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Urban wastewater – A potential irrigation source for summer paddy (*Oryza sativa* L.) in India

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Abstract – **An attempt has been made to study the impact of urban wastewater irrigation on summer paddy productivity, varietal response and soil properties. Paddy and soil samples were collected from selected peri-urban villages of Bhubaneswar, India, from fields receiving contrast irrigation sources (urban wastewater and river water) under similar agro-climatic and socioeconomic conditions. Major plant nutrients content were higher in wastewater irrigated soils, whereas pH was lower. Wastewater irrigation increased grain and straw yield. Concentrations of Zn, Fe, Cr, Mn and Cu were higher in soil, grains and straw of paddy when irrigated with wastewater. Response to wastewater irrigation varied with paddy variety. The ANOVA with the inclusion of pH as covariate revealed that the efficient management of soil pH would increase grain yield of rice by 318 kg ha^{-1}. Wastewater irrigation saved about \$ 50 ha^{-1} towards the cost of fertilizer for growing paddy.**

Keywords – **Wastewater Characteristics, Summer Paddy, Heavy Metal, Metal Enrichment, Varietal Response**

I. Introduction

Urban wastewater (untreated or partially treated) with its rich plant nutrient contents and perpetual availability, is a resource used by many peri-urban farmers and has a significant impact on their livelihoods worldwide. In fact, 20 million hectares are irrigated with wastewater in the world and 10% of total food production comes from wastewater irrigated areas [1]. India is also no exception, which produce more than 62000 mld (million litre daily) wastewater from cities and towns having treatment capacity of about 27 percent leaving more than 70% of wastewater untreated [2]. The use of wastewater for irrigation is increasing among peri-urban farmers due to rise in water scarcity [1, 3]. The reported area of wastewater irrigation in India is 73000 ha [4]. While Buechler and Mekala [5] estimated that even just along the Musi River that runs through Hyderabad city in Andhra Pradesh approximately 40,000 ha of land were irrigated with urban and industrial wastewater diluted with fresh river water. Although no official estimates are available but actual figures seems to be much higher than 73000 ha. Both the positive and negative impact of wastewater irrigation in India is reported. It has benefits associated with some hazards e.g groundwater contamination, heavy metal accumulation in soils and food [6] and possible infections from range of pathogens [7]. Reports are also available of heavy metals accumulation of both the exceeding safe limit and within safe limit [8]. The Risk of bio-transfer of heavy metals has been reported by many in India [9]. Due to the proximity to urban centres, vegetables are important crops in peri-urban areas and have important contribution to the urban food basket [10, 11]. Thereby, scientific studies investigating the use of untreated wastewater use were more focused on vegetable production systems [12, 13, 14]. While, the cereal that provides household food security and wastewater-dependent livelihood activities in many countries [15, 16] is inadequately studied. The present study reports the impact of wastewater irrigation on soil properties in terms of key nutrients and heavy metals in paddy soils, crop and varietal response. The objectives of the study were to study, i) Effect of wastewater irrigation on soils and summer paddy crop (*Oryza sativa* L.) and ii) Response of paddy(*Oryza sativa* L.) varieties to wastewater irrigation.

II. Materials and Methods

2.1 Study area

Odisha state is one of the largest producers of rice in India and contributes almost one tenth of the total rice production of the country. Rice cultivation covers 77.7% of total cultivated area of the state. Bhubaneswar city (latitude 20°5' and longitude 85°82') is an expanding state capital of Odisha in India, accommodating 0.75 million population in an area of 135 sq. km. The city continue to grow and has achieved the highest growth rates experienced by any other capital city in the country. In absence of sewerage system, people in Bhubaneswar are using septic tanks and soak pits. In most places of the city, wastewater is discharged in to open drains without any treatment, which joins to a natural drain, Gangua nala. This drain receives about 107.25 mld (million litre daily) of wastewater within the city of which 47.6 mld is from domestic sources, 29.3 mld from industrial area and 30.35 mld from mixed sources. More than 3000 ha area between Daya west branch canal and Gangua nala is irrigated with Gangua water (wastewater) in non rainy seasons between October and April (Fig 1). Three villages Joypurpatna, Bikipur and Itipur were selected for the study due to their similar socio-economical proximity, agro-climatic situation and use of contrasting irrigation sources *viz.* wastewater (from Gangua nala) and river water (Daya river) for more than twenty years in crop fields.

The soils in Joypurpatna, Bikipur and Itipur villages are Typic Endoaquepts. The main crops in non-rainy or dry season (*Rabi,* December to April) in this area are summer paddy in low lands and vegetables namely okra, bitter gourd, pumpkin, ridge gourd in medium lands. Paddy is grown both for domestic consumption and sale. The socioeconomic survey shows that the number of cattle per household was 1.3, and the paddy straw is sold for livestock in other areas (U.S. \$ 182 per ton) as well. The dominant varieties of paddy grown between December and April in the villages are *Naveen, Parijat, Lalat and Khandagiri*. In the study villages, water is lifted from Daya river on one side and Gangua nala on other side for irrigation. Farmers used 1000 $\pm$ 20 mm of irrigation water through 8 number of irrigations for paddy cultivation during January to April in 2010. Annual precipitation in 2010 was 1,687 mm, while the amount received during January to April was only 22.8 mm while the pan evaporation during the period was 484 mm. The annual mean minimum and maximum temperatures were 25^0C and 40^0C during the year. Fertilizer application in the form of 75 kg of urea (34 kg N), DAP 60 kg (12 kg N and 28 kg P_2O_5 equivalent) and 80 kg of MOP (48 kg K_2O) was used for paddy cultivation in RI soils by the farmers. While no fertilizer was used in WW soils. Expenditure on fertilizer was about $ 50 per hectare. The other costs were similar for both the irrigation sources.

2.2 Water characterization

Quality of water from both the sources were analyzed in the study villages with reference to international guidelines [17] at 30 days interval between January and April 2010. The samples from the river and wastewater (Gangua nala) were collected at lifting points for analysis. pH and EC were measured at the sampling points by Orion Multiparameter (Eutech Instruments). The samples were collected in clean plastic bottles with two subsets according to the standard method of sampling [18]. Total N (TN) from unfiltered digested samples using semi-automatic Kjeldahl N Analyser (Kelplus – Classic DX) followed by titration, P by Stannous Chloride Method, Na and K by flame photometer were determined according to the standard methods. Calcium and Mg were determined by Versenate titration method [18]. SAR was calculated using the equation 1

$$SAR = Na^+/[Ca + Mg]^{1/2} \quad \ldots\ldots\ldots(1)$$

Iron, Mn, Zn, Cd, Cr and Pb were determined using Atomic Absorption Spectrophotometer (Varian, Spectra AA) as per the standard methods [18].

