



## Physical and microbiological health of soil under wastewater irrigation in tuberose (*Polianthes tuberosa*)

D S GURJAR<sup>1</sup>, R SINGH<sup>2</sup>, R KAUR<sup>3</sup> and K P SINGH<sup>4</sup>

ICAR-Indian Agricultural Research Institute, New Delhi 110 012

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### ABSTRACT

A field experiment was conducted to find out the short term impact of wastewater irrigation on physical and microbiological soil health in tuberose (*Polianthes tuberosa* L. cv. Prajwal) at Water Technology Centre farm of ICAR-Indian Agricultural Research Institute, New Delhi during three consecutive seasons of 2013-14, 2014-15 and 2015-16. Seven treatments were 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; T-7, Control groundwater irrigation at 1.0 ID/CPE in randomized block design with three replications. Results indicated that soil physical properties such as bulk density, saturated hydraulic conductivity and porosity at both the soil depths of 0-15 and 15-30 cm in tuberose were significantly not changed due to application of wastewater irrigations scheduled at various ID/CPE. Significantly higher population density of fecal coliform bacteria was observed in treatment plot where wastewater irrigations were applied at 1.4 ID/CPE as compared to groundwater irrigations applied at 1.0 ID/CPE under all soil sampling dates, viz. 30, 60, 90 and 120 days after planting of tuberose bulbs.

**Key words:** ID/CPE, Pathogens, Physical properties, Tuberose, Wastewater irrigation

Rapid growth in urban populations leads to urbanization and industrialization which results diversion of larger amounts of fresh-water in to domestic, commercial, and industrial sectors, which generate greater volumes of wastewater (Asano *et al.* 2007; Gurjar and Kaur 2018). In urban and peri-urban areas of our country, farmers are deliberately using undiluted wastewater as it provides nutrients or is more reliable or cheaper than other water sources (Keraita and Drechsel 2004). However, the wastewater irrigation practices having threat to human health and environment as it possess harmful pathogens and heavy metals (Qadir *et al.* 2007 (Kaur *et al.* 2012 ). Additionally, farmers, consumers, and some government agencies in many countries are not fully aware of the potential impacts of irrigation with wastewater on irrigated soil and human health (Qadir *et al.* 2010). Moreover, the quality of wastewater may affect water movement through the soil, either because of differences in the compositions of the percolating solutions, or as a result of changes in the

chemical and physicochemical properties of the wastewater-irrigated soil (Lado and Hur 2009). Hence, it is clear that wastewater irrigation may enhance the soil health through addition of nutrients or may damage by increasing salinity, clay dispersion, reduction of infiltration rate and hydraulic conductivity and enhanced pathogen load (Bichai *et al.* 2012, Urbano *et al.* 2015). Therefore, the public awareness on the issue of impact of wastewater irrigation on soil health is necessary (Cui *et al.* 2005). Keeping in view, the present study was undertaken to assess the short-term impact of wastewater irrigation on physical and microbiological health of soil 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. Soil of the experimental site was sandy loam (0-30cm). Soil pH<sub>2</sub> (7.69) and EC<sub>2</sub> (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

<sup>1</sup>Scientist (e mail: dsgurjar79@gmail.com), <sup>2</sup>Principal Scientist (e mail: rk132.iari@gmail.com), Water Technology Centre, <sup>3</sup>Principal Scientist (e-mail: kpsingh.dfr@gmail.com), Division of Floriculture and Landscaping, <sup>4</sup>Senior Scientist (e mail: rajendra.singh\_phyto@yahoo.com), Division of Soil Science and Agricultural Chemistry.

(P, 26 kg/ha) and available potassium (K, 284 kg/ha) were medium as per soil fertility ratings. Bulk density of soil was  $1.52 \text{ Mg/m}^3$  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. 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,  $5.4 \times 10^5$  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. Seven treatments, viz T-1, Wastewater irrigation at 0.6 ID/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 50 mm. 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 ( $6 \text{ m}^2$ ) and depth of unit irrigation (0.05 m), 300 litres of water was required to irrigate each plot of tuberose. A Digital Handheld Water Velocity Meter (Model: Global Water-a xylem brand FP-01 1212) was used to ensure the accurate and same volume of water application in each treatment plot. Disturbed and undisturbed soil samples were collected just before digging of bulb of tuberose at the depths of 0-15 and 15-30 cm. Bulk density (BD) was determined from the soil cores using the procedure given by Veihmeyer and Hendrickson (1948) and saturated hydraulic conductivity was determined by constant head permeameter (Singh *et al.* 2004). Soil moisture retention at field capacity and permanent wilting point were measured by pressure plate apparatus. Microbiological properties of wastewater and groundwater irrigated soils in terms of fecal coliform bacteria was enumerated by using fresh soil samples which were collected from each plot at 30, 60, 90 and 120 days after planting of tuberose bulbs. The coliform

