Journal of AgriSearch, 10 (3): 158-162
An Open Access International Peer Reviewed Quarterly

ISSN : 2348-8808 (Print), 2348-8867 (Online)
https://doi.org/10.21921/jas.v10i03.13766

Impact of Wastewater Irrigation on Growth, Yield, and Water Productivity of Toria and Sunflower Crops

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ABSTRACT

Population growth, urbanisation, better housing conditions, and economic growth have all contributed to a rise in the volume of wastewater produced by home, industrial, and commercial sources. Millions of small-scale farmers in urban and peri-urban areas of developing countries rely on wastewater or wastewater-polluted water sources to irrigate crops. A pot experiment with sunflower and toria crops under different wastewater and freshwater ratios was studied with two methods viz cyclic and mixing irrigation methods. Results showed that in sunflower head diameter, 1000 achene weight, number of achenes per head and head weight and test weight was 13.6%,22.7%,6.3%,55.2% and 52.4% higher in T5 (100% wastewater irrigated) than T1 (100% freshwater irrigated). A similar trend was observed in toria where yield under T5 was 35% higher than T1. Water productivity and other yield attributes were also higher under T5 treatments. The result indicates that in peri-urban areas wastewater can be used as an alternative source of irrigation but an analysis of wastewater for its safety must be done before using it for irrigation purposes.

Keywords: Freshwater, Irrigation, Oilseed, Wastewater,

ARTICLE INFO

Received on	:	05.08.2023
Accepted on	:	15.09.2023
Published online	:	30.09.2023

INTRODUCTION

With increasing pressure from industries, agriculture, population and expanding urbanisation, demand for freshwater is increasing. At the same time, climate change and population pressure is aggravating the current pressure on freshwater resources. Of all the sectors, agriculture is the largest user of freshwater globally, using around 70% of all the freshwater (Dickin *et al*. 2016). At one end we are struggling for freshwater resources and at another end we need to tackle and manage enormous wastewater generation with increasing urbanisation. Wastewater is gradually seen as one of the options that can meet growing water demands. Out of which agriculture is one of the users of wastewater which can help in achieving food as well as water security (Harmel *et al*. 2020). Wastewater is mostly used by peri-urban and peri-industrial farmers for irrigating their crops as it is available around the year and can benefit in terms of the nutrient requirement of the crops. Wastewater irrigation can reduce up to 45% of fertilizer cost in wheat and up to 90% in alfalfa crops (Zhang and Shen 2019). Moreover, less fertilizer use encourages saving of the input cost and less eutrophication of water bodies. However untreated wastewater poses several environmental and health related risks to soil, crops, human and animal health (Zhang and Shen 2019)

India is already bearing the brunt of water scarcity as seen in many parts of the country. According to the reports of National Commission on Integrated Water Resources Development (https://www.adriindia.org/adri/indiawater facts), India's irrigation water requirement will be an additional 71 billion cubic meters (bcm) and 250 bcm by 2025 and 2050 respectively compared to the 2010 level (557 bcm). While its major irrigation requirement is met through groundwater resources with increasing climate variability and demand from other sectors it must be met from other alternative sources. Wastewater is one such option. Wastewater is one underutilised resource which can be tapped for irrigation purposes. Use of industrial or domestic wastewater is a very common practice in many parts of the world (Fito *et al*. 2021; WHO 2006). In developing countries including India due to huge cost involvement most of the wastewater remains untreated and goes into nearby rivers and streams. Currently, India can treat only 37% of its wastewater generated and the rest remains untreated (CPCB, 2016) indicating that most of the sewage in diluted, untreated, or partially treated goes into nearby rivers and streams. These streams or canals are then used as irrigation water source by farmers. Irrigation with untreated wastewater is common in

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peri urban and peri-industrial area of India especially in eastern India where water crisis is common in post monsoon season due to which farmers are reluctant to take up second crop. The study area of Angul, Odisha is one of the industrial clusters of India. Agriculture is one of the main livelihood sources of Angul Odisha. The region falls in Agro-climatic of Eastern Plateau & Hill region with annual rainfall of 1400mm (Department of Agriculture, Odisha). Although the rainfall is sufficient, still because of hilly terrain and low soil moisture availability, taking up second crop is a challenging task. Wastewater is abundantly available especially in peri-industrial areas of Angul which can be utilised by farmers for irrigating their crops, but we are not sure of its impact on crops. Therefore, to test the suitability of wastewater for irrigation especially for *rabi* crops toria and sunflower were taken up to explore an option for safe and sustainable agriculture in eastern part of India. Moreover, we tested the conjunctive use of wastewater with freshwater on yield and productivity of sunflower and toria crops.

