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Ecofriendly Utilization of distillery wastes for sustaining soil health in *Typic haplustert*

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ABSTRACT

Industrialization is believed to be an index of modernization and it has its unavoidable impacts on pollution of air, water and soil depending upon the type of industry, nature of raw material used and the manufacturing process involved. Since industrialization and pollution are complementary to each other, necessary steps need to be taken for proper disposal of industrial wastes. The sugarcane based industries like distilleries produce a large amount of byproducts like Raw Spent Wash (RSW), Treated Distillery Effluent (TDE) and Biocompost (BC). The Treated Distillery Effluent is waste water, which could be recycled in agriculture both as irrigation water and as a source of plant nutrients. The beneficial effect of organic matter for enhancing the soil fertility and thereby improving the crop productivity is well established. Thus, the soil application of TDE could offer the double benefit of safe disposal of wastes and its effective utilization for agricultural production. Keeping this fact in view, a field experiment was conducted to study the effect of Treated Distillery Effluent (TDE) and biocompost on soil chemical and biological properties using paddy as a test crop (ADT- 43). Based on the increase in soil chemical and biological properties, it can be concluded that TDE @ 1.0 lakh litres ha^{-1}(M3) or TDE @ 1.5 lakh litres ha^{-1} (M4) along with 37.5% N as urea + 37.5 % N as biocompost (S7) can be recommended as a nutrient source for paddy crop.

Keywords: Treated distillery effluent, Biocompost, Paddy

1. INTRODUCTION

Sugar industry based distillery wastes were hitherto considered as unwanted waste has been now used as a means to support sustainable agriculture. Application of TDE on soils is one of the most economical resources for the soil fertility amelioration through improvement in soil water holding capacity, texture, structure and nutrients retention. Now days, due to the increasing number of sugar mills and distillery units, application of distillery effluent on soil nearly become mandatory. These compounds may change the physico- chemical and biological properties of the soil. The available nutrient status of the soil is an important property which support the crop growth while, the crop growth and dry matter accumulation depends upon the ability of the soil to supply nutrients; the nutrients release from the soil in turn depends upon the demand from the growing plants. Therefore, the main objectives of the present study were to evaluate the effect of different application rates of distillery wastes, on soil chemical and biological properties in *Typic haplustert.*

2. MATERIAL AND METHODS

Field experiment was conducted using paddy as a test crop (ADT- 43). The experiment was conducted in a split plot design with four main plots *viz.*, control; TDE @ 0.5 lakh litres ha^{-1}; TDE @ 1.0 lakh litres ha^{-1}; TDE @ 1.5 lakh litres ha^{-1}. Different levels of N fertilizers *viz.*, 100 per cent N as urea, 75 per cent N as urea, 100 per cent N as biocompost, 75 per cent N as biocompost, 75 per cent N as urea and 25 per cent N as biocompost, 37.5 per cent N as urea and 37.5 per cent N as biocompost and control were imposed as seven subplot treatments and the treatments were replicated twice. TDE was uniformly applied to each plot as per the treatment schedule at 45 days before planting.

The soil of the experimental field belongs to *Typic haplustert*, neutral in pH (pH 7.58) and low in EC (0.30 dSm^{-1}). The organic carbon content (4.00 g kg^{-1}) and the alkaline $KMnO_4$-N (162 kg ha^{-1}) were found to be low. The Olsen-P level (16 kg ha^{-1}) and the NH_4OAc-K (205 kg ha^{-1}) were medium. The bacterial, fungal and actinomycetes population were found to be 10.2 x 10^6 CFU g^{-1} of soil, 14 x 10^4 CFU g^{-1} of soil, 5.1 x 10^3 CFU g^{-1} of soil respectively. The urease and dehydrogenase activity were found to be 4.5 µg NH_4-N g^{-1} dry soil hr^{-1} and 2.5 µg TPF g^{-1} dry soil hr^{-1} respectively. The enzymes viz., Dehydrogenase and urease activities were estimated by Chendrayan *et al.*, (1980) and Bremner and Mulvany (1978) respectively. The data on various characters studied during the investigation were statistically analyzed by the method given by Gomez and Gomez (1984). The critical difference was worked out at 5 per cent (0.05) probability levels.

Bio-compost is prepared by utilizing the pressmud (an organic solid material obtained as by-product from sugar industries) as a raw material and the composