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Effect of Treated Tannery Effluent Mixed With Domestic Wastewater Application on *Gomphrena globosa* (Vadamalli)

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ABSTRACT

Tannery wastes are ranked as the one of the highest pollutant sources among all the industries. Proven studies about the benefits of these wastes by way of nutrient addition and growth promotion create a great demand for use of such water in agriculture. Treated tannery effluent mixed with domestic wastewater irrigation provides nutrient enriched water supply for irrigation, besides it is a reliable and inexpensive system of wastewater treatment and disposal. The present study was carried out to estimate the effect of combined application of treated tannery effluent (TTE) along with domestic wastewater (DWW) on growth characters and yield attributes viz., plant height, number of branches, spike or flower weight of *Gomphrena globosa* (Vadamalli), and soil microbial population and enzyme activities. The yield of *Gomphrena globosa* being increased in red and black soil was 30.07 per cent and 29.48 per cent over control. The soil microbial population and enzyme activities such as urease, phosphatase and dehydrogenase were higher under treated tannery effluent mixed with domestic wastewater irrigation. Hence treated tannery effluent mixed with domestic wastewater (1:3 ratio) helps to improve the soil health and yield.

INTRODUCTION

One of the unique features of the leather industry sector in India is that it occurs in groups right from primitive time. States like Tamil Nadu, West Bengal and Uttar Pradesh together account for 88% of the tannery units of the country (CLRI 2011, Vijayanand & Hemapriya 2014). Annually, tanneries process 500,000 tons of hides and 314 tons of skins (Sugasini & Rajagopal 2015). Nearly 30-35 L of water is used per kg of leather processing and 10% of the water is used during dehairing, pickling, dying and washing (Krishnamoorthi et al. 2009). A total annual discharge of wastewater from these tanneries is 9,420,000 m^3, which generates about 100,000 m^3 of wastewater per day (Mohan et al. 2006).

In Tamil Nadu alone, there are about 1120 tanneries located in Vellore, Ranipet, Trichy, Dindigul, Erode and Pallavaram in Chennai (Noorjahan 2014) and 80% of the total tanned leather was processed through vegetable tanning process. There are about 39 units located in Dindigul cluster and all are connected to CETP (Hashim et al. 2010, Gupta et al. 2014). Even though TNPC had directed tannery CETPs to reuse treated wastewater by installing MBR and RO, but most of the treated wastewater is being disposed off on land (HRTS system) and Sengankulam Lake of CETP in Dindigul. The effluent discharged after vegetable tanning operations mostly loaded with the high concentration of sodium chloride, sulphate, bicarbonate, calcium and magnesium and high amount of chromium salts in case of chrome tanning process. These pollutants will affect the land, surface water and groundwater (Mondal et al. 2005, Karthikeyan et al. 2010) and in most developing countries tannery effluents are discharged directly into the aqueous system without treatment (Verheijen et al. 1996, Favazzi 2002). Tanneries show a prominent shift towards the adoption of cleaner practice in recent decades with high number of dedicated CETPS (Gupta et al. 2014).

Agricultural production is responsible for the vast majority of freshwater use i.e., up to 85% (Shiklomanov 2003) and is going to be doubled by 2050. With all the river basins having a deficit volume of water for irrigation, the effluent from industries can reduce the pressure on water scarcity for irrigation (Thirunavukarasu & Lourdraj 2005). This wastewater contains not only high salt content, but it also is an important source of reusable wastewater, fertilizer and soil conditioner.

At the same time, everincreasing population impose continuous pressure on limited freshwater resources. The per capita water availability is decreasing, and on the other hand the demand is increasing. Therefore, treated wastewater appears to be the visible and viable option and to be the only water resource that is increasing as other sources are dwindling. Yadav et al. (2002) reported that long term utilization of domestic wastewater adds large amounts of major and micronutrients to the soil. There is great demand for the use of domestic sewage, apart from being sanitized, it can become an important source of re-usable water, fertilizer, soil conditioner and energy (Leal et al. 2011).

Dilution helps in reducing the concentration of pollutants present in the effluent. The level of dilution depends on many things such as water availability, level of effluent at which it stimulates plant growth and puts forth no harm or the accumulation of toxic constituents in the plant parts. So the present investigation was conducted to evaluate the application of a dilution mixture of DWW and TTE as a source of irrigation on non flower crop and soil microbial activities.