MATERIALS AND METHODS

The pot experiment was conducted for two seasons (*rabi*) from October to March 2017 and 2018 at experimental farm of Indian Institute of Water Management, Deras, Odisha (20.30 °N, 87.48 °E). Ten seeds of two oilseed crops i.e. Sunflower (MSFH 17) and Toria (PT 303) were taken in cement pots (with diameter of 30 cm and height of 60 cm) and sowed to a depth of 5 cm and later on thinned to 5 plants per pot at three leaf stage of seedlings. Pots were filled with 20 kg of soil from the paddy field of the farm area. The soil belongs to *Aeric Haplaquepts* of Inceptisol order. The pH of the soil was 6.4, electrical conductivity 0.081 dS m^{-1}, organic carbon 0.41%, Available N 177 kg ha^{-1}, Available P 18.8 kg ha^{-1} and available K 131 kg ha^{-1}, Exchangeable Ca and Mg was 4.7 and 1.3 Cmole kg^{-1} respectively. Chemical fertilizer (N, P, K) were applied to the pots at 60-80-60 and 50-25-25 kg ha^{-1} in sunflower and toria respectively. The wastewater was carried out from Angul region to determine its suitability for irrigation in different combination with freshwater in farms of ICAR-Indian Institute of Water Management, Bhubaneswar. All the other agronomic practices were followed as per standard procedures. Pots were arranged in randomised complete block design with five irrigation treatment T1 (100% FW), T2 (75% FW; 25% WW), T3 (50% FW; 50% WW), T4 (25% FW; 75% WW) and T5 (100% WW). FW is freshwater and WW is wastewater. Irrigation was given by two methods of application (mixing and cyclic) with three replications totalling to 60 pots under net-house (Table 1). In mixing method of irrigation, required amount of water was given by mixing FW and WW in accordance with the treatment, while in cyclic method of irrigation same amount of water was given in pot as mixing method but alternatively as FW or WW as per the treatment. Soil water content was maintained at 70% of water holding capacity in all the pots. All the wastewater characteristics were determined as per the standard procedures following APHA, 2017. All the yield attributes and yield of crops were of the crop were taken at regular intervals and at harvest.

Statistical analysis of data was performed using SPSS. The treatment means were compared at 5% level of probability using student t-test and working out CD values. The treatments which were non-significant CD values were not reported in the paper.

Table 1: Treatment details

Treatment	Freshwater (FW) and Wastewater (WW) proportion
T1	Control (100 % FW)
T2	75% FW,25%WW
T3	50% FW,50%WW
T4	25% FW,75%WW
T5	100% WW
Method of irrigation: Mixing and Cyclic	

RESULTS AND DISCUSSION

Wastewater Characteristics

Wastewater was alkaline in nature with pH of 7.51 which was within the permissible limit of 8.5 as per BIS,2004 (6.5-8.5) and electrical conductivity of 0.52 dS m^{-1} which was found to be within the permissible limit. Dissolved oxygen (DO), biological oxygen demand (BOD) and Chemical oxygen demand (COD) was also within the range as given by BIS. Total dissolved solid (TDS) was below 500 mg L^{-1} (384 mg L^{-1}). Similarly, ammoniacal nitrogen, nitrate nitrogen and phosphate phosphorous and potassium were within the permissible limit as prescribed by BIS (2004) (Table 2).

