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Impact of wastewater irrigation on vegetative growth, flowering characteristics, keeping quality and productivity of tuberose (*Polianthes tuberosa*)

D S GURJAR[1], R KAUR[2] and K P SINGH[3]

ICAR-Indian Agricultural Research Institute, New Delhi 110 012

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ABSTRACT

A field experiment was conducted to assess the impact of wastewater irrigation on vegetative growth, flowering characteristics, keeping quality and productivity of tuberose (*Polianthes tuberosa* L. *cv.* Prajwal) at WTC farm of ICAR-Indian Agricultural Research Institute, New Delhi during three consecutive seasons of the year 2013-14, 2014-15 and 2015-16. Seven treatments were taken as 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 the vegetative growth parameters such as days to sprouting of bulb, days to spike emergence, number of leaves/clump, length and width were not much changed, whereas the significantly higher values of flowering parameters such as spike length, rachis length and number of florets/spike were observed under application of wastewater irrigations at 1.2 ID/CPE. Keeping quality parameters such as durability of spike and flower in field and vase life of spike and flower were not significantly affected due to application of wastewater irrigations in tuberose. Significantly higher marketable cut spike and loose flower yield was observed where wastewater irrigations applied at 1.2 ID/CPE. It is concluded that wastewater irrigation is suitable for enhancing the productivity of tuberose without deteriorating the keeping quality of tuberose flowers.

Key words: Conjunctive use, ID/CPE, Irrigation, Keeping quality, Tuberose, Wastewater

The rapid growth in population increases urbanization and industrialization which results in scarcity of fresh water for irrigation. However, larger amounts of freshwater are diverted to domestic, commercial, and industrial sectors, which generate greater volumes of wastewater (Qadir *et al.* 2007a). In India, only 24% of wastewater generated by households and industry is treated before its use in agriculture or disposal to rivers (Minhas and Samra 2003). Wastewater treatment plants in most cities in developing countries are non-existent or function inadequately (Qadir *et al.* 2007b). Therefore, wastewater in partially treated, diluted or untreated form is diverted and used by urban and peri-urban farmers to grow a range of crops (Ensink *et al.* 2007). The untreated wastewater contains pathogens and toxic pollutants which will cause harm to the human health and environment. 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 meager 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 almost nil information available on application of wastewater irrigations in tuberose. Therefore, it is an urgent need to conduct a study for judging the suitability of wastewater irrigation for tuberose. Keeping in view, the present study was undertaken to assess the impact of wastewater irrigation on vegetative growth, flower productivity and keeping quality of tuberose.

MATERIALS AND METHODS

A field experiment was conducted for three consecutive

[1]Scientist (e mail: dsgurjar79@gmail.com), [2]Principal Scientist (e mail: rk132.iari@gmail.com), Water Technology Centre, [3]Principal Scientist (e mail: kpsingh.dfr@gmail.com), Division of Floriculture and Landscaping.

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. Soil pH_2 (7.69) and EC_2 (0.27 dS/m) were optimum. Mean soil organic carbon (0.32 %), available nitrogen (H 128 kg/ha) as low, available phosphorous (H 26 kg/ha) and available potassium (H 284 kg/ha) were medium. Bulk density of soil was 1.52 Mg/m^3 at a depth of 0-30 cm. Quality characteristics of water, wastewater and groundwater, used for irrigation in tuberose are illustrated in Table 1. 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 different ID/CPE ratio, a climatological approach of irrigation scheduling. ID, depth

Table 1 Quality characteristics of water used for irrigation in tuberose (Mean values of 10 monthly samples)

