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Utilization of Coffee Pulp Effluent in Agriculture and Its Impact on Soil and Water Environment

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Abstract

The studies on chemical and biological nature of coffee pulp effluent samples collected at monthly intervals during October to March, 2003-04 from 22 different pulping units located at Chikmagalur, Hassan and Coorg districts of Karnataka revealed that coffee pulp effluent is highly acidic in reaction (pH : 3.9) and had high soluble salt content (1.71 dS/m). The total suspended solids (4,360 mg/liter), dissolved solids (6,350 mg/liter), BOD (13,784 mg/liter) and COD (25,912 mg/liter) were above the ISI limits. There was variation in the composition of pulp effluent during different months of collection and also from one pulping unit to another. The coffee pulp effluent is poor in major nutrients (N : 0.068, P : 0.003 and K : 0.048%) content but contains appreciable quantity of micronutrients (Fe : 17.17, Mn : 0.56, Zn : 0.51 and Cu : 1.57 ppm).The effluent had more number of fungal and bacterial colonies and less number of actinomycetes population. The beneficial microbes like N-fixers and phosphate solubilizers were in substantial number. The direct effect of effluent irrigation treatments on yield and quality of baby corn and soil properties indicated that alternate or 1 : 1 ratio of raw effluent and fresh water irrigations were found to be better with positive impact on the soil environment. However, treated effluent irrigations was found to improve the soil properties to a greater extent. The study on residual effect of effluent irrigations on yield and quality of rice and soil properties did not differ significantly. However, protein content of paddy grains and enzymes activities in the soils were significantly influenced by residual effect of raw effluent and treated effluent irrigations, respectively. The studies on impact of coffee pulp effluent discharge over the years on physico-chemical properties of soils indicated that fields, which received coffee pulp effluent over the years showed slight increase in the fertility status of soil as compared to other fields, which had no history of effluent application. The studies on surface and ground water quality nearby coffee pulping units of Karnataka revealed that there was no pollution hazard. Majority of water samples tested belongs to C_1S_1 and C_1S_2 class of USDA classification for irrigation purposes.
Key words : Coffee pulp effluent, Crops yield, Quality, Soil health, Water quality.

In the era of globalization and industrialization, there is increasing demand for good quality produce and pollution free environment. On the contrary, many of the industries make use of large quantities of good quality water and discharge the entire quantity in the form of waste water with the objectionable odor, taste and harmful constituents which may pose threat to soil and water, the two most important natural resources which hold the key for our safe living. Majority of the industries are agro-based and one such agro-based industry is coffee processing industry. Coffee is processed either by wet method or dry method to produce washed and unwashed coffee, respectively. The wet method of processing of coffee fruits results in superior quality coffee as compared to dry method of processing. Around 75—80% of *arabica* coffee and 10—15% of *robusta* coffee is processed by wet method as washed coffee. In this process, large quantities of pulp and pulp effluent are generated as major byproducts (Mburu and Mwaura 1996).In the coffee processing industries, while processing, 2.23 lakh tons of coffee through wet processing, 8.4 million m^3 of waste water is generated. The consumption of water varies from 9 to 13 m^3 and from 17 to 20 m^3 per ton of coffee processed with or without recycling, respectively (Mburu et al. 1994). The coffee pulp effluent is rich in pectins, sugars, mucilage and is known to have high biological oxy-

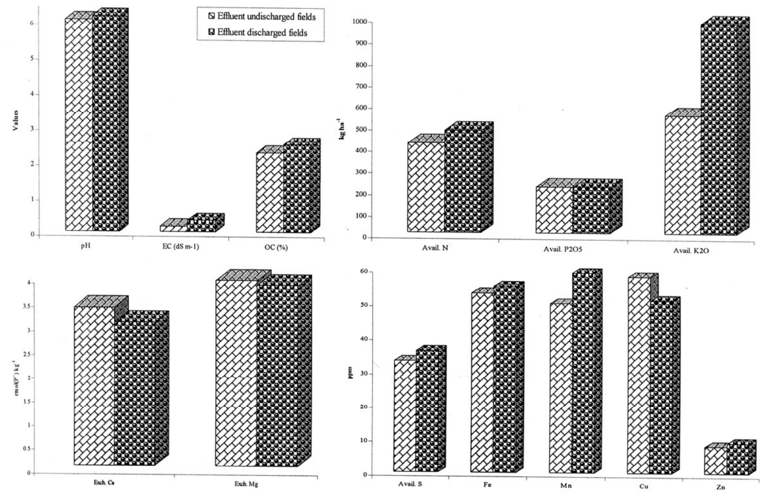

Figure 1. Physico-chemical properties of coffee pulp effluent discharged and undischarged fields.

gen demand (BOD), chemical oxygen demand (COD), total suspended solids and dissolved solids with very low pH of 4 to 4.5 (Anand Alwar (1998). In the wet method, coffee with mucilage is obtained after pulping and later mucilage is removed by subjecting coffee fruits to fermentation. It results in development of undesirable microorganisms which causes off-flavour of coffee and production of unwanted toxic compounds in the effluent and bad odor due to production of acetic (Bernhard 1980).

Aagaard (1961) from Kenya reported that processing of coffee by wet pulping is inevitable for pro-

Table 1. Chemical and biological nature of coffe pulp effluent. Figures in parentheses indicate average value of 57 samples collected from 22 different pulping units.

	pH	EC (dS/m)	SS (mg/l)	DS (mg/l)	BOD (mg/l)	COD (mg/l)	
Chemical Parameters							
Coffee pulp effluent	3.4–4.3 (3.9)	0.28–4.59 (1.71)	130–16,400 (4,360)	530–20,670 (6,350)	1,966–29,903 (13,784)	4,876–43,272 (25,912)	
ISI Standards	5.5–9.0	< 1.00	100	2,100	30	250	
Nutrients							
	Total N (%)	Total P (%)	Total K (%)	Fe	Micronutrients (ppm) Mn	Zn	Cu
Coffe pulp effluent	0.068	0.003	0.048	17.17	0.56	0.51	1.57
Biological Parameters							
	Bacteria (CFU × 10^5)	Fungi (CFU×10^4)	Actinomycetes (CFU×10^3)		N-fixer (CFU×10^3)	PSB (CFU×10^4)	
Coffee pulp effluent	17.30	29.36	2.37		6.99	6.93	

Table 2. Yield of baby corn and paddy as influenced by direct and residual effect of coffee pulp effluent irrigations and application of soil amendments. M : Main plot, M_1 : Fresh water irrigation, M_2 : Raw coffee pulp effluent irrigation, M_3 : 1 : 1 fresh water and coffee pulp effluent irrigation, M_4 : Alternate irrigation of coffee pulp effluent and fresh water, M_5 : Treated coffee pulp effluent irrigation. S : Sub-plot, S_1 : Absolute control, S_2 : RDF + FYM, S_3 : RDF + FYM + Lime.

	Baby corn							
	Baby corn yield (q/ha)				Fresh straw yield (t/ha)			
Treatments	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_1	37.6	95.1	97.7	76.8	5.5	15.4	15.9	12.3
M_2	47.9	95.4	88.3	77.2	4.7	13.7	10.7	9.7
M_3	61.8	90.5	83.1	78.5	6.7	16.2	15.5	12.8
M_4	52.1	96.1	88.8	79.0	6.5	16.8	14.9	12.7
M_5	27.5	36.0	52.1	38.6	2.6	4.0	5.4	4.0
Mean	45.4	82.6	82.0		5.2	13.2	12.5	
	M	S	M × S		M	S	M × S	
SE ±	8.5	3.3	11.3		1.2	0.6	1.5	
CD at 5%	27.8	11.0	NS		3.3	1.7	4.5	

Table 2. Continued.

	Paddy							
	Grain yield (q/ha)				Straw yield (t/ha)			
Treatments	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_1	62.2	61.7	49.8	57.9	9.5	8.3	10.0	9.3
M_2	45.9	60.1	55.9	54.0	8.5	10.2	8.6	9.1
M_3	54.7	64.4	57.8	59.0	9.8	9.8	9.9	9.8
M_4	58.0	55.8	53.5	55.7	9.6	9.0	8.4	9.0
M_5	55.8	60.1	43.8	53.2	8.9	10.8	9.7	9.8
Mean	55.3	60.4	52.2		9.3	9.6	9.3	
	M	S	M × S		M	S	M × S	
SE ±	2.7	1.7	4.2		0.4	0.3	0.7	
CD at 5%	NS	5.1	NS		NS	NS	NS	

ducing good quality coffee. But by-products of wet processing of coffee particularly coffee pulp effluent can cause considerable pollution to nearby water courses which are the main source of water not only for coffee processing but also for domestic and agricultural purposes. In the bio-diverse Western Ghats of Karnataka, coffee is being grown over decades and recently emphasis is being given to production of quality coffee by subjecting coffee fruits to pulping. In this process, a huge volume of pulp effluent is generated which is posing problem of disposal as it has high pollution potential. In contrast to this, the pulp effluent is a rich source of nutrients and organic matter and hence can be used as a resource for growing crops during the lean season. In this context, an attempt was made to characterize coffee pulp effluent for assessing its harmful effects, if any, on soil health and water quality besides direct and residual effect of coffee pulp effluent irrigation on crops yield, quality and soil properties were studied in detail in farmer's field in Coorg district of Karnataka.

Methods

Characterization of Coffee Pulp Effluent (CPE)

Coffee pulp effluent samples were collected from 22 different pulping units in Hassan, Coorg and Chikmagalur districts of Karnataka, India at monthly intervals during the coffee processing season of 2003-04 (December to March). While identifying the

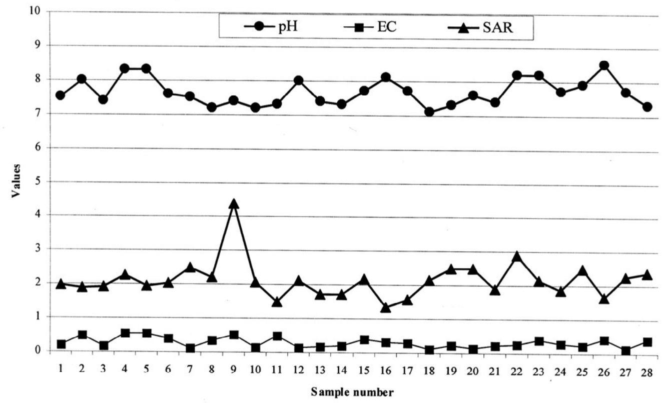

Figure 2. pH, EC (dSm^{-1}) and SAR of water samples collected near the coffe pulping units of Hassan, Coorg and Chikmagalur districts of Karnataka.

pulping units for taking sample, care was taken to draw the representative sample at the nearest outlet of the pulping units. The effluent samples collected were analyzed for various chemical and biological nature of the effluent.

