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Impact of Sewage on Seed Germination and Growth of *Kharif* and *Rabi* Crops

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Abstract Wastewater is an effective source for irrigation of crop. Sewage generated from a hostel of Thapar University campus, Patiala was used for growing *Kharif* crops (Lady Finger & Pearl millet) and *Rabi* crops (Wheat, Fenugreek, Mustard & Cluster bean) for 35 days in plastic cups at laboratory scale. When sewage was applied at 50%, 100% individually, the dilution of 50% supported better growth of crops. Both sewage and soil used showed absence of metal constituents and hence non-possibility of their accumulation in the grown crops. Germination period of crop was observed and it was found different from crop to crop, four days in Lady finger as against eight days in Fenugreek. The biomass was higher in *Kharif* crops than was in *Rabi* crops. Composition of soil was estimated and it was found that the nutrients (organic carbon, nitrogen, phosphorus, potassium) had enriched the treated soil besides aiding the growth of crop. The study was found promising suggesting that the sewage could be used as an irrigating medium for crops. However, several growth parameters are to be optimized before sewage is tried for application at commercial scale.

Keywords: Sewage water, Kharif crop, Rabi crop, Seed germination, Irrigation

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1. INTRODUCTION

Developing countries like India are experiencing unparallel growth and rapidly increasing water supply and sanitation coverage will continue to release growing volumes of waste water. With increasing global population, the gap between the supply and demand for water is widening and is reaching such alarming levels that in some parts of the world it is posing a threat to human existence. It is an opportune time, to refocus on one of the ways to recycle water through the reuse of urban waste water for irrigation and other purposes. This could release clean water for use in other sectors that need fresh water and provide water to sectors that can utilize wastewater experiment for irrigation [1].

Agriculture is a major activity in India. Fresh water (ground and surface) is in huge demand to meet the needs of human beings. The industrial waste is altogether more complex (quality and quantity) than domestic sewage. Sewage is a source of nutrients, and if planned wisely, finds as a substitute for conventional water for irrigation. The principal impurities in polluted waters are organic matter and plant nutrients. With increasing global population, the gap between the supply and demand for water is widening and is reaching such alarming levels that in some parts of the world it is posing a threat human existence. It is a crucial time to refocus on one of the ways to recycle water through the reuse of urban wastewater for irrigation.

Pandey et al. [2] have used fertilizer wastewater, which recommended standard norms for land irrigation. Reuse of sewage as irrigation water is one of the best options to reduce the stress on limited fresh water available today and to meet the nutrient requirement of crops. A pot culture experiment was carried out by Mani and Bhaskaran [3] to elucidate an appropriate dilution of dying factory effluent for irrigating agricultural cotton and sorghum crops. Reddy and Borse [4] reported the application of sewage on seed germination and seedling growth of methi which shows that at lower concentration there was significant increase in the percentage of seed germination and other growth parameters whereas Hussein et al. [5] observed higher yield in the crop when higher amount of sewage sludge was utilized. Singh and Agrawal et al. [6] suggested that recommended use of sewage sludge improved the fertilizing value of soil and increased the yield of mungbean whereas higher rate of sewage sludge application increased the heavy metal content in seeds. Gu et al. [7] studied that whether the addition of sewage sludge increased the metal content in soil but it did not affect the growth of ryegrass. Therefore, the present study was made to analyse the wastewater generated from Thapar Technology Campus and its effect on the growth parameters of *Kharif* and *Rabi* crops.

2. MATERIALS AND METHODS

Material and methods was divided into two parts:

(1) Analysis of wastewater

(2) Analysis of soil before germination and after harvesting of crops

2.1 Collection of samples

Sewage: Sample of sewage was collected from the septic tank of one of Boys hostel of Thapar Technology Campus. 25-30 L of sample collected once was stored at 4°C in a cold room. Sewage was analyzed for several physico-chemical characteristics. Proportions of sewage used for germination of *Kharif* and *Rabi* crops were: Sewage (100%), Sewage + Water (50% + 50%) and Water (100%).

Soil: Soil sample was collected at depth of 2 cm from agriculture field of Thapar Technology Campus. Sufficient care was given to obtain representative samples by adopting proper procedure.