Table 2: Characteristics of wastewater used

Characteristics	2018
pH	7.51
EC (dS m^{-1})	0.52
NH_4-N (mg L^{-1})	15.8
NO_3-N (mg L^{-1})	24.6
P (mg L^{-1})	3.2
K (mg L^{-1})	4.2
SO_4-S (mg L^{-1})	348.7
Alkalinity (mg L^{-1})	21.6
SAR $(meq/L)^{1/2}$	2.2
Cd (ppm)	0.02
Cr (ppm)	0.07
Ni (ppm)	0.04
Pb (ppm)	0.51

Effect of wastewater and freshwater irrigation on sunflower crop

Irrigation was given through mixing and cyclic method of irrigation under different treatments as presented in table 3. Sunflower crop showed higher head diameter, head weight in treatment T5 (100% WW irrigation) (Table 3). Although numerically it was higher in T5 but the values were not statistically significant either in ratios (treatments T1 to T5) or method of irrigation viz cyclic or mixing. 1000 achene weight in sunflower was highest in T5 (35.7g) which was at par with T4 (33.8g) but was statistically significant from other

Table 3: Effect of industrial wastewater in conjunction with freshwater on yield and yield attributes of sunflower

Head dm (cm)				1000 achene weight (g)			Number of Achenes/heads			Head Weight (g)			Seed Yield (kg/ha)			Test weight (g)		
	Mixing	Cyclic	Mean	Mixing	Cyclic	Mean	Mixing	Cyclic	Mean	Mixing	Cyclic	Mean	Mixing	Cyclic	Mean	Mixing	Cyclic	Mean
T1	13.1	13.3	13.2	25.7	22.5	29.1	305.3	302.6	303.9	15.9	14.9	15.4	1202.0	1198.2	1200.0	4.3	4.2	4.2
T2	13.6	13.4	13.5	27.6	23.4	30.5	310.9	305.7	308.3	17.5	16.0	17.3	1242.0	1233.3	1237.5	4.7	4.4	4.6
T3	14.13	13.7	13.9	29.5	28.2	31.5	312.0	310.2	310.6	19.6	18.3	18.9	1259.3	1254.3	1256.8	5.4	5.0	5.2
T4	14.67	14.23	14.5	36.8	31.1	33.8	319.9	316.5	318.2	21.1	20.9	20.9	1385.3	1358.7	1372.0	5.8	5.4	5.6
T5	15.23	14.73	15.0	40.4	39.4	35.7	324.0	321.8	322.9	24.2	23.5	23.9	1424.2	1409.7	1416.9	6.7	6.2	6.4
Mean	**14.2**	**13.9**		**39.6**	**24.6**		314.2	311.4		18.7	19.9		1302.6	1290.7		5.4	5.0	
LSD (0.05)																		
			NS			NS			NS			NS				NS		NS
			NS			12.8			6.03			NS				10.14		0.85
			NS			18.12			8.54			NS				NS		NS

treatments (T1 to T3). The mixing and cyclic method of irrigation did not show any significant variation. However, interaction of methods and ratios (treatments) had significant interaction of LSD (p at 0.05) of 12.82 (Table 3). The highest seed yield was found in T5 treatment (1416.9 kg/ha) which was at par with T4 (1372.0 kg/ha) which varied significantly with other treatments. There was no significant difference in the treatment yield of T1, T2 and T3. Similarly, 100 seed weight (test weight) of sunflower crop was found highest in T5 (6.4g) with 100% wastewater treatment which was at par with T4 (5.6g) (75% wastewater treatment and 25% freshwater) which was statistically significant from T1 to T3 treatments with LSD value of 0.85. The method of irrigation applied i.e. mixing the FW and WW or cyclic (giving WW and FW alternatively according to the treatment) did not showed significant variation (Table 3). The reason for higher yield in wastewater treatments was due to presence of sulfur in it. Sulphur being an essential nutrient for growth and yield in oilseed crops (Dubey *et al.* 2021). An increase in sulfur supply, the primordial flower's capacity for tissue differentiation from internal meristematic to reproduction and developmental activity causes its expansion leading to production of more flowers, achenes and more seeds (Chahal *et al.* 2020).

Effect of wastewater and freshwater irrigation on toria crop

In toria, siliqua length was found highest in T5 (6.6 cm), however among the treatment it was non-significant (Table 4). The number of siliquae per plant was found to be highest in T5 (91.2) which was statistically at par with T4 (85.5). T4 and T5 were statistically higher than other treatments with lowest number of siliquae in T1 (68.7) (Table 4). Seeds per siliqua was highest in T5 (18.5) which was statistically significant at P 0.05 level with all other treatments as shown in table 4. The lowest seeds per siliqua were found in T1 (13.2). T5 yield was found to be highest at 1176.8 kg/ha which was statistically significant

Table 4: Effect of industrial wastewater in conjunction with freshwater on yield and yield attributes of Toria

Treatments	Siliqua Length (cm)			No of Siliqua/plant			Seeds/siliqua			Seed Yield (kg/ha)			Test Weight (g)		
	Mixing	Cyclic	Mean	Mixing	Cyclic	Mean	Mixing	Cycli	Mean	Mixing	Cyclic	Mean	Mixing	Cyclic	Mean
T1	4.7	4.5	4.6	71.3	66.0	68.7	13.9	12.6	13.2	864.5	874.9	869.7	5.2	5.0	5.1
T2	5.3	4.9	5.1	74.7	70.7	72.7	14.4	13.5	13.9	909.6	929.1	919.4	5.9	5.8	5.8
T3	5.5	5.3	5.4	80.7	77.7	79.2	15.2	14.8	15.0	993.2	1013.6	1003.4	6.2	6.0	6.1
T4	6.0	6.3	6.1	88.3	82.7	85.5	16.2	17.7	16.9	1077.2	1128.0	1102.7	6.5	6.5	6.5
T5	6.6	6.6	6.6	95.0	87.3	91.2	17.5	19.2	18.4	1174.8	1178.7	1176.8	6.9	6.9	6.8
Mean	**5.6**	**5.5**		**82.0**	**76.9**		**15.4**	**15.6**		**772.2**	**788.3**		**6.0**	**6.1**	
LSD (0.05)															
Method			NS			NS			NS			**NS**			NS
Ratio			NS			10.6 7			0.87			**44.21**			0.33
MxR			NS			NS			NS			**NS**			NS

than other treatments. Yield was 35% higher with wastewater irrigation compared to freshwater irrigation which may be attributed to the nutrient content present in it which helped in higher yield including sulfur present in it which is one of the most essential nutrients for oilseeds. Methods of irrigation either cyclic or mixing did not make any significant impact in terms of different parameters in toria. 1000 seed weight (test weight) was lowest in T1 (4.2g) and increased progressively with increase in wastewater proportion with highest test weight in T5 (6.8g) which was statistically significant with other treatments and at par with T4 (5.6g) as shown in table 4.

Effect of industrial wastewater in conjunction with freshwater on SPAD and Plant height

The maximum significant plant height of toria was observed at 105 DAS (104.3 cm) (Fig. 1) and sunflower at 75 DAS (106.9cm) in T5 (Fig. 2) which was at par with T4 (98.1cm in toria and 102.6 cm in sunflower) over T1 (83.8 cm in toria and 95 cm in sunflower). As wastewater contains nutrients like nitrogen, phosphorous, potassium, sulfur which helps in better plant growth compared to normal freshwater therefore the difference in height is being observed with highest in 100% wastewater use. SPAD values were taken at vegetative, flowering and maturity stages of both the crops under different treatment. fig. 3 shows that statistically no significant variation was observed in SPAD values amongst treatments in sunflower crops. Similar trend was observed in toria crop (data not presented).

Photosynthesis, transpiration, and stomatal conductance in mustard and toria crops

Photosynthetic rate varied significantly from T1(12.1 μmole $CO_2 m^{-2} s^{-1}$ in mustard and 22.6 μmole $CO_2 m^{-2} s^{-1}$ in sunflower) to T4 which was at par with T5 (16.23 μmole $CO_2 m^{-2} s^{-1}$ in mustard and 31.2 μmole $CO_2 m^{-2} s^{-1}$ in sunflower). Stomatal conductance was significantly higher in T5 (300.3 and 307.3 mmolem^{-2}s^{-1} respectively in sunflower and mustard) compared to 100% freshwater i.e. T_1 (244.7mmole m^{-2}s^{-1} in mustard and 272 mmole m^{-2} s^{-1} in sunflower). Transpiration rate was found to be non-significant (fig. 5 a, b, c).

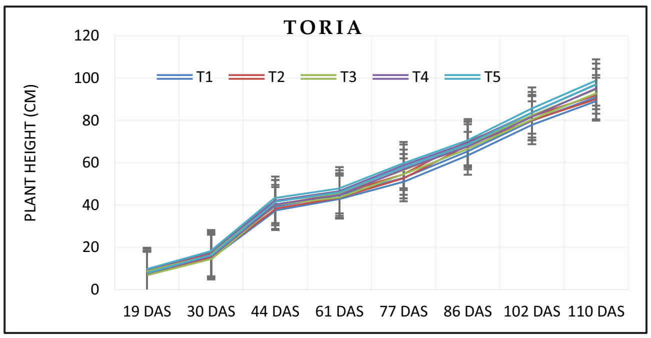

Fig. 1: Plant height in Toria under different wastewater treatment

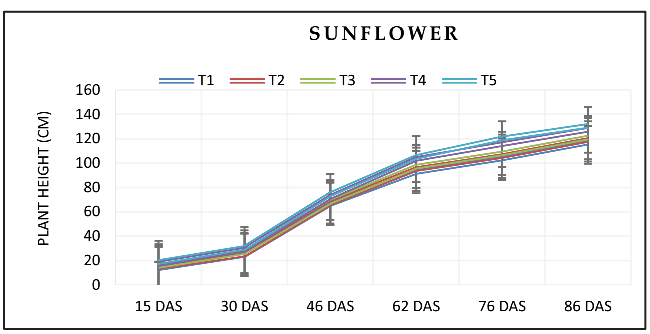

Fig. 2: Plant height in Sunflower crop under different wastewater treatment

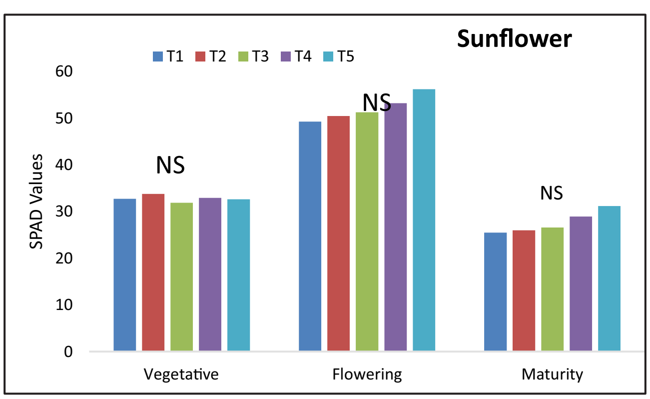

Fig. 3: SPAD value at vegetative, flowering and maturity stages of sunflower crop

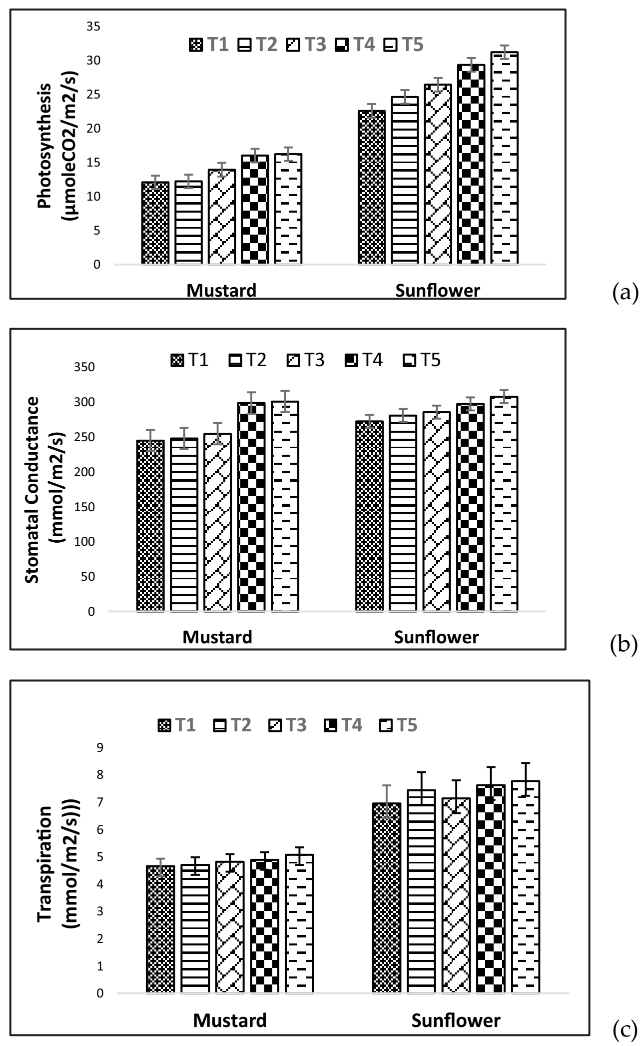

Fig. 4: Photosynthesis, transpiration and stomatal conductance of mustard and toria crops under different treatments.

