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Irrigation requirement, water use efficiency and bulb productivity of tuberose (*Polianthes tuberosa*) under varied wastewater-groundwater irrigation regimes

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ABSTRACT

A field experiment was conducted to assess the impact of wastewater irrigation on bulb productivity and water use efficiency in tuberose (*Polianthes tuberosa* L.) under varied wastewater-groundwater irrigation regimes at Water Technology Centre (WTC) farm of Indian Agricultural Research Institute, New Delhi during three consecutive years (2013-16). The experiment comprised varied wastewater irrigation schedules [at 0.6, 0.8, 1.0, 1.2 and 1.4 irrigation depth (ID)/cumulative pan evaporation (CPE) ratios], conjunctive use of ground and municipal wastewaters (at ID/CPE of 1.0) and only groundwater irrigations (at ID/CPE of 1.0) were laid-out in randomized block design with three replications. Results indicated that maximum irrigations (32 nos.) were applied in the plots where wastewater irrigations applied at 1.4 ID/CPE, whereas minimum irrigations (14 nos.) were applied in the treatment of wastewater irrigations at 0.6 ID/CPE. Irrigation requirement of tuberose was appreciable which increased from 700 mm to 1600 mm with increasing ID/CPE. The data on bulb parameters such as number of bulblets (bulbs having diameter less than 20 mm), number of bulbs (bulbs having diameter more than 20 mm), bulb diameter, bulb length, weight of bulblets, weight of bulbs, and total bulb yield/plant were significantly not altered under application of wastewater irrigation at different ID/CPE, whereas appreciably higher values were observed in the treatment where wastewater irrigations were applied at 1.2 ID/CPE.

Key words: Bulb productivity, ID/CPE, Tuberose, Wastewater irrigation, Water use efficiency

Wastewater may be a reliable water source for crop production where freshwater is scarce due to its high nutrient potential which can help in reducing input costs. Use of wastewater for irrigation and aquaculture is a common practice in India, but is usually part of the informal sector which does not receive much recognition from the government (Buechler and Devi 2003). As untreated wastewater contains pathogens and toxic pollutants and when it is used for irrigating food crops then it may cause harm to the human health through food chain contamination. In such a condition, growing of flower crops with wastewater irrigation can be a good option to the urban and peri-urban farmers for improving their livelihood without entering the contaminants in the food chain. Due to the adequate availability, less energy requirement and nutrient richness, wastewater can be a safe and economical alternate source of irrigation water for cultivation of tuberose in urban and peri-urban areas. Tuberose (*Polianthes tuberosa* L. cv. Prajwal) is one of the most important commercially grown flower crop in India. Its popularity is mainly due to the sweet fragrance as well as the long keeping quality of the flower spikes. The flower spikes of tuberose has high market price and usually blooms during summer season when there is meagre supply of other flowers in the market. It is estimated that in India tuberose is commercially cultivated over 30000 ha area (Singh *et al.* 2010). The quantity as well as the quality of the flower spikes depends on a number of factors out of which inadequate water supply is the most important factor limiting tuberose productivity. A perusal of literature, however, shows that there is meagre information available on impact of wastewater irrigations on bulb productivity and water use efficiency of tuberose. Therefore, the present study was undertaken to assess the bulb productivity and water use efficiency 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 was