Characteristic	Unit	GW	WW	MPLI	Source
Irrigation quality parameters					
pH	0-14	7.55	7.58	6.4-8.0	FAO, (1985)
EC	dS/m	2.12	1.82	3.0	FAO, (1985)
Sodium (Na^+)	meq/l	11.25	9.85	40	FAO, (1985)
Calcium (Ca^{2+})	meq/l	5.28	4.88	20	FAO, (1985)
Magnesium (Mg^{2+})	meq/l	4.22	3.74	5	FAO, (1985)
Carbonate (CO_3^{2-})	meq/l	ND	ND	0.10	FAO, (1985)
Bicarbonate (HCO_3^-)	meq/l	5.24	5.85	10	FAO, (1985)
Chloride (Cl^-)	mg/l	285.2	322.8	350	FAO, (1985)
Fluoride (F^-)	mg/l	0.35	0.48	1.0	FAO, (1985)
Sulphate (SO_4^{2-})	mg/l	45.32	58.78		
SAR	$(mmol/L)^{0.5}$	5.16	4.73	10	Richard, (1954)
RSC	meq/l			2.5	Richard, (1954)
Nutrient potential parameters					
Total nitrogen	mg/l	6.24	26.32	30	FAO, (1985)
Phosphate-Phosphorous	mg/l	1.22	4.52	2	FAO, (1985)
Potassium	mg/L	4.45	12.22	2	FAO, (1985)
Sulphur	mg/l	45.32	55.24		
Total zinc (Zn)	µg/l	8.52	85.22	2000	FAO, (1985)
Total copper (Cu)	µg/l	3.51	12.16	200	FAO, (1985)
Total iron (Fe)	µg/l	985.25	2566.85	5000	FAO, (1985)
Total manganese (Mn)	µg/l	2.24	48.57	200	FAO, (1985)
Pollution parameters					
BOD	mg/l	ND	188.56	100	CPCB, (2008)
COD	mg/l	ND	356.78		
Total lead (Pb)	µg/l	ND	6.87	5000	FAO, (1985)
Total cadmium (Cd)	µg/l	ND	0.28	10	FAO, (1985)
Total nickel (Ni)	µg/l	3.52	5.58	200	FAO, (1985)
Total cobalt (Co)	µg/l	ND	0.45	50	FAO, (1985)
Total chromium (Cr)	µg/l	22.10	52.45	100	FAO, (1985)
Total arsenic (As)	µg/l	36.58	56.24	100	FAO, (1985)
Total coliforms	MPN/100ml	ND	540×10^3	10000	CPCB, (2008)

GW, Groundwater; WW, Wastewater, MPLI, Maximum permissible limit for irrigation water; ND, Not detected; SAR, Sodium adsorption ratio; RSC, Residual sodium carbonate; BOD, Biochemical oxygen demand; COD, Chemical oxygen demand.

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 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 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. The data on vegetative growth parameters such as number of days for sprouting (at the time of sprouting of 50% bulb), plant height (height from base of the plant to the first open floret), number of leaves/plant/clump (counted at the time of opening of first floret), leaf length (base to tip), leaf width (mid leaf portion), and number of days to spike emergence and flowering parameters such as number of days to opening first floret, spike length (base of the plant to the upper most flower bud), rachis length (flowering portion), number of floret s/spike, floret length, floret diameter, flower length, flower diameter were measured from five tagged plants in each plot at the time of opening of first floret and mean value was worked out for further statistical analysis. Keeping quality parameters such as durability of whole spike and flower at field, vase life of spike and flower were observed. The durability of whole spike and open flower at field condition were determined by counting the days from opening of first to last florets and days from opening of floret to drying of open flower, respectively from selected three plants in each plot. Vase life of spikes and flowers were determined by dipping the cut spikes, selected from three plants in each plots, in 500 ml conical flask filled with distilled water and put at room temperature in the laboratory and count the days from opening of first floret to last floret. Spike yield (number of spikes/ha) was estimated from monthly recorded data on number of spikes produced by each plot. Loose flower yield was calculated by recording the weight of 10 flowers in each plot then multiplying the mean number floret/plant and total number of plant in each plot. Data on different vegetative growth, flowering, keeping quality and yield of flowers related 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 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 different vegetative growth, keeping quality and yield 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.