Selection of crops: Selection of crops for *Kharif* and *Rabi* season was done by manual published by Punjab Agriculture University (PAU), Ludhiana (*Table 1*).

2.2 Seedling and growth of crops

Plastic cups were used. 350 gm of soil was placed in cups and the seeds were seeded into it after washing with tap water. Four seeds were introduced into each cup. 10-15 ml of sewage was applied a day in each pot for irrigation purpose. The pots were maintained at ambient temperature (varying from 5°C –35°C) from the adverse environment conditions. Seeds, growth of plants were observed on 4, 8, 12, 35 days in terms of length of plumules, radicals, shoot and root, number of leaves, plant weight etc. Besides the crop harvested finally at 35 days was also analyzed for chlorophyll content.

2.3 Characterization of sewage and soil

The sewage was characterized by physical, chemical and biological parameters [8]. Soil was characterized for physical and chemical parameters [9], cation exchange capacity [10] and soil texture [11].

Table 1: Type of plant species grown in ***Kharif*** and ***Rabi*** season

Type	Crop	Sowing time	Harvesting time
Kharif crops	Lady finger (*Abelmoschus esculentus*) Peral millet (*Pennisetum glaucum*)	October	November
Rabi crops	Wheat (*Triticum aestivum*) Fenugreek (*Trigonella foenumg raecum*)	January	February
	Mustard (*Brassica campestris*) Cluster beam (*Cyamopsis psoralioides*)	March	April

Seeds: Seeds were purchased from PAU Ludhiana.

2.4 Plant Characteristics

(i) Root & Shoot length,
(ii) Plants wet and dry weight, and
(iii) Chlorophyll content at 645 & 663 nm [12].

3. RESULTS AND DISCUSSIONS

Physical and chemical characterization of sewage is essential before conducting the studies on plant growth. The results of sewage characterization are presented in Table 1. The results indicate most of parameters of sewage within permissible limits for irrigation purpose and presence of chromium (Cr), iron (Fe) and nickel (Ni) is absent. The effect of higher concentrations of pollutants in sewage on plant growth was studied by Nashikkar [13] and was concluded that seedling were retarded in initial stages. Partially treated effluent adversely affected soil fertility, crop production and land value etc. Saeed-ur-Rehman et al. [14] found retarded growth of canola (Brassica) seeds at 20, 40, 60, 80 and 100% municipal wastewater with maximum inhibition at 100% compared to control.

Divya et al. [15] studied impacts of treated sewage effluent on seed germination and vigour index of monocots and dicot seeds whereas Akkjait and Nuamkongman [16] used soil amended with municipal solid waste incineration fly ash (MSWIFA) and sewage sludge (SS) as fertilizer substitutes on seed germination and growth parameters of sweet corn (*Zea mays* L.). It was found that combined use of MSWIFA and SS resulted in highest seed germination without addition of fertilizer on agricultural soil.

The quality assessment of industrial wastewater for safe irrigation was conducted by Pandey and Singh [17] and concluded that the permissible limit of these may enhance the organic matter percentage in soil, which may be useful for crop production and enriching soil fertility. High total suspended solids (TSS) and total dissolved solids (TDS) can also cause clogging in the soil, resulted in low amount of oxygen in dissolved form, which decrease the growth and development of the seedling [18]. Levy et al. [19] observed that wastewater irrigation may increase the pH, organic carbon, phosphate, but decreased water holding capacity (WHC) in soil after prolong use. It is obvious that prolong application of industrial wastewater which is rich in nutrients will tend to increase the soil nutrients but it is important to utilize the wastewater after treatment. High electrical conductivity in irrigated water may lead to accumulation of salts in crop land which may inhibit the availability of nutrients to many standing crops and also found DO level very low which again inhibit plant growth [20].

3.1 Characterization of soil

The soil used in the study was of clay loamy in nature with slightly acidic pH 6.8. The nitrogen phosphorous and potassium is 0.53%, 0.052% and 0.057% respectively, indicated the nutritional level of soil. Absence of Fe, Ni and Cr indicated non-possibility for their accumulation in crops as sewage too, earlier showed absence of all metals (Table 2). A high water holding capacity (9.14%) and organic carbon of 5.9% made the soil suitable for growth of crops. The cation exchange capacity was observed 15.3 meq/100 g which is good for plant growth.

