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Effect of Wastewater Fertigation on Growth Performance, Yield and Quality Parameters of *Solanum melongena* L. (Local Long)

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ABSTRACT

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Wastewater can be utilized in a variety of ways like irrigation of agricultural land, landscape, aquaculture, urban, industrial, recreational use and also for groundwater recharge. The major objective of wastewater use in agriculture is to optimize its benefits in terms of fertigation *i.e.*, irrigation and nutrient supply with which it is loaded. In the present study, an experiment was carried out to assess the growth performance of *Solanum melongena* L. (Local Long) under irrigation with different concentrations of domestic wastewater (grey and black water) in combination with recommended dose of fertilizers (RDF). This field experiment was carried out for two consecutive years 2012-2013 and involved 6 treatments (T1–T6) with three replications in RCBD. Before being utilized, wastewater was stabilized for 20-25 days in open containers. The study shows that the concentrations of the various physico-chemical parameters (*viz.*, pH, EC, OC, N, P, K, Ca, Mg, Cu, Fe, Mn, Zn, Cd, Ni, Cr, Pb) of waste water and pre and post experiment soil samples are within permissible limits. The highest yield of brinjal (330.04 q ha⁻¹) was recorded in T1 (Recommended dose of fertilizers =RDF) followed by 299.59 q ha⁻¹ (T5=50% black water and 50% RDF), 287.69 q ha⁻¹ (T4: 50% grey water and 50%RDF), 280.62 q ha⁻¹ (T6: 50% black water and 50% grey water), 273.48 q ha⁻¹ (T₂: 100% grey water) and least of 266.33 q ha⁻¹ in T3 (100% black water). Quality parameters *viz.*, TSS, ascorbic acid, Chl-a, Chl-b, total-chl, carbohydrates and protein content between various treatments exhibited different trends. This study urges upon the averment that irrigation with stabilized grey and black water does not have any adverse effects on the soil chemistry and thus there is an option for recycling of wastewater in agriculture

Introduction

With ever increasing population and shrinkage of land resources, demand for food and freshwater is a growing concern. Wastewater is generated in bulk quantity from both domestic as well as industrial estates and

its crude disposal into the environment is posing a tremendous threat to environment. In developing countries including India, wastewater is commonly a choice for irrigating agricultural field (Nath *et al.*, 2009). Globally, approximately 20% of manufactured nitrogen and phosphorous is

contained in domestic wastewater (Batstone *et al.*, 2015) and it has been considered as low price fertilizer because of its high N, P and K content (Chaw and Reves, 2001) although domestic wastewater by itself cannot completely fulfill fertilizer requirements but combinations of wastewater with other nutrient sources can work wonders. Waste water is rich in organic matter and also contains appreciable amounts of macro and micro-nutrients (Gupta *et al.*, 1995). Accordingly nutrients levels of soil are expected to improve considerably using continuous irrigation with waste water (Ramirez-Fuentes *et al.*, 2002; Rattan, *et al.*, 2005). Thus, recycling of wastewater shall pave avenues in agricultural industry in terms of minimizing the use of inorganic fertilizers whose long-term utilization pose negative pressures on natural environment. The main objective of this experiment was to estimate the growth performance, quality parameters and yield responses of Brinjal (*Solanum melongena* L. Local Long) under irrigation with different doses of untreated domestic wastewater (grey and black water). Moreover, effect of wastewater fertigation on the physicochemical parameters of soil and plant tissues was studied to investigate the prospects of safe use of urban wastewater for irrigation.

Materials and Methods

Study area

The experiment was conducted during summer (Kharif) 2012 and 2013 in the experimental field at FoA Wadura, SKUAST-K, ($34^{\circ} 20' 55.72''\text{N}$ and $74^{\circ} 24' 6.26''\text{E}$, Altitude of 1580 m a.s.l), Kashmir. The area is characterized by temperate climatic conditions with mean maximum and minimum temperature during the growing season as 26.08°C and 11.78°C respectively.

Experimental design and the crop

The field was prepared for assessing the impact of different concentrations of wastewater and recommended doses of fertilizers on growth, yield and quality of *Solanum melongena* L. Local Long, one of the prime grown summer vegetables of Kashmir Valley. The experiment was laid in completely randomized block design and involved six treatments (T1: Recommended dose of fertilizers; T2: 100% Grey water; T3: 100% Black water; T4: 50% Grey water + 50% RDF; T5: 50% black water + 50% RDF; T6: 50% black water + 50% Grey water) each with three replication and an untreated control (C) irrigated with fresh water. The fertilizers N, P and K were applied to the crop at the rates of 120, 90 and 60 (kg ha^{-1}), as urea, DAP and MOP respectively. The plot dimension for the experiment was 2.4×1.8 m with 45 cm spacing between the plants and 60 cm between the rows. The grey water and black water for irrigation was obtained from the hostels and households located in the vicinity of the university campus and stabilized in open tanks for 20-25 days before being put to use.