The pH of both the water sources was within acceptable range of 6.5 to 8.5 for irrigation. The electrical conductivity, SAR and nitrogen values indicate slight to moderate restriction for use of both the water sources. The heavy metal concentrations viz. Fe, Mn, Zn, Cr, and Cd were higher in wastewater than those in river water. Concentrations of Mn and Cd in wastewater exceeded the permissible limit (Table 1).

2.3 Soil and plant analyses

Plant samples were collected at physiological maturity of rice varieties in April 2010 from river irrigated (RI)_and adjacent wastewater irrigated (WW) fields. Five plots of each variety with 3 subplots (each 5m^2) were sampled. A total of 60 subplots each from - RI and - WW plots were used for recording yield. Yield attributes were recorded in the field, *viz* plant height and number of panicles per m^2. The above ground biomass was harvested from 5 m^2 plots at 0.1 m above the ground as per farmers practice. The grains per panicle were recorded by taking average of 10 panicles. Separation of straw and grain was done manually and fresh weight was recorded by portable balance. The samples were collected in pre labeled muslin cloth bags. In laboratory, the straw samples were air dried (maximum and minimum relative humidity 75% and 67% and mean maximum and minimum temperature 37.2^{0}C and 25^{0}C). Yields were reported at 10% and 14% moisture content for grain and straw, respectively. The replications of each plot were mixed and about 200 g of composite straw and grain samples were oven dried separately at 80^{0}C and then powdered using stainless steel grinder to pass through 2mm sieve and stored for analysis. The ground paddy grain and straw samples (0.2g) were analyzed for total N by Kjeldahl method after digestion with concentrated sulfuric acid (H_2SO_4) and then measuring the quantity of NH_4 produced[19]. The 0.2g plant samples were digested with tri-acid mixtures (HNO_3:H_2SO_4:$HClO_4$ 5:1:2) in open tube method and analyzed for P by spectrophotometer[20], K by flame photometry [21], 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) [22].

Approximately 1kg of soil sample was collected from each subplot at 0-15 cm depth into a bucket, mixed thoroughly, and finally, 500g of composite sample was collected through Quartile procedure. Samples were air dried followed by oven drying at 105^{0}C, 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 soil : water) by digital EC meter (Model 'EC Testr', Eutech Instruments, Malaysia), organic carbon (OC) by Walkley and Black method of wet oxidation [23], available N by alkaline permanganate method as described by Subbiah and Asija 1956 [24] using Semi-automatic N Analyser (Kelplus – Classic DX), available P by Bray's extractant method [25], Exchangeable K and Na by flame photometer after extraction with 1N ammonium acetate [24]. 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 What man 42 followed by Atomic Absorption Spectrophotometric detection, (Varian, Model Spectra AA) using 'metal standards' as mentioned earlier.

Enrichment factors were calculated to determine the degree of soil pollution rather heavy metal accumulation in contaminated soils (WW) with respect to uncontaminated soils (RI). Enrichment Factor = Concentrations of metal in WW soils/ Concentration of metal in RI soils [26].

Statistical analyses were performed with the software SPSS 13.0 for Windows. The statistical significance of differences in the variables between treatments was assessed. Those differences with $P < 0.05$ were deemed statistically significant.

III. Results and Discussion

3.1 Irrigation and varietal differences with irrigation sources

The grain yield, straw yield and number of panicles per square meter in WW plots were significantly higher by 7, 9.3 and 5.3 percent, respectively, than RI plots (Table 2). Significant differences among varieties were also observed regarding grain and straw yield, number of panicle under the WW and RI plots. *Lalat* showed maximum grain and straw yields with both the irrigation sources followed by *Naveen, Parijat* and *Khandagiri*. Among the varieties, *Naveen* showed 12 % and 15% increase in grain and straw yield in WW over RI plots, followed by *Khandagiri* (10 and 15% respectively for grain and straw) while *Lalat* showed minimum. This suggests that *Naveen* and *Khandagiri* were more responsive probably, to the elevated level of macronutrients in wastewater irrigated soils while *Lalat* variety could not exploit it. Grains per panicle and 1000 grain weight did not vary with irrigation sources while differences with varieties were observed. No significant differences were observed in nitrogen contents in both the grain and straw due to irrigation sources and varieties. However, grain phosphorus concentrations significantly varied with irrigation sources while potassium in grain was significantly higher in wastewater irrigated soils and showed varietal differences also. The wastewater irrigated soils had significantly lower mean grain-straw ratio (0.93), indicative of comparatively higher vegetative growth in wastewater irrigated soils. Probably higher level of major nutrients in WW soils encouraged vegetative growth in comparison to RI soil. Therefore irrigation with wastewater has a positive impact on the productivity of paddy grain. Higher straw (biomass) in wastewater irrigated soils can add to farmers sale proceeds to the tune of 130 USD $ha^{-1.}$ Among the varieties the grain straw ratio varied significantly.

3.2 Impact of irrigation sources on soil characteristics

The basic assumption of the study in the farmers' fields was that all fields under the study had similar type of soils, agricultural practices and climatic condition where impact of two different irrigation sources was compared. No significant difference in the soil properties (Table 3) with the rice varieties was observed under the same irrigation type conform the assumption. The soil pH, EC, organic carbon, nitrogen level, exchangeable potassium and available phosphorus varied significantly with irrigation sources. Decreased pH and increased EC were observed with WW soils. Rapid salinization of wastewater irrigated soils and loss in productivity is well reported [27]. But the soil EC (1:5) in WW soils in the present study were below the threshold value of 3 dS m^{-1} (ECe) for paddy cultivation [28], though, the mean EC value in WW plots were three times than that in RI plots. The mean ECe (Electrical Conductivity of saturation extract of soil) was calculated in line with the ECe values [ECe = EC (1:5 soil : Water) x 6.5] as determined by Murtaza et al.[29] and were 0.83 and 0.25 dS m^{-1} for WW and RI soils under the present investigation. In spite of long period of wastewater irrigation, the EC values did not reach critical limits. Probably, the soils under the study receive more than 1600 mm rainfall per annum preventing accumulation of salts through leaching. The accumulation of salts and increased EC is more pronounced in arid areas[30]. The Gangua water had higher level of nutrient elements than Daya river water (Table 3). Organic carbon, available N, Bray's extractible P, exchangeable K were significantly higher by 32, 44, 61 and 44 percent respectively in WW soils than RI soils.

Significant correlation between organic carbon and nitrogen indicates the possibility of nitrogen enrichment from organic matter added through wastewater irrigation. Significant negative correlation between pH and organic carbon and available N may be attributed to the decomposition of organic matter producing intermediate organic acids lowering the soil pH and releasing organically bound N. Soil P and pH showed significant relation in the observed pH range (Table 4).

3.3 Factors affecting yield of paddy

Significant differences in yield and yield attributes were observed between WW and RI plots and among varieties as well. To understand the soil factors contributing to the increased paddy yield, factorial ANOVA without and with the inclusion of factors *viz.* pH, EC, organic carbon, soil available N, Bray's P and exchangeable K as covariate was done as they were significantly different RI and WWfields. Increased salinity with wastewater irrigation as observed in the present study has been reported by many workers due to accumulation of salts [31]. In the present study, factorial ANOVA with covariate suggests that EC had no significant negative effect on grain and straw yield of paddy (Fig 2, Table 5). However, soil available N has significant positive effect on the grain and straw yield across the varieties with irrigation. The present study suggests that due to varietal responses to elevated N level in WW plots higher grain and straw yield of paddy was observed. The varietal responses varied significantly with all the considered factors. The pH covariate as appeared in the model was evaluated at 5.63. Lower pH in WW soils (mean 5.51) had decreased the grain and straw yield of paddy and the varietal difference had significant effect on yield while pH was included as covariate (Fig 2a, Table 5). That signifies, had the pH in WW soils been raised to 5.63 there would have been increase of 318 kg ha^{-1} of mean grain yield of rice. This suggests that increase of soil pH alone with liming materials can increase paddy yield in WW soils in such condition.

3.4 Effect of irrigation source on soil and paddy grain and straw

The tri-acid digested Zn, Fe, Mn and Cr concentrations were significantly higher in WW soils whereas Pb and Cu concentrations were at par between irrigation sources. This is conspicuous by their higher concentrations in wastewater sources (Table 1) even though metal concentrations were below the permissible limits. Similar observations were reported by many [26, 32] Maximum permissible limits for heavy metals in soils are 300 mg kg^{-1} for Zn, 3 mg kg-^{1} for Cd, 300 mg kg-1 for Pb, 140 mg kg^{-1} for Cu and 150 mg kg^{-1} for Cr [33]. No significant difference was also observed in metal concentrations of soils under different varieties (Table 6). The heavy metal concentrations in soils were in the order Fe>Mn>Zn>Pb>Cr>Cd>Cu in both the types of irrigated soils. Enrichment factors [26] were calculated to determine the degree of soil pollution rather heavy metal accumulation in WW soils with respect to RI soils.

Higher enrichment values (>1) indicate higher accumulation of metals, leading to higher concentration in WW soils, thereby, increased heavy metal concentrations in cultivated crops in WW soils. The enrichment factors were in the order Mn (2.24) >Zn (1.48) >Fe (1.34) > Cu (1.27) > Cr (1.17) > Cd (0.098) > Pb (0.41). However, higher Cd concentration in RI soils (with lower Cd in water) than GI soils (non-significant) points towards other factor(s) of geogenic and/or anthropogenic origin. The main difference between farmers' practices between RI and GI soils is application of fertilizers in RI soils. Farmers use about 60 kg DAP along with other fertilisers in summer paddy apart from phosphatic doses in *kharif* seasons (June – November). Phosphatic fertilisers are known sources of Cd and could have contributed in RI soil Cd [34].

The heavy metal concentrations in grain and straw are shown in Table 7 and 8. The Fe concentrations in grain and Zn, Fe and Cr in straw varied significantly with irrigation type and were higher in WW soils than RI soils. The metal concentrations in grain were below the maximum permissible limits of 60 mg kg^{-1} Zn, 20.0 mg kg^{-1} Cr, 5.0 mg kg^{-1} Pb [35]. The metal concentrations were higher in straw than grain under both the irrigation type. However, Cd concentrations were found beyond the maximum permissible limit (0.2 mg/kg) with both the type of irrigation. Probably lower soil pH contributed to higher Cd mobility in soil and their bioavailability rendering higher Cd uptake by plants A review of the solid-liquid partitioning of Cd in soil showed that the mobility of Cd in soil consistently increases with decreasing soil pH [36]. Cadmium is a potentially toxic component for consumption and it's higher concentrations in plants is a concern and may be attributed to it's high mobility [37]. The transfer of Cd from soil to plants can be reduced with appropriate soil management like application of liming materials which may reduce it's bioavailability [38].

The Cd concentration was higher than the maximum permissible limit <1.0 mg kg^{-1} (for animal feed) in straw with both the types of irrigation whereas Pb was within the maximum permissible limit of 10 mg kg^{-1} (Directive 86/278/EC). No significant variation in Cd, Pb, Cr and Mn concentrations in paddy straw with irrigation type and variety was observed. However, higher Cd concentration is a concern for using paddy straw even for animal feed.

IV. Conclusion

Wastewater irrigation has increased the level of plant nutrients in soil, while salinity did not reach the critical level. Increased productivity of both the paddy grains and straw in wastewater irrigated soils is beneficial to the livelihood for farmers. The magnitude of the increase in paddy yield with wastewater irrigation is dependent on suitable paddy variety. Therefore, selection of variety should be based on both the genetic potential and responsiveness to wastewater irrigation. In the present investigation, *Naveen* was most responsive variety for wastewater irrigation. Moreover, fertilizer cost of summer paddy cultivation is saved up to USD 50 ha^{-1} with wastewater irrigation. Amelioration of soil pH may give further increase in paddy yield and economic gain in wastewater irrigated soils.

Heavy metals in wastewater-irrigated soil were within the maximum permissible limits. Their concentration in paddy grain and straw were also within permissible limits [33]. However, the concentration of Cd in both the grain and straw was beyond the permissible limits in the wastewater as well as river water irrigated soils. Thus, wastewater is not the source of increased Cd in plant.

Therefore, wastewater irrigation had a positive impact on nutritional status of soil, paddy grain and straw yield and income of farmers. The benefit can be further extended with the right paddy variety.

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References

[1] Wastewater Use in Irrigated Agriculture: Management Challenges in Developing Countries, In: Scott CA (ed), Wastewater Use in Irrigated Agriculture: Confronting the Livelihood and Environmental Realities, Ottawa, Canada, CAB International, International Water Management Institute and International Development Research Centre, Wallingford, UK pp 1-10.

[2] CPCB (2009) Status of water supply, wastewater generation and treatment in Class I cities and Class II towns of India. Series: CUPS/70/2009-10. Central Pollution Control Board, India.

[3] Radcliffe JC (2004) Water recycling in Australia Australian Academy of Technological Sciences and Engineering, Parkville, Victoria, Web http://wwwatseorg.au. Accessed on 15th December 2014.

[4] Strauss M and Blumenthal U (1990) Human waste use in Agriculture and Aquaculture: Utilisation practices and health Perspectives. IRCWD Reports 09/90. International Reference Centre for Waste Disposal (IRCWD). Duebendorf, Germany

[5] Buechler S, Mekala GD (2003) Wastewater as a Source of Multiple Livelihoods? A Study in Rural Andhra Pradesh, South India. In: Devi R, Ahsan N (eds.), Water and Wastewater: Perspectives of Developing Countries. London, UK: International Water Association.

