Toxic heavy metals accumulation in spike and bulb parts of tuberose

Heavy metals (Ni, Pb, Cd, Cr) contents in the spike and bulb parts (Table 3) of tuberose, grown under varied wastewater-groundwater irrigation regimes, were also estimated. Heavy metals present in the municipal wastewater used for irrigation tend to accumulate in the soils, become bio-available and eventually get translocated to plants (Toze 2006). Concentrations of Ni, Pb, Cd and Cr and in the spike under consideration varied from 5.06 to 6.28, 9.90 to 12.47, 0.24 to 0.30 and 1.51 to 1.60 mg/kg, respectively and in bulb parts of tuberose varied from 2.61 to 3.30, 7.34 to 9.94, 0.26 to 0.31 and 0.84 to 0.88 mg/kg, respectively at different irrigation regimes. Due to low heavy metal concentrations in the irrigation waters, high soil pH and low organic carbon contents (Mantovi *et al.* 2005), metal concentrations in the plant parts under consideration were observed to be well below their critical levels (such as Ni: 10–100 mg/kg dry matter, Pb: 30–300 mg/kg dry matter, Cd 5–30 mg/kg dry matter and Cr: 5–30 mg/kg dry matter as proposed by Kabata-Pendias and Pendias (1992) and hence did not contribute to any visual plant injury symptoms during the study period. However, the nickel and lead concentrations were observed to be in high concentrations, whereas

cadmium and chromium concentrations were observed to be in very low concentrations as compared to critical limits for even food (Ni: 2.5 mg/kg, Pb: 1.3 mg/kg Cd: 1.5 mg/kg and Cr: 1.5 mg/kg; Awashthi 2000, FSSAI 2011) indicated its high phytoremediation potential for metals particularly for nickel and lead. It is also clear from Table 4 that significantly higher nickel (Ni), lead (Pb), cadmium (Cd) and chromium (Cr) concentrations in spike (6.28, 12.47, 0.30 and 1.60 mg/kg, respectively) and bulb (3.30, 9.94, 0.31 and 0.88 mg/kg, respectively) were observed under wastewater irrigations scheduled at 1.4 ID/CPE which were at par with the treatments of wastewater irrigation scheduled at 1.2 and 1.0 ID/CPE and significantly higher over remaining treatments. However, in general, spike and bulb of tuberose produced through wastewaters (either alone or in conjunction with groundwater) were found to be associated with higher toxic heavy metals (Ni, Pb, Cd, Cr) concentrations than those produced from groundwater alone at 1.0 ID/CPE. This might be due to presence of higher concentration of heavy metals in wastewater as compared to groundwater. This is in concurrence with the findings recorded by Rattan *et al.* (2005) in crops irrigated with municipal sewage. Frequent use of sole wastewater applications, irrigation scheduled at higher ID/CPE, i.e. 1.4 ID/CPE, also seems to be associated

Table 3 Heavy metals (mg/kg) accumulation in spike and bulb parts of tuberose under varied wastewater-groundwater irrigation regimes (Pooled data of 3 years)

Treatment	Ni		Pb		Cd		Cr	
	Spike	Bulb	Spike	Bulb	Spike	Bulb	Spike	Bulb
Wastewater irrigation at 0.6 ID/CPE	5.17	2.74	10.42	7.94	0.25	0.27	1.49	0.83
Wastewater irrigation at 0.8 ID/CPE	5.62	2.96	11.24	8.65	0.27	0.29	1.57	0.86
Wastewater irrigation at 1.0 ID/CPE	5.83	3.07	11.60	9.10	0.28	0.30	1.58	0.87
Wastewater irrigation at 1.2 ID/CPE	6.16	3.20	12.14	9.59	0.29	0.30	1.59	0.87
Wastewater irrigation at 1.4 ID/CPE	6.28	3.30	12.47	9.94	0.30	0.31	1.60	0.88
Conjunctive irrigation at 1.0 ID/CPE	5.35	2.81	10.69	8.19	0.26	0.28	1.56	0.86
Groundwater irrigation at 1.0 ID/CPE	5.06	2.61	9.90	7.34	0.24	0.26	1.51	0.84
SEm±	0.15	0.06	0.22	0.21	0.01	0.01	0.02	0.01
LSD (P=0.05)	0.47	0.20	0.69	0.64	0.02	0.03	0.05	0.03

with significantly higher concentrations of toxic heavy metals (Ni, Pb, Cd, Cr) in spike and bulb parts of tuberose as it applies maximum numbers of irrigation and more volume of water to be used for irrigating tuberose. Moreover, toxic heavy metals (Ni, Pb, Cd, Cr) concentrations in spike and bulbs of tuberose were found to be about 7-26 % and 6-35 %, respectively higher under wastewater irrigations as compared to groundwater irrigations scheduled at same ID:CPE ratio of 1.0. Dutta *et al.* (2000) have also earlier reported higher metals concentration in plant grown on soils irrigated with domestic sewage from IARI.

Conclusion

It is concluded that the significantly higher amount of major nutrients (N, P and K), micronutrients (Zn, Mn, Cu, Fe) and toxic heavy metals (Ni, Pb, Cd, Cr) accumulations in spike and bulb of tuberose are to be associated with wastewater irrigations as compared to groundwater irrigations. Frequent wastewater irrigations (1.4 ID/CPE) are more prone to accumulate higher concentrations of macro and micro-nutrients as well as toxic heavy metals in spike and bulb of tuberose.

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