Water analysis

Samples of grey water, black water and fresh water were subjected to chemical analysis during both the years of experimentation. Physicochemical parameters viz., pH and EC (Piper, 1966), N, P, K, alkalinity, Ca, Mg, Zn, Cu, Mn, Fe, Cd and Ni were determined following APHA, 2005.

Soil analysis

Composite soil samples were collected from each plot at the depth of 0-30 cm before transplantation and after harvest. Samples were oven dried, ground, sieved and analysed for pH, EC (Piper, 1966), total N by Kjeldahl

method (Jackson, 1973), available P (Olsen, 1954), organic carbon (Walkely and Black, 1934) and exchangeable Ca, Mg and K using the ammonium acetate method (Hesse, 1971). Further Zn, Mn, Cu, Fe, Ni and Cd were analysed by using atomic absorption spectrophotometer.

Crop yield and plant tissue analysis

Fruit samples were harvested from each plot, dried in a hot air oven at 70°C for 48 hours, powdered in a grinder and subjected to chemical analysis for the estimation of carbohydrate (Dobois *et al.*, 1956), protein (Lowry *et al.*, 1951) and ascorbic acid contents (Sadasivam and Balasubramanian, 1987). Fruit samples were also analyzed for TSS by using Refractometer. Photosynthetic pigments in the foliage were also estimated (Hiscox and Isrealstam, 1979). Mineral contents of plant tissues were determined by the method of wet oxidation using a mixture of HNO₃ and HClO₄ (AOAC, 1984). Total N was determined by the Kjeldahl method (Jackson, 1973), P by blue phosphomolybdic complex by a spectrophotometer, K by flame photometer and Ca, Mg, Zn, Fe, Mn, Cu, Cd and Ni by atomic absorption spectrophotometer. Total weight of fruits (kg/plot) at each picking was added to obtain the total fruit yield per plot and expressed as quintals per hectare (q ha⁻¹). Pooled data of the two years recorded during the experiment was subjected to ANOVA, followed by least significant difference (CD, $p \leq 0.05$) using R software statistical package (Gomez and Gomez, 1984).

Results and Discussion

Water chemistry

Data regarding the physicochemical characteristics of black, grey and fresh water are presented in Table 1. The values were in lower levels than those permitted for upper

threshold set of irrigation water and safe reuse in agriculture. According to PCB (2003), pH of wastewater should range between 6.5 and 8.5 and EC should not exceed 2.25 dS/m. Our study show that both these parameters of wastewater were within range. Alkalinity, phosphate, Na, Ca, Mg, Zn, Cu, Fe, Mn and Cd were found higher in grey water compared to black and fresh water while as chloride, flouride, sulphate, ammonium and potassium were found in higher concentration in black water. The concentration of Ni and Pb did not show any significant variation. However all the parameters were within permissible limits.

Physico-chemical characterization of the soil

The texture of soil was loamy and wastewater treatments did not pose any considerable effect on the soil pH value as also reported by Shahalam *et al.* (1998) (Table 2). The soil pH of various treatments ranged from 6.24 to 7.53 while EC ranged from 0.20 to 1.05. Significant increase in EC was detected in soil after the experiment (Vela *et al* 2007, Lone *et al.*, 2013), which might be due to the relatively higher EC of waste water and formation of metallic salts-complexes of organic matter and heavy metals (Ahmed *et al.*, 2010). Though N and P contents did not exhibit any significant change, the composition of K show increased trends in the treatments T6 (under irrigation with 50% black and 50% grey water) which may be due to the fact that the availability of major macronutrients in wastewater was high and enhanced their concentration in soil. Similarly, the contents of micronutrients (Fe, Mn) were found higher in the treatments (T6) while as Zn and Cu were higher in the treatments (T3) under irrigation with 100% black water. The Ca was higher in treatments (T4) with 50% grey water and 50% RDF while as Mg was found highest in T2 with 100% grey water.

Growth response, yield and fruit quality

There has been significant effect of treatments on the fresh / dry, root /shoot biomass as well as leaf area of the crop. Compared to other treatments, T₁ (RDF), recorded the highest values of these parameters (Table 3). However, in other treatments the differences have been only marginal. The highest yield of brinjal was recorded in T₁ (330.04 q ha⁻¹) which might be due to the application of balanced dose of inorganic fertilizers and

organic manures to the soil followed by 299.30q ha⁻¹ in T5, 287.69 q ha⁻¹ in T4, 280.62 q ha⁻¹ in T6, 273.48 q ha⁻¹ in T6 and least 266.30 q ha⁻¹ in T3 (Table 4). Significant increase in growth parameters of crops on application of sewage sludge has also been reported by Bozkurt and Yarılgac, 2003). Quality parameters viz., ascorbic acid and Chl-b were higher in T5 while as TSS, Carbohydrates and proteins were higher in T1 (Table 5).

