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Short-term impact of wastewater irrigation on chemical soil health in tuberose (*Polianthes tuberosa*)

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ABSTRACT

A field experiment was conducted to find out the short term impact of wastewater irrigation on chemical soil health in tuberose (*Polianthes tuberosa* L. *cv.* Prajwal) at WTC farm of ICAR-Indian Agricultural Research Institute, New Delhi during three consecutive seasons (2013-14, 2014-15 and 2015-16). Treatments comprised of 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. Chemical parameters (pH, EC, OC), primary nutrients (N, P and K), micronutrients (Zn, Mn, Cu and Fe) and toxic heavy metals (Ni, Pb, Cd, Cr) contents in soil were analysed from collected soil samples at harvest of tuberose. Analytical results indicated that pH and EC were not altered while organic carbon, primary nutrients contents (N, P and K) and micro nutrients (Zn, Cu, Fe, Mn) content significantly increased in soils irrigated with wastewater. However, the contents of heavy metals in irrigated soil were not significantly altered with wastewater irrigation at 1.0 ID/CPE and same with groundwater irrigation. Wastewater irrigation had the positive impacts on soil chemical health in terms of enhanced level of organic matter, primary and micro nutrients contents in soil.

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

A huge quantity of freshwater is being diverted into non-farm sectors such domestic, commercial and industrial sectors which result in generation of large amount of wastewater from urban areas (Qadir *et al.* 2007). In India, only 24% of wastewater generated by households and industry is treated before its use in agriculture or disposal to rivers and rest go as untreated in the environment (Minhas and Samra 2004, Minhas *et al*. 2006). Land application of untreated wastewater for irrigation may be a safe and low cost wastewater disposal strategy. Moreover, the use of wastewater in agriculture has many advantages such as supply of nutrients like nitrogen (N), phosphorous (P), potassium (K) and other essential micronutrients as well as organic carbon content for the crops, 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, Gurjar *et al*. 2016, Gurjar and Kaur 2018). Hence, the farmers of peri-urban areas are deliberately using wastewater to grow a range of crops (Ensink *et al.* 2007, Qadir *et al*. 2010). However, utilization of wastewater resources is essential for meeting the nutrients requirement of crops, increase production and ever increasing demand for irrigation water. But on the other hand it may have some disadvantages such as soil salinization, damage of sensitive crops, loss of soil infiltration capacity, hydraulic conductivity and contamination of soil by heavy metals as well as pathogen (Cirelli *et al*. 2012, Pedrero *et al*. 2012, Nogueira *et al*. 2013) which may be indicated by total *fecal coliforms* load in wastewater irrigated soil. Sharma *et al*. (2006) also supported that wastewater is a potential source of heavy metals such as copper (Cu), cadmium (Cd), zinc (Zn), lead (Pb), nickle (Ni), and chromium (Cr). Moreover, the long term use of wastewater irrigation may build up the heavy metals in irrigated soil even though heavy metals are present in wastewater at very low concentration (Rattan *et al*. 2005). Heavy metals are persistent, so long-term application of wastewater increases their availability in the soil and consequently in the plants (Bohn *et al*. 1985). Hence, it is clear that wastewater irrigation may be enhanced the soil health through addition of nutrients or may be damaged by increasing salinity, clay dispersion, reduction of infiltration rate and hydraulic conductivity and enhanced the pathogen load (Bichai *et al*. 2012, Urbano *et al.* 2015). Therefore, the public awareness on the issue of wastewater irrigation and food contamination is necessary to be increased (Martin and Coughtry 1982, Cui *et al*. 2005). Hence, growing the

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non-food crops under wastewater irrigation is very much necessary for avoiding food chain contamination. Keeping in view, the present study was undertaken to assess the short-term impact of wastewater irrigation on soil health under cultivation of tuberose (*Polianthes tuberosa* L. *cv.* Prajwal).