For the experiment, two crops, *Kharif* and *Rabi* have been utilized. The different types of *Kharif* crop (i) Lady finger (ii) Pearl millet, and *Rabi* crop (i) Wheat (ii) Fenugreek (iii) Mustard (iv) Cluster bean has been used for growth with sewage water (*Table 3*).The crops were irrigated with 50% diluted sewage (1:1 sewage: water) and raw sewage separately as against control sample and growth observations were recorded after 4, 8, 12, and 35 days. Pandey and Singh [17] has used fertilizer factory waste and indicate significant increase in various parameters line EC, BOD, COD, phosphate TS, TDS, TSS etc. in comparison to the control. These values were compared with recommended standard norms otherwise it may cause salinity of soil and cause inhibitory effect on growth and yield of crop. Tomer and Singh [21] discussed that

Table 2: Physico-chemical characteristics of soil.

Parameters	Results
pH	6.83
Soil texture	Clay loam
Conductivity	0.033 mhos/cm
Water holding capacity	9.14 (% dry wt)
Cation exchange capacity	15.3 me/100g
Organic Carbon	6.9 %
Chromium	NIL
Iron	NIL
Nickel	NIL
Total Nitrogen	0.53%
Total Phosphorous	0.054%
Available Potassium	0.057 %

high temperature, acidic pH, higher concentration of inorganic salts, organic matter caused soil salinity and high osmotic pressure in the soil solution after irrigating with distillery effluent decreased the seed germination drastically. Uzair et al. [22] observed the effects of municipal wastewater on plant growth and their performance of plants grown in polluted water, where tree remained weak, having less height pronounced reduction in fresh and dry shoot and root weights.

3.2 Seeds germination

Germination was 100% with crops such as lady finger (LF), pearl millet (PM), wheat and fenugreek (F) after 4 days whereas it was 50% with mustard (M) on 4th day and 100% on 8th day. Germination was the slowest (100% after 8 days) with cluster bean (*Table 4*). The germination period seeds and harvesting period of crops depend on atmospheric temperature, moisture availability, soil characteristics and nature of crop. Some crops like paddy, sugar, cane take one year and bamboo takes several years for yielding the harvest. Manisha et al. [23] had studied the impact of sewage dilution (100, 75, 50, 20 and 0%) on seed germination and carbohydrate content of *Vigna unguiculata* seedlings. In their results, they found that 75% sewage dilution is better for seed germination and carbohydrate content. Reddy and Borse [4] reported increased seed germination in *Trigonella foenum* var. *Graccum* L. (methi) at lower concentration of sewage water. Pradhan et al. [24] studied the interactions between sewage irrigation and fertilizer levels on the growth and yield parameters of wheat and black gram in field conditions. No significant difference on the seed germination and yield of wheat and black gram was observed. Divya et al. [15] used 10-100% sewage effluent and found 10-30% dilution showed highest shoot, root length and maximum seedling whereas above 30% sewage addition, negative effects on growth was observed.

The presence of heavy metals in water is a serious problem because these elements can enter in food chain and the biological cycle. The adverse effect of heavy metal pollution and their phytotoxicity through the untreated sewage water was observed by Pandey and Tripathi (2) which showed that phytotoxic effects gives oxidative stress to growing plants. Heidari and Sarani [25] found inhibitory effect of lead and cadmium on seed germination, seedling growth and antioxidant enzyme activities of mustard crop mustard (*Sinapis arvensis* L.) at higher concentration (>300 μM).

3.3 Seedling and crop growth of *Kharif* crop

The observations from 4 days to 12 days majorly included length measurement of plumule and radicals, number of leaves, plant weight (both dry and wet)

Table 3: Composition of sewage.