MATERIALS AND METHODS

The treated tannery effluent and domestic wastewater samples were collected from CETP, Dindigul, Tamil Nadu. Physico-chemical and biological properties of the irrigation sources were determined as per the standard procedures (APHA 2005). Pot culture experiment comprising six treatments was carried out with two different soils i.e., black cotton and red soils to study the effect of the wastewater on growth and yield of *Gomphrena globosa (*Vadamalli). Treatment comprised six levels of irrigation sources viz., T1 - Control , T_2 - Domestic wastewater alone, T_3 - 25 per cent TTE + 75 per cent DWW, T_4 - 50 per cent TTE + 50 per cent DWW, T_5 - 75 per cent TTE + 25 per cent DWW, T_6 - Treated tannery effluent alone. All the manures and fertilizers were applied to the crop based on the quantity of soil (10 kg). As per the treatment equal quantity of water was added throughout the study period. Germination percentage, plant height and number of branches were calculated at 30, 60 days and at the harvest time. The soil samples used for the study were analysed as per the standard procedure. Soil enzyme activities were analysed to know the effect on microbial metabolism.

The urease activity of the soil was measured according to the method prescribed by Hoffman (1965), phosphatase activity according to the method prescribed by Tabatabai & Bremner (1969) and dehydrogenase activity according to the method prescribed by Chendrayan et al. (1980). All the statistical analysis was performed as per the procedure given by Gomez & Gomez (2010).

RESULTS AND DISCUSSION

Characterization of the treated tannery and domestic wastewater: The physico-chemical and biological properties of the effluent samples are given in Table 1. The analysis revealed that the pH was neutral with high EC in tannery wastewater (9.2 dSm^{-1}) compared to domestic wastewater (1.2 dSm^{-1}) with low BOD, COD and objectionable TDS and colour. 80% of the tanneries use vegetable tanning process, which uses tan barks, powdered plant or aqueous extracts of those parts which are comprised of polyphenols (Covington 1997).

The dark colour of the tannery effluent may be due to excess polyphenols which make them unfit for consumption (Goel 1997, Smrithi & Usha 2012). High EC of the tannery wastewater is due to excessive dissolved salts. The composition of the solids present in tannery effluent depends upon the nature and quality of hides and skins processed in the tannery (Islam et al. 2014). Considerable amount of essential nutrients viz., Ca, Mg, N, P, K were observed in TTE and DWW. Na, Cl^- and SO_4^{2-} were estimated to be higher as 48, 60, and 15.1 (meq L^{-1}) for treated tannery effluent. Chloride is an indicator of pollution when present in higher concentrations (Singh et al. 2009 and Chakrapani 2005). Sodium chloride is used as a dehydrating and antiseptic agent, which may be the source of chloride in treated tannery effluent which is in line with the findings of Mehdi (2005). The presence of very high amounts of chloride and sulphate is responsible for high hardness and further it increases the degree of eutrophication (Kannan et al. 2009).

In addition, the characteristics of different dilution were also analysed before using the mixed water for irrigation. Dilution of 25% treated tannery effluent + 75% domestic wastewater contained neutral pH, considerable reduction in EC, TDS and TSS. The effluent contained salts like sodium (16.7 meq L^{-1}), chloride (19.4 meq L^{-1}), and sulphate (10.6 meq L^{-1}) in addition to other cations like calcium, magnesium and potassium. Carbonate (1.6 meq L^{-1}), bicarbonates (8.4 meq L^{-1}), DO (3.4 mg L^{-1}), BOD (28.1 mg L^{-1}) and COD (176.2 mg L^{-1}) values are below the CPCB limits. The dilution of the treated tannery effluent with domestic wastewater helps in reducing the concentration of the pollutant present in the treated tannery effluent. This is in accordance with the report of Chandha & Pandey (1993), who observed that treated tannery effluent may be used for irrigation purpose through proper dilution.

Soil enzyme activities: The red and black soils used for the study were low in available nitrogen, medium in available phosphorus and high in available potassium. All the treatments with different combinations of effluent irrigation enhanced the enzyme activity over control (Figs. 1-3). Treatment T_3 recorded the highest urease activity of 9.3 and 8.7 g of ammoniacal-N released kg^{-1} soil 24 h^{-1} in both red and black soils respectively.