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 was 710 mm of long period average. Soil of the experimental site was sandy loam (0-30cm). Soil pH (7.69) and EC (0.27 dS/m) were optimum. Mean soil organic carbon (OC, 0.32%) as well as available nitrogen (N, 128 kg/ha) were low whereas, available phosphorous (P: 26 kg/ha) and available potassium (K, 284 kg/ha) were medium as per soil fertility ratings. Bulk density of soil was 1.52 Mg/m^3 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. NPK content 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 was 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 /N, 4.5 mg/l/P, 12 mg/l/K 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. Seven treatments, viz. T-1: Wastewater irrigation at 0.6 Irrigation Depth (ID)/Cumulative Pan Evaporation (CPE), T-2: Wastewater irrigation at 0.8 ID/CPE, T-3: Wastewater irrigation at 1.0 ID/CPE, T-4: Wastewater irrigation at 1.2 ID/CPE, T-5: Wastewater irrigation at 1.4 ID/CPE, T-6: Conjunctive use of groundwater and wastewater irrigation at 1.0 ID/CPE in cyclic mode and T-7: Control (groundwater irrigation at 1.0 ID/CPE) were laid out in a randomized block design (RBD) 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, was determined by adding daily data of pan evaporation. Daily pan evaporation data was based on open pan USWB. Class I Pan Evaporatorimeter, was 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 a source of 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 m^2) and depth of unit irrigation (50mm), 300 litres 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 plot. Soil samples were collected just before digging of bulb of tuberose at the depths of 0-15 and 15-30 cm. Soil pH and EC were determined at 1:2 soil and water ratio using a glass electrode and conductivity bridge, respectively (Jackson 1973). Soil organic carbon (SOC) was determined by dichromate oxidation (Walkley and Black 1934) and available nitrogen (N) by the alkaline potassium permanganate distillation method (Subbiah and Asija 1956) using nitrogen analyzer. Available phosphorus (P) in soil was determined by extracting samples with 0.5 M $NaHCO_3$, and determining P colorimetrically using molybdate (Olsen *et al.* 1954) using UV visible spectrophotometer. Available potassium (K) was determined using 1N ammonium acetate extraction followed by flame photometer (Jackson 1973). Diethylene triamine penta acetic acid (*DTPA*) micro-nutrients and heavy metals (Fe, Cu, Mn, Zn, Cr, Ni, Pb and Cd) contents in soil were measured by Inductively Coupled Plasma Spectrophotometer (ICP-MS) as per standard method (Lindsay and Norvell 1978, APHA 2005). The mean values of all the analyzed soil health parameters were calculated. The analysis of variation (ANOVA) technique was carried out on the data for each parameter as applicable to randomized block design (Gomez and Gomez 1983). The significance of the treatment effect was determined by using F-test, and to determine the significance of the difference between the means of the two treatments, least significant differences (LSD) were estimated at 5% probability level, and Duncan's multiple range test was used for comparing three or more means at the same probability level.

RESULTS AND DISCUSSION

Data set on chemical properties of soils irrigated with wastewater under cultivation of tuberose for 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 have been reported in this paper.

Impact on pH, EC and organic carbon of soil

It is revealed in Table 1 that the pH and EC of the irrigated soil significantly not altered with different treatment of wastewater irrigations under various irrigation schedules based on ID/CPE. The range of pH of soil was slightly alkaline (7.65 – 7.84 and 7.59 – 7.84 at soil depth of 0-15 and 15-30 cm, respectively) under all the treatments of the present study. Salinity in terms of electrical conductivity (EC) were also significantly not changed due to wastewater irrigations. EC of irrigated soil at the depths of 0-15 and 15-30 cm was varied from 0.18 to 0.28 and 0.16 to 0.19 dS/m, respectively under all the treatments. Significantly

Table 1 Short term impact of wastewater irrigation on soil reaction (pH), soil salinity (EC) and organic carbon content of soil at the depths of 0-15 and 15-30 cm in tuberose (Mean data of 3 years)

Treatment	pH		EC (dS/m)		Organic carbon (%)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Wastewater irrigation at 0.6 ID/CPE	7.72	7.72	0.22	0.17	0.32	0.16
Wastewater irrigation at 0.8 ID/CPE	7.80	7.74	0.18	0.17	0.33	0.17
Wastewater irrigation at 1.0 ID/CPE	7.71	7.68	0.20	0.16	0.34	0.18
Wastewater irrigation at 1.2 ID/CPE	7.79	7.84	0.22	0.18	0.35	0.21
Wastewater irrigation at 1.4 ID/CPE	7.84	7.59	0.21	0.16	0.38	0.23
Conjunctive irrigation at 1.0 ID/CPE	7.78	7.78	0.20	0.16	0.32	0.20
Groundwater irrigation at 1.0 ID/CPE	7.65	7.75	0.28	0.19	0.30	0.15
SEm±	0.08	0.07	0.03	0.01	0.01	0.01
LSD (P=0.05)	NS	NS	NS	NS	0.03	0.03

