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Peri-Urban Vertisol Properties as Influenced by Sewage and Bore Well Water Irrigation to Wheat (*Triticum aestivum* L.)

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Abstract

Field experiment was conducted in farmer's field near Agricultural Research Station, Dharwad, Karnataka State, India which was on the bank domestic sewage course in split plot design with three replications. Main plots included two types of lands (land irrigated with sewage water since 1970 and land irrigated with bore well water since 1992). Sub plots allotted with sources of irrigation consisted of sewage alone, bore well water alone (good water) and alternate sewage and bore well water. Analysis of sewage water for major and minor plant nutrients content revealed its potential as source of nutrients and water for crop growth. The soil physical properties especially bulk density and moisture holding capacity was improved significantly in sewage land over bore well irrigated land. Yield of wheat crop was positively correlated with these soil properties. There was reduction in soil pH in sewage land (7.24) over bore well irrigated land (7.65). The sewage irrigated land recorded significantly more bacterial and fungal colonies, dehydrogenase and alkaline phosphatase enzymes activities in soil. Sources of irrigation also differed significantly producing the highest microbial colonies, phosphatase and dehydrogenase enzymes activity in sewage water irrigation treatment followed by alternate irrigation as sewage water is good source of organic phosphorus (11.9–17.3 ppm). Irrigation with sewage water improved the performance of wheat crop as evidenced by higher grain yield (4100 kg ha^{-1}), protein content in grains (12.8%), and dry gluten (8.9%) compared to bore well water irrigation. Characterization of domestic sewage effluent showed that it can be used as source of irrigation water and top dressing nutrients.

Keywords: Sewage; Land; Irrigation; Bacteria; Fungi; Dehydrogenase; Phosphatase; Yield

Introduction

Sewage is defined as the waste water of a community [1]. Typical content of organic and inorganic suspended solids range from 100-350 mg l^{-1}. The suspended solids content is very important parameter in evaluating sewage for irrigation since they clog the soil pores and components of water distribution system. The composition of sewage of tropical and temperate countries was given by Mara and are as follows Table 1.

These composition sewage effluents vary from time to time even at same location depending on developmental activities and volume of water used domestic purpose. Discharge of huge volume of waste water originated from domestic, commercial, industrial and other public uses into natural water sources makes them unfit for human usage. Every year about 300 million tons of organic waste is generating in India and fertilizer potential of this organic biomass has been estimated at around 15 million tons. In India, sewage farming alone could contribute 16,000 tons of nutrients per annum [2].

Thus irrigation with sewage provides the crop a cheap source of water, nutrients and at the same time avoids problem of its disposal [3,4]. Utilization of this domestic sewage for crop production may reduce the amount of water pollution as well as serve as water and nutrient source for crop. And same time numerous micro-organisms possibly present in the sewage water moves through the soil is of more concern. Evaluating the particular sewage on health of plant and soil is need of the hour in the context of safe recycling of waste water. Application of sewage caused reduction in yield of crops due to presence of plant pathogens [5,6]. Baraman [7] observed adverse effects of sewage irrigation on growth and yield of pulses and oil seeds. In contrast, sewage irrigation improved the yield of several crops [8-10]. Sewage irrigation supported the population of N-fixers such as Azotobacter, Rhizobium and fungi involved in organic matter decomposition [11]. The plant pathogens present in sewage subjected to normal die-off which takes several weeks to few months [12].

With these ideas, a field experiment was conducted to study the effect of sewage irrigation on physico-chemical properties and microbial dynamics in the sewage irrigated soil vis-a-vis bore well water irrigation.