Similarly, phosphatase activity in red soil ranged from 7.7 to 11.3 , 7.90 to 11.7 and 7.10 to 10.7 µg PNPP g^{-1} of soil at 30, 60 DAT and at harvest stage respectively. In case of

Table 1: Characterization of treated tannery effluent and domestic wastewater.

Parameters	Treated tannery Effluent (TTE)	Domestic wastewater (DWW)	Bore well water	25% TTE +75% DWW	50% TTE +50% DWW	75% TTE +25 % DWW
Physico Chemical Properties						
pH	7.6	7.4	7.10	7.46	7.5	7.54
EC (dS m^{-1})	9.2	1.2	0.43	3.2	5.3	6.4
TSS (mg L^{-1})	760	230	225	356	510	632
TDS (mg L^{-1})	5900	770	80	2060	3412	4116
Total solids (mg L^{-1})	6660	1000	305	2416	3922	4748
Carbonates (mg L^{-1})	BDL	2.0	0.9	1.6	0.8	0.4
Bicarbonates (mg L^{-1})	17.2	8.8	0.04	8.4	12.7	14.8
DO (mg L^{-1})	2.1	3.8	5.6	3.4	2.8	2.3
BOD (mg L^{-1})	27	28.5	6.10	28.1	28.4	28.7
COD (mg L^{-1})	210	160	42.0	176.2	185.4	198.8
Organic matter (%)	2.5	2.6	BDL	2.56	2.55	2.54
Calcium (meq L^{-1})	5.0	3.4	0.8	4.2	4.8	4.9
Magnesium (meq L^{-1})	6.2	8.2	0.12	4.8	5.4	5.8
Sodium (meq L^{-1})	48	9.8	0.14	16.7	24.8	36.5
Potassium (meq L^{-1})	4.75	7.5	BDL	6.9	5.7	4.3
Chloride (meq L^{-1})	60	11.2	0.05	19.4	32.6	48.9
Sulphate (meq L^{-1})	15.1	8.7	0.04	10.6	13.9	14.8
SAR	6.9	3.7	0.16	3.6	4.6	5.8
ESP (%)	7.80	3.9	1	3.8	5.1	6.64
Total nitrogen (mg L^{-1})	18.8	48	BDL	42.3	36.8	22.7
Total phosphorus (mgL^{1})	3.6	19	BDL	15.2	9.4	6.2
Total potassium (mg L^{-1})	4.8	36.7	BDL	32.4	18.6	9.3
NO_3-N (mg L^{-1})	0.07	0.42	BDL	0.32	0.26	0.10
Phosphate (mg L^{-1})	8.2	26	0.16	21.5	19.6	17.4
Zn (mg L^{-1})	0.23	0.07	0.01	0.04	0.09	0.12
Fe (mg L^{-1})	1.45	0.23	0.02	0.98	1.01	1.20
Mn (mg L^{-1})	0.05	0.66	BDL	0.22	0.18	0.09
Copper (mg L^{-1})	BDL	0.08	0.01	0.02	0.01	BDL
Lead (mg L^{-1})	BDL	0.19	BDL	0.06	0.03	0.01
Nickel (mg L^{-1})	BDL	BDL	BDL	BDL	BDL	BDL
Cadmium (mg L^{-1})	0.08	0.02	BDL	0.03	0.06	0.07
Chromium (mg L^{-1})	BDL	BDL	BDL	BDL	BDL	BDL
Biological Properties (Cfu mL^{-1})						
Bacteria × 10^6	10	18	7	16	13	11
Fungi × 10^4	7	11	3	10	9	8
Actinomycetes × 10^3	BDL	BDL	BDL	BDL	BDL	BDL
Total coliform count	6	8	BDL	7	7	6

black soil, phosphatase activity ranged from 10.9 to 12.4 and 11.3 to 12.6 and 10.4 to 11.7 µg PNPP g^{-1} of soil at 30, 60 DAT and at harvest stage, respectively. The soil phosphatase activity increased due to continuous effluent irrigation. A similar trend was observed in case of dehydrogenase enzyme activity also irrespective of the stages.