Impact on vegetative growth parameters

There was no significant difference recorded on days required to sprouting of tuberose bulb due to the application of wastewater irrigation at different ID/CPE ratio (Table 2). The minimum and maximum days required to sprouting of bulb were recorded as 16.6 and 17.6, respectively. The early spike emergence (72.6 days) was observed where the wastewater irrigation was applied at 1.2 ID/CPE while delayed spike emergence was found in the treatment plots (75 days) with groundwater irrigation at 1.0 ID/CPE. However, the difference was not significant among the different treatments in case of number of days taken to spike emergence of tuberose. The maximum number of leaves/plant (76.76) were recorded under the treatment receiving wastewater irrigation at 1.2 ID/CPE and minimum

Table 2 Impact of wastewater irrigation on vegetative growth parameters of tuberose (pooled data of 3 years crop season, 2013-16).

Treatment	Number of days to sprouting	Number of days to spike emergence	Number of leaves/ clump	Leaf length (cm)	Leaf width (cm)
Wastewater irrigation at 0.6 ID/CPE	16.67	74.67	65.24	44.89	2.03
Wastewater irrigation at 0.8 ID/CPE	17.67	74.33	68.84	45.60	2.05
Wastewater irrigation at 1.0 ID/CPE	18.33	73.33	71.27	45.95	2.03
Wastewater irrigation at 1.2 ID/CPE	17.00	72.67	76.76	46.03	2.02
Wastewater irrigation at 0.4 ID/CPE	16.67	74.33	75.27	44.81	2.05
Conjunctive irrigation at 1.0 ID/CPE	17.67	73.67	68.95	44.63	2.03
Groundwater irrigation at 1.0 ID/CPE	17.33	75.00	63.32	44.30	2.03
SEm±	0.78	1.47	7.29	4.11	0.02
LSD (P=0.05)	NS	NS	NS	NS	NS

number of leaves (63.32) in the plots where groundwater irrigation was given at 1.0 ID/CPE. There was no significant difference in the number of leaves per clump under different treatment of wastewater irrigation (Table 2). Numerically, the higher leaf production in tuberose with increasing application of wastewater may be due to addition of NPK nutrients through wastewater irrigation. Kumar *et al.* (2002) observed that application of phosphorous fertilizer increased leaf production in tuberose that supported the present experimental result. The effect of wastewater irrigation on leaf length in tuberose was not significant (Table 2). The maximum leaf length (46.03 cm) was recorded in the treatment where wastewater irrigation was applied at 1.2 ID/CPE followed by wastewater irrigation at 1.0 ID/CPE whereas minimum leaf length (44.30 cm) was recorded in control plant where groundwater irrigation was applied at 1.0 ID/CPE. Gowda *et al.* (1991) and Singh *et al.* (2001) observed that application of phosphorous fertilizer increased leaf length of tuberose that supported the result of present experiment. The widest leaves (2.05 cm) were recorded in the treatment plots where wastewater irrigation was applied at 1.2 ID/CPE ratios. In contrast, narrowest leaves (2.0 cm) were found in the experimental plots irrigated with groundwater irrigation at 1.0 ID/CPE. However, the difference was not significant in case of leaf breadth with increasing application of wastewater irrigation. This result was in agreement with that of Gupta *et al.* (2006) who reported that leaf breadth increased in phosphorus applied plants than control plants.