Material and Methods

Description of location and experimental layout

The field experiment was conducted on farmers field in Dharwad (15° 26' N latitude, 75° 07'E longitude, altitude of 678m MSL), Karnataka state, India during winter seasons for two consecutive years. Experimental site receives a mean annual rainfall of 762 mm which is fairly distributed from April to December. Both, sewage irrigated land and bore well irrigated lands were silt clay loam. More than 80 million liters of waste water generating from Hubli-Dharwad twin cities, second largest in Karnataka State, India is mainly domestic origin. The sewerage system for Dharwad city was divided into four drainage streams, determined by topography of the city; Madihal, Hirekeri, Narendra and Lakamanhalli. Untreated sewage water of Dharwad joins to number of small streams on its way to Tupari a large stream which ultimately meets Malaprabha River, a main potable water source for Hubli - Dharwad city. It may continue to pollute all water sources on its course. Majority of farmers are unaware of its potentiality as a source of nutrients and in fact they have notion that sewage water will spoil their soil and crops grown even under good management system. The experiment was laid out in split plot design with three replications. Main plots constituted two types of lands (land irrigated with sewage since 1970 and land irrigated with bore well since 1992). These two types of lands were situated in contiguous, but separated by field bund. Bore well irrigated land had never received sewage irrigation and vice-versa. Sub plots allotted with sources of irrigation consisted of sewage alone, bore well water alone (best available water for irrigation) and alternate sewage and bore well water. The recommended dose chemical fertilizer to wheat crop was 100:75:50 kg N, P_2O_5 and K_2O per hectare. These nitrogen, phosphorus and potash were applied in the form of urea, diammonium phosphate and muriate of potash respectively. The crop was harvested at 105 DAP. Grain yield and yield attributes were recorded at the time of harvesting. Treatment wise soil samples were collected before layout of experiment and after crop harvest for analysis of physico-chemical properties and microbial dynamics.

At each irrigation sewage effluent and bore well water were collected for characterization with respect its physico-chemical properties.

Components	Concentration (mg 1^{-1})						
	Kenya (Nairobi)	Kenya(Nakurh)	India (Kodungaiyur)	Peru (Lima)	Israel (Herzliya)	USA (Allenown)	UK (Yeoril)
BOD (mg l^{-1})	448	940	282	175	285	213	324
Total soluble solids (g l^{-1})	550	662	402	196	427	186	321
Total dissolved solids (g l^{-1})	503	611	1060	1187	1094	502	-
Chlorides (ppm)	50	62	205	-	163	96	315
Ammonical N (ppm)	67	72	30	-	76	12	29

Table 1: Composition of sewage of tropical and temperate countries.

Planting and after care

Bread wheat variety *Triticum aestivum*, DWR-162 was planted at the seed rate of 150 kg ha^{-1} in 22.5 cm row spacing on November 1st in both the years. Bore well water was provided immediately after planting for both the lands and thereafter the crop was irrigated (boarder strip) as per treatments based on crop critical stages approach for irrigation (crown root initiation, peak tillering production, flowering, grain formation, grain development and grain dough stage).Depth of water provided at each irrigation was 60 mm. Crop was inter cultivated at 25 and 45 days after planting (DAP). Crop was top dressed two times with 30 kg nitrogen in the form of urea at boot leaf stage and at a thesis. Weeds were managed with post emergent spray of 2-4-D at the rate of 2.5 liters ha-1 on 20 DAPS. One hand weeding and two inter cultivations were also carried out to keep weeds under control. The major pest of the region like termites and leaf rust were not notice on the crops in both sewage and bore well irrigated lands.

Analysis of soil and plant samples for estimation of nutrients

The soil samples collected from 0-30 cm depth after harvest of crop were analyzed for some of the physico-chemical properties. The procedures adopted for estimation and initial soil test results were presented in Table 2. EC dS m^{-1}, pH, organic carbon %, available N kg ha^{-1}, P_2O_5 kg ha^{-1}, K_2O kg ha^{-1}, DTPA extractable Cu ppm, Fe ppm, Mn ppm and Zn ppm in sewage irrigated land were 0.42, 7.3, 0.86, 235.8, 29.5, 458.6, 1.61, 6.50, 18.50 and 0.42; whereas for bore well irrigated land these values were 0.31, 7.95, 0.43, 141.5, 17.90, 387.5, 1.18, 4.06, 12.20 and 0.23 respectively [13].