The treatment combination, T_3S_2 recorded the highest mean enzyme activity and the lowest value was recorded by T_6S_3. The increased urease, phosphatase and dehydrogenase activity in soils with an increase in the period of treated tannery effluent, mixed with domestic wastewater irrigation might be due to the increased microbial populations, which help in the mineralization and degradation of organic matter. The increase in organic matter content, which serves as a nutrient source for microorganisms, might increase the enzyme activity under effluent irrigated soils. The same type of observation was recorded by Abhijeet (2010), who reported that the treated tannery effluent mixed with domestic wastewater increased the soil enzyme activity.

The environment is under increasing pressure from solid and liquid waste emanating from the leather industry. The byproducts of the leather manufacturing process cause significant pollution unless treated in some way prior to discharge (Karunya et al. 1994). He reported that the effluent concentration at 75 and 100 per cent killed the plants and only 25 per cent was found to be suitable.

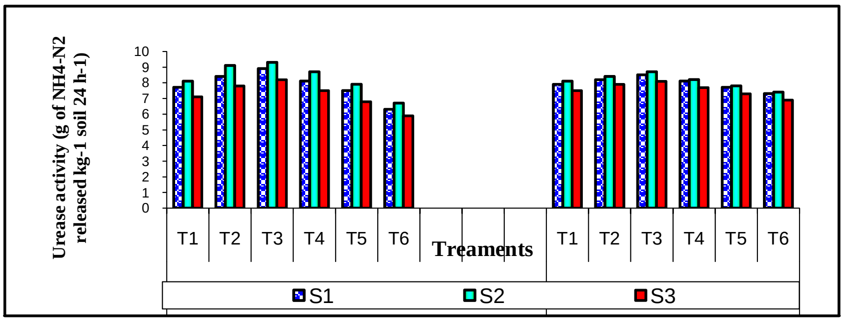

Fig.1: Effect of treated tannery effluent mixed with domestic wastewater on soil urease enzyme activity in *Gomphrena globosa* (Vadamalli) under pot culture study.

T_1 : Control; T_2: 100% DWW; T_3: 25% TTE+ 75% DWW; T_4: 50% TTE + 50% DWW; T_5: 75% TTE + 25% DWW; T_6: 100% Treated tannery effluent S_1: 30 DAT ; S_2: 60 DAT; S_3: At harvest stage.

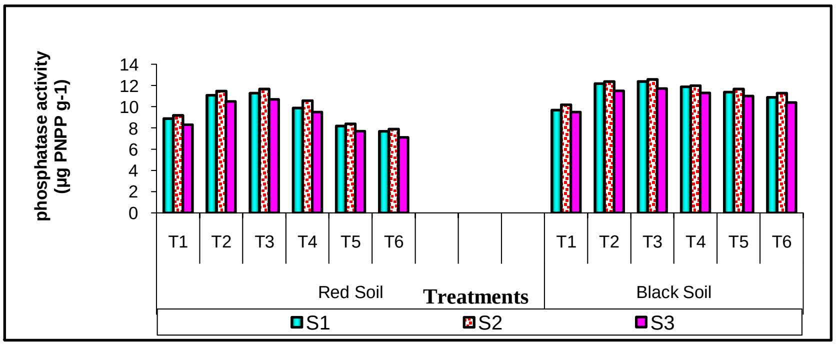

Fig. 2: Effect of treated tannery effluent mixed with domestic wastewater on soil phosphatasse activity in *Gomphrena globosa* (Vadamalli) under pot culture study.

T_1: Control; T_2: 100% DWW; T_3: 25% TTE + 75% DWW; T_4: 50% TTE + 50% DWW; T_5: 75% TTE + 25% DWW; T_6: 100% Treated tannery effluent S_1: 30 DAT; S_2: 60 DAT; S_3: At harvest stage.

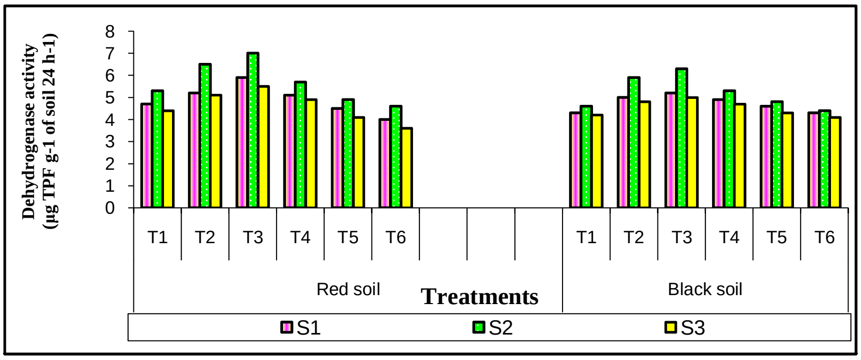

Fig. 3: Effect of treated tannery effluent mixed with domestic wastewater on soil dehydrogenase activity in *Gomphrena globosa* (Vadamalli) under pot culture study.