higher organic carbon content of soil was observed in the treatment plots, where wastewater irrigation was applied at 1.4 ID/CPE. This is may be due to presence of higher organic carbon content in wastewater as compared to groundwater. Organic carbon content in the soil depths of 0-15 and 15-30 cm ranged from 0.30 to 0.38% and 0.15 to 0.23%, respectively, under various treatments. In comparison of wastewater and groundwater irrigation at same 1.0 ID/CPE, wastewater irrigation increased OC content of the soil by 13.33% and 20.0% at 0-15 and 15-30 cm soil depth, respectively. Rattan *et al.* (2005) reported an increment of 59% in OC content of soil having long-term use of sewage irrigation of peri-urban agricultural land under the Keshopur effluents irrigation scheme (KEIS) of the Delhi government, India. Similarly, Bansal *et al.* (1992) have reported a 47.9% increase in OC content of topsoil (0–15 cm) receiving industrial wastewater for irrigation as compared to the soil irrigated with tube well water at a site situated in Jamalpur, a village near the industrial town of Ludhiana, Punjab.

Impact on major nutrients

The application of wastewater irrigations at different irrigation scheduling from 0.6 to 1.4 ID/CPE, significantly influenced the nitrogen, phosphorous and potassium contents in both the soil depths of 0-15 and 15-30 cm in tuberose (Table 2). Significantly higher available nitrogen content at 0-15 cm (168.7 kg/ha) and 15-30 cm (146.0 kg/ha) was recorded under wastewater irrigations scheduled at 1.4 ID/CPE which was significantly higher over remaining treatments. Saha *et al*. (2010) was found 11.4% more available N content in sewage-irrigated root zone soils compared to groundwater-irrigated soil. Phosphorous content significantly higher at soil depths of 0-15cm (39.20 kg/ha) and 15-30 cm (19.20 kg/ha) in tuberose was also recorded under wastewater irrigations scheduled at 1.4 ID/CPE as compared to other treatments. Siebe (1998) also observed significant increase in available P due to long-term wastewater irrigation near Mexico City. Significantly higher potassium content in soil of depth 0-15 cm (243.2 kg/ha) and 15-30 cm (223.3 kg/ha) was observed in the treatment plots, where wastewater irrigations were applied at 1.4 ID/CPE and which were significantly higher over remaining treatments. Long-term sewage application has been found to increase available K content in soils of different places (Ryan *et al.* 2006). The higher contents of

Table 2 Short-term impact of wastewater irrigation on primary nutrients (N, P and K) of soil at the depths of 0-15 and 15-30 cm in tuberose (Mean data of 3 years)

Treatment	Available nitrogen (kg/ha)		Available phosphorous (kg/ha)		Available potassium (kg/ha)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Wastewater irrigation at 0.6 ID/CPE	160.1	134.3	34.9	14.7	219.3	199.2
Wastewater irrigation at 0.8 ID/CPE	160.9	135.8	35.3	15.1	220.2	200.1
Wastewater irrigation at 1.0 ID/CPE	162.5	138.2	36.1	15.9	223.2	203.1
Wastewater irrigation at 1.2 ID/CPE	164.8	142.1	37.2	17.1	225.6	205.4
Wastewater irrigation at 1.4 ID/CPE	168.7	146.0	39.2	19.0	243.2	223.3
Conjunctive irrigation at 1.0 ID/CPE	159.3	140.5	34.5	14.4	218.1	197.9
Groundwater irrigation at 1.0 ID/CPE	157.0	133.5	33.3	13.2	214.9	195.6
SEm±	1.18	1.43	0.59	0.58	2.99	3.05
LSD (P=0.05)	3.68	4.47	1.84	1.83	9.31	9.51