[6] Ensink, JHJ, van der Hoek W, Matsuno Y, Munir S, Aslam MR (2002) Use of untreated wastewater in peri-urban agriculture in Pakistan : Risk and Opportunities, IWMI Research Report 64, Colombo, Sri Lanka, International Water Management Institute

[7] Shuval HI, Adin A, Fattal B, Rawitz E, Yekutiel P, (1986). Wastewater Irrigation in Developing Countries: Health Effects and Technical Solutions. Washington DC: The World Bank.

[8] Singh, A. K., Raychaudhuri, Mausumi, Jain, S. K. and Chandra,Ravish, (2016). Sewage Water Irrigation and Heavy Metal Accumulation in Vegetables in Patna By Pass Area – A case study. RAU Bulletin No.02/IWM. AICRP on Irrigation Water Management, Rajendra Agricultural University, Pusa, Samastipur, Bihar - 848125, India, 16 p.

[9] Sharma RK, Agrawal M (2005) Biological effects of heavy metals: An overview J. Environ. Biol. 26 (2 suppl), 301-313.

[10] Drechsel P, Graefe S, Sonou M and Cofie O (2006) Informal Irrigation in Urban West Africa:
An Overview, Research Report no 102, IWMI, Colombo wwwiwmicgiarorg/Publications/IWMI_Reports/PDF/pub102/RR102pdf.

[11] FAO (2011) The place of urban and peri-urban agriculture in national food security programmes Integrated Food Security

Support Service Policy and Programme Development Support Division Technical Cooperation Department Rome, Italy ISBN 978-92-5-106845-8 p 44
[12] Bahmanyar, MA (2008) Cadmium, nickel, chromium and lead levels in soils and vegetables under long-term irrigation with industrial wastewater. Comms Soil Sc Plant Anal 39: 2068-2079
[13] Singh A, Sharma RK, Agarwal M, Marshall F (2010) Health risk assessment of heavy metals via dietary intake of foodstuffs from the wastewater irrigated site of a dry tropical area of India. Food Chem Toxicol 48: 611–619.
[14] Chandran S, Niranjana V, Bennyjoseph V (2012) Accumulation of heavy metals in wastewater irrigated crops in Madurai. India J Environ Res Dev 6 : 432- 438
[15] Juwarkar A (1988) Bioaccumulation of zinc by Pencillium Sp. J Current Sci. 57: 251-252
[16] Cao ZH, Hu Z Y (2000) Copper contamination in paddy soils irrigated with wastewater. Chemosphere 41: 3-6.
[17] Ayers RS, Westcot DW (1985). Water quality for agriculture FAO, Irrigation and Drainage Paper. 29, Rev 1, Food and Agriculture Organization of the United Nations, p 174
[18] Tomar M (1999) Quality Assessment of Water and Wastewater. LEWIS Publishers Boca Raton London New York Washington, DC p 260.
[19] Bremner JM, Mulvaney CS (1982). Nitrogen – Total. In: Page AL et al. (eds) Methods of Soil Analysis Part 2, 2nd ed, Agron Monogr 9 ASA and SSSA, Madison, WI, pp 595-624.
[20] Moore KP (1992) Determination of Phosphorus in Plant Tissue by Colorimetry. In: Plank CO (chief ed), Plant Analysis Reference Procedures for the Southern Region of the United State Southern., Coop Ser Bull, 368, pp 29 – 31
[21] Yoshida S, Forno AD, Cock J, Gomez AK (1976) Laboratory Manual for Physiological Studies of Rice, IRRI, Los Banos, Philippines, 83 p
[22] Isaac RA, Kerber JD (1971) Atomic absorption and flame photometry: Techniques and uses in soil, plant, and water analysis In: Walsh L M (ed) Instrumental Methods for Analysis of Soils and Plant Tissue. Soil Sci Soc Am, Madison, WI, pp 18-37,
[23] Jackson ML (1973) Soil Chemical Analysis, Prentice Hall of India Pvt Ltd, New Delhi.
[24] Baruah TC, Barthakurand HP (1997) A Textbook of Soil Analysis, 334, Vikas Publishing House Pvt Ltd, New Delhi
[25] Dickman SR and Bray RH. (1940) Colorimetric determination of phosphate Ind Eng Chem Anal Ed 12: 665-668
[26] Barman SC, Sahu RK, Bhargava SK, Chatterjee C (2000). Distribution of heavy metals in wheat, mustard and weed grown in fields irrigated with industrial effluents Bull Environ. Contam Toxicol 64: 489-496
[27] Matthew McCartney, Christopher Scott, Jeroen Ensink, BinBin Jiang and Trent Biggs (2008). Salinity implications of wastewater irrigation in the musi river catchment in india, Cey. J. Sci. (Bio. Sci.) 37 (1): 49-59.
[28] Maas EV, Grattan S R (1999) Crop yields as affected by salinity. In: Skaggs RW, van Schilfgaarde J (eds), Agricultural Drainage, Agron Monogr 38 ASA, CSSA, SSA, Madison, WI, pp 55–108
[29] Murtaza G, Ghafoor A, Qadir M (2006) Irrigation and soil management strategies for using saline-sodic water in a cotton-wheat rotation. agric Water Manag 81: 98-114
[30] Hayes AR, Mancino CF and Pepper IL (1990) Irrigation of Turf grass with Secondary Wastewater Effluent: I Soil and Leachate Water Quality. Agron J 82: 939-943.
[31] Rusan MJM, Hinnawi S, Rousan L (2007) Long term effect of waste water irrigation of forage crops on soil and plant quality parameters. Desalinization 215:143-152
[32] Sharma RK, Agarwal M, Marshall F (2007) Heavy metal contamination of soil and vegetables in subarban areas of Varanasi. India Ecotoxicol Environ Saf 66: 258-266
[33] European Union. (2002). Heavy Metals in Wastes, European Commission on Environment (http://ec.e uropa.eu/environment/waste/studies/pdf/heavy metals report.pdf) Accessed on 13th July 2015
[34] SCHER (2015) Scientific Committee on Health and Environmental Risks, Opinion on 14 new conclusions regarding future trends of cadmium 15 accumulation in EU arable soils. http://ec.europa.eu/health/scientific_committees. Accessed on 10 july 2015.
[35] WHO/FAO. (2007). Joint FAO/WHO Food Standard Programme Codex Alimentarius Commission 13th Session. Report of the Thirty Eight Session of the Codex Committee on Food Hygiene. Houston, United States of America, ALINORM 07/30/13.
[36] Smolders E (2001) Cadmium uptake by plants. International Journal of Occupational Medicine and Environmental Health, Vol. 14, No. 2, 177—183, 2001
[37] Beesley L, Moreno-Jime´nez E, Rafael C, Nicholas L and Dickinson N. (2010). Mobility of arsenic, cadmium and zinc in a multi-element contaminated soil profile assessed by in-situ soil pore water sampling, column leaching and sequential extraction. Environ Pollut 158: 155–160
[38] Lombi E, Tearall KL, Howarth JR, Zhao FJ, Hawkesford, MJ, McGrath SP (2002) Influence of iron status on cadmium and zinc uptake by different ecotypes of the hyperaccumulator Thlaspi caerulescens Plant Physiol 128: 1359-1367.