Table.1 Physicochemical characteristics of irrigation water

Parameters	Waste/ Fresh Water		
	Black	Grey	Fresh
pH (1:2.5)	6.80	7.42	7.10
EC (dSm ⁻¹)	0.85	0.78	0.47
Alkalinity (mg/l)	150.2	180.99	125.13
Nitrate N (mg/l)	41.09	10.0	3.36
Phosphate (PO ₄) (mg/l)	3.4	6.21	0.6
Chloride (Cl ⁻) (mg/l)	524.7	206.99	1.96
Fluoride (F ⁻) (mg/l)	0.16	0.14	0.10
Sulphate (mg/l)	1.785	0.804	0.529
Ammonium (mg/l)	169.81	90.22	2.25
Sodium (mg/l)	16.53	17.78	7.31
Potassium (mg/l)	83.92	17.61	0.51
Calcium (mg/l)	47.14	48.31	23.89
Magnesium (mg/l)	10.18	10.44	5.74
Zn (mg/l)	0.99	5.45	0.47
Cu (mg/l)	0.35	0.98	0.23
Fe (mg/l)	0.57	0.88	0.10
Mn (mg/l)	0.17	0.65	0.08
Cd (mg/l)	0.245	0.609	0.020
Cr (mg/l)	0.226	0.226	0.226
Pb (mg/l)	0.001	0.001	0.001
Ni (mg/l)	0.076	0.076	0.076

Table.2 Physico- chemical characteristics of the soil of *S. melongena* plots after the treatments

Treat ment	pH	EC	OC	N	P	K	Ca	Mg	Cu	Zn	Mn	Fe	Pb	Ni	Cd	Cr
		dSm ⁻¹	(%)	(kg/ha)			(ppm)									
Initial status	7.56	0.26	0.75	95.74	8.42	133.8	123.75	30.58	1.18	1.41	7.92	24.14	0.98	1.92	0.012	1.76
T1	6.95	0.20	0.99	116.8	22.2	125.25	101.66	22.05	1.05	1.61	8.83	28.9	0.99	1.98	0.011	1.72
T2	7.53	0.52	1.05	117.25	23.08	120.81	102.11	23.05	1.69	1.21	8.95	30.14	1.01	2.2	0.014	1.98
T3	6.24	0.63	0.98	116.99	22.88	120.09	101.12	22.95	1.73	1.91	8.94	29.95	1.05	2.36	0.014	1.97
T4	7.51	0.91	0.91	115.89	22.9	119.05	105.81	19.9	1.19	1.18	8.81	27.91	0.99	2.38	0.170	1.85
T5	6.55	0.51	0.91	117.2	22.5	118.95	101.99	18.85	1.25	1.11	8.92	28.91	0.99	2.21	0.017	1.8
T6	6.60	1.05	0.95	117.35	23.25	126.01	103.85	17.51	1.45	1.01	9.05	32.23	1.04	2.19	0.016	1.95
C.D (p≤0.05)	0.02	0.12	0.05	10.25	2.38	15.24	11.25	2.53	NS	0.12	0.09	5.26	0.09	NS	NS	NS

T1: Recommended dose of fertilizers; T2: 100% Grey water; T3: 100% Black water; T4: 50% Grey water+ 50%RDF; T5: 50% black water + 50% RDF; T6: 50% black water + 50% Grey water;

Table.3 Effect of different concentrations of wastewater on growth parameters of *Solanum melongena* L. (Local Long)

Treatment	Root length (cm)	Shoot length (cm)	Root fresh Wt (g)	Root dry Wt (g)	Shoot fresh Wt (g)	Shoot dry Wt (g)	Leaf area (Cm ²)
T1	13.03	95.70	51.48	26.08	310.37	91.00	109.47
T2	12.97	79.37	43.37	23.82	260.37	69.64	88.37
T3	12.67	82.37	31.37	17.61	177.37	49.60	83.57
T4	12.12	87.03	54.15	26.73	268.37	80.32	71.17
T5	13.97	83.37	34.58	22.03	237.37	54.31	90.77
T6	14.37	90.03	26.18	17.78	157.37	37.82	94.77
C.D(p≤0.05)	0.79	8.21	9.79	3.19	53.55	18.61	13.41

T1: Recommended dose of fertilizers; T2: 100% Grey water; T3: 100% Black water; T4: 50% Grey water+ 50%RDF; T5: 50% black water + 50% RDF; T6: 50% black water + 50% Grey water

Table.4 Effect of different concentrations of wastewater on yield parameters of *Solanum melongena* L. (Local Long)