Parameters	Results mg/l	Effluent standards for sewage water discharge on land for irrigation (NEERI, 1981)
pH	7.2	5.5–9.0
Temperature (ºC)	25ºC	Not exceed 40ºC
Turbidity (NTU)	18	–
Total solids (TS)	1640	–
Total dissolved solids (TDS)	1348	2100
Suspended solids (SS)	292	200
Conductivity (mhos/cm)	0.25	–
Chloride	187	600
Sulfate	26.6	1000
Ammonical nitrogen	5.3	50
Organic nitrogen	6.4	–
Total hardness	193	–
Ca hardness	121	–
Mg hardness	72	–
Phosphorous	1.89	–
Potassium	1.63	–
Iron	NIL	0.3
Chromium	NIL	0.1
Nickel	NIL	–
Chemical oxygen demand (COD)	200	250
Biological oxygen demand (BOD)	8	100

etc. whereas after 35 days, in addition to the above chlorophyll content from harvested crop was measured in all three replicates: sewage (50% and 100%) and the control. Jyoti and Laura (2014) used sewage water (50 and 100%) in pigeonpea crop and found that 100% sewage reduced the growth drastically whereas crop with 50% sewage had normal growth. Menon and Palathingal [26] also used sewage water for the growth of red amaranth (*Amaranthus tricolor*, WILLD.). It was found that nutritive value like vitamin C, protein,

Table 4: No. of seeds germinated of different crops (*Kharif & Rabi*) after 4 and 8 days.

Kharif & Rabi crops	No. of Seed sown in each pot	No. of Seed germinate in 4 days	% germination	No. of Seed germinate in 8 days	% germination
Lady finger	2.0	2.0	100%	–	–
Pearl millet	2.0	2.0	100%	–	–
Wheat	2.0	2.0	100%	–	–
Fenugreek	2.0	2.0	100%	–	–
Mustard	2.0	1.0	50%	2.0	100%
Cluster bean	2.0	1.0	50%	2.0	100%

N, P and iron content was more in plants irrigated with sewage water whereas other morphological characters like root and shoot length, size of the lamina, length of the internode, fresh weight and dry weight were found to be lower than plants irrigated with potable water.

The crops grown in *Kharif* were lady finger and pearl millet. Diluted sewage supported crop better in terms of plumule, root and weight of crops

Table 5a: Growth Pattern of *kharif* crop (Lady Finger and Pearl Millet; 4, 8 and 12 days).

Sample	**Length of plumule (cm)**		**Length of radical (cm)**		**Plant wet weight (mg)**		**Plant dry weight (mg)**		**Number of leaves**	
					4 days crop					
	LF	PM	LF	PM	LF	PM	LF	PM	LF	PM
Water	1.92	0.53	2.78	1.62	76.2	74.5	26.6	25.2		
Sewage + Water	2.32	0.72	3.32	3.25	95.8	96.5	37.2	28.5		
Sewage	1.55	0.48	2.27	1.46	62.3	53.5	23.5	16.8		
					8 days crop					
Water	6.14	4.52	4.52	3.93	287.0	235.2	105.5	65.3	2.0	2.0
Sewage + Water	7.52	5.32	4.93	4.45	398.7	346.3	128.2	85.2	2.0	2.0
Sewage	5.75	3.27	3.87	2.87	265.2	232.5	96.3	53.7	2.0	2.0
					12 days crop					
Water	8.58	7.56	5.85	5.23	678.2	768.25	145.7	236.2	2.0	2.0
Sewage + Water	9.85	8.83	6.70	6.36	751.2	883.76	236.2	338.7	2.0	3.0
Sewage	8.12	6.12	4.32	4.89	605.7	756.38	118.5	223.5	2.0	2.0

Note LF: Lady Finger; PM: Pearl Millet

Table 5b: Growth Pattern of *kharif* crop (Lady Finger and Pearl Millet; 35 days).

Sample	Shoot length (cm)		Root length (cm)		Plant height (cm)		Plant wet wt. (mg)		Plant dry wt. (mg)		No. of leaves		Chlorophyll (mg/g)	
	LF	PM	LF	PM	LF	PM	LF	PM	LF	PM	LF	PM	LF	PM
Water	18.9	6.2	6.2	6.86	21.5	21.5	4667.9	3899.8	2846.3	2319.5	4.0	4.0	1.35	1.36
Sewage + Water	19.8	8.6	7.1	7.07	22.6	22.8	5593.8	4518.6	3680.6	2863.9	4.0	5.0	1.43	1.45
Sewage	16.6	5.1	5.9	6.23	19.4	20.6	4236.6	3443.5	2623.5	2065.2	3.0	3.0	1.30	1.30

