Conjunctive use of urban wastewater with other water source for vegetable production

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Introduction

Water scarcity needs no introduction as it is a universal problem. It has been increasing all over the world and in many countries may become absolute by the year 2025 (Secklar et al 1998). In India also, the problem is compounded everyday with increasing population with higher per capita income, urbanization, industrial growth, and demand for agricultural and allied sectors. India has 16% of world's population but only 4% of the total available fresh water. Many challenges are encountered in addressing the demand for water as most parts of the country face water scarcity in some or other parts of a year. In many states ground water extraction exceeds the annual recharge resulting in receding ground water table. The rapid growth in urbanization in India led to generation of about more than 38000 mld (million litre daily) of urban wastewater from Class I cities and class II towns out of which only 11787 mld is being treated with a capacity gap of 26467 mld which needs urgent attention (CPCB 2010). If managed properly, urban wastewater is a useful source for irrigation containing valuable plant nutrients. Otherwise, it has associated risks e.g. metal pollutants and pathogens. More than 72000 ha area in India are irrigated with urban wastewater (mostly untreated) to produce various crops (predominantly vegetables) in close proximity with city areas. The quality of such produce is a concern. Hence, an attempt has been made to study the impact of untreated wastewater and other water source on vegetable yield and quality. The effect of irrigation with waste water was compared with the irrigation from river water of Daya (branch of Mahanadi river) and with conjunctive use of river water and wastewater.

Material and Methods

A field experiment was conducted in seven farmers' field in 2010 and 2011 at village Joypurpatna (20.20 N, 85.83E) with four vegetables viz. okra, bitter gourd, cucumber and ridge gourd. Each vegetable was grown in plot size of 100 m^2 with three irrigation resources as treatments and seven adjacent farmer's fields as replicates. Thus, four different experiments were conducted for four vegetables in Randomised Block Design. The three treatments were T_1: River water, T_2: Wastewater (from Gangua nala) and T_3: River water + wastewater (1:1).

The replications of each plot were mixed and about 200 g of composite fruit samples separately were oven dried at 80^0C and then powered using stainless steel blender to pass through 2mm sieve and stored for analysis. The 0.2g plant samples were digested with tri-acid (HNO_3:H_2SO_4:$HClO_4$ 5:1:2) in open tube method. The digested samples were analysed for phosphorus by spectrophotometer (Moore 1992), potassium by flame photometry (Yoshida, *et* al 1976), Zn, Fe, Cu, Mn, Cd, cr and Pb by Atomic Absorption Spectrophotometer (Model Spectra AA, Varian) using 'metal standards' (AAS Standards, Sisco Research Laboratories, India) (Isaac and Kerber 1971).

Approximately 1kg of soil samples were collected from each subplot at 0-15 cm depth into a bucket, mixed thoroughly, and only about 500g of composite sample was collected through Quartile procedure. Samples were air dried followed by oven dry at 80^0C, ground by mortar and pestle to pass through 2mm sieve to retain for analysis. The soils were analyzed for pH (1:2.5 soil-water) by pH meter (Model pH Tester 30, Eutech Instruments), electrical conductivity (1:5 water, soil-water) by digital EC meter (Model 'EC Testr', Eutech Instruments, Malaysia), organic carbon by Walkley and Black method of wet oxidation (Jackson 1973), available N by alkaline permanganate method as described by Subbiah and Asija 1956 (Barauh and Barthakur.1997) using Semi-automatic N Analyser (Kelplus – Classic DX), available P by Bray's extractant method (Dickman and Bray 1940), Exchangeable K and Na by flame photometer after extraction with 1N ammonium acetate (Gupta and Varshney 1997). For total heavy metals viz Fe, Cu, Zn, Mn, Cd, Pb and Cr, soils were digested with tri-acid (HNO_3:H_2SO_4:$HClO_4$ 5:1:2) in open tube, filtered through Whatman 42 followed by Atomic Absorption Spectrophotometric detection, (Varien, Model Spectra AA) using 'metal standards' as mentioned earlier.

Results and Discussion

The soils had mean initial pH 5.75, EC 80 µS/cm, total N 0.021% permanganate oxidisable N 281 kg/ha, 48 kg/ha P_2O_5 and 182 kg exchangeable K_2O and 30 ppm sodium. The Gangua water had pH 6.7, EC 0.48 dS/m, 25 ppm NO_3^-, 2.8 ppm P, 10 ppm K, 35 ppm Na, 0.615 ppm Fe, 0.075 ppm Mn. The Table1 shows the change in some soil chemical properties under the influence of different water sources.

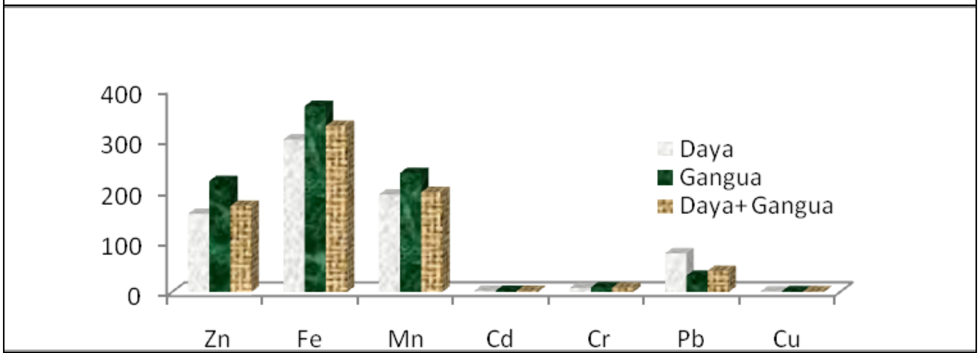
Table 1 Soil chemical properties under different treatments.

Soil Parameters	Initial	Daya (T1)	Gangua (T2)	Daya+Gangua (T3)
pH (1:2.5)	5.75 $\pm$ 0.16	5.95 + 0.13	5.82 + 0.19	5.83 + 0.21
EC (µS cm^{-1})	80 $\pm$ 13	85 $\pm$ 15	96 $\pm$ 19	88 $\pm$ 21
OC (g kg^{-1})	5.61 $\pm$ 0.35	5.60 $\pm$ 0.43	5.64 $\pm$ 0.41	5.62 $\pm$ 0.34
TN (%)	0.21 $\pm$ 0.02	0.21 + 0.03	0.22 + 0.02	0.21 + 0.02
Av N (kg ha^{-1})	281 $\pm$ 28	302 $\pm$ 34	316 $\pm$ 35	310 $\pm$ 42
P_2O_5 (kg ha^{-1})	48 $\pm$ 13	49 $\pm$ 16	42 $\pm$ 18	43 $\pm$ 21
K_2O (kg ha^{-1})	182 $\pm$ 18	188 $\pm$ 21	193 $\pm$ 25	191 $\pm$ 19
Na (mg kg^{-1})	30 $\pm$ 9	33 $\pm$ 11	38 $\pm$ 16	35 $\pm$ 14

The mean soil pH under all the three types of irrigation increased from the initial pH level (5.61) as the water sources had pH much higher than soil pH. The higher electrical conductivity in only wastewater irrigated fields was conspicuous due to addition of salts present in urban wastewater. The soil organic C in T2 (wastewater) and T3 soils was higher probably due to addition of organic pollutants carried usually by urban wastewater. Total N, phosphorus and potassium levels in soils under all the treatments were at par while mean available N in T2 was 12% higher than initial mean soil available N.

Insignificant differences in total heavy metal contents in soils under the different treatments were observed. However, the mean heavy metal concentrations in soils under different treatments were in the order T2>T3>T1 and were within the permissible range of metals (WHO/FAO 2007).

Figure 1 Heavy metal concentrations in soils under different irrigation



The mean concentrations of Pb, Cr and Cd in fruit parts of okra and ridge gourd are shown in figure 2 and 3. Under the treatments the mean concentrations of Pb, Cr and Cd did not vary significantly in the fruit parts of the vegetables. The concentrations of both the Cr and Pb were below the maximum permissible level (WHO/FAO 2007) while the Cd level was above the permissible level of 0.2 ppm under all the treatments suggesting other source of possible contamination than wastewater.