The pH of coffee pulp effluent was determined potentiometrically without any dilution using glass electrode pH meter (Piper 1996) and electrical conductivity (EC) of the filtrate was measured by using conductivity meter (Jackson 1973), while total suspended and dissolved solids by residue method (Rodier 1975), biological oxygen demand (BOD) by iodometric method (APHA et al. 1975) and chemical oxygen demand (COD) by potassium dichromate method (APHA et al. 1975). A known volume of coffee pulp effluent sample was evaporated to dryness on hot plate followed by predigesting with 5 ml concentrated nitric acid over night and was digested on a hot plate with diacid mixture (HNO_3 : $HClO_4$ in 10 : 4 ratio) until a snow white residue was formed. It was cooled and made to a known volume with distilled water. This extract was used for analysis of major nutrients (except nitrogen) and micronutrients content of the effluent (Piper 1996). For determination of

Table 3. Quality parameters of dehusked baby corn and paddy grains as influenced by direct and residual effect of coffee pulp effluent irrigations and application of soil amendments.

	Dehusked baby corn								Paddy grains			
Treat-	Sugar (%)				Protein (%)				Protein (%)			
ments	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_1	0.016	0.014	0.015	0.015	21.9	18.6	20.4	20.3	6.73	7.11	7.06	6.97
M_2	0.015	0.015	0.016	0.015	19.6	19.4	18.9	19.3	9.12	8.56	7.81	8.50
M_3	0.015	0.015	0.016	0.015	21.3	20.7	22.2	21.4	6.62	7.49	7.19	7.10
M_4	0.015	0.015	0.016	0.015	21.1	20.9	22.5	21.5	7.13	7.00	6.87	7.00
M_5	0.018	0.016	0.017	0.017	24.0	16.6	20.2	20.3	6.88	7.06	7.44	7.13
Mean	0.016	0.015	0.016		21.6	19.2	20.8		7.30	7.45	7.27	
	M	S	M × S		M	S	M × S		M	S	M × S	
SE ±	0.000	0.000	0.001		0.568	0.473	1.034		0.005	0.004	0.009	
CD at 5%	0.001	0.001	NS		NS	1.396	NS		0.018	0.012	0.029	

Table 4. Physico-chemical properties of soil after the harvest of crops as influenced by direct (DE) and residual (RE) effect of coffee pulp effluent irrigations and application of soil amendments.

Treat-ments	pH		EC (dS/m)		OC (%)		Avail N		Avail P_2O_5 (kg/ha)		Avail K_2O		Exch Ca [cmol (p^+)/kg]		Exch Mg	
	DE	RE	DE	RE	DE	RE	DE	RE	DE	RE	DE	RE	DE	RE	DE	RE
Main plot																
M_1	5.3	5.0	0.14	0.10	1.18	0.90	324	345	34.9	25.2	178	103	2.77	2.53	1.89	1.29
M_2	5.5	5.2	0.12	0.11	0.95	0.96	333	342	38.5	29.3	327	159	2.95	2.24	1.78	1.17
M_3	5.3	5.2	0.22	0.11	1.02	0.96	382	366	36.9	21.5	255	113	2.89	2.61	1.60	1.16
M_4	5.3	4.9	0.11	0.09	0.93	1.00	356	357	41.1	22.3	171	94	2.53	2.36	1.56	1.17
M_5	5.7	5.3	0.24	0.14	1.12	1.00	358	345	33.5	21.9	414	201	2.22	2.94	1.57	1.33
SE ±	0.1	0.1	0.05	0.02	0.08	0.06	5	5	5.3	2.0	36	24	0.32	0.38	0.15	0.15
CD at 5%	NS	NS	NS	NS	NS	NS	17	15	NS	NS	116	NS	NS	NS	NS	NS
Sub-plot																
S_1	5.5	5.1	0.20	0.12	0.90	0.99	344	356	42.6	22.1	292	138	2.47	2.43	1.47	1.21
S_2	5.4	5.1	0.13	0.11	1.09	0.95	332	342	33.9	24.6	255	127	2.69	2.52	1.84	1.16
S_3	5.4	5.1	0.17	0.11	1.14	0.95	335	355	34.4	25.4	260	138	2.86	2.66	1.73	1.30
SE ±	0.7	0.1	0.02	0.01	0.07	0.04	4	4	2.7	2.3	13	10	0.12	0.16	0.18	0.10
CD at 5%	NS	NS	NS	NS	0.20	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (M×S)																
SE ±	0.2	0.1	0.06	0.02	0.15	0.09	9	9	7.2	4.6	43	30	0.38	0.48	0.36	0.24
CD at 5%	NS	NS	NS	NS	NS	NS	26	27	NS	NS	NS	NS	NS	NS	NS	NS

Table 4. Continued.