Table 1. Water qualities of wastewater (Gangua drain) and Daya river water

Parameter	Gangua nala (drain)	Daya river	guidelines FAO (1985)
pH[1]	6.70^{a} (± 0.21)	8.44^{b} (± 0.42)	6.5 – 8.5 (NormalRange)
EC (dS/m)[2]	0.48^{a} (± 0.14)	0.24^{b} (± 0.11)	SM
SAR [3]	4.3^{a} (± 1.6)	2.9^{b} (± 0.34)	SM
Elemental composition (mg/kg)		Maximum permissible limit	
TN	26^{a} (± 4.6)	14^{b} (± 3.2)	35
P	2.8^{a} (± 0.72)	0.52^{b}(± 0.29)	-
K	10.3^{a} (± 4.1)	2.7^{b}(± 1.3)	-
Fe	1.24^{a} (± 0.421)	0.546^{b}(± 0.123)	5.0
Mn	0.32^{a} (± 0.061)	0.044^{b}(± 0.022)	0.2
Zn	0.11^{a} (± 0.032)	0.062 (± 0.041)	2.0
Cr	0.086^{a} (± 0.042)	0.063^{b}(± .034)	0.1
Cd	0.014^{a} (± 0.008)	0.010^{b}(± 0.006)	0.01
Pb	1.13^{a} (± 0.16)	1.02^{a} (± 0.19)	5.0

Values followed by a different letter are significantly different for the same parameter STDEV values in parenthesis. Slight to moderate restriction (SM). Sources: Ayers and Westcott (1985).

Table 2 Yield and yield attributes of paddy under the influence of water sources and variety

Water source	Paddy Variety	Grain yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Grains/ Panicle (g)	Panicle m^{-2}	1000 grain wt (g)	Grain N%	Straw N%	Grain P%	Grain K%	Grain-straw ratio
RI	Naveen	4360^{bc} ± 100	4500^{c} ± 171	78.2^{b} ± 4.97	249^{c} ±7.8	24.1^{ab} ± 0.33	1.491^{a} ± 0.39	0.902^{a} ± 0.21	0.22^{a} ± 0.02	0.532^{bc} ± 0.04	0.970 ± 0.019
	Parijat	4300^{c} ± 117	4485^{c} ± 97	66.8^{c} ± 3.96	319^{a} ± 7.8	21.1^{d} ± 0.44	1.365^{a} ± 0.11	0.809^{a} ± 0.07	0.210^{abc} ± 0.01	0.492^{c} ± 0.05	0.959 ± 0.019
	Lalat	4830^{a} ± 225	5090^{a} ± 306	83^{a} ± 3.16	259^{bc} ± 7.9	23.5^{c} ± 0.27	1.428^{a} ± 0.22	0.753^{a} ± 0.16	0.224^{a} ± 0.02	0.578^{ab} ± 0.03	0.950 ± 0.021
	Khandagiri	3590^{e} ± 227	3850^{d} ± 303	67.5^{c} ± 3.16	228^{d} ± 9.6	23.6^{c} ± 0.37	1.365^{a} ± 0.11	0.566^{a} ± 0.09	0.208^{abc} ± 0.01	0.512^{c} ± 0.03	0.934 ± 0.019
	Mean	4270 ± 228	4481 ± 219	73.9 ± 3.81	264 ± 8.3	23.1 ± 0.36	1.412 ± 0.06	0.757 ± 0.14	0.216 ± 0.01	0.529 ± 0.04	0.953± 0.020
WW	Naveen	4860^{a} ± 167	5170^{a} ± 193	81.4^{ab} ± 3.43	270^{b} ±13.1	24.2^{a} ± 0.33	1.547^{a} ± 0.31	0.903^{a} ± 0.17	0.200^{bcd} ±0.02	0.570^{ab} ± 0.05	0.940 ± 0.016
	Parijat	4500 ^{bc} ± 177	4830^{b} ± 239	68.5^{c} ± 3.04	331^{a}± 7.0	21.3^{d} ± 0.33	1.449^{a} ± 0.37	0.910^{a} ± 0.33	0.217^{ab} ± 0.01	0.572^{ab} ± 0.08	0.932 ± 0.017
	Lalat	4990^{b} ± 185	5210^{a} ± 249	85.2^{a} ± 3.76	261^{b} ± 9.6	23.6^{c} ± 0.30	1.582^{a} ± 0.53	1.007^{a} ± 0.23	0.196^{cd} ± 0.02	0.610^{a} ± 0.05	0.958 ± 0.013
	Khandagiri	3930^{d} ± 264	4390^{c} ± 397	69.3^{c} ± 3.53	249^{c} ± 7.9	23.7^{bc} ± 0.29	1.477^{a} ± 0.33	0.868^{a} ± 0.49	0.183^{d} ± 0.01	0.604^{a} ± 0.04	0.897 ± 0.027
	Mean	4570 ± 199	4900 ± 219	76.1 ± 3.44	278 ± 9.4	23.2 ± 0.30	1.514 ± 0.06	0.922 ± 0.06	0.199 ± 0.01	0.589 ± 0.02	0.932 ± 0.018
Analysis of variance	Water(w)	*	*	ns	*	ns	ns	ns	*	**	*
	Variety(v)	**	**	*	*	**	ns	ns	ns	*	**
	w*v	**	ns	ns	*	ns	ns	ns	ns	ns	ns

Values followed by a different letter are significantly different. ** and * indicate significance at 1 and 5 % respectively.

Table 3. Soil parameters under the influence of different water sources and paddy variety