Impact on flowering parameters

There was no significant difference ocurred on days required to opening of first floret in the spike of tuberose (Table 3). The minimum days required to opening of first floret in spike (96.67 days) was found from the plot of wastewater irrigation at 1.2 ID/CPE and the maximum days (99.34) was observed from groundwater irrigation at 1.0 ID/CPE. Significantly highest spike length (101.93 cm) was found in the irrigated plots where wastewater irrigation scheduled at 1.2 ID/CPE, whereas lowest spike length at harvest (82.75 cm) was found from the groundwater irrigated plots at 1.0 ID/CPE. The length of rachis at harvest was also found significant with the application of wastewater irrigation at different ID/CPE (Table 3). The highest length of rachis at harvest (35.20 cm) was recorded from wastewater irrigation at 1.0 ID/CPE, whereas the lowest length of rachis at harvest (31.73 cm) was recorded from groundwater irrigation at 1.0 ID/CPE. The increase of rachis length of tuberose under wastewater irrigation may be due to supply of additional NPK nutrients by wastewater. Singh *et al.* (1976) also reported that higher length of rachis with increased level of NPK application. The number of florets/spike significantly varied with the application of wastewater irrigation at different ID/CPE (Table 3). The highest number of florets/spike (55.73) was performed under wastewater irrigation at 1.2 ID/CPE and the lowest number of florets/spike (50.53) was found from groundwater irrigated plots at 1.0 ID/CPE. Yadav (2007) reported that number of floret per spike was remarkably increased with N and P application, alone and in combination. The impact of wastewater irrigation on floret length in tuberose was not significant (Table 3). The maximum floret length (5.22 cm) was measured in the treatment where wastewater irrigation was applied at 1.2 ID/CPE followed by wastewater irrigation at 1.4 ID/CPE whereas minimum leaf length (5.16 cm) was recorded where groundwater irrigation was applied at 1.0 ID/CPE. The thick florets (diameter 1.05 cm) were obtained in the treatment plots where wastewater irrigation was applied at 1.2 ID/CPE ratios. Contrary to this, thin florets (diameter 1.02 cm) were found in the experimental plots irrigated with groundwater irrigation at 1.0 ID/CPE. However, there was no difference on floret diameter and length of open flower with increasing application of wastewater irrigation. The maximum flower length (6.32 cm) was recorded in the treatment where wastewater irrigation was applied at 1.2 ID/CPE followed by wastewater irrigation at 1.4 ID/CPE, whereas minimum leaf length (6.26 cm) was recorded where groundwater irrigation was applied at 1.0 ID/CPE (Table 3). The broad open flowers (diameter 4.26 cm) were recorded in the treatment plots where wastewater irrigation was applied at 1.2 ID/CPE ratios. Contrarily, narrow open flowers (diameter 4.22 cm) were found in the

Table 3 Impact of wastewater irrigation on flowering parameters of tuberose (pooled data of 3 years crop season, 2013-16).

Treatment	Number of days to opening first floret	Spike length (cm)	Rachis length (cm)	Number of florets/ spike	Floret length (cm)	Floret diameter (cm)	Flower length (cm)	Flower diameter (cm)
Wastewater irrigation at 0.6 ID/CPE	97.67	83.23	32.90	51.53	5.17	1.03	6.27	4.24
Wastewater irrigation at 0.8 ID/CPE	99.33	89.3	34.03	53.07	5.21	1.04	6.31	4.25
Wastewater irrigation at 1.0 ID/CPE	99.67	99.02	34.23	53.80	5.18	1.03	6.28	4.23
Wastewater irrigation at 1.2 ID/CPE	96.67	101.93	35.20	55.73	5.22	1.05	6.32	4.26
Wastewater irrigation at 0.4 ID/CPE	98.67	99.28	35.03	55.60	5.21	1.03	6.31	4.24
Conjunctive irrigation at 1.0 ID/CPE	97.67	96.24	33.40	53.40	5.18	1.04	6.28	4.25
Groundwater irrigation at 1.0 ID/CPE	99.34	82.25	31.73	50.73	5.16	1.02	6.26	4.22
SEm±	1.17	0.58	0.87	1.61	0.04	0.01	0.04	0.02
LSD (P=0.05)	NS	9.9	2.67	4.95	NS	NS	NS	NS

Table 4 Impact of wastewater irrigation on keeping quality and marketable yield of tuberose (pooled data of 3 years crop season, 2013-16).