analysis was done using 10-fold serial dilution (10 ml, 1.0 ml, 0.1 ml) for 10 gram of each fresh soil sample in 90 ml of 0.9% NaCl water. Coliform bacterial density in a soil sample was determined by serial dilution in multiple tubes (five tubes) using the fermentation technique with lactose broth (medium). The results were expressed as most probable number (MPN) index/100 ml, based on tabulated probability tables (WHO 1989, APHA 2005). The MPN index of confidence limits for various combinations was determined in 10 mL tubes by observing the positive (production of acid and gas) and negative (no reaction) multiple-tube fermentation. Three dilutions in decimal series were employed and three replications were taken for each dilution (Oblinger and Koburger 1975). The BOD and COD in water samples were measured by standard methods (APHA 2005). Micronutrients and heavy metals in water samples were measured by ICP-MS. 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 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 physical and microbiological properties of soils irrigated with wastewater under cultivation 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.

### *Impact on physical properties of soil*

There were no significant differences recorded on soil physical properties such as bulk density, saturated hydraulic conductivity and porosity at both 0-15 and 15-30 cm soil depths in tuberose under application of wastewater irrigation at different ID/CPE ratio (Table 1). This could be because the period of experiment was short. Moreover, the short term application of wastewater may not sufficient to change the physical properties of soil (Gurjar *et al.* 2016). Significantly higher maximum water holding capacity of soil (43.30%) was observed in the treatments plots where wastewater irrigations were applied at 1.4 ID/CPE under the soil depth of 0-15 cm whereas, it was significantly not different among the treatments at 15-30 cm of soil depth. This might be due to addition of organic matter in the upper layer of soil by wastewater irrigations. The range of bulk density, saturated hydraulic conductivity, porosity and maximum water holding capacity at the soil depths of 0-15

Table 1 Short term impact of wastewater irrigation on physical properties of soil at the depths of 0-15 and 15-30 cm (Pooled data of 3 years)

Treatment	Bulk density (Mg/m <sup>3</sup> )		Saturated hydraulic conductivity (cm/hr)		Porosity (%)		Maximum water holding capacity (%)	
	0-15 cm	15-30 cm	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	1.57	1.67	0.67	0.53	40.9	37.8	39.6	37.7
Wastewater irrigation at 0.8 ID/CPE	1.55	1.65	0.65	0.51	41.4	38.3	40.6	38.3
Wastewater irrigation at 1.0 ID/CPE	1.53	1.63	0.63	0.49	42.1	39.1	42.1	37.7
Wastewater irrigation at 1.2 ID/CPE	1.55	1.65	0.65	0.51	41.6	38.6	41.6	38.2
Wastewater irrigation at 1.4 ID/CPE	1.51	1.61	0.61	0.47	42.9	39.8	43.3	38.1
Conjunctive irrigation at 1.0 ID/CPE	1.55	1.65	0.65	0.51	41.6	38.6	41.6	38.6
Groundwater irrigation at 1.0 ID/CPE	1.57	1.67	0.67	0.53	40.9	37.8	40.1	37.0
SEm±	0.01	0.01	0.01	0.01	0.47	0.46	0.50	0.33
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	1.56	NS

and 15-30 cm were varied as 1.51 to 1.57 Mg/m<sup>3</sup> and 1.61 to 1.67 Mg/m<sup>3</sup>, 0.61 to 0.67 cm/hr and 0.47 to 0.53 cm/hr, 40.9 to 42.9% and 37.8 to 39.8% and 39.6 to 43.3% and 37.0 to 38.6%, respectively under various treatments. It is clear that wastewater irrigations were not to be provided the much quantity of organic matter in the irrigated soils. Hence, physical properties of irrigated soil were significantly not altered under wastewater irrigations. This was very much supported by Mathan (1994) as he recorded significantly lower bulk density and increased hydraulic conductivity in sewage farm soils with sewage irrigation for 15 years. It was further supported by Antil *et al.* (2007) and stated that the long-term application may affect the physical, chemical and biological properties of soils. Rattan *et al.* (2001) observed enhanced water holding capacity of soils due to continuous application of sewage waters/wastewaters.