Treatments	Avail S (ppm)		DTPA extractable micrountrients (ppm) Fe		Mn		Zn		Cu	
	DE	RE	DE	RE	DE	RE	DE	RE	DE	RE
Main plot										
M_1	22.1	16.3	295	328	60	37	1.43	2.00	11.8	13.4
M_2	20.0	14.0	300	360	42	39	1.15	1.71	9.6	13.2
M_3	25.2	14.0	284	329	58	54	1.38	1.79	10.8	11.6
M_4	21.5	14.8	353	343	45	41	1.31	1.86	12.5	11.9
M_5	20.6	17.5	311	313	73	70	1.56	1.74	12.4	12.4
SE ±	1.65	1.20	26	25	2	9	0.11	0.11	1.3	0.8
CD at 5%	NS	NS	NS	NS	7	NS	NS	NS	NS	NS
Sub-plot										
S_1	22.2	15.5	291	332	51	54	1.32	1.82	10.7	13.1
S_2	21.7	16.5	319	335	66	46	1.45	1.87	12.1	11.4
S_3	21.8	14.0	315	337	50	45	1.32	1.78	10.8	13.1
SE ±	0.98	0.89	19	13	2	2	0.07	0.05	0.2	0.7
CD at 5%	NS	NS	NS	NS	7	7	NS	NS	NS	NS
Interaction (M×S)										
SE ±	2.43	9.61	43	34	7	10	0.17	0.14	2.0	1.5
CD at 5%	NS	NS	NS	NS	14	31	NS	NS	NS	NS

nitrogen, a known volume of the effluent was evaporated and was digested with concentrated sulfuric acid in presence of digestion mixture by boiling till a bluish green residue was formed. The nitrogen in the digested sample was determined by micro Kjeldahl distillation method (Piper 1996). The enumeration of

Table 5. Enzymes activity of soil after harvest of baby corn and paddy as influenced by direct (DE) and residual (RE) effect of coffee pulp effluent irrigations and application of soil amendments.

Treat-ments	Alkaline phosphatase (µg PNP/g/h)								Acid phosphatase (µg PNP/g/h)							
	S_1		S_2		S_3		Mean		S_1		S_2		S_3		Mean	
	DE	RE	DE	RE	DE	RE	DE	RE	DE	RE	DE	RE	DE	RE	DE	RE
M_1	54	51	62	58	55	48	57	52	155	149	169	159	156	149	160	152
M_2	35	31	55	50	37	32	42	38	148	140	147	141	168	159	154	146
M_3	74	70	60	55	58	53	64	60	173	164	164	160	167	158	168	161
M_4	77	71	42	39	40	37	53	49	166	158	161	153	152	146	159	152
M_5	73	68	65	61	66	61	68	63	167	160	161	160	176	169	168	163
Mean	63	58	57	53	51	46			162	154	160	155	164	156		
	M		S		M × S				M		S		M × S			
SE ±	0.5	0.3	0.4	0.3	0.8	0.6			0.1	1.0	0.1	0.80	0.2	1.8		
CD at 5%	1.7	0.9	1.0	0.9	2.5	1.8			0.4	3.2	0.3	NS	0.6	5.4		

Table 5. Continued.

Treatments	Urease (μg NH_4-N/g/h							
	S_1		S_2		S_3		Mean	
	DE	RE	DE	RE	DE	RE	DE	RE
M_1	11	8	17	14	24	19	17	14
M_2	23	20	15	11	17	13	18	15
M_3	15	12	18	15	16	13	16	13
M_4	18	15	12	9	18	15	16	13
M_5	21	17	23	19	20	15	21	17
Mean	18	14	17	13	19	15		
	M		S		M × S			
SE ±	0.4	0.6	0.4	0.5	0.8	1.0		
CD at 5%	1.1	2.1	1.1	1.3	2.4	3.2		

total bacteria, fungi, actinomycetes, free living N-fixers and phosphate solubilizers in the effluent was carried out by following the standard dilution plate count technique.

Direct and Residual Effect of CPE Irrigations on Baby corn-Paddy Cropping System

The field experiments were conducted at farmer's field, near Coffee Research Sub-Station, Chettalli, Coorg district situated in the Western Ghats of Karnataka, India during summer and *kharif* seasons of 2003-04 in split-plot design with three replications. The experiment was conducted on a piece of land which was not irrigated with effluent in the past and has easy access in terms of transportation of effluent from coffee pulping unit to the experimental site. The texture of soil was sandy loam with 75.7% sand, 13.8% silt and 10.6% clay. The soils are near neutral (pH : 6.8) in reaction, high in organic carbon content (1.15%) and normal with respect to salt content (0.13 dS/m). The available nitrogen content (211 kg/ha) of soil was low whereas available phosphorus (50 kg P_2O_5/ha) and potassium (290 kg K_2O/ha) content of soil were medium.

The treatments included five main plot treatments viz. M_1 : Irrigation with fresh water alone, M_2 : Irrigation with raw effluent alone, M_3 : Irrigation with 1 : 1 ratio of raw effluent and fresh water, M_4 : Alternate irrigation of raw effluent and fresh water and M_5 : Irrigation with treated effluent (Physical : 1.0%

charcoal, Chemical : 0.5% lime and Microbial consortium : *Phenerochaete chrysosporium* and *Pleurotus sajorcaju*) alone and three sub-plot treatments viz., S_1 : Absolute control, S_2 : RDF + FYM and S_3 : RDF + FYM + Lime. Baby corn (var PAC 791) crop was used for testing its performance under direct effect of coffee pulp effluent irrigation treatments and application of soil amendments during summer season of 2003-04. Amendments viz., lime at 625 kg/ha and FYM at 10 t/ha were applied 15 days before sowing based on the sub-plot treatments.