nitrogen, phosphorous and potassium in irrigated soil of tuberose under wastewater irrigations applied at 1.4ID/CPE may be due to frequent or more numbers of irrigation were applied at higher ID/CPE. Moreover, wastewater contain higher amount of nutrients as compared to groundwater. Available nitrogen, phosphorous and potassium content in irrigated soil at depths of 0-15 and 15-30 cm were varied as 157.0 to 168.7 kg/ha and 133.5 to 146.0 kg/ha, 33.3 to 39.2 kg/ha and 13.2 to 19.0 kg/ha and 214.9 to 243.2 kg/ha & 195.6 to 223.3 kg/ha, respectively. It is also clear that wastewater irrigated plots had higher available NPK in soil as compared to groundwater irrigation at same ID/CPE. This finding is supported by some other studies, which have shown increments in N and P contents in the soil irrigated by wastewater as compared to those irrigated with tube well water (Azad *et al.* 1987, Dutta *et al*. 2000, Tiwari *et al*. 2003). Moreover, the several researchers reported that municipal wastewater is rich in organic matter and also contain appreciable amounts of major and micronutrients (Feign *et al*. 1991, Pescod 1992 Gupta *et al*. 1998, Brar *et al*. 2000). Accordingly, nutrient levels of soils and plants are expected to improve considerably with continuous irrigation with sewage water or wastewater (Baddesha *et al*. 1986, Narwal *et al.* 1993). Increase in OC content of the soil due to wastewater irrigation is shown to increase the available as well as total nutrients in the soils (Yadav *et al*. 2002).

Impact on micro-nutrients

It is evident from the data in Table 3 that application of wastewater irrigations at different ID/CPE showed statistically significant difference in the contents of available zinc (Zn), manganese (Mn), copper (Cu) and iron (Fe) in soil at both the depths of 0-15 and 15-30 cm in tuberose. Significantly higher zinc content in soil at 0-15 cm (0.74 mg/kg) and 15-30 cm (0.68 mg/kg) was observed under wastewater irrigations scheduled at 1.4 ID/CPE which was at par with the treatments of wastewater irrigation scheduled at 1.2 and 1.0 ID/CPE and significantly higher over remaining treatments. Available manganese content was observed significant higher in both the soil depths of 0-15 cm (7.56 mg/kg) and 15-30 cm (6.25 mg/kg) in tuberose at wastewater irrigations scheduled at 1.4 ID/CPE which was at par in the treatments of wastewater irrigations scheduled at 1.2 and 1.0 ID/CPE and significantly higher as compared to other remaining treatments. Significantly higher available copper contents in 0-15 cm (0.32 mg/kg) and 15-30 cm (0.23 mg/kg) soil depths 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 ID/CPE and significantly higher over the remaining other treatments. Significantly higher iron content in the soil depth of 0-15 cm (7.05 mg/kg) and 15-30 cm (5.51 mg/kg) was 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 irrigated soil of tuberose at 1.0 ID/CPE, it was found that the micronutrient content of soil was higher in wastewater irrigated, than groundwater irrigated plots, in both the soil depth (0-15 and 15-30 cm) under grown of tuberose. This might be due to presence of higher concentration of micronutrients in wastewater as compared to groundwater. Higher microbial population and their metabolic activity (microbial biomass C, dehydrogenase enzyme activity, and CO_2 evolution) in wastewater/sewage-irrigated soil as compared to groundwater irrigated plots may be the main reason for enhanced availability of micronutrients in wastewater irrigated soil as reported by Saha *et al.* (2010). Moreover, the frequent or more numbers of irrigation and higher volume of water application may be the main reason for the significantly higher values of micro-nutrients (Zn, Mn, Cu, Fe) in soil, under treatment of wastewater irrigation scheduled at 1.4 ID/CPE. This finding is supported by Brar *et al*. (2000) and they have reported continuous irrigation with sewage water or wastewater appreciably to be improved the nutrient levels of irrigated soils. Higher accumulation of micro- nutrients in soil was also observed under irrigation with wastewater or sewage by Yadav *et al.* (2002).

Table 3 Short term impact of wastewater irrigation on micro-nutrients of soil at the depths of 0-15 and 15-30 cm in tuberose (Mean data of 3 years)

Treatment	Zn (mg/kg)		Mn (mg/kg)		Cu (mg/kg)		Fe (mg/kg)	
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
Wastewater irrigation at 0.6 ID/CPE	0.66	0.59	6.77	5.20	0.29	0.19	6.38	4.84
Wastewater irrigation at 0.8 ID/CPE	0.65	0.58	7.09	5.52	0.28	0.19	6.26	4.76
Wastewater irrigation at 1.0 ID/CPE	0.66	0.59	7.24	5.76	0.29	0.19	6.38	4.88
Wastewater irrigation at 1.2 ID/CPE	0.71	0.65	7.48	6.33	0.31	0.21	6.79	5.29
Wastewater irrigation at 1.4 ID/CPE	0.74	0.68	7.56	6.25	0.32	0.23	7.05	5.51
Conjunctive irrigation at 1.0 ID/CPE	0.67	0.60	6.89	5.26	0.29	0.20	6.46	4.96
Groundwater irrigation at 1.0 ID/CPE	0.64	0.57	6.68	4.98	0.28	0.19	6.23	4.71
SEm±	0.02	0.02	0.11	0.20	0.01	0.01	0.16	0.17
LSD (P=0.05)	0.07	0.06	0.34	0.62	0.02	0.03	0.51	0.52

Table 4 Short term impact of wastewater irrigation on heavy metals of soil at the depths of 0-15 and 15-30 cm in tuberose (Mean data of 3 years)

Treatment	Ni (mg/kg)		Pb (mg/kg)		Cd (mg/kg)		Cr (mg/kg)	
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
Wastewater irrigation at 0.6 ID/CPE	0.19	0.13	0.28	0.18	0.01	0.01	0.05	0.04
Wastewater irrigation at 0.8 ID/CPE	0.22	0.17	0.30	0.20	0.01	0.01	0.06	0.05
Wastewater irrigation at 1.0 ID/CPE	0.23	0.19	0.31	0.23	0.01	0.01	0.06	0.06
Wastewater irrigation at 1.2 ID/CPE	0.24	0.19	0.32	0.25	0.01	0.01	0.06	0.06
Wastewater irrigation at 1.4 ID/CPE	0.25	0.21	0.37	0.27	0.02	0.01	0.06	0.06
Conjunctive irrigation at 1.0 ID/CPE	0.22	0.17	0.32	0.24	0.01	0.01	0.06	0.06
Groundwater irrigation at 1.0 ID/CPE	0.18	0.13	0.27	0.19	0.01	0.01	0.06	0.04
SEm±	0.02	0.03	0.04	0.05	0.00	0.00	0.00	0.00
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Impact on toxic heavy metals

It is revealed from Table 4 that the heavy metals (Ni, Pb, Cd, Cr) content in the soil at both the depths of 0-15 and 15-30 were significantly not differed among the various treatments of wastewater irrigation. 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 in the soil at the depth of 0-15 and 15-30 cm were varied from 0.18 to 0.25 mg/kg & 0.13 to 0.21 mg/kg, 0.27 to 0.37 mg/kg & 0.18 to 0.27 mg/kg, 0.01 to 0.02 mg/kg & 0.01 to 0.01 mg/kg and 0.05 to 0.06 mg/kg & 0.04 to 0.06 mg/kg, respectively under wastewater irrigations at different ID/CPE in tuberose. Appreciably higher heavy metals content in soil were observed in the wastewater irrigated plots than the groundwater irrigated plots at same ID: CPE ratio 1. This might be due to higher concentration of heavy metals in wastewater as compared to groundwater. The concentrations of all the heavy metals in soil were less than the Indian permissible limits or critical soil concentration values (mg/kg) for phyto-toxicity of heavy metals (Ni: 75-150 mg/kg, Pb: 250-500 mg/kg and Cd: 3-6 mg/kg) as given by Awashthi (2000). It is also clear from data mentioned in the Table 4 that short-term application of wastewater having low concentration of heavy metals is not capable for significantly build-up the metals in irrigated soil.

It is concluded that the short-term application of wastewater irrigation significantly increased the amount of primary nutrients (N, P and K), micronutrients (Zn, Mn, Cu and Fe) in soil as compared to groundwater irrigations. Short term application of wastewater with low concentration of toxic heavy metals (Ni, Pb, Cd and Cr) was significantly not build-up the metals in irrigated soil at both the depths of 0-15 and 15-30 cm. Frequent applications of wastewater irrigation (1.4 ID/CPE) was more prone to be accumulat higher concentrations of macro and micro-nutrients as well as toxic heavy metals in irrigated soils in tuberose. As overall, short term application of wastewater irrigation may improv the soil health under cultivation of tuberose. However, periodical monitoring of wastewater quality and health of irrigated soils needs to be monitored. Long term study is required to know the accumulation of heavy toxic metals in soil as well as uptake by tuberose. It is also suggested to study the effect of wastewater irrigation on self life of tuberose, as it is a high value cut flower.

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