Properties	Sewage land	Bore well irrigated land	Method
I. Physical properties			
1. Particle size analysis			
Coarse sand (%)	6.1	6.5	International pipette method [14]
Fine sand (%)	16.5	15.7	
Silt (%)	18.5	18.1	
Clay (%)	58.5	59.3	
2. Bulk density (Mg m^{-3})	1.23	1.32	Core sampler method [15]
II. Chemical properties			
Electrical conductivity (dS m-l)	0.42	0.31	EC bridge [16]
pH	7.3	7.95	1 : 2.5 soil: water suspension [16]
Organic carbon (%)	0.86	0.43	Walkley and Black's wet oxidation method [16]
Available N (kg ha^{-l})	235.8	141.5	Alkaline permanganate method [17]
Available P_2O_5 (kg ha^{-l})	29.5	17.9	Olsen's method [18]
Available K_2O (kg ha^{-l})	458.6	387.5	Extraction with NH40AC [15]

Table 2: Methods employed to estimate physico-chemical properties of experimental soils

Characterization of sewage and bore well water

Sewage effluent samples collected during cropping season were analyzed for physico-chemical properties viz., BOD_5 (ppm), total solids(g l^{-1}), pH, electric conductivity (dS m^{-1}), chlorides (me l^{-1}),

SO_4(me l^{-1}), total Kjeldal N (ppm), total P (ppm) according to Standard Methods proposed by American Public Health Association APHA [19]. The mean data were presented in Table 3. The COD concentration was determined by the closed reflux, colorimetric method (Standard Method (SM) 5220 D). The BOD (5) was determined using the manometric method (SM 5210 D), in which the sample was digested during 5 days of incubation on a shaker base at 20 ± 1°C. The TDS were determined using SM 2540 B, in which the samples were centrifuged at 4,000 rpm for 20 min and dried to a constant weight at 105°C. The samples were filtered within 12 h of collection, and the filter was frozen prior to extraction. Total coliform analyses were performed using a chromogenic medium. The samples were analyzed using the Quanti-Tray®/2000 Inc.) method and were incubated at 37°C for 24 h. Yellow wells indicated total coliforms, and yellow/fluorescent wells indicated the presence of *E. coli.*

Character	Value	Character	Value
pH	7.54	SO4(me l^{-1})	7.75
EC (dS m^{-1})	0.79	Kjeldal N (ppm)	29.2
Total solids(g l^{-1})	708.5	Total P (ppm)	13.1
BOD5 (ppm)	141.4	Total K(ppm)	54.7
Chlorides(me l^{-1})	8.4	Ca (ppm)	10.85
Mg (ppm)	6.38	Mn (ppm)	0.15
Na (ppm)	47.6	Cd (ppm)	BDL
Zn (ppm)	0.31	Ni (ppm)	BDL
Cu (ppm)	0.16	Cr (ppm)	0.004
Fe (ppm)	1.24	Pb(ppm)	0.029
Microbial population in sewage water used for irrigation			
Total bacteria colonies	12.5 to 15.5 x 10^{-6}	Total Actinomycetes	1..0 to 1.5 x10^{-4}
Total fungi colonies	2.8 to 4.5 x 10^{-5}	Total E coli	4.2 to 5.0x10^{-5}

Table 3: Sewage effluent characters and microbial population in sewage during cropping season (mean of two years)

Microbial estimation in soil and sewage water

Freshly collected sewage water and soils irrigated with sewage and bore well water were estimated for total bacterial, fungal actinomycetes population by standard serial dilution plate count method using soil extract agar for bacteria [20], Martin rose Bengal agar for fungi [21] and Kuster's agar for actinomycetes [22]. Coliforms were estimated in sewage samples using eosine methylene blue (EMB). Plates were incubated at 28 ± 2°C in an incubator and colony counts were recorded after 3 to 6 days of incubation. The microbial populations were expressed as number of colony forming units per g soil or per ml sewage water.

Enumeration of seed micro flora

Ten grams of seeds were suspended in 90 ml sterile distilled water in 150 ml Erinemeyer flask. It was hand shaken for five minutes and six fold serial dilutions were made using the above" suspension. One ml of each of the dilution was transferred into sterile triplicate plates for the isolation of bacteria, fungi and actinomycetes using nutrients agar, rose bengal agar and Kuster's agar respectively. Petri plates were incubated at 29 ± 1°C and average microbial counts were recorded on the 5th day of incubation [23].

Estimation of soil enzymes activity

Dehydrogenase enzyme activity in soil samples was determined by following the procedures as described by Casida et al. [24]. The values were expressed as mg TPF g^{-1} day^{-1}. Similarly alkaline phosphatase enzyme activity of soil samples was determined by procedure of Evazi and Tabutavbai [25]. And estimations were expressed as mg P-nitro phenol $g^{-1}h^{-1}$.