After baby corn crop, paddy (var IR 64) was transplanted during *kharif* season of 2004 in the same plots without any treatments to study the residual effect of coffee pulp effluent irrigations and application of soil amendments. The land was ploughed with spade to remove weeds and to crush the clods without mixing the previous treatments. The soil was brought to fine tilth and perfect leveling was done within each plot. Fertilizer doses of 150 : 75 : 40 NPK kg/ha to baby corn and 75 : 75 : 90 NPK kg/ha to paddy were applied as per the recommendation. These nutrients were applied in the form of urea, rock phosphate and muriate of potash. Fifty per cent of nitrogen and full dose of phosphorus and potassium were applied at the time of sowing/ transplanting and the remaining 50% nitrogen was top dressed in the form of urea to 25 days after sowing / transplanting. Submerged condition was maintained using good quality irrigation water till fifteen days before harvesting the paddy crop in all the plots. All aftercare operations were carried out as and when required. Apart from yield observations, crop quality and soil properties were determined after the harvest of each crop separately.

Collection and Analysis of Plant Samples for Quality Parameters

Five plant's dehusked baby corn and paddy grains were collected from each plot separately at harvest and dried in an oven at 60 C. The dried samples were ground to a fine powder using mixer grinder and stored for analysis. The sugar content of dehusked baby corn was determined by following Dubois method (Dubois et al. 1956) while crude protein content of dehusked baby corn and paddy grains were determined using the procedure as described by Lowery et al. (1951).

Collection and Analysis of Soil Samples

Surface soil samples (0—15 cm) were collected from each plot after harvest of each crop separately as per standard procedures outlined by Jackson (1973). Besides, a total of thirty surface soil samples (0—15 cm depth) were collected from Hassan, Coorg and Chikmagalur districts of Karnataka. Among these samples, 15 were collected from fields which have different history of effluent application and rest from fields which have no history of effluent application and the impact of long term discharge of coffee pulp effluent on soil properties was studied by analyzing the samples for pH, EC, organic carbon and available major, secondary and micronutrients status. The soil samples were dried in shade, powdered with wooden mallet, passed through 2 mm sieve and stored in clean polythene bags for analysis. For the determination of organic carbon, 2 mm sieved soil was further powdered in an agate mortar and pestle and passed through 0.2 mm sieve and stored in paper covers for analysis.

Soil pH was estimated in the 1 : 2.5 (soil : water) suspension using glass electrode pH-meter, while the electrical conductivity (EC) of the supernatant was measured by using conductivity meter after keeping the samples overnight for settling of the soil particles (Jackson 1973). Organic carbon was determined by following the Walkley and Black's wet-oxidation method as described by Jackson (1973). Available nitrogen was determined by alkaline potassium permanganate method as described by Subbiah and Asija (1956). Available phophorus was extracted with Bray's No. 1 extractant and determined by spectrophotometric method (Jackson 1973). Available potassium was determined Flame photometrically using neutral normal ammonium acetate extractant (Jackson 1973). Exchangeable calcium and magnesium were determined as outlined by Hesse (1971) and available sulfur by turbidometry (1965). The DTPA extractable iron, manganese, zinc and copper were determined using atomic absorption spectrophotometer (Lindsay and Norvel 1978). Urease, acid phosphatase and alkaline phosphatase activities were determined as soon as the fresh soil samples were collected immediately after harvest of each crop separately following standard procedures (Tabatabai and Bremner 1969). Crops yield, quality and soil parameters were statistically analyzed by adopting procedures as outlined by Sundararaj et al. (1972).

Collection and Analysis of Water Samples

The effect of effluent discharge over the years on quality of both surface and ground water was assessed by collecting requisite number of water samples from nearby water bodies such as ponds, open wells and bore wells at 1—2 km distance from the coffee processing units. The suitability of water samples for irrigation was assessed following the USSL Staff (1954) classification of irrigation water, which is based on electrical conductivity and sodium adsorption ratio of the water samples. The pH of water samples was determined potentiometrically using glass electrode pH meter (Piper 1996) and electrical conductivity (EC) was measured using conductivity meter (Jackson 1973), while Ca^{2+} and Mg^{2+} by EDTA titration method (Page et al. 1998) and Na^+ by Flame photometric method (Jackson 1973). The sodium adsorption ratio (SAR) was calculated using the method given by Richards (1954) as SAR = $Na^+ / [(Ca^{2+} + Mg^{2+}) / 2]^{1/2}$.

Results and Discussion

Characterization of Coffee Pulp Effluent for Its Pollution and Nutrient Potentials

The coffee pulp effluent samples collected were analyzed for various parameters and compared with the standards prescribed by Indian Standard Institution (ISI) for discharge on soil or into water bodies (Table 1). The values for different parameters varied among effluents and within the effluent across the different months of pulping. The pH ranged from 3.4 to 4.3 with an average value of 3.9 and it was far below the ISI standards and highly acidic in reaction (21). The total soluble salts content of the effluent ranged from 0.28 to 4.59 dS/m with an average value of 1.71 dS/m. Total suspended and dissolved solids varied from 130 to 16,400 and 530 to 20,670 mg/liter with mean values of 4,360 and 6,350 mg/liter, respectively. The suspended and dissolved solids were well above ISI limits of 100 and 2,100 mg/liter, respectively during most of the times. The concentration of BOD and COD also varied at each time of collection (1,966 to 29,903 and 4,876 to 43,272 mg/liter for BOD and COD, respectively) and were above ISI limits of 30 and 250 mg/liter, respectively (Hedoo and Patil 2003). The average values recorded were 13,784 and 25,912 mg/liter for BOD and COD, respectively. These results are inconformity with those findings of Anand Alwar (1998). The variation in values for different parameters among the pulping units and within the effluent collected from a pulping unit during different months of pulping may be attributed to method adopted by the farmers, number of discs used in pulping machine, quantity of water used for processing and also type coffee fruit processed.

The coffee pulp effluent is poor in major nutrients content (N : 0.068 ; P : 0.003 and K : 0.048%) but contains appreciable quantities of micronutrients (Fe : 17.17, Mn : 0.56, Zn : 0.51 and Cu : 1.57 ppm). The diversity of micro-organisms was noticed in the effluent. The effluent has more number of fungal (29.36) and bacterial (17.30) colonies but less number of actinomycetes population (2.37). The beneficial microbes like free living N-fixers and phosphate solubilizers were more in number (6.99 and 6.93, respectively). The plausible reason for higher microbial population in the effluent might be attributed to high organic load in the effluent. Similarly, Augustine Selvaseelan et al. (2001) observed more microbial activity in paper and pulp mill effluent.

Direct and Residual Effect of CPE Irrigations on Baby corn-Paddy Cropping System

Yield. The direct effect of coffee pulp effluent irrigations and application of soil amendments on baby corn yield (Table 2) revealed that alternate irrigation of raw effluent and fresh water recorded significantly maximum baby corn yield (79.0 q/ha) followed by irrigation with 1 : 1 ratio of raw effluent and fresh water (78.5 q/ha) whereas, irrigation with 1 : 1 ratio of raw effluent and fresh water recorded significantly maximum fresh fodder yield (12.8 t/ha) followed by alternate irrigation of raw effluent and fresh water (12.7 t/ha) over treated effluent irrigation (38.6 q/ha and 4.0 t/ha for baby corn and fresh straw yields, respectively) and the remaining treatments were on par with alternate or 1 : 1 ratio of raw effluent and fresh water irrigation treatments. Among amendments, application of RDF + FYM recorded significantly higher baby corn (82.6 q/ha) and fresh fodder (13.2 t/ha) over control (45.4 q/ha and 5.2 t/ha, respectively). The interaction between effluent irrigation and soil amendments application did not differ significantly with respect to baby corn yield. However, alternate irrigation of raw effluent and fresh water in combination with RDF + FYM recorded significantly higher fresh fodder yield (16.8 t/ha) over all the effluent irrigation treatments in combination with control and more particularly treated effluent irrigation in combination with all other soil amendments application treatments. The plausible reason for higher yields in case of alternate or 1 : 1 ratio of raw effluent and fresh water irrigations might be due to dilution effect where the extent of dilution was two times when compared to raw effluent irrigation. The dilution is known to bring down the harmful effects of effluent by reducing BOD and COD levels and salt concentration,thus favoring crop growth. Similar results have been obtained by Kamalam and Raj (1980) and Sukanya and Meli (2003).

Grain and straw yields of paddy did not differ significantly due to residual effect of effluent irrigation (Table 2). However, the grain and straw yields recorded were ranged from 53.2 to 59.0 q/ha and 9.0 to 9.8 t/ha, respectively due to residual effect of effluent irrigations. This might be due to the fact that coffee pulp effluent does not contain any harmful and toxic chemicals except high BOD and COD values, which might be reduced when applied to the soil due to biodegradation and dilution / dispersion of the wastes (Baruah et al. 1993).

Crop Quality. The data on sugar and crude protein content (Table 3) of dehusked baby corn as influenced by direct effect of coffee pulp effluent irrigations revealed that treated effluent irrigation significantly influenced the sugar content (0.017%) of dehusked baby corn over all other effluent irrigation treatments (0.015%) while crude protein content of dehusked baby corn did not differ significantly due to nature of irrigations. The plausible reason for higher sugar content of dehusked baby corn due to treated effluent irrigation might be due to high sugar content in the effluent (Anand Alwar 1998) and enhanced availability of sugars to the crop as a result of biodegradation of suspended and dissolved solids of effluent by the microbial treatment (Baruah et al. 1993) and crude protein content of dehusked baby corn did not differ significantly due to coffee pulp effluent irrigations might be due to poor content of nitrogen in the coffee pulp effluent. Sukanya and Meli (2003) indicated that higher dilution level of distillery effluent in the ratio of 1 : 50 on wheat crop was found better in terms of productivity while, the quality parameters were enhanced at lower dilution levels.

