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Response of Treated and Untreated Domestic Waste Water Irrigation on Yield, Water Productivity and Economics of Cluster Bean

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A B S T R A C T

A field experiment was conducted to study the response of Engineered constructed wetland treated and untreated domestic wastewater irrigation on vegetative growth, yield, water productivity of cluster bean and soil properties at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during Rabi/Summer 2015-16. The study consisted of six different sources of irrigation water i.e., Domestic wastewater, Engineered constructed wetland (ECWL) treated wastewater, fresh water, fresh water alternated with domestic wastewater, fresh water alternated with ECWL treated wastewater and ECWL treated wastewater alternated with domestic wastewater. Results indicated that higher yield of cluster bean (8874 kg/ ha) was recorded in domestic waste water as compared to fresh water (5145 kg/ha). However, it was on par with treated waste water alternated with domestic waste water (7703 kg/ha). Higher water productivity was achieved with domestic waste water (164.03 kg/ha-cm) followed by treated waste water alternated with domestic waste water (142.38 kg/ha-cm). Significantly higher net returns (Rs 1,34,440/ha) and B:C ratio (4.12) were obtained with application of domestic waste water as compared with all other treatments except treated waste water alternated with domestic waste water (Rs.1,11,023/ha and 3.58, respectively). The highest and lowest net profit of Rs 2485 and 1106 were obtained per cm use of water in case of domestic waste water and fresh water irrigation, respectively. However higher net profit of Rs 2052 per cm water used was also recorded in treated waste water alternated with domestic waste water. Insignificant difference with respect to soil pH and electrical conductivity was recorded under different sources of irrigation at 0-20cm and 20-40 cm soil depth. Significant difference in available nitrogen content was observed at both the soil depths due to different source of the irrigation water. Higher amount of potassium was recorded in domestic waste water which was on par with treated waste water alternated with domestic waste water. Higher calcium and magnesium concentration was also recorded with domestic waste water as compared with all other sources of irrigation.

Introduction

The re-use of wastewater in agriculture is gaining wider acceptance in many parts of the world especially in regions with water scarcity, growing urban populations, and rising demand for irrigation water (Meli *et al.,* 2002). The discharge of untreated wastewater from households and industries is a threat to nature and humans in developing areas and causes eutrophication of surface waters and transmission of waterborne diseases, and the situation is getting worse with the rapid urbanisation without proper sanitation. About 38,354 million litres per day (MLD) sewage is generated in major cities of India, however, the total sewage treatment capacity in these cities is only 11,786 MLD (Kaur *et al.,* 2012).

A large portion of this surplus sewage of 26,568 MLD leads to widespread water pollution. Conventional wastewater treatment technologies such as activated sludge process, membrane bioreactors and membrane separation are rather expensive and not entirely feasible for widespread application in rural areas and they require guaranteed power supply, replaceable spare parts and a skilled labour for operation and maintenance (Chen *et al.,* 2014; Kivaisi, 2001). Thus, selecting low-cost and efficient alternative technologies for wastewater treatment is significant especially in developing regions.

Constructed wetlands (CWs) for wastewater treatment are potentially a good solution for treating domestic and industrial wastewaters. The advantages of the CWs technology are simple to construct, operate and low operation and maintenance costs since no mechanical components or external energy supply is required (Rousseau *et al.,* 2004; Kivaisi, 2001; Rai *et al.,* 2013). CWs are suitable since they can be efficient in removal of BOD and pathogens whereas removal of nutrients is often more limited. Several researchers Jan Vymazal (2014), Suhad *et al.,* (2017), Azize Dogan Demir and Ustan Sahin (2017) and Datta *et al.,* (2016) highlighted the importance of re-use of treated waste water in water scarcity areas.

Keeping these in view the necessity of re-use of waste water for irrigation and the importance of treatment of waste water through ECWL technology, field experiments were conducted at UAS, Dharwad during rabi/summer-2015-16 to study the response of treated and untreated waste water irrigation on crop response, water productivity and economics of cluster bean.

The effect of different sources of irrigation water on soil chemical properties is also studied.

Materials and Methods

A field experiment was conducted during Rabi/Summer 2015-16 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. The site was situated at a latitude of 15º26'N and longitude of 75º07'E with an altitude of 678 m above MSL and falls in the northern transitional zone of Karnataka. The soil of the experiment site was sandy clay loam with low organic carbon and soil available nitrogen and medium in available phosphorus and high in available potassium. Soil analysis of the experimental site before the conduct of the experiment is presented in table 1. Soil and water were analyzed using standard procedure indicated by Tandon (2008).

Engineered Constructed Wetland (ECWL) with capacity to treat 50 m^3 day^{-1} was established under Water4crops project, Department of Biotechnology, Government of India to treat the domestic wastewater generated from the University campus. ECWL treated wastewater, domestic wastewater and bore well water available at campus were used as a source of irrigation in the experiment. Macrophtyes of *Typha latifolia* and *Bracharia mutica* were used in the ECWL filled with filter bed with gravels (< 40 mm) to a depth of 50 cm; fine sand to a depth of 25 cm and charcoal to a depth of 5 cm. The water quality parameters were analyzed at fortnightly interval and mean of the data for the growing season is presented in table 2.

The experiment was laid out in randomized complete block design with four replications and consisted of six different sources of irrigation water i.e., T1: Domestic wastewater (DWW), T-2 : Engineered constructed wetland (ECWL) treated wastewater (TWW), T-3: Fresh water (Bore well water –FW), T-4 : Freshwater alternated with domestic wastewater (FW-DWW), T-5: Freshwater

alternated with ECWL treated wastewater (FW-TWW) and T-6: ECWL treated wastewater alternated with domestic wastewater (TWW-DWW)

Cluster bean (cv PNB) was sown on 12/01/2016 during *rabi/summer* 2015-16 at a spacing of 45 cm x 20 cm following the recommended package of practices. Recommended dosage of fertilizer 25:75:60 kg N, P_2O_5, K_2O/ ha was applied to the crop. Cumulative weight of the periodic harvest of cluster bean was accounted and presented as yield per plant. Net plot yield of cluster bean as influenced by the treatment were arrived and expressed as t/ha. Irrigation was scheduled at 50 per cent depletion of soil moisture. Volumetric method was used to measure the water applied to each plot. Two common irrigations with a depth of 30 mm with good quality bore well water were applied for establishment through sprinklers. Thirteen irrigations were given with an average depth of 35.2 mm for each irrigation and total water applied during the entire cropping period was 541.4 mm which includes effective rainfall of 23.4 mm. Water productivity was calculated and expressed as kg/ha-cm. Influence of the treatments on crop performance in monetary terms were expressed as net return (Rs/ha), B: C ratio and net profit per cm of water used. Statistical analyses of the observed biometric and yield parameters were also carried out as per Gomez and Gomez (1984). Influence of different sources of water on soil chemical properties at different depths were studied at harvest stage. Soil pH was determined in 1:2.5 soil-water suspension by potentiometric method using a pH meter. Electrical conductivity was determined using conductivity bridge. Available nitrogen in soil was estimated by following alkaline permanganate method and available potassium in soil was determined by following extraction with ammonium acetate and estimated by using flame photometer.

Results and Discussion

Vegetative growth and yield parameters

Influence of source of irrigation water on plant height was found to be significant with domestic wastewater with higher plant height (75.15cm) as compared to freshwater (63.48) (Table 3). More number of branches per plant was recorded under domestic wastewater irrigation (7.48) followed by treated wastewater alternated with domestic wastewater (7.38) and minimum in fresh water irrigated plots (6.35). Yield attributes includes number of fruits/plant (70.79) and fruit weight / plant (141.57 g) were found to be higher in domestic wastewater followed by treated wastewater alternated with domestic wastewater (67.07 and 134.15 g, respectively).

Lesser number of fruits and fruit weight per plant were recorded in case of fresh water alone (58.37 and 119.23 g). Higher yield (8874 kg/ ha) was recorded with application of domestic wastewater as compared to fresh water (5145 kg/ha). However it was on par with treated wastewater alternated with domestic wastewater (7703 kg/ha) (Table 3). Improvement in the growth and development of the plants irrigated with treated sewage water was due to increased supply of nitrogen in the form of NH_4^+ which promoted dry matter production and increase in leaf nitrogen accumulation in soil (Norgueira *et al.,* 2013). Al-Lahham (2003) observed increase in the fruit size and weight with increase in quantity of the treated wastewater clearly indicating the increase in nutrient addition leading to increase in the yield. Finley *et al.,* (2008) obtained higher yields with untreated wastewater irrigation as compared to fresh water irrigation. Similar results were observed by Almuktar *et al.,* (2015), Prazeres *et al.,* (2014) and Cireli *et al.,* (2012) with application of treated wastewater in comparison to fresh water application alone.