Water source	Variety	pH	EC (dS m^{-1})	Org C (g kg^{-1})	N (kg ha^{-1})	Exch. K_2O (kg ha^{-1})	P_2O_5 (kg ha^{-1})
RI	Naveen	5.74^{a} ± 0.06	0.043^{b}± 0.01	0.40^{b} ± 0.06	129^{b} ± 14.5	260^{b} ± 67	31^{a} ± 8.15
	Parijat	5.77^{a} ± 0.04	0.052^{b} ± 0.01	0.37^{b}± 0.1	122^{b} ± 13.7	432^{b} ± 118	26^{ab} ± 5.40
	Lalat	5.73^{a} ± 0.05	0.047^{b} ± 0.01	0.40^{b} ± 0.08	136^{b} ± 23.5	251^{b} ± 78	25^{bc} ± 2.20
	khandagiri	5.74^{a} ± 0.03	0.038^{b} ± 0.01	0.40^{b} ± 0.08	125^{b} ± 10.9	245^{b} ± 77	30^{ab} ± 4.60
	Mean	5.74 ± 0.05	0.045 ± 0.01	0.39 ± 0.01	128 ± 18.5	297± 85	28 ± 5.90
WW	Naveen	5.49^{c} ± 0.12	0.135^{a} ± 0.01	0.52^{a} ± 0.04	186^{a} ± 15.3	461^{a} ± 49	50^{cd} ± 8.30
	Parijat	5.62^{b} ± 0.09	0.121^{a} ± 0.03	0.50^{a} ± 0.05	182^{a} ± 24.8	410^{a} ± 116	44^{e} ± 11.6
	Lalat	5.57^{bc} ± 0.13	0.120^{a} ± 0.01	0.54^{a} ± 0.05	190^{a} ± 18.8	420^{a} ± 78	36de ± 6.30
	khandagiri	5.37^{d} ± 0.1	0.132^{a} ± 0.02	0.52^{a} ± 0.06	179^{a}± 22.6	415^{a} ± 131	44^{cde} ± 6.26
	Mean	5.51± 0.12	0.127^{b} ± 0.01	0.52 ± 0.02	184 ± 20.4	427 ± 93.5	45 ± 8.30
Analysis of variance	Water(w)	*	**	**	**	*	**
	Variety(v)	ns	ns	ns	ns	ns	*
	w*v	ns	ns	ns	ns	*	ns

Values followed by a different letter are significantly different. ** and * indicate significance at 1 and 5 % respectively.

Table 4: Pearson's correlations among soil parameters

Parameters	pH	OC	Av N	Soil P
OC	-.51**			
Av N	-.63**	.64**		
Soil P	0.49**	-.41**	-.62**	
Soil K	0-.29	.27	.39*	-.49**

Values followed by a different letter are significantly different. ** and * indicate significance at 1 and 5 % respectively

Table 5. Results of factorial ANOVA (SPSS Ver 13) with covariates

Dependent variable	Covariate	Covariate	Factors		
			variety	Irrigation	Variety *irrign
Grain yield			**	**	**
	pH	ns	*	*	ns
	EC	ns	ns	ns	ns
	OC	ns	*	*	**
	Av N	*	**	**	ns
	Av P	ns	**	ns	**
	Exch K	ns	**	*	**
Straw yield			**	**	**
	pH	ns	*	*	ns
	EC	ns	**	ns	ns
	OC	ns	ns	**	*
	Av N	ns	*	**	ns
	Av P	*	ns	ns	*
	Exch K	**	**	**	*
Grain N			ns	ns	ns
	pH	ns	ns	ns	ns
	EC	ns	ns	ns	ns
	OC	ns	ns	ns	ns
	Av N	ns	ns	*	ns
	Av P	ns	ns	ns	ns
	Exch K	***	ns	***	ns

Values followed by a different letter are significantly different. ** and * indicate significance at 1 and 5 % respectively

Table 6. Total heavy metal content (mg/kg) in soils under the influence of water sources and paddy variety

Water source	Variety	Zn	Fe	Mn	Cd	Cr	Pb	Cu
RI	Naveen	$125^{d} \pm 19$	$310^{b} \pm 41.2$	$170^{b} \pm 32$	$2.1^{a} \pm 0.28$	$7.30^{c} \pm 2.08$	$74.7^{a} \pm 6.90$	$0.68^{a} \pm 0.4$
	Parijat	$161^{cd} \pm 17$	$295^{b} \pm 43.7$	$166^{b} \pm 30$	$2.0^{a} \pm 0.33$	$7.66^{c} \pm 1.81$	$75.3^{a} \pm 14.7$	$0.88^{a} \pm 0.44$
	Lalat	$160^{cd} \pm 24$	$289^{b} \pm 102$	$178^{b} \pm 21.3$	$2.0^{a} \pm 0.21$	$7.94^{bc} \pm 1.93$	$66.0^{a} \pm 2.30$	$0.88^{a} \pm 0.24$
	Khandagiri	$168^{bc} \pm 23$	$309^{b} \pm 60$	$177^{b} \pm 31.7$	$1.96^{a} \pm 0.37$	$7.46^{c} \pm 1.55$	$73.2^{a} \pm 12.8$	$0.93^{a} \pm 0.27$
	Mean	154 ± 3.2	301 ± 28	172 ± 4.96	2.0 ± 0.07	7.59 ± 0.23	72.3 ± 10.30	0.84 ± 0.10
WW	Naveen	$196^{bc} \pm 15$	$409^{a} \pm 39$	$391^{a} \pm 46.1$	$2.31^{a} \pm 0.71$	$9.06^{ab} \pm 1.12$	$73.0^{b} \pm 20.8$	$1.01^{a} \pm 0.52$
	Parijat	$202^{b} \pm 52$	$425^{a} \pm 23$	$386^{a} \pm 33.4$	$1.86^{a} \pm 0.54$	$8.65^{abc} \pm 1.32$	$76.6^{b} \pm 18.1$	$1.10^{a} \pm 0.72$
	Lalat	$254^{a} \pm 45$	$387^{a} \pm 21$	$385^{a} \pm 24.4$	$1.82^{a} \pm 0.53$	$8.39^{abc} \pm 0.79$	$79.4^{b} \pm 19.30$	$1.01^{a} \pm 0.29$
	Khandagiri	$266^{a} \pm 26$	$386^{a} \pm 22$	$380^{a} \pm 42.8$	$1.83^{a} \pm 0.27$	$9.55^{a} \pm 1.32$	$74.6^{b} \pm 15.50$	$1.13^{a} \pm 0.70$
	Mean	229 ± 16.8	402 ± 8.5	385 ± 9.8	1.96 ± 0.18	8.91 ± 0.25	75.9 ± 15.71	1.06 ± 0.20
Analysis of variance	water(w)	**	*	**	ns	*	ns	ns
	variety(v)	**	ns	ns	ns	ns	ns	ns
	w*v	ns	ns	ns	ns	ns	ns	ns

Values followed by a different letter are significantly different. ** and * indicate significance at 1 and 5 % respectively.