The residual effect of raw effluent irrigation resulted in significantly higher crude protein content (8.50%) of paddy grains over all other irrigation treatments (6.97 to 7.13%). Among residual effect of amendments, application of RDF + FYM resulted in significantly higher crude protein content (7.45%) of paddy grains over all other sub plot treatments (7.27 to 7.30%). The residual effect of raw effluent irrigation in combination with control recorded significantly higher crude protein content (9.12%) of paddy grains. The reason that could be attributed to higher crude protein content of paddy grains due to residual effect of raw effluent irrigation might be due to more availability of nutrients as a result of complete degradation of raw effluent over a period. Since bio-degradation is a slow process, the succeeding paddy crop has been benefited by the residual effect of raw effluent irrigation. Salakinkop et al. (1999) found that quality parameters of wheat improved under raw sewage irrigation.

Physico-Chemical Properties of Soil. The data on physico-chemical properties of soil as influenced by direct and residual effect of coffee pulp effluent irrigations and application of soil amendments (Tables 4) revealed that soil reaction, soluble salts content, organic carbon, available phosphorus, exchangeable calcium and magnesium, available sulfur and DTPA extractable iron, zinc and copper did not differ significantly due to direct effect of effluent irrigations. However, available nitrogen, potassium and DTPA extractable manganese content of soils differed significantly due to direct effect of effluent irrigations. Similarly, physico-chemical properties of soil did not differ significantly due to residual effect of effluent irrigations except available N content of soil.

The 1 : 1 ratio of raw effluent and fresh water irrigation recorded significantly higher available nitrogen content (382 kg/ha) of soil over all other irrigation treatments (324 to 358 kg / ha). Significantly lower available N content of soil was noticed in fresh water irrigation (324 kg/ha). The reason that could be attributed to higher available N content of effluent treated soils (333 to 358 kg/ha) might be due to enormous quantity of nitrogen addition through effluent and fertilizer application had definitely contributed for increased availability of nitrogen in soil at the harvest of the crop. Similar results were found by Nagaraja (1981) who noticed an increase in the level of nitrogen when soil was irrigated with sewage effluent. Sukanya and Meli (2003) found that the diluted distillery effluent and raw effluent irrigated plots showed increased availability of nitrogen. The residual effect of 1 : 1 ratio of raw effluent and fresh water irrigation recorded significantly higher available N content (366 kg/ha) of soil, which was found to be on par with residual effect of alternate irrigation of raw effluent and fresh water. Significantly lower available N content (342 kg/ha) of soil was noticed due to residual effect of raw effluent irrigation, which was found to be on par with residual effect of fresh water irrigation (345 kg/ha) and treated effluent irrigation (345 kg/ha). The available potassium content of soils was significantly influenced by direct effect of effluent irrigation treatments. Treated effluent irrigation recorded significantly higher available potassium content of soils (414 kg/ha), which was found to be at par with raw effluent irrigation (327 kg/ha). This might be due to rate of mineralization of coffee pulp effluent is directly related to the release of potassium in soil. The results obtained from the present study are in conformity with the findings of Mitra and Gupta (1999) who also found that potassium concentration was at moderate to high level when soil was irrigated with sewage effluent. Patak et al. (1998) observed appreciable increase in available potassium status of soils irrigated with distillery effluent. Similarly, DTPA extractable Mn differed significantly due to effluent irrigations, soil amendments application and interaction between them. Treated effluent irrigation recorded significantly higher values of DTPA extractable Mn (73 ppm), which was found to be significantly superior over all other irrigation treatments (42 to 60 ppm).

Bio-chemical Properties of Soil. The alkaline phosphatase, acid phosphatase and urease activities were significantly influenced by effluent irrigations, soil amendments application and interaction between them (Table 5). Significantly higher alkaline phosphatase (68 µg PNP/g per h), acid phosphatase (168 µg PNP/g per h) and urease (21 µg NH_4-N/g per h) activities were noticed in soils irrigated with treated coffee pulp effluent. Whereas, significantly lower alkaline phosphatase (42 µg PNP/g per h) and acid phosphatase (154 µ PNP/g per h) activities were noticed in soils irrigated with raw coffee pulp effluent. But significantly lower urease (16 µ g NH_4-N/g per h) activity was noticed in the soils due to alternate irrigation of raw effluent and fresh water. Acid phosphatase (64 µg PNP/g per h) and urease (19 µg NH_4-N/g per h) activities were found to be significantly higher in soils amended with RDF + FYM + Lime application, whereas sub-plot treatment control significantly higher alkaline phosphatase activity (63 µg PNP/g per h). Alternate irrigation of raw effluent and fresh water recorded significantly higher alkaline phosphatase (77 µg PNP/g per h) activity in combination with sub-plot treatment control. The treated effluent irrigation recorded significantly higher acid phosphatase (176 µg PNP/g per h) activity in combination with sub-plot treatment RDF + FYM + Lime application. Whereas, urease (24 µg NH_4-N/g per h) activity was significantly higher in soils irrigated with fresh water in combination with application of RDF + FYM + lime.