Statistical analysis

The data of various parameters on soil and plant growth, biochemical, biophysical and yield attributes recorded for 2 years was analyzed in triplicates and subjected to ANOVA (analysis of variance) in accordance to field design using M-Stat package to quantify and evaluate the sources of variation. All the pooled data collected from split plot design analysis were subjected to Duncan's multiple range test (DMRT). The treatment means were compared at a significant level of 0.05 and ranking of treatments denoted by alphabets. The treatments denoted by different letters in the each column of tables and figures represent significantly different values among the treatments.

Treatment	pH			EC (dS m^{-1})			Organic carbon (%)		
	First year	Second year	Pooled	First year	Second year	Pooled	First year	Second year	Pooled
Land (L)									
Sewage irrigated (L_1)	7.27a	7.22a	7.24a	0.420a	0.432a	0.426a	0.900a	0.886a	0.893a
Borewell irrigated (L_2)	7.63b	7.68b	7.65b	0.349b	0.348b	0.348b	0.428b	0.442b	0.435b
LSD (5%)	0.117	0.058	0.093	0.0505	0.0523	0.0365	0.0328	0.0535	0.0243
Source of irrigation (S)									
Sewage water (S_1)	7.35b	7.35b	7.35c	0.367a	0.400a	0.384a	0.682a	0.728a	0.705a
Borewell water (S_2)	7.53a	7.59a	7.56a	0.400a	0.375a	0.388a	0.628b	0.585c	0.606c
Alternate (S_3)	7.47ab	7.42b	7.44b	0.386a	0.392a	0.389a	0.680a	0.677b	0.679b
LSD (5%)	0.141	0.088	0.051	0.055	0.068	0.031	0.039	0.039	0.018

Table 4: Soil reaction (pH), electrical conductivity (dS m^{-1}) and organic carbon (%) after harvest of crop as influenced by types of lands and sources of irrigation (mean of two years) (a, b, c: Means followed by same letter do not differ significantly at 5 per cent level of significance)

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Results and Discussion

Influence of type of land

Bulk density soil was the lowest in sewage land (1.23 Mg m^{-3}) compared to bore well irrigated land (1.33 Mg m^{-3}) due to influence higher organic carbon accumulation over long period of sewage water irrigation. Sewage land (55.2%) had a capacity to hold maximum water compared to bore well irrigated land (50.8%) would be because of high porosity, low bulk density and better soil structure Table 3. Tripathi [26] also noticed improvement in soil properties Sewage land recorded the lowest soil pH (7.24) as a result of decomposition of added organic matter through sewage water during which organic acids and $C0_2$ must have been produced by soil microorganisms and those have been responsible for reduction in soil pH Table 4. Olaniya [27] also found decreased bulk density and increased electrical conductivity of soil due to application of municipal wastes. Sewage land increased the EC of soil significantly (0.43 dS m^{-1}). Increased EC in sewage land could be due to addition of salts of chlorides and sulphates through sewage water. Improvement in soil physical properties due to sewage irrigation was also noticed by Dodolina [28] and Salakinkop et al. [29]. Sewage land (0.89 %) accumulated significant and twice the organic carbon that was recorded in the bore well irrigated land (0.43%) (Table 5 and Figure 1).

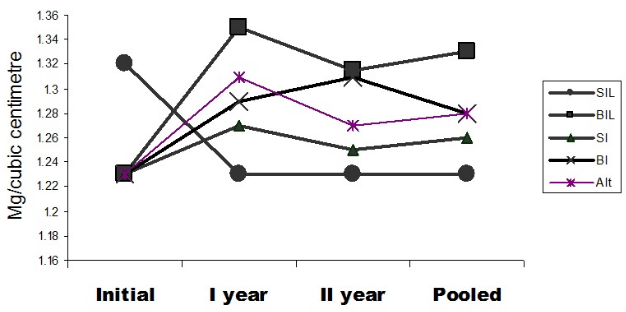

Figure 1: Organic Carbon as influenced by type of lands and sources of irrigation.

Biological activities and their influence on performance of wheat crop were studied in two types of lands Enumeration of colony forming units in the soil showed significantly higher bacterial and fungal population in sewage irrigated land compared to bore well irrigated land Table 4. Unnamalai et al. [30] also noticed increased colony farming units of microbes in industry wastes applied plots and sewage farms compared to control. Improved organic matter and nutrient status contributed by long term sewage irrigation encouraged the luxurious growth of micro-organisms and thereby enhanced enzymatic activities in sewage irrigated land. Stademan [31] noticed increased enzymatic activities in sewage sludge and pig slurry applied land. Alkaline phosphatase and acid phosphatase enzymes are responsible for converting organic phosphorus into available form. Both these enzymes were present significantly higher concentration in sewage irrigated land compared to bore well irrigated land. The concentration of alkaline phosphatase enzyme was almost double the concentration of acid phosphatase in both years. This was due to influence of soil pH on the relative dominance alkaline phosphatase producing micro-organisms. Presence of higher concentration phosphatase enzyme indicates more population of phosphorus solubilising micro-organisms.

Treatment	MWHC (%)			BD (Mgm^{-3})		
	First year	Second year	Pool ed	First year	Second year	Pool ed
Land (L)						
Sewage irrigated (L_1)	55.85a	54.58a	55.21 a	1.23a	1.23a	1.23a
Bore well irrigated (L_2)	51.17b	50.55b	50.86 b	1.35b	1.315b	1.33b
LSD (5%)	1.745	3.248	2.014	0.088	0.023	0.085
Source of irrigation (S)						
Sewage water (S_1)	53.72a	52.92a	53.32 a	1.27a	1.25a	1.26a
Bore well water (S_2)	53.06a	51.59a	52.32 a	1.29a	1.31a	1.28a
Alternate (S_3)	53.76a	53.19a	53.47 a	1.31a	1.27a	1.28a
LSD (5%)	2.137	3.978	1.457	0.111	0.039	0.036

Table 5: Maximum water holding capacity (%) and bulk density (Mg m^{-3}) of soil after harvest of crop as influenced by types of lands and sources of irrigation (mean of two years) a, b: Means followed by same letter do not differ significantly at 5 per cent level of significance. (*LSD applicable to Duncan's multiple range tests at 5 per cent; *Means followed by same letters do not differ significantly)

The organic form of phosphorus was converted to inorganic form as evidenced by improved available phosphorus in sewage irrigated land (30.9 kg ha^{-1}) compared to bore well irrigated land (24.5 kg ha^{-1}).Therefore there was positive and significant correlation between phosphates enzyme activity in soil and yield of wheat crop (0.62^*). Yield of crop depend on many growth factors which mainly include soil, climatic and plant parameters. In the present study soil properties mainly water holding capacity, bulk density and nutrient availability were improved resulting increased grain yield of wheat crop. Further growth and yield attributes of crop were also improved in sewage irrigated land compared to bore well irrigated land.

Similarly higher activity of microbes denoted by increased concentration of dehydrogenase enzyme was noticed in sewage irrigated land compared to bore well irrigated land Table 6. Shrikanthimathi and Salakinkop and Hunshal [32,33] also noticed higher activity of dehydrogenase enzyme and faster decomposition of organic material in sewage amended soil than unamended soil. This enzyme is responsible for decomposition of organic matter. The higher organic carbon content in sewage irrigated land (0.89 %) increased the activity of dehydrogenase enzyme and thereby improved available nutrient status especially nitrogen in sewage irrigated land. There is well established doubt that sewage water and sewage irrigated land pollute the grains by microbial contamination. Roger and Hessettine [34] recorded higher population of bacteria on surface of wheat grain followed by fungi and actinomycetes. Present study revealed that neither sewage water nor sewage irrigated land did increase the bacterial, fungal and actinomycetes colonies on grain surface compared to bore well water Table 4. But normal population of phyllosphere micro flora was observed on wheat grain surface.