Water productivity and economic analysis

The total water applied including effective rainfall for all the treatments was 541 mm. Higher water productivity of 164.03 kg/ha-cm was achieved with domestic wastewater followed by treated wastewater altered with domestic wastewater (142.38 kg/ha-cm) and lower water productivity of 95.103 kg/ha-cm was recorded with fresh water (Table 4).

Higher net return (Rs 1,34,440/ha) and B:C ratio (4.12) were observed with application of domestic wastewater as compared to all other treatments except treated waste water altered with domestic waste water (Rs.1,11,023/ha and 3.58, respectively). The highest and lowest net profit of Rs 2485 and 1106 were obtained per cm use of water in case of domestic wastewater and fresh water irrigated cluster bean. However the combination of TWW with DWW also recorded higher net profit of Rs 2052 per cm water used. Treated sewage wastewater usage was economical in comparison to the irrigation through fresh bore well water (Nogueira *et al.,* 2013). Similar results were also observed by Manjunatha *et al.,* (2017[a] and 2017[b]) and reported that

irrigating brinjal and chilli crops with domestic wastewater resulted in significantly higher yield, water productivity, net returns and B:C ratio followed by alternative application of engineered constructed wetland treated wastewater and domestic wastewater.

Soil properties

Insignificant difference with respect to soil reaction (pH) and conductivity (EC) was recorded under different sources of irrigation at 0-20cm and 20-40 cm soil depth. Significant difference was recorded with respect to available nitrogen content observed at both depths due to different source of the irrigation water. Higher available nitrogen content (263.42 kg/ha) was recorded in the plots irrigated with the domestic waste water at 0-20 cm depth, which was on par with treated waste water alternated with domestic waste water. Lower available nitrogen content (206.95 kg/ha) was recorded in the soil irrigated with fresh water which was on par with freshwater altered with domestic wastewater (Table 5). Similar trend with respect to the available nitrogen content in the soil was observed at 20-40 cm depth.

Table.1 Initial soil properties of the experimental site

Properties	Values
pH	7.10
EC (dS m^{-1})	0.42
Organic carbon (g kg^{-1})	4.4
Available nitrogen (kg ha^{-1})	173.2
Available Phosphorus (kg ha^{-1})	27.3
Available Potassium (kg ha^{-1})	423.5
Exch-Ca [cmol (p^{+}) kg^{-1}]	18.5
Exch-Mg [cmol (p^{+}) kg^{-1}]	12.25
Available zinc (mg/kg)	1.4
Available iron (mg/kg)	5.3
Bulk density (Mg m^{-3})	1.42
Water soluble aggregates (%)	39.50

Table.2 Chemical properties of the different source of irrigation water during the cropping period

Parameters	Fresh water /bore well water	Domestic wastewater	ECWL treated water
pH	7.68	7.51	7.48
EC (dS m^{-1})	0.79	1.37	1.21
Total N (mg/l)	0.65	20.8	11.5
$NH^+_4 - N$ (mg/l)	0.35	12.0	5.8
NO^-_3- N (mg/l)	0.2	5.2	2.7
Phosphate (ppm)	0.3	10.1	5.6
Ca + Mg (me/l)	4.2	10.8	7.4
Sodium (ppm)	3.2	8.1	5.6
Potassium (ppm)	5.1	5.4	3.8
Chloride (ppm)	2.1	7.2	4.8
Bicarbonate (me/l)	2.5	10.3	4.9

Table.3 Vegetative growth and yield parameters of cluster bean as influenced by different sources of irrigation water

Source of irrigation water	Plant height (cm)	No. of branches/ plant	No. of fruits /plant	Fruit weight /plant (g)	Yield (kg/ha)
T$_1$: Domestic wastewater (DWW)	75.15	7.48	70.79	141.57	8874
T$_2$: Treated wastewater (TWW)	68.52	6.92	65.87	131.73	6229
T$_3$: Freshwater (FW)	63.48	6.35	58.37	119.23	5145
T$_4$: Freshwater + Domestic wastewater	69.11	7.00	64.34	130.83	6682
T$_5$: Freshwater + Treated wastewater	64.60	6.50	65.41	128.68	6202
T$_6$: Treated wastewater + Domestic wastewater	71.92	7.38	67.07	134.15	7703
S.Em±	2.85	0.47	2.17	4.34	436
CD (P=0.05)	8.58	NS	6.54	13.09	1243