Water productivity of sunflower and toria crop under different wastewater treatments

Water productivity refers to magnitude of output receive from input water applied as unit base. In simple terms water productivity is yield obtained from one per unit of water used. In our study, the quantum of water used was same for all the treatments. Water used was 0.014 and 0.016 m^3 in toria and sunflower respectively. As the yield was found higher in wastewater irrigated pots therefore the water productivity also showed similar trend since the denominator is same for all the treatments. Water productivity was highest in T5 with value of 1.59 and 1.13 in sunflower and toria crop which was 17.3 and 35.3 % respectively higher than freshwater (T1) irrigated crops (Table 5)

Table 5: Water productivity (kgm^{-3}) of sunflower and mustard crop under pot experiment

Treatment	Sunflower	Toria
T1	1.35	0.84
T2	1.39	0.89
T3	1.41	0.97
T4	1.54	1.06
T5	1.59	1.13

CONCLUSION

Use of wastewater has gained significance globally due to limited water sources and expensive treatment of discharged wastewater. Wastewater contains nutrients and organic matter which are helpful in plant growth with soil enrichment but concern for toxic elements in wastewater makes its use uncertain for our health and soil ecosystem. In our study, wastewater was found beneficial for oilseed crops as the source of wastewater was from near power plants which contained sulphur in appreciable amounts which benefitted the crops in terms of yield attributes and yield. In our experiment irrigation with wastewater where 75% wastewater and 25% freshwater combination stand out as best treatment in terms of water savings and safe use in agriculture, but the long-term evaluation and influence on various soil types in the regions need to be examined before proceeding for irrigation.

REFERENCES

APHA. 2017. Standard methods for the examination of water and wastewaters. Water Environment Federation, Chair Eugene W. Rice, American Public Health Association Andrew D. Eaton, American Water Works Association.

Central Pollution Control Board [CPCB].2016. CPCB bulletin, Ministry of Environment and Forests, Govt. of India. Available at: https://cpcb.nic.in.

Chahal HS, Sing A and Malhi GS.2020. Role of Sulphur nutrition in oilseed crop production-A review. *Journal of Oilseed Brassica* **11**(2):95-102.

Dickin SK, Schuster-Wallace CJ, Qadir M and Pizzacalla K.2016. A review of health risks and pathways for exposure to wastewater use in agriculture. *Environmental Health Perspectives* **124**(7):900-909.

Dubey R, Raychaudhuri M, Brahmanand PS and Rautaray SK.2021. Effects of wastewater from peri-industrial site on soil physico-chemical properties in tropical environment. *Journal of Soil and Water Conservation* **20**(3):335-341.

Fito J and Van Hulle SW.2021. Wastewater reclamation and reuse potentials in agriculture: towards environmental sustainability. *Environment, Development and Sustainability* **23:**2949-2972.

Harmel RD, Chaubey I, Ale S, Nejadhashemi AP, Irmak S, DeJonge KC, Evett SR, Barnes EM, Catley-Carlson M, Hunt S and Mani I.2020. Perspectives on global water security. *Transactions of the ASABE* **63**(1):69-80.

World Health Organization. 2006. WHO guidelines for the safe use of wastewater excreta and greywater (Vol. 1). World Health Organization.

Zhang Y and Shen Y.2019. Wastewater irrigation: past, present, and future. Wiley Interdisciplinary Reviews: *Water* **6**(3): p.e1234.

Citation:
Dubey R, Raychaudhuri M, Brahmananad PS, Kumar S, Singh A K and Upadhyaya A.2023. Impact of wastewater irrigation on growth, yield, and water productivity of toria and sunflower crops. *Journal of AgriSearch* **10**(3): 158-162