Treatment	Bacteria	Fungi	Actinomycetes	Bacteria	Fungi	Actinomycetes
Land	**On surface of grains**			**In the root zone of crop**		
Sewage irrigated	34.67a	7.31a	2.69a	4.368a	12.88a	28.83a
Borewell irrigated	33.37b	6.65b	2.34b	3.365b	12.22b	27.17b
CD (5%)	2.35	1.33	0.87	0.325	0.259	2.162
Source of irrigation						
Sewage	33.88a	6.81a	2.52a	4.100a	12.81a	28.41a
Borewell	33.83a	7.04a	2.50a	3.557c	12.21b	27.14a
Alternate	34.33a	7.10a	2.54a	3.943a	12.64a	28.46a
CD (5%)	NS	NS	NS	0.2266	0.025	NS

Table 6: Population of bacteria, fungi and actinomycetes on grain surface (no. x10^{-4}) and in soil sample (no. x 10^{-5} g^{-1}) after harvest of crop as influenced by types of lands and sources of irrigation (mean of two years) a, b, c: Means followed by same letter do not differ significantly at 5 per cent level of significance.

Therefore sewage irrigated land recorded higher grain yield (4368 kg ha^{-1}) and protein per cent (12.88) compared to bore well irrigated land which produced 3365 kg ha^{-1} grains, 12.20 per cent protein content in grains Table 7 which could be due to increased soil productivity as evidenced by higher microbial population. Their enzymatic activities, organic matter and nutrients status in sewage irrigated land. Similarly improved yield of rice was noticed with use urban compost [35,36].

Influence of sources of irrigation

Sources of irrigation did not influence the bulk density. The highest bulk density of soil was noticed in bore well irrigated land under bore well irrigation and was on par with all interactions in bore well irrigated land Table 3 and Figure 2. Soil pH reduction was more in sewage water irrigation than alternate irrigation. Bore well water irrigation recorded the highest pH (7.56). Treatment interactions in sewage land recorded lower pH than interactions in bore well irrigated land. Sources of irrigation did not differ significantly to alter the soil electricity (EC) Table 4. Sewage water irrigation revealed the highest organic carbon content followed by alternate irrigation, whereas bore well water irrigation recorded the lowest. Higher number of soil bacterial and fungal colonies was noticed in both sewage and alternate irrigation than bore well water irrigation. Actinomycetes population did not influence by the sources of irrigation. Sewage irrigation supported the population of N-fixers and fungi involved in organic matter decomposition [11]. Microbes helped in composting of organic matters [37]. Deficiency of micronutrients especially Zn, Fe, Cu and Mn is common in black cotton soil due to intensive cultivation of HYV, hybrids, mono cropping and non-availability of sufficient organic sources of nutrient to correct the deficiency. Sewage effluent in present study corrected these deficiency and also supplemented the part of the major plant nutrients as effluent water contain considerably good amount of total N (29.2 ppm), total P (13.1ppm), total K (54.7 ppm), Zn (0.31ppm), Cu (0.16 ppm), Fe (1.24 ppm) and Mn (0.15 ppm). The nutrient content of the effluent used for irrigating wheat crop is presented Table 1. By looking at BOD levels, it was said that domestic originated sewage of present study was weak and fit for irrigation. Sewage effluent having BOD within 100-150 ppm was preferred for irrigation [38] and for wheat crop, it could be 260 ppm. Thus sewage water irrigation at critical stages of crops acted as top dressed fertilizers and thereby enhanced the activity of bacteria, fungi and actinomycetes. Organic matter and nutrients present in sewage water acted as source of carbon and energy for microbes due to which there was maximum bacterial and fungal colonies in sewage and alternate irrigation treatments. Further, increased beneficial microbes must have also contributed to available nutrient pool as they decompose the organic matter added through sewage Figure 3.

Treatment	Alkaline phosphatase (mg P-nitrophenol g^{-1} h^{-1})			Dehdrogenase (mg TPF g^{-1} day^{-1})			Avail. P (Kg ha^{-1})
	First year	Second year	Pooled	First year	Second year	Pooled	Pooled
Land							
Sewage irrigated	99.77a	107.41a	103.59a	34.83a	42.38a	38.61a	30.98a
Borewell irrigated	88.45b	88.92b	88.19b	27.17b	28.30b	27.74b	24.50b
CD (5%)	3.8	5.42	2.79	2.15	4.28	2.11	1.87
Source of irrigation							
Sewage	96.92b	101.00a	98.94b	32.50a	38.15a	35.33a	29.52a
Borewell	83.74c	86.66b	85.20c	28.63b	32.50b	30.56c	25.48b
Alternate	101.70a	105.40a	103.50a	31.88a	35.39ab	33.63b	28.23a
CD (5%)	4.65	4.99	2.2	1.66	3.98	1.42	1.47

Table 7: Alkaline phosphatase and acid phosphatase activity (mg P-nitrophenol g^{-1} h^{-1}) in soil as influenced by types of lands and sources of irrigation(mean of two years) a, b, c: Means followed by same letter do not differ significantly at 5 per cent level of significance.

The maximum decomposition of organic matter could be evidenced by significantly the highest dehydrogenase activity in sewage water irrigation (35.3 mg TPF g^{-1} day^{-1}) followed by alternate irrigation (33.6 mg TPF g^{-1} day^{-1}). The sewage water irrigation recorded higher acid and alkaline phosphatase activity as sewage itself was good source of organic phosphorus (11.9 – 17.3 ppm) Table 6. Yield of wheat crop positively correlated with enzyme activities of microbes Figure 4.

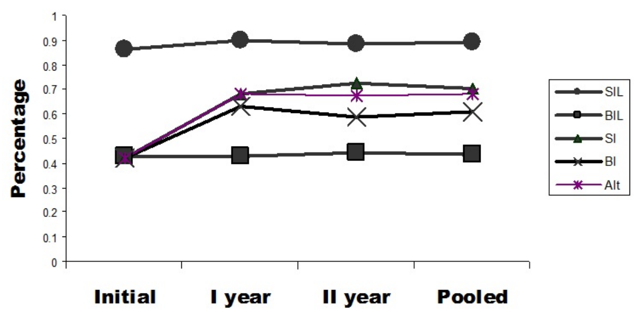

Figure 2: Bulk density as influenced by type of lands and sources of irrigation.

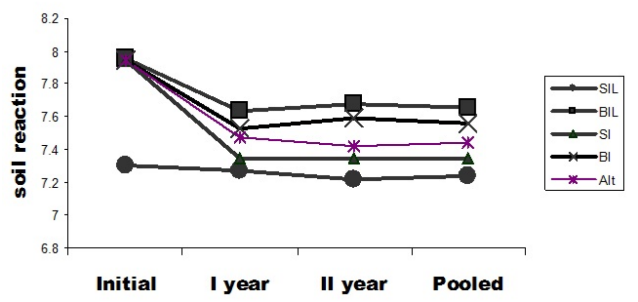

Figure 3: pH as influenced by type of lands and sources of irrigation.

Sources of irrigation did not differ significantly with respect to bacterial, fungal and actinomycetes population on grain surface Table 5. Normal populations of phyllosphere microflora were observed. Radhakrishna [39] also isolated population of bacteria from sorghum ears at different stages of maturation under sewage irrigation.

Sources of irrigation differed significantly having the highest grain yield in sewage irrigation (4100 kg ha^{-1}) followed by alternate irrigation (3940 kg ha^{-1}) Table 7. The conjunctive use of sewage and good water has also been recommended to improve the yield of many crops without pollution effect [40,41]. The bore well water irrigation recorded the lowest grain yield (3550 kg ha^{-1}).

Wheat grain protein and gluten contents were also the highest in sewage irrigation followed by alternate irrigation compared to bore well irrigation. Bore well irrigation did not increase the protein content and subsequently the gluten because of limited supply of nitrogen. Whereas, in sewage irrigation and alternate irrigation, the nitrogen contribution would have increased the nitrogen content in grain and ultimately protein and grain yield.

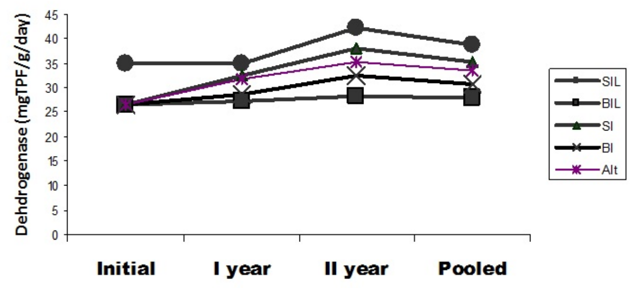

Figure 4: Dehydrgenase activity as influenced by type of lands and sources of irrigation.

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