Table.4 Water productivity and net profit of cluster bean as influenced by different source of water

Source of irrigation water	Water productivity (Kg/ha-cm)	Gross return (Rs/ha)#	Net return (Rs/ha)	Net profit / cm of water (Rs)	B:C ratio
T$_1$: Domestic wastewater (DWW)	164.03	177480	134440	2485	4.12
T$_2$: Treated wastewater (TWW)	115.14	124580	81540	1507	2.89
T$_3$: Freshwater (FW)	95.10	102900	59849	1106	2.39
T$_4$: Freshwater + Domestic wastewater	123.51	133640	90592	1674	3.10
T$_5$: Freshwater + Treated wastewater	114.64	124040	80992	1497	2.88
T$_6$: Treated wastewater + Domestic wastewater	142.38	154060	111023	2052	3.58

Market rate of cluster bean Rs. 20/kg

Table.5 Influence of different sources of irrigation water on soil chemical properties

Source of irrigation water	pH		EC (dS/m)		Nitrogen (kg/ha)		Potassium (kg/ha)		Ca (meq/100g)		Mg (meq/100g)	
	0-20 cm	20-40 cm	0-20 cm	20-40 cm	20-40 cm	0-20 cm	20-40 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
T1: Domestic wastewater (DWW)	7.87	7.87	0.452	0.340	263.42	222.66	443.63	293.10	26.50	22.50	13.75	12.75
T2: Treated wastewater (TWW)	7.87	7.88	0.550	0.382	238.34	197.57	423.80	258.10	22.00	20.00	14.75	13.75
T3: Freshwater (FW)	7.94	7.85	0.526	0.456	206.95	159.93	396.15	266.45	19.25	16.50	11.50	15.50
T4: Freshwater + Domestic wastewater	7.91	7.83	0.575	0.460	210.09	191.30	421.68	258.40	21.25	20.50	13.50	15.00
T5: Freshwater + Treated wastewater	7.88	7.86	0.559	0.418	238.34	203.84	414.65	252.15	19.80	22.00	21.70	10.25
T6: Treated wastewater + Domestic wastewater	7.86	7.91	0.474	0.340	260.29	213.25	440.75	291.80	22.75	23.25	16.50	13.25
SEm±	0.04	0.02	0.062	0.037	7.68	6.99	8.07	10.32	1.39	1.93	2.76	1.94
CD (p=0.05)	NS	NS	NS	NS	23.14	21.07	24.34	31.10	4.19	NS	NS	NS

Conjunctive use of the domestic wastewater with treated wastewater resulted in progressive improvement comparable to the application of the domestic wastewater alone at both depths of soils. This is attributed to the addition of higher amount of nitrogen to soil through treated waste water and domestic waste water. Such results were also reported by Salakinkop and Hunshal (2014) and Abdel (2015).

Sources of irrigation water resulted in significant difference with respect to potassium content in the soil at different depths. Higher amount of potassium (443.63 kg/ha) was recorded in domestic sewage water irrigation which was on par with treated waste water alternated with domestic waste water at 0-20 cm. Lower values of the potassium was recorded with the application of freshwater as source of irrigation. Similar trend of results was recorded at a lower soil depth of 20-40 cm. These results are in conformity with the findings of Abdel (2015), Salakinkop and Hunshal (2014), and Chopra *et al.,* (2013).

Significant difference in concentration of the calcium due to the source of irrigation water was recorded at 0-20 cm (Table 5). Higher calcium concentration was recorded with domestic wastewater application, which was on par with all the other sources of irrigation water except fresh water. Whereas, the difference in calcium concentration at 20-40 cm depth was insignificant. Magnesium concentration observed at 0-20 cm and 20-40 cm depth resulted in non-significant difference due to the source of irrigation water.

Engineered constructed wetland treated wastewater can be used as irrigation source for recovery of water and nutrients resource in areas of fresh water shortage with exercised care in selection of crops and avoiding direct contact of the vegetables with treated wastewater. Instead of direct usage of domestic sewage water alone for vegetable production, conjunctive use of domestic sewage water either with Engineered constructed wet land treated domestic sewage water or with fresh water seems to be an better alternate/viable solution from the point of yield, economics, net profit and environment aspects.

Acknowledgment

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