Note LF: Lady Finger; PM: Pearl Millet

throughout, the growth period than with control and undiluted sewage. The enhanced growth characteristics of crops from 4 days to 35 days indicated the facilitating role of sewage (Table 5 a, b) after 35 days. Thangavel and Balagurunathan [27] studied the effect of tannery effluent on germination and growth of certain plants crop. Dilution of effluent at 75 times showed the highest germination percentage in all the crops tried, but 50 times dilution showed the maximum shoot and root lengths. The inhibition and promotion in both germination and growth were due to high and low salt concentration at lower and higher dilution respectively and the increased length of root and shoot might be due to the nutrients contained by the effluent.

Biomass of the crops includes its weight and is overall representation of several plant characteristics. Hence, wet weights of harvested crops after 35 days were measured at different combinations of sewage and mentioned in Table 5a & b. The maximum wet weight 5593.8 mg was observed in lady finger and minimum 4518.6 mg in Pearl millet in 1:1 mixture of sewage and water. The wet weight in sewage is 4236.6 mg in Lady Finger and 3443.5 mg in Pearl millet which is lesser, than control which is 4667.9 mg, 3899.8 mg respectively in Lady Finger and Pearl millet (Table 5a). At the end of 12 days the length of plumule and length of radical found maximum 9.85 cm and 6.7 cm in lady finger and pearl millet respectively in combination of water and sewage. In the end of 35 days as plant grow well its shoot and root length taken into consideration and found that length of plumule and radical was maximum in water and sewage (1:1) mixture (Table 5b).

The total number of leaves was found same in water and in combination with sewage but less in sewage. The chlorophyll content is 1.43 mg/g and 1.45 mg/g in combination of sewage and water in lady finger and pearl millet, respectively (Table 5b). These result indicates that nutrients which were supplied through sewage get diluted in mixture (1:1) ratio and is perfect for the growth of plant where as raw sewage shows inhibition in every parameter whether it is length of plumule, radical or number of leaves and plant dry and wet weight etc. Malla et al. [28] studied the short term effect of sewage for irrigation on Indian Spinach, carrot and cauliflower and, found that sewage irrigation improved physico-chemical properties and fertility. Zaki and Shaaban [29] used primary and secondary treated sewage effluent on growth, yield and yield component of sunflower (*Helianthus annuus* L.var. Euroflour). It was observed that the growth parameters such as plant height, stem length, root length, number of leaves plant^{-1}, chlorophyll and carotenoid content, etc. increased as the plants were irrigated with treated sewage water compared to control plants (irrigated with well water). So, the authors concluded that treated sewage water can safely be used for irrigation.

3.4 Seedling and crop growth of *Rabi* crop

In *Rabi* crop wheat, fenugreek, mustard and cluster bean have been used for experimentation. The experiment conditions are same as in *Kharif* except natural conditions and same observations were found in these crops also. The maximum efficiency was found in sewage water mixture in all observations except in chlorophyll which is overall having less amount means ranges 0.45 to 0.63 mg/g but higher range was 1.18 to 1.23 mg/g. Here, the maximum chlorophyll in 1:1 (sewage:water) mixture was 1.2 mg/g in mustard and 0.62 mg/g in cluster bean. It was also concluded by some authors that chlorophyll and protein content was very sensitive to pollutants and thus could be used as bio indicators.

The total plant wet weight and dry weights have the same trend in *Rabi* and *Kharif* crops. The maximum wet weight in wheat (*Rabi* crop) is 4845.5 mg in sewage + water (1:1) mixture and minimum 776.8 mg in fenugreek, where as in raw sewage the maxim+um wet weight was 3897.9 mg in wheat crop and minimum was 585.9 mg in fenugreek; which is lesser than control 4339.7 and 643.6 mg, respectively, in wheat and fenugreek. This shows some inhibition in crop growth irrigated with raw sewage. Similar pattern shown in *Kharif* crop where maximum wet weight was 5593.8 in lady finger and minimum was 4518.6 mg in Pearl millet in 1:1 mixture of sewage + water. Again raw sewage shows least value.

The average plant wet and dry weight of *Rabi* crop is presented in (Table 6a, b and 7a, b). The total percent increase in wet weight of plant (20.08% in fenugreek) was observed in mixture (1:1 sewage:water) over control (water) followed by 15.57, 15 and 11.65% respectively, in cluster bean, mustard and wheat. Whereas decrease in 8.9% in fenugreek, 9.29% in cluster bean, 4.55% in mustard and 10.18% in wheat was observed in raw sewage.

Table 6a: Growth pattern of *Rabi* Crop (Mustard and Cluster bean; 4, 8 and 12 days).

Sample	Length of plumule (cm)		Length of radical (cm)		Plant wet weight (mg)		Plant dry weight (mg)		Number of leaves	
4 days crop										
	Must	CB	Must	CB	Must	CB	Must	CB	Must	CB
Water	1.63	1.75	1.32	1.21	43.7	36.9	16.5	18.9	2.0	2.0
Sewage + Water	1.86	1.89	1.75	1.65	55.6	47.8	20.2	20.6	2.0	2.0
Sewage	1.35	1.32	1.12	1.16	32.3	30.5	14.3	16.5	2.0	2.0
8 days crop										
Water	3.55	2.75	2.15	2.16	189.2	98.7	98.5	26.3	2.0	2.0
Sewage + Water	4.65	3.32	2.37	2.25	221.6	110.4	118.9	48.5	2.0	2.0
Sewage	3.18	2.13	1.63	1.89	123.5	86.8	53.2	21.7	2.0	2.0
12 days crop										
Water	6.86	5.72	3.65	3.75	365.1	247.6	195.2	123.5	2.0	2.0
Sewage + Water	7.42	5.93	5.62	4.87	478.8	338.5	232.5	186.2	2.0	2.0
Sewage	5.63	4.85	3.56	2.63	354.3	223.2	158.6	116.8	2.0	2.0

M – Mustard; CB -Cluster bean

In *Kharif* crop, the maximum increase in plant wet weight was found again in sewage and water (1:1) mixture which is 19.83 mg in lady finger and 15.86 mg in pearl millet and decrease over the control in sewage is –9.23 and –11.7 mg, respectively.

Table 6b: Growth pattern of *Rabi* Crop (Mustard and Cluster bean; 35 days).

Sample	Shoot length (cm)		Root length (cm)		Plant height (cm)		Plant wet wt. (mg)		Plant dry wt. (mg)		No. of leaves		Chlorophyll (mg/g)	
	Must	CB	Must	CB	Must	CB	Must	CB	Must	CB	Must	CB	Must	CB
Water	9.55	6.5	5.56	5.6	12.8	7.8	2085.6	1355.2	905.6	576.6	4.0	4.0	1.20	0.53
Sewage + Water	10.82	7.3	7.86	5.9	14.5	8.5	2398.5	1545.7	986.5	689.3	4.0	4.0	1.23	0.62
Sewage	8.16	6.2	4.12	4.5	11.2	7.3	1889.7	1228.6	898.9	456.8	4.0	4.0	1.18	0.45

Must – Mustard; CB -Cluster bean

3.5 Plant dry weight

The dry weight of the plant in both *Rabi* and *Kharif* crop have the same result as in wet weight. The percent of dry weight increase over the control in 1:1 ratio of sewage and water, where as it decreases in raw sewage. The total number of leaves is more or less same in control (only water) and in mixture of sewage and water (1:1) whereas it decreases in raw sewage. Same observations were found in chlorophyll content (*Table 5a, b; 6 a, b* and *7a, b*). Results indicated that concentrated sewage is inhibitory for growth may be due to excess of nutrient supplementation. The municipal waste such as garbage and sewage sludge has been used to improve the soil conditions. Aydin et al. [30] reported that sewage sludge is preferred because it has high amount of organic matter which affects the water holding capacity, nutrient availability and soil fertility positively by improving the physical and chemical features of soil. Therefore, reuse of sewage is one of the best options to reduce the stress but after some treatment because it creates both opportunities and problems [31].

Crops, as the basic source of essential substance and nutrients do not always contain sufficient amounts of these essential nutrients to meet dietary

Table 7a: Growth pattern of *Rabi* Crop (Wheat and Fenugreek; 4, 8 and 12 days).