T_1: Control; T_2: 100% DWW; T_3: 25% TTE + 75% DWW; T_4: 50% TTE + 50% DWW; T_5: 75% TTE + 25% DWW; T_6: 100% Treated tannery effluent S_1: 30 DAT; S_2: 60 DAT; S_3: At harvest stage.

Tanning industrial wastes are a serious threat when they pollute streams, freshwater bodies and land. The wastes from this industry rank among the most polluting of all industrial wastes (Javaid 2000). Chemicals such as sodium chloride, sodium sulphite, lime and chromium used at different stages of tanning process are present in the discharged effluent. When used for irrigation, the effluent containing chromium in non-permissible limits can prove to be phytotoxic. Chromium exists in two oxidation states, trivalent (CrIII) and hexavalent (CrVI). Both the forms are toxic to

Table 2: Effect of treated tannery effluent mixed with domestic wastewater irrigation on plant height (cm) and branch number in pot culture study.

Treatments	*Gomphrena globosa* (Vadamalli)															
	Plant height (cm)								Branch number							
	Red soil				Black soil				Red soil				Black soil			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	19.2	26.1	36.5	27.3	18.9	25.8	35.4	26.7	6	12	16	11	5	10	15	10
T_2	25.3	32.5	42.4	33.4	24.8	29.9	40.9	31.9	12	21	28	20	10	19	26	18
T_3	26.1	34.6	45.6	35.4	25.6	31.2	43.6	33.5	13	24	31	23	11	23	29	21
T_4	22.5	28.4	37.2	29.4	21.7	26.4	35.8	27.9	7	13	18	13	5	11	17	11
T_5	15.2	21.3	28.9	21.8	14.9	19.8	27.8	20.8	5	9	13	9	3	7	12	7
T_6	12.1	18.2	22.1	17.5	11.2	16.8	20.9	16.3	2	5	9	5	1	3	8	4
Mean	20.1	26.9	35.5	27.5	19.5	25.0	34.1	26.2	8	14	19	14	6	12	18	12

	SEd	**CD (0.05)**	**SEd**	**CD (0.05)**	**SEd**	**CD (0.05)**	**SEd**	**CD (0.05)**
S	0.18	0.36	0.17	0.34	0.09	0.19	0.08	0.17
T	0.25	0.51	0.24	0.48	0.13	0.27	0.12	0.25
ST	0.44	0.88	0.42	0.84	0.23	0.48	0.21	0.43

T_1 : Control ; T_2: 100% DWW; T_3 : 25% TTE+ 75% DWW; T_4 : 50% TTE + 50% DWW ; T_5 : 75% TTE + 25% DWW ; T_6: 100% Treated tannery effluent S_1: 30 DAT ; S_2: 60 DAT; S_3 : At harvest stage, DWW- Domestic Wastewater, TTE- Treated Tannery Wastewater

the plants and inhibit germination, reduce growth, generate oxidative stress, decrease protein content, inhibit photosynthesis and alter enzyme activities in the exposed plants (Panda & Choudhury 2005, Shankar et al. 2005).

At the same time in response to the damaging effects of environmental stresses, plants have evolved a variety of antioxidant defence mechanisms in response to stress (Jung & Kuk 2003).