Fig 2 Heavy metal concentration in okra fruits

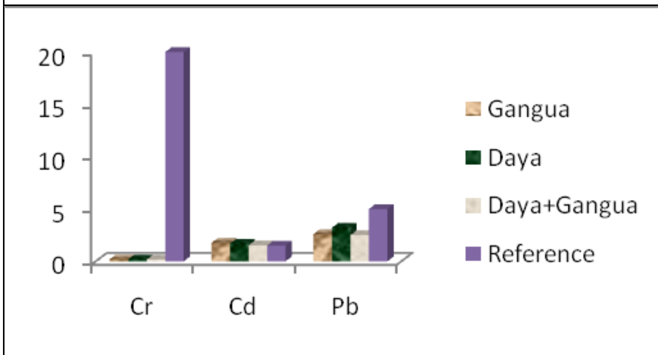


Fig 3 Heavy metal concentration in ridge gourd fruits

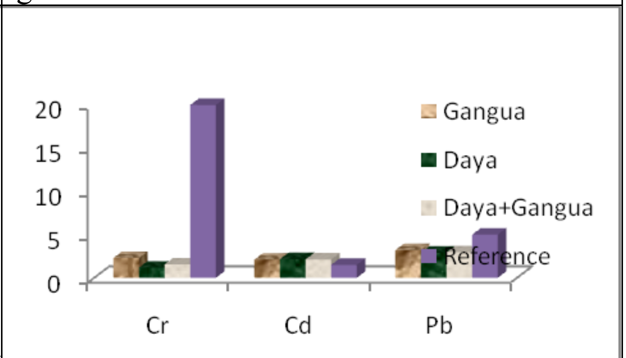


Table 2 Yield and yield attributes of vegetables with different water sources

Ridgegourd	Vine length (cm)	Yield (t/ha)	Number of fruits/plant	Fruit weight (g)
Daya water irrigated	348 ± 22	15.3 ± 0.54	34.7 ± 2.28	55.1 ± 2.34
Gangua water irrigated	355 + 8	16.6 ± 0.66	36.6 ± 2.27	58.3 ± 1.99
Daya and Gangua	350 ± 14	16.2 ± 0.45	36.2 ± 2.05	57.7 ± 0.83
Bitter gourd				
Daya water irrigated	292 ± 7	11.7 ± 0.82	32.8 ± 1.44	28.4 ± 1.56
Gangua water irrigated	303 ± 10	12.6 ± 0.46	35.6 ± 1.97	31.2 ± 3.022
Daya and Gangua	295 ± 13	12.2 ± 0.61	33.8 ± 1.97	29.9 ± 3.13
Cucumber				

Daya water irrigated	165 ± 13.3	8.51 ± 0.29	9.3 ± 0.95	70.3 ± 5.8
Gangua water irrigated	169 ± 1.4	9.2 + 0.19	10.1 ± 0.57	73.2 ± 1.82
Daya and Gangua	166 ± 11.42	8.97 ± 0.18	9.8 ± 0.54	72 ± 2.98
Okra				
Daya water irrigated	69.7 ± 2.24	8.37 ± 0.65	10.2 ± 0.69	14.3 ± 0.27
Gangua water irrigated	71 ± 1.85	8.79 ± 0.34	11.6 ± 0.98	15.1 ± 0.322
Daya and Gangua	70.7 ± 3.59	8.45 ± 0.43	10.8 ± 1.35	14.7 ± 0.235

There was an increasing trend for the yield and yield attributes viz. vine length, fruits per plants, fruit weights of test crops irrigated with Gangua water as compared with those irrigated with Daya water (Table 2). The yield advantage ranged from 9% (13.1 t/ha) for bitter gourd to 15% (9.2 t/ha) with cucumber. When the crops were irrigated with Daya and Gangua water (1:1), yield advantage was also noted which ranged from 3% with okra to 11% with ridge gourd

Conclusion

It may be concluded that conjunctive use of wastewater with river water other source may save up to 50% of fresh water. The heavy metal concentrations were within permissible in edible parts of vegetables grown with conjunctive irrigation. However, higher level of Cd is a concern which may be addressed through addition of ameliorative agents like lime for reduced uptake of Cd (Lombi et al 2002).

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