Sample	Length of plumule (cm)		Length of radical (cm)		Plant wet weight (mg)		Plant dry weight (mg)		Number of leaves	
4 days crop										
	Wh	Fen	Wh	Fen	Wh	Fen	Wh	Fen	Wh	Fen
Water	0.4	0.95	1.3	1.12	75.2	25.7	21.6	15.9	2.0	2.0
Sewage + Water	0.5	1.23	1.6	1.53	88.5	36.5	29.2	18.3	2.0	2.0
Sewage	0.3	0.78	1.2	0.95	64.3	19.7	18.5	10.8	2.0	2.0
8 days crop										
Water	1.6	2.98	3.5	1.89	236.5	69.6	129.3	23.8	2.0	2.0
Sewage + Water	1.8	3.15	3.8	2.13	348.2	98.7	198.6	34.5	2.0	2.0
Sewage	1.4	2.63	3.3	1.64	203.6	58.6	118.5	20.3	2.0	2.0
12 days crop										
Water	3.9	5.12	4.6	2.53	875.6	125.9	286.9	51.5	2.0	2.0
Sewage + Water	4.5	5.58	5.3	3.67	989.5	168.3	349.3	75.4	2.0	2.0
Sewage	3.6	4.52	4.2	2.98	864.8	108.6	278.6	45.2	2.0	2.0

Wh – Wheat; Fen – Fenugreek

Table 7b: Growth pattern of *Rabi* Crop (Wheat and Fenugreek; 35 days).

Sample	Shoot length (cm)		Root length (cm)		Plant height (cm)		Plant wet wt. (mg)		Plant dry wt. (mg)		No. of leaves		Chlorophyll (mg/g)	
	Wh	Fen	Wh	Fen	Wh	Fen	Wh	Fen	Wh	Fen	Wh	Fen	Wh	Fen
Water	16.36	8.56	6.24	4.58	22.6	9.32	4339.7	643.6	2264.2	289.6	4.0	4.0	1.25	1.23
Sewage + Water	18.25	8.92	6.85	5.07	23.5	9.34	4845.5	776.8	2553.5	358.6	4.0	4.0	1.36	1.36
Sewage	15.33	7.76	6.15	4.35	20.8	8.25	3897.9	585.9	2055.6	235.2	4.0	4.0	1.23	1.15

Wh – Wheat; Fen – Fenugreek

requirements. The application of N, P, K, S and organic carbon fertilizers generally increases crop yield as well as nutritional quality. For example, fertilizer increased protein concentration in cereals and pulses, oil conc. in soil seed crops, starch conc. in tubers and concentration of essential amino acids and vitamin in vegetables. However, excessive fertilizer application especially nitrogen fertilizer, can result in undesirable changes such as increase in nitrate, acid to sugar ratio [32].

3.6 Soil analysis after 35days

During the growth of crops after 35 days, the soil was estimated for major chemical characteristic such as organic carbon and nutrients like N, P, K (Table 8). Organic carbon, Nitrogen, phosphorous and potassium in soil irrigated with undiluted sewage was highest with *Kharif* crops whereas in control it was the lowest. Similar findings were found with *Rabi* crop also. Malla et al. [28] studied the short term effect of different dilutions of sewage water on physico-chemical properties of sandy loam and sandy clay loam soil and found the improvement of soil structure in short times.

Nitrogen is major plant nutrient contributed due to sewage. After incorporation into protoplasm, in bacteria, unutilized portion appears as residue in soil. Potassium and phosphorous levels in soil contributed due to crop irrigation with sewage. By comparing the soil characteristics of 35 days with original soil characteristics (Table 8) it is observed that major change observed with OC and N, whereas it was insignificant with P and K. It can also happen that leguminous plants fix atmospheric N_2 and enrich soil with nitrate. Hence, there would be change in C/N ratio of original soil and crop growth soil. The increase in N, P and K content of soil with prolonged irrigation was also reported by Waly et al. [33]. Ramirez et al. [34] reported the carbon nitrogen dynamics in soil irrigated with water for different lengths of time and assessed the impact on crop growth.

Table 8: Soil analysis (nitrogen, phosphorous, potassium and organic carbon) of *Kharif* and Rabi crops after 35 days.