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710 mm. Soil of the experimental site was sandy loam. Soil pH_2 (7.69) and EC_2 (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/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, 5.4×10^5 MPN/100 ml 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 Evaporatorimeter, were received from IARI website and source of data was from a meteorological observatory located in research farm of Division of Agricultural Physics, 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 m^2) 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. Daily crop evapotranspiration (ETc) was measured by multiplying daily pan evaporation (Epan) data with pan factor (0.75) and crop coefficient (Kc) value (Epan × sKpan × Kc = ETc). Kc value of 0.8 (as average value of Kc for most of the crops available in FAO literatures) was assumed for tuberose as Kc value for tuberose as it is not available in the literature. Water use efficiency of tuberose was measured by using the following the formula WUE = Yact/ETact, where Yact is the actual marketable bulb yield of tuberose (kg/ha) and ETact is the actual seasonal crop water consumption by evapotranspiration (mm) which was taken total ETc value of whole tuberose cultivation period. The data on bulb parameters such as number of bulblets (bulbs having diameter less than 20 mm), number of bulbs (bulbs having diameter more than 20 mm), bulb diameter, bulb length, weight of bulblets, weight of bulbs, and total bulb yield/plant were recorded and than calculated for per ha area basis. Data on different parameters were statistically analyzed. The mean values of all the recorded characters 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 1984). 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 different bulb parameters of tuberose of three years seasons were statistically analyzed. It has been observed that the main effect of year, interaction effects of year and irrigation were not significant at $P < 0.05$ for all parameters. Thus, it has been established that the year effect was rather negligible, and the pooled average data for three seasons are reported in this paper.

Table 2 Irrigation requirement of tuberose under varied wastewater-groundwater irrigation regimes (Mean values of three crop seasons 2013-16)

Treatment	Pan evaporation (Epan, mm)	Crop evapo-transpiration (ETc, mm)	Rainfall (mm)	Effective rainfall (ER, mm)	Epan-ER (mm)	Irrigations applied (No)	Irrigation requirement (mm)
Wastewater irrigation at 0.6 ID/CPE	1646	922	638	496	1150	14	700
Wastewater irrigation at 0.8 ID/CPE	1646	922	638	496	1150	19	950
Wastewater irrigation at 1.0 ID/CPE	1646	922	638	496	1150	23	1150
Wastewater irrigation at 1.2 ID/CPE	1646	922	638	496	1150	27	1350
Wastewater irrigation at 1.4 ID/CPE	1646	922	638	496	1150	32	1600
Conjunctive irrigation at 1.0 ID/CPE	1646	922	638	496	1150	23	1150
Groundwater irrigation at 1.0 ID/CPE	1646	922	638	496	1150	23	1150

Impact on irrigation requirement of tuberose

It is observed from data presented (Table 2) that total pan evaporation (Epan), crop evapotranspiration (ETc), rainfall and effective rainfall were 1646, 922, 638 and 496 mm, respectively. A value of 1150 mm was received when effective rainfall was subtracted from total pan evaporation. Maximum irrigations (32 nos.) were applied in the plots where wastewater irrigations applied at 1.4 ID/CPE, whereas minimum irrigations (14 nos.) were applied in the treatment of wastewater irrigations at 0.6 ID/CPE. Irrigation requirement of tuberose was appreciable increased from 700 mm to 1600 mm with increasing ID/CPE. The variation in irrigation requirement is the only effect of treatments where irrigation was applied at different ID/CPE. Therefore, it is obvious that the irrigation applied at higher value of ID/CPE means frequent application of irrigations so that more number of irrigations or higher irrigation requirement as compared to irrigation applied at lower values of ID/CPE under same growth period of tuberose. It is also indicated from Table 2 that the water requirement for Pan Evaporation is more than the irrigation requirement of tuberose. The effective rainfall was subtracted from Epan value and that was same with irrigation requirement of tuberose at 1.0 ID/CPE. Crop water requirement or crop evapotranspiration is less than irrigation requirement in all the treatment except where wastewater irrigation was applied at 0.6 ID/CPE. The application of irrigation water at 0.6 ID/CPE indicated the deficit application of irrigation water.

Impact on bulb productivity and water use efficiency of tuberose

It is clear from Table 3 that application of wastewater irrigations at different ID/CPE showed statistically no significant difference on number of bulblets/plant, bulbs/plant, bulb length, bulb diameter, bulblets yield/ha, bulb yield/ha and total bulb productivity as well as bulb water use efficiency of tuberose under application of wastewater irrigations at different ID/CPE. However, the appreciably highest number of bulblets/plant (26.33) and bulb/plant (1.68) were found from plots of wastewater irrigations scheduled at 1.2 ID/CPE, whereas the lowest number of bulblets/plant (22.0) and bulb/plant (1.32) were observed in the treatment plots where wastewater irrigations given at 0.6 ID/CPE. The appreciably highest bulb length (8.51 cm) and diameter (4.42 cm) were observed in the treatment where wastewater irrigations were applied at 1.2 ID/CPE while lowest values of bulb length (7.37 cm) and bulb diameter (3.88 cm) were found in the treatment plots where groundwater irrigations given at 1.0 ID/CPE. The highest yield of bulblets (12.64 t/ha), bulb (3.33 t/ha) and total bulb productivity (15.97 t/ha) were recorded from the wastewater irrigated plots scheduled at 1.2 ID/CPE and the lowest yield of bulblets (10.28 t/ha), bulb (2.66 t/ha) and total bulb productivity (12.94 t/ha) were recorded from plots where wastewater irrigations scheduled at 0.6 ID/CPE. The bulb water use efficiency of tuberose was obviously higher (17.32 kg/ha-mm) in the treatment where wastewater irrigations scheduled at 1.2 ID/CPE, whereas the lowest (14.03 kg/ha-mm) in the treatment where wastewater irrigations scheduled at 0.6 ID/CPE. The higher values of above parameters under wastewater irrigations at 1.2 ID/CPE may be due to higher nitrogen, phosphorous and potassium supplied by wastewater through higher number of irrigations. This is may be also due to less salinity in the wastewater as compared to groundwater. Rathore and Singh (2009) stated that the growth and development of foliage, flower and bulbs yield of tuberose are directly related with nitrogen fertilization. They have also stated that formation and development of spikes and bulbs of tuberose depends upon two major factors promotion of cell proliferation and storage of starch in the resulting cells. Cell division and cell enlargement are accelerated by ample supply of nitrogen because one of the main functions of nitrogen is the initiation of meristematic activity. Marscher (1983) reported that the favorable effect of nitrogen in promoting growth of bulb of plant might be due to the fact that nitrogen application increased more metabolite transport for growth.

It is concluded that a tuberose crop can be grown successfully under wastewater irrigation without an adverse impact on its bulb yield. The optimum irrigation requirement of tuberose crop is 1350 mm. Higher water use efficiency and bulb productivity of tuberose can be

Table 3 Impact of varied wastewater-groundwater irrigation regimes on bulb productivity and water use efficiency of tuberose

Treatment	Bulblets/ plant (No.)	Bulbs/ plant (No.)	Mean bulb length (cm)	Mean bulb diameter (cm)	Bulblets yield (t/ha)	Bulb yield (t/ha)	Total bulb productivity (t/ha)	Water use efficiency (kg/ha-mm)
Wastewater irrigation at 0.6 ID/CPE	22.00	1.32	7.97	3.94	10.28	2.66	12.94	14.03
Wastewater irrigation at 0.8 ID/CPE	23.67	1.33	8.24	3.99	10.59	2.78	13.37	14.50
Wastewater irrigation at 1.0 ID/CPE	24.67	1.67	8.30	4.26	11.66	2.98	14.63	15.87
Wastewater irrigation at 1.2 ID/CPE	26.33	1.68	8.51	4.42	12.64	3.33	15.97	17.32
Wastewater irrigation at 1.4 ID/CPE	26.00	1.67	8.26	4.28	12.51	3.25	15.76	17.10
Conjunctive irrigation at 1.0 ID/CPE	24.00	1.33	8.23	4.24	11.49	2.94	14.43	15.65
Groundwater irrigation at 1.0 ID/CPE	23.00	1.33	7.37	3.88	11.24	2.78	14.01	15.20
SEm±	1.81	0.35	0.50	0.15	1.57	0.37	1.48	1.60
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

attained with application of wastewater irrigation at 1.2 ID/CPE in sandy loam soils as compared to groundwater irrigation or control.

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