Treatment	Fruit No/plant	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Yield /plant (g)	Yield/plot (kg)	Yield/ha (q)
T1	12.03	14.67	6.70	90.79	856.50	15.18	330.04
T2	10.62	11.70	5.53	88.03	708.97	12.97	273.48
T3	10.37	13.03	5.58	88.37	690.37	12.69	266.30
T4	11.12	13.70	6.03	87.37	746.12	13.58	287.69
T5	11.37	14.70	6.05	88.37	776.37	13.98	299.30
T6	10.87	14.03	5.53	87.70	727.67	13.24	280.62
C.D(p≤0.05)	0.70	1.05	0.41	1.20	70.92	1.07	28.31

T1: Recommended dose of fertilizers; T2: 100% Grey water; T3: 100% Black water; T4: 50% Grey water+ 50%RDF; T5: 50% black water + 50% RDF; T6: 50% black water + 50% Grey water

Table.5 Effect of different concentrations of wastewater on quality parameters of *Solanum melongena* L. (Local Long)

Treatment	TSS (Brix)	Ascorbic acid (mg/100g)	Chl-a (mg/g tissue)	Chl-b (mg/g tissue)	Total -chl (mg/g tissue)	Carbohydrate (%)	Protein (%)
T1	8.97	16.97	3.08	2.70	3.46	6.60	3.72
T2	7.67	20.97	3.21	3.07	4.22	6.25	3.64
T3	7.48	18.77	3.05	3.00	3.87	6.22	3.68
T4	7.38	18.37	3.03	2.95	3.77	6.38	3.70
T5	7.87	21.57	3.14	3.09	4.06	6.43	3.70
T6	8.18	13.77	3.07	2.99	3.86	6.30	3.66
C.D(p<0.05)	1.08	3.24	0.10	0.17	0.29	0.16	0.04

T1: Recommended dose of fertilizers; T2: 100% Grey water; T3: 100% Black water; T4: 50% Grey water+ 50% RDF; T5: 50% black water + 50% RDF; T6: 50% black water + 50% Grey water

Table.6 Major nutrient and heavy metals level in fruit of *Solanum melongena*

Treatments	Major Nutrients			Micronutrient Cations				Heavy metals (ppm)			
	N	P	K	Zn	Cu	Fe	Mn	Pb	Ni	Cd	Cr
T1	1.28	0.67	1.22	10.4	2.9	48.5	25.19	0.63	0.59	0.21	1.2
T2	1.10	0.44	0.86	13.61	4.9	62.9	26.80	1.23	0.65	0.24	1.25
T3	1.09	0.42	0.81	12.51	4.4	57.60	26.20	1.20	0.63	0.23	1.23
T4	1.16	0.49	1.02	11.81	4.5	54.0	24.58	1.04	0.58	0.18	1.12
T5	1.26	0.54	1.16	11.22	4.2	52.8	24.20	1.02	0.57	0.16	1.10
T6	1.12	0.48	0.96	12.85	4.7	60.0	26.60	1.22	0.61	0.22	1.20
C.D(p<0.05)	0.5	0.1	0.3	0.80	0.90	2.1	1.2	0.21	NS	NS	NS

T1: Recommended dose of fertilizers; T2: 100% Grey water; T3: 100% Black water; T4: 50% Grey water+ 50% RDF; T5: 50% black water + 50% RDF; T6: 50% black water + 50% Grey water

The major nutrients (N, P, K) were found highest in T1 and the values for T5 were at par with it. These results reveal that irrigation with black and grey water had a positive effect on plant productivity, probably due to additional nutrient content, thereby a lower cultivation cost is expected due to lesser fertilizer utilization. These findings are in agreement with the findings of Khaled *et al.*, (2013). The accumulation of inorganic elements in fruits (Table 6) was not related to the respective accumulation in soil. Micronutrients (Zn, Cu, Fe, Mn) and Heavy metals exhibited similar trend and highest value was observed for T2 followed by T6. The concentration of heavy metals (Pb, Ni,

Cd and Cr) and microelements was below any toxicity levels. These findings are in conformity with the findings of Arcadia *et al.*, (1998). Thus, regardless of the different concentrations of wastewater treatments alone or in combination or in consonance with recommended fertilizer dose, the concentration of the nutrients varied within the usual levels in plant tissues and did not cause any nutritional problems in the plants (Panoras and Ilias, 1999).

In conclusion, wastewater effectively increased the yield of brinjal crop probably due to high nutrient value of the wastewater. Thus, wastewater can be managed in an

ecofriendly fashion by its exploitation in the agro-ecosystems. The results show that the accumulation of toxic and nutritive elements in plant tissues and the soil varied in low levels and did not cause any nutritional instability in the plants.

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