Crop	Soil analysis	Nitrogen (mg/g)	Phosphorous (mg/g)	Potassium (mg/g)	Organic Carbon (%)
		Kharif crops			
Control	Water	1.53	0.054	0.055	6.1
	Soil+sewage+water	1.66	0.069	0.079	5.8
	Soil+sewage	1.75	0.078	0.085	6.0
Lady finger	Water	1.10	0.053	0.055	4.3
	Soil+sewage+water	1.52	0.056	0.065	4.4
	Soil+sewage	1.66	0.070	0.074	4.9
Pearl millet	Water	1.20	0.052	0.056	4.3
	Soil+sewage+water	1.50	0.041	0.064	4.4
	Soil+sewage	1.64	0.068	0.075	4.7
		Rabi crops			
Control	Soil+ water	1.58	0.062	0.069	5.2
	Soil+ sewage+ water	1.69	0.068	0.077	5.9
	Soil+ sewage	1.78	0.079	0.086	6.3
Wheat	Soil+ water	1.00	0.052	0.056	4.4
	Soil+ sewage+ water	1.55	0.055	0.062	5.1
	Soil+ sewage	1.68	0.068	0.075	3.7
Fenugreek	Soil+ water	1.20	0.052	0.057	3.7
	Soil+ sewage+ water	1.54	0.056	0.063	4.2
	Soil+ sewage	1.69	0.069	0.076	4.9
Mustard	Soil+ water	1.20	0.052	0.056	4.3
	Soil+ sewage+ water	1.53	0.054	0.063	4.4
	Soil+ sewage	1.65	0.068	0.074	4.9
Cluster bean	Soil+ water	1.20	0.052	0.054	4.3
	Soil+ sewage+ water	1.52	0.055	0.062	4.2
	Soil+ sewage	1.65	0.069	0.073	4.9

The availability of N, P and K, organic carbon and metallic cation content values were significantly higher in sandy clay loam soil than in sandy loam soil. Sandy loam soil contained a higher value of a $CaCO_3$ content which decreased on application of sewage water as such or in its dilution. The sludge application increased soil organic matter associated nutrients and improved physical properties. However, soil electrical conductivity increased with increasing sludge application to levels that may affect growth of salt sensitive crops and works against long term application that may impair essential soil functions.

Bansal [35] studied heavy metal pollution in soil and plant (barley and corn) due to sewage irrigation. Soil and plants under sewage irrigation showed higher concentration of heavy metals when compared to field irrigated by tube well water. Metabolic activity of soil microorganisms have also been reported to increase when sewage effluent is used for irrigation [36]. The important aspect of sewage water irrigation is that it contributes in reducing stress on the amount of water that needs to be extracted from environmental water sources [37] for various purposes like for agriculture. Raw and untreated sewage in injudicious due to accumulation of heavy metals but the sewage used in this study (Thapar Campus) was not having any metal.

Pietz [38] reported that increase of corn crop yield was due to sewage adding up N, P, K, Fe and organic carbon to soil. The germination and growth of crops generally depends on quality of seeds, climatic conditions, soil characteristics such as water and air content, biota and type of crops cultivation. Although several parameters were not considered within the scope of study, the results obtained were quite interesting and optimizing all the operating variables is an essential.

CONCLUSIONS

Based on the results obtained and discussions made, following conclusions are drawn:

1. The germination period varied seed to seed. It was early in crops of *Kharif* (100% germination in 4 days) and delayed in crops of *Rabi* (100% germination in 8 days). However, the unseen factors behind and controlling the germination are matter of interest.
2. Sewage diluted 50% is very efficient for growing the crops than water alone or undiluted sewage. The absence of metals in sewage and soil showed their non-possibility of accumulation in crops. Biomass of crops of *Kharif* is found higher than that of *Rabi* season.
3. The composition of sewage also reveals that it requires treatment before it is applied to grow crops. The type of treatment to be adapted should consider technical and economical aspects.
4. Sewage besides supporting the growth of crops, left nutrients into the soil thus enriching its quality. Organic carbon, nitrogen was found major in

5. comparison to other nutrients C/N like phosphorous, potassium. Change of C/N ratio of treated soil than original soil decides the further sustainability of soil for crop growth.

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