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Table 7. Heavy metal content in paddy grain (mg/kg) under the influence of water sources and paddy variety

Water source	Variety	Zn	Fe	Mn	Cd	Cr	Pb
RI	Naveen	29.65[a] ± 3.5	157[ab] ± 27.3	148[a] ± 24	1.98[a] ± 0.7	1.20[a] ± 0.8	1.003[a] ± 0.3
	Parijat	29.96[a] ± 4.6	151[b] ± 9.4	137[ab] ± 35	1.90[a] ± 0.3	1.33[a] ± 1.0	0.944[a] ± 0.2
	Lalat	32.8[a] ± 4.4	160[ab] ± 19.6	142[a] ± 19	2.06[a] ± 2.1	1.25[a] ± 0.8	0.997[a] ± 0.1
	khandagiri	30.4[a] ± 8.3	164[ab] ± 18.8	143[a] ± 18	1.98[a] ± 0.7	1.37[a] ± 0.3	1.0 13[a] ±0.2
	Mean	30.69 ± 1.42	158± 5.32	143 ± 4.7	1.98 ± 0.07	1.29 ± 0.08	0.990 ± 0.03
WW	Naveen	37.53[a] ± 11.2	169[ab] ± 11.9	112[bc] ± 6.4	1.73[a] ± 1.2	1.26[a] ± 0.8	0.953[a] ± 0.3
	Parijat	31.29[a] ± 11.3	170[ab] ± 7.2	110[c] ± 23	1.61[a] ± 0.7	1.47[a] ± 0.9	0.956[a] ± 0.1
	Lalat	34.1[a] ± 3.8	176[a] ± 8.9	110.[c] ± 6.2	1.85[a] ± 0.5	1.33[a] ± 0.5	0.983[a] ± 0.3
	khandagiri	39.95[a] ± 10.4	171[ab] ± 13.7	110[c] ± 6.1	1.73[a] ± 1.2	1.41[a] ± 0.5	1.024[a] ± 0.3
	Mean	35.72 ± 3.80	172 ± 3.13	110 ± 1.23	1.73 ± 0.10	1.37 ± 0.09	0.980 ± 0.03
Analyses of variance	water(w)	ns	*	ns	ns	ns	ns
	variety(v)	ns	ns	ns	ns	ns	ns
	w*v	ns	ns	ns	ns	ns	ns

Values followed by a different letter are significantly different. ** and * indicate significance at 1 and 5 % respectively

Table 8. Heavy metal content in paddy straw (mg/kg) under the influence of water sources and paddy variety

Water source	Variety	Zn	Fe	Mn	Cd	Cr	Pb
	Naveen	61.3[ab] ± 5.7	407[bcd] ± 67	1231[a] ± 65	2.09[a] ± 0.7	1.26[a] ± 0.8	1.45[a] ± 0.5
	Parijat	55.5[abcd] ± 7.5	381[d] ± 47	1196[a] ± 79	2.01[a] ± 0.5	1.47[a] ± 0.9	1.47[a] ± 0.4
	Lalat	58.9[abc] ± 3.1	384[d] ± 39	1227[a] ± 53	2.24[a] ± 0.6	1.33[a] ± 0.5	1.37[a] ± 0.5
	Khandagiri	63.7[a] ± 12.6	394[cd] ± 44	1160[a] ± 107	1.98[a] ± 0.5	1.41[a] ± 0.5	1.46[a] ± 0.3
	Mean	59.9 ± 3.5	392 ± 11	1203 ± 33	2.08 ± 0.12	1.37 ± 0.09	1.44 ± 0.05
WW	Naveen	50.4[cd] ± 15.5	444[ab] ± 42	1227[a] ± 86	2.16[a] ± 0.9	2.01[a] ± 0.6	1.56[a] ± 0.4
	Parijat	53.2[bcd] ± 4	441[ab] ± 31	1177[a] ± 98	1.83[a] ± 1.4	1.99[a] ± 1.1	1.65[a] ± 0.5
	Lalat	54.5[abcd] ± 8.8	438[abc] ± 44	1110[a] ± 176	2.20[a] ± 1.2	2.02[a] ± 1.5	1.53[a] ± 0.5
	Khandagiri	47.2[d] ± 7.7	471[a] ± 36	1189[a] ± 95	1.61[a] ± 1.1	1.99[a] ± 1.1	1.56[a] ± 0.3
	Mean	51.3 ± 3.24	448 ± 15	1176 ± 49	1.95 ± 0.55	2.01 ± 0.01	1.58 ± 0.05
Analysis of variance	water(w)	**	*	ns	ns	*	ns
	variety(v)	ns	ns	ns	ns	ns	ns
	w*v	ns	ns	ns	ns	ns	ns

Values followed by a different letter are significantly different. ** and * indicate significance at 1 and 5 % respectively

FIGURE CAPTION PAGE

Fig 1. Sample Collection Site

Fig 2a Differences in Grain Yield (kg ha^{-1}) under WW and RI Soils following Factorial ANOVA with and without pH as Covariate

Fig 2b Differences in Grain Yield (kg ha^{-1}) under WW and RI Soils following Factorial ANOVA with and without Organic C as Covariate

Fig 2c Differences in Grain Yield (kg ha^{-1}) under WW and RI Soils following Factorial ANOVA with and without Soil Available N as Covariate

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Fig 2d Differences in Grain Yield (kg ha^{-1}) under WW and RI Soils following Factorial ANOVA with and without EC as Covariate