Treatment	Spike durability at field (days)	Flower durability at field (days)	Vase life of spike (days)	Vase life of flower (days)	Marketable spike yield (No./ha)	Loose flower yield (t/ha)
Wastewater irrigation at 0.6 ID/CPE	13.67	3.67	11.33	3.33	223333	14.52
Wastewater irrigation at 0.8 ID/CPE	14.33	3.67	11.33	3.00	226111	15.22
Wastewater irrigation at 1.0 ID/CPE	14.67	3.33	11.67	3.33	242778	16.13
Wastewater irrigation at 1.2 ID/CPE	14.68	3.68	12.33	3.67	266111	19.26
Wastewater irrigation at 0.4 ID/CPE	13.33	3.33	11.67	3.00	263333	17.99
Conjunctive irrigation at 1.0 ID/CPE	14.00	3.33	12.00	3.00	235556	15.48
Groundwater irrigation at 1.0 ID/CPE	13.33	3.00	11.00	3.00	222778	14.33
SEm±	0.49	0.30	0.29	0.22	4076.07	0.84
LSD (P=0.05)	NS	NS	NS	NS	12560	2.59

experimental plots irrigated with groundwater irrigation at 1.0 ID/CPE. However, the difference was not significant in case of flower diameter with increasing application of wastewater irrigation.

Impact on keeping quality

The long durability of spike at field (14.68 days) was observed where the wastewater irrigation was applied at 1.2 ID/CPE while short durability of spike at field (13.33 days) was found in the treatment plots with groundwater irrigation at 1.0 ID/CPE (Table 4). However, the difference was not significant among the different treatments in case of durability of spike at field condition. The long durability of open flower at field (3.68 days) was observed where the wastewater irrigation was applied at 1.2 ID/CPE while short durability of spike at field (3 days) was found in the treatment plots with groundwater irrigation at 1.0 ID/CPE. However, the difference was not significant among the different treatments in case of durability of open flower of tuberose at field condition. The maximum vase life of spike (12.33 days) was observed where the wastewater irrigation was applied at 1.2 ID/CPE while minimum vase life of spike (11.00 days) was found in the treatment plots with groundwater irrigation at 1.0 ID/CPE (Table 4). However, the difference was not significant among the different treatments in case of vase life of spike of tuberose. The maximum vase life of flower (3.67 days) was observed where the wastewater irrigation was applied at 1.2 ID/CPE while minimum vase life of flower (3.00 days) was found in the other treatment plots. However, the difference was not significant among the different treatments in case of vase life of flower of tuberose.

Impact on marketable yield of tuberose

Significantly highest number of cut spikes/ha (266111) were produced under the treatment plots where the wastewater irrigation was applied at 1.2 ID/CPE while lowest number of cut spikes/ha (222778) were produced under the treatment plots where the groundwater irrigations were applied at 1.0 ID/CPE (Table 4). These results were in conformity with Pal and Biswas (2005) who reported that zero or lesser amount of P application had the lowest number of flowers/spike as compared to higher doses in tuberose. The highest loose flower yield (19.26 t/ha) was obtained under the treatment plots where the wastewater irrigation was applied at 1.2 ID/CPE while the lowest loose flower yield (14.33 t/ha) was found under the treatment plots where the groundwater irrigations were applied at 1.0 ID/CPE. Increased marketable yield of tuberose (number of cut spike and loose flower weight) under application of wastewater irrigations was may be due higher nutrient potential present in the wastewater. Flower yield variations in tuberose due to phosphorus application was also observed by many researchers (Yadav 1985, Kumar *et al*. 2002, Mohanasundaram *et al.* 2003, Gupta *et al.* 2006, Patel *et al.* 2006, Sultana *et al.* 2006). Talukdar *et al.* (2003) recorded profound increase in the size of spikes in tuberose and concluded that nitrogen application is beneficial for enhancing the number of spikes.

It is concluded that a tuberose crop can be grown successful under wastewater irrigation without an adverse impacts on its keeping quality (vase life), growth and yield. Higher tuberose productivity in terms of maximum vegetative growth, more spike production, increased number of florets/spike and flower yield can be 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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