Biometric parameters: Biometric parameters were significantly influenced by irrigation water (Table 2). Taller plant growth in domestic water irrigated plots was reported by Kumar & Reddy (2007). As the concentration of the tannery effluent increases, the plant height decreased significantly and the maximum plant height was observed in T_2 (100% DWW) and T_3 (25% TTE + 75% DWW) and least plant height was recorded in 100% TTE. This shows the effect of nutrients present in the wastewater used for irrigation. This was in accordance with the report of Kumar and Reddy (2007). The effect was comparable with normal water irrigation. The same trend was observed in case of number of branches also, which again confirms the effect of nutrients in the wastewater. The treatment T_3 (25% TTE + 75% DWW) recorded the highest plant height of 45.6 cm in red soil and 43.6 cm in black soil, and branch number of 31 in red soil and 29 in black soil at the time of harvest. The treatment T_6 (100% TTE) recorded the shorter plants invariably at all the stages. Indra (2003) also reported maximum plant height and more number of branches in *Amaranthus* when grown on soil with 25% treated tannery effluent irrigation, which is in contrary with the report of Zereen et al. (2013). Sangeetha et al. (2012) reported that diluted effluents improve plant yield with a very low compromise with the nutrient quality and thus the metals and organic components of the effluent may be beneficial, if present in permissible limits. Despite the tannery wastes and domestic wastewater contain high concentrations of various elements, treated tannery effluent diluted with domestic wastewater did not indicate any adverse effect on the plant growth and soil microbial activities (Mariappan et al. 2001, Malafaia et al. 2015, Jagathjothi et al. 2015).

Effect on flower yield: Significant differences among the irrigation sources were observed with regard to flower yield plant^{-1} in both the soil types (Table 3). Irrigation with normal water recorded higher flower yield per plant which was comparable with irrigation of 100% DWW. This was followed by the mixing ratio of 25%TTE + 75% DWW and least flower yield was recorded under 100% TTE. Application of 25 per cent effluent showed better results compared to higher concentrations in both the soils. Treatments in red soil with different concentrations of tannery effluent recorded better results as compared to the black cotton soil. The plants grown in the treatment with 100 per cent tannery effluent concentration were collapsed due to higher concentration.

Among the treatments, the treatment T_3 (25% TTE + 75% DWW) recorded the highest individual spike and flower weight and yield per plant irrespective of the crops, followed by T_2 (100 % DWW), and the least values were re-

Table 3: Effect of treated tannery effluent mixed with domestic wastewater irrigation on individual spike (flower) weight (g) and spike (flower) yield per plant (g) in pot culture study.

Treatments	*Gomphrena globosa* (Vadamalli)								
	Individual flower weight (g)			Flower yield per plant (g)			Flower yield (t ha^{-1})		
	R.soil	B.soil	Mean	R. soil	B. soil	Mean	R.soil	B.soil	Mean
T_1	0.90	0.70	0.80	20.0	18.0	19.0	2.95	2.16	2.56
T_2	1.40	1.10	1.25	24.0	22.0	23.0	4.60	4.16	4.38
T_3	1.80	1.60	1.70	28.0	25.0	26.5	5.86	5.73	5.80
T_4	1.00	0.80	0.90	21.0	19.0	20.0	4.15	3.91	4.03
T_5	0.70	0.50	0.60	13.0	10.0	11.5	2.35	2.73	2.54
T_6	0.60	0.30	0.45	8.00	5.00	6.50	1.53	1.44	1.49
Mean	1.07	0.83	0.95	19.0	16.5	17.7	3.57	3.36	3.46
SEd	0.02		0.01	0.30		0.20	0.05		0.05
CD (0.05)	0.04		0.03	0.60		0.40	0.12		0.11

T_1 : Control ; T_2: 100% DWW; T_3 : 25% TTE+ 75% DWW; T_4 : 50% TTE + 50% DWW ; T_5 : 75% TTE + 25% DWW ; T_6: 100% Treated tannery effluent S_1: 30 DAT ; S_2: 60 DAT; S_3 : At harvest stage, DWW- Domestic wastewater, TTE- Treated Tannery wastewater.

corded by 100% TTE (T_6). Significant interaction between the treatments was observed in both the crops and this may be due to the reduced concentrations of toxic ions in the root zone which enhanced the crop growth and yield (Castilhos et al. 2002). Various studies have shown the demands for the use of sewage wastewater in agriculture because of its nutritional quality (Leal et al. 2011, Fonseca et al. 2005, 2005a and 2007, Nath 2009, Andrade-Filbo et al. 2013). Though these wastes are useful in agriculture, still there is a resistance from farmers with few practical applications. Therefore, we can conclude that dilution of tannery effluent may help to reduce the adverse impact when used for crop irrigation without significant loss in yield compared to undiluted tannery wastewater.

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