#### Impact on microbiological properties of soil

Significantly higher population density of fecal coliform bacteria was observed in treatment plot where wastewater irrigations were applied at 1.4 ID/CPE as compared to groundwater irrigations applied at 1.0 ID/CPE under all

soil sampling dates, viz. 30, 60, 90 and 120 days after planting of tuberose bulbs (Table 2). However, fecal coliform population in the treatment plots of wastewater irrigations at 1.2 and 1.0 ID/CPE were statistically at par whereas it was significantly higher in the treatment plots of wastewater irrigations at 0.8 and 0.6 ID/CPE as compared to irrigated soil of treatment plot of wastewater irrigations applied at 1.4 ID/CPE. Moreover, it is also indicated that wastewater irrigations significantly has to be increased the population density of fecal coliform bacteria as high as 131.8%, 271.9%, 338.0% and 650% at 30, 60, 90 and 120 days after planting of tuberose bulbs, respectively as compared to groundwater irrigations applied at same 1.0 ID/CPE ratios. This might be due to more number of wastewater irrigations were applied in the treatment plots of wastewater irrigations at 1.4 ID/CPE as wastewater contains higher population of fecal coliform bacteria. These results are having very much close proximity with the finding of Deskmukh *et al.* (2011) as they have reported that there was significant increase in bacterial and fungal count in sewage-irrigated soils as compared to their respective control. The population density of bacteria and fungi in waste water-irrigated soils increased with the

Table 2 Short term impact of wastewater irrigation on microbiological properties of soil at a depth of 0-15 cm in tuberose (Pooled data of 3 years)

Treatment	Fecal coliform (MPN/100 ml)			
	30 days after planting	60 days after planting	90 days after planting	120 days after planting
Wastewater irrigation at 0.6 ID/CPE	12.7 × 10 <sup>3</sup>	20.0 × 10 <sup>3</sup>	29.7 × 10 <sup>3</sup>	42.3 × 10 <sup>3</sup>
Wastewater irrigation at 0.8 ID/CPE	15.7 × 10 <sup>3</sup>	22.3 × 10 <sup>3</sup>	30.7 × 10 <sup>3</sup>	45.0 × 10 <sup>3</sup>
Wastewater irrigation at 1.0 ID/CPE	18.0 × 10 <sup>3</sup>	24.7 × 10 <sup>3</sup>	33.0 × 10 <sup>3</sup>	46.0 × 10 <sup>3</sup>
Wastewater irrigation at 1.2 ID/CPE	20.0 × 10 <sup>3</sup>	25.7 × 10 <sup>3</sup>	34.0 × 10 <sup>3</sup>	54.0 × 10 <sup>3</sup>
Wastewater irrigation at 1.4 ID/CPE	21.7 × 10 <sup>3</sup>	28.0 × 10 <sup>3</sup>	37.0 × 10 <sup>3</sup>	57.7 × 10 <sup>3</sup>
Conjunctive irrigation at 1.0 ID/CPE	17.7 × 10 <sup>3</sup>	24.0 × 10 <sup>3</sup>	32.3 × 10 <sup>3</sup>	46.0 × 10 <sup>3</sup>
Groundwater irrigation at 1.0 ID/CPE	7.7 × 10 <sup>3</sup>	6.6 × 10 <sup>3</sup>	7.5 × 10 <sup>3</sup>	6.1 × 10 <sup>3</sup>
SEm±	1.8 × 10 <sup>3</sup>	1.06 × 10 <sup>3</sup>	1.1 × 10 <sup>3</sup>	1.8 × 10 <sup>3</sup>
LSD (P=0.05)	5.5 × 10 <sup>3</sup>	3.3 × 10 <sup>3</sup>	3.4 × 10 <sup>3</sup>	5.7 × 10 <sup>3</sup>

duration of sewage water application and decreased with increasing depth (Deskmukh *et al.* 2011). According to Yaron *et al.* (1984), the vadose zone, especially its upper few centimeters, is a large microbiological reactor. This was also discernible in the present case across the depth in vadose zone. Adesemoye *et al.* (2006) reported an increase in fungal and bacterial population densities due to the wastewater irrigation. Masto *et al.* (2008) also reported the changes in soil biological characteristics of sewage-irrigated soils of IARI farm, New Delhi.

It is concluded that the short application of wastewater irrigation does not alter the physical properties of soil. However, the pathogen load in soil was significantly increased with the number of wastewater irrigation in tuberoses. However, periodical monitoring of wastewater quality and health of irrigated soils needs to be monitored.

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