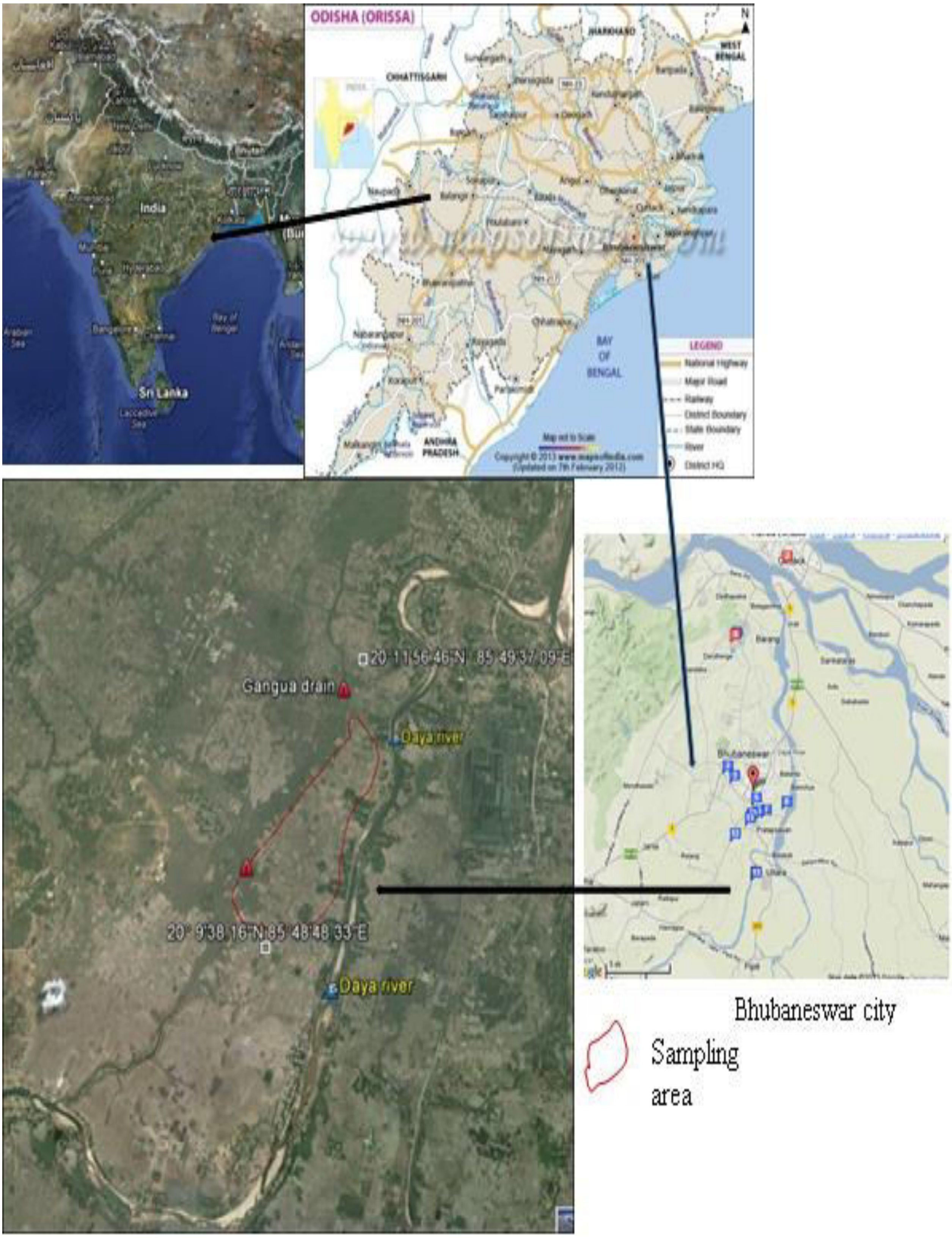

Fig 1. Sample collection site

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Fig. 2a Differences in grain yield (kg ha^{-1}) under WW and RI soils following Factorial ANOVA with and without pH as covariate

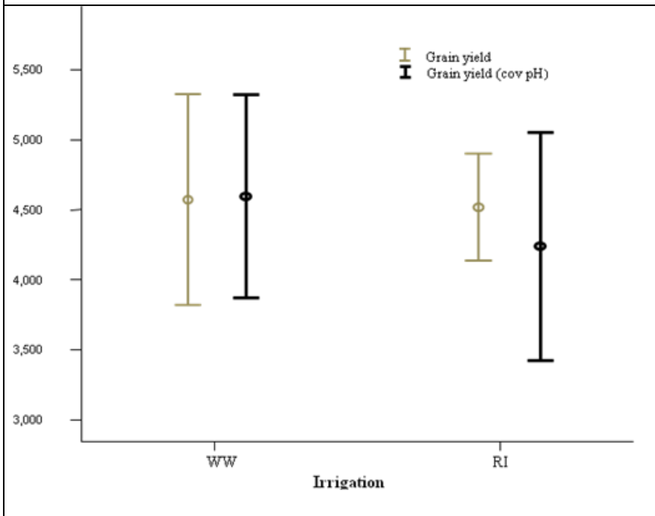


Fig. 2b Differences in grain yield (kg ha^{-1}) under WW and RI soils following Factorial ANOVA with and without organic C as covariate

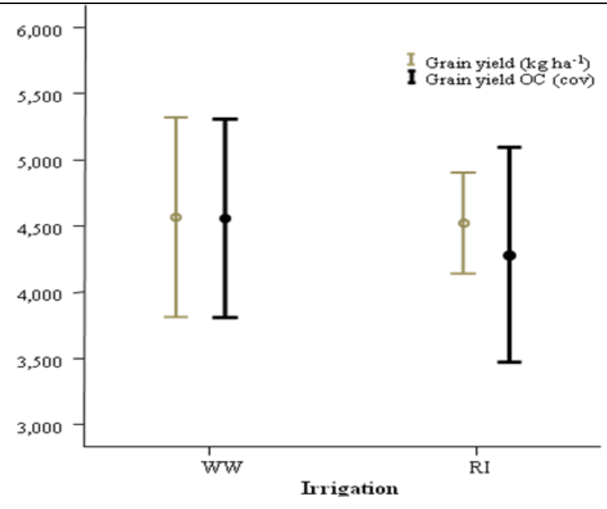


Fig. 2c Differences in grain yield (kg ha^{-1}) under WW and RI soils following Factorial ANOVA with and without Soil available N as covariate

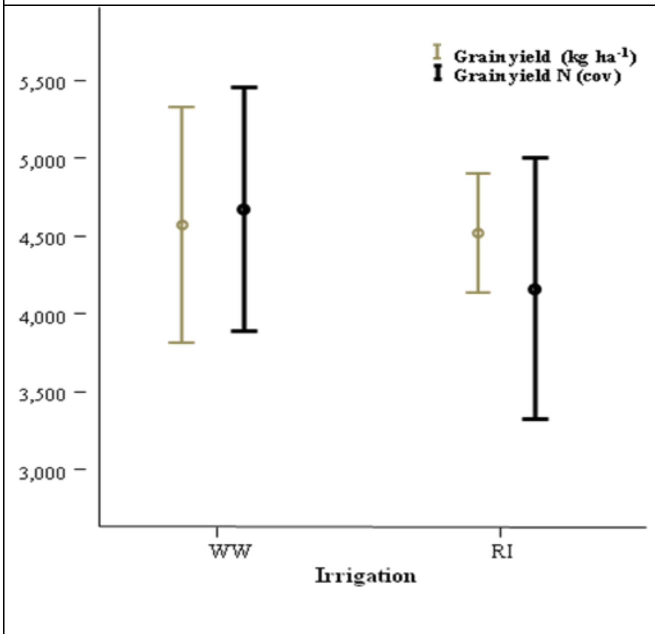
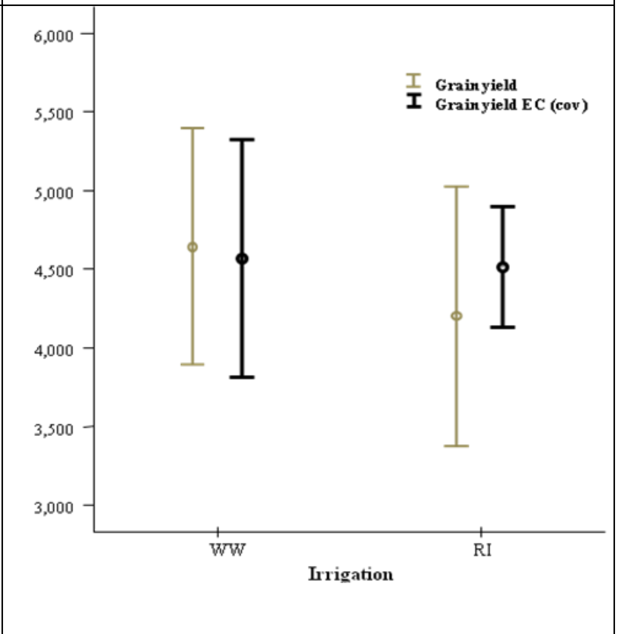


Fig. 2d Differences in grain yield (kg ha^{-1}) under WW and RI soils following Factorial ANOVA with and without EC as covariate



(At 95% confidence level)