The residual effect of treated effluent irrigation recorded significantly higher alkaline phosphatase (63 µg PNP/g per h), acid phosphatase (163 µg PNP/g per h) and urease (17 µg NH_4-N/g per h) activities in the soil. Residual effect of raw effluent irrigation resulted in significantly lower alkaline phosphatase (38 µg PNP/g per h) and acid phosphatase (146 µg PNP/g per h) activities in soil. But residual effect of 1 : 1 or alternate irrigation of raw effluent and fresh water resulted in significantly lower urease (13 µg NH_4-N/g per h) activity in the soil. The residual effect of sub-plot treatment RDF + FYM + lime application recorded higher acid phosphatase (156 µg PNP/g per h) and urease (15 µg NH_4-N/g per h) activities in the soil. Whereas, the residual effects of sub-plot treatment control recorded significantly higher alkaline phosphatase activity (58 µg PNP/g per h) in soil. The residual effect of alternate irrigation of raw effluent and fresh water recorded significantly higher alkaline phosphatase (71 μg PNP/g per h) activity in combination with sub-plot treatment control. The treated effluent irrigation recorded significantly higher acid phosphatase (169 μg PNP/g per h) activity in combination with sub-plot treatment RDF + FYM + Lime application. Whereas, residual effect of raw effluent irrigation recorded significantly higher urease (20 μg NH_4-N/g per h) activity in combination with sub-plot treatment control. The higher phosphatase and urease activities in effluent treated soils might be due to addition of high organic load in the effluent. Chhonkar and Tarafdar (1984) observed significant positive correlation of phosphatase activity with organic matter. Similarly, Kumar and Waget (1984) observed a linear relationship between soil urease activity and soil organic carbon content.

Fertility Status of Effluent Discharged Fields

Fertility status of surface soil samples (0—15 cm depth) collected from farmer's fields that had different history of effluent application and had no history of effluent application is given in Figure 1. The results indicated that they were acidic in soil reaction. There was negligible difference in soil reaction between the soil samples collected from effluent discharged (6.1) and undischarged (6.0) fields. The total soluble salts content of soil was quite low in all the fields, irrespective of whether effluent was discharged or not. However, it was relatively higher in effluent discharged fields (0.32 dS/m) as compared to undischarged fields (0.15 dS/m). The organic carbon content of all the surface soil samples was quite high and it was relatively more in soil samples collected from effluent discharged fields (2.47%) as compared to effluent undischarged fields (2.23%). These results are inconformity with the findings of Annadurai et al. (1999) who reported that pH, EC and organic carbon content of soil increased with increase in concentration of effluent added due to high organic load. The available nitrogen content of soil was medium in both effluent discharged and undischarged fields whereas, available phosphorus and potassium content of soils were quite high, irrespective of whether effluent was applied or not. There was no difference in the available phosphorus content (212 kg P_2O_5 / ha) of soil between the samples collected from effluent discharged and undischarged fields. This might be attributed to poor content of phosphorus in the coffee pulp effluent (Singh and Bahadm 1975). The available nitrogen (473 kg/ha) and potassium (975 kg K_2O/ha) were relatively higher in effluent discharged fields as compared to effluent undischarged fields (413 and 548 kg/ha, respectively). This might be due to high organic load and appreciable quantity of N and K present in the effluent. The exchangeable calcium and magnesium were found to be adequate in all fields. However, application of effluent decreased the exchangeable calcium and magnesium content of soil (Jadhav and Sawant 1975). The available sulfur status of soil was high in both effluent discharged (36 ppm) and undischarged (33 ppm) fields. The DTPA extractable micronutrients content of effluent discharged fields were higher except Cu than effluent undischarged fields. This might be due to high organic matter and micronutrients content in the effluent (Zalawadia et al. 1997). Similarly, Devarajan and Oblisami (1995) reported that distillery spent wash application increased the availability of N, P, K, Ca, Mg and micronutrients contents in soil besides increased the organic matter content of soil.

Quality of Water Nearly Coffee Pulping Units

Indiscriminate discharge of effluent over the years might have resulted in pollution of nearby surface and ground waters. However, analytical data (Fig. 2) on quality of water samples collected near the coffee pulping units indicated that most of water samples tested was neutral to alkaline in reaction and the values ranged from 7.1 to 8.5. The total soluble salts content was quite negligible and the values ranged from 0.11 to 0.54 dS/m. The SAR values were ranged between 1.36 to 4.37 and thus, these waters can be rated into safe category (SAR < 10) of sodicity Richards 1954). The suitability of water for irrigation was assessed following the U. S. S. L. Staff (1954) classification of irrigation water, which is based on EC and SAR of water samples, revealed that among 28 water samples tested, 13 samples were in C_1S_1 class and remaining 15 samples were in C_2S_1 class and also indicated that water can be used for drinking purposes. The plausible reason for non-pollution of water bodies nearby coffee pulping units even though it had high suspended and dissolved solids as well as high BOD and COD values might be due to biodegradation and dilution/dispersion of the wastes (Baruah et al. 1993).

Conclusion

This study indicated the possibility of utilization of coffee pulp effluent as a source of nutrients and water. Effluent can find a better place in soils, which are poor in organic matter. Based on the chemical analysis of effluent, it can be said that the effluent is having certain constituents like total solids (suspended and dissolved solids), BOD and COD values above the specified limits which may pose problem if the effluent is used for crop production for a long period. However, it is comparatively less harmful, if the effluent is used as alternate irrigation of raw effluent and fresh water or 1 : 1 ratio of raw effluent and fresh water irrigation or treated effluent irrigation to raise a short duration crop like baby corn in coffee growing areas. Normally, the effluent is discharged indiscriminately into paddy lands over a small area without growing any crop. Under such situations, utilizing the effluent for raising a crop would aid to increase cropping intensity besides, reducing possible ill effect of effluent on subsequent rice crop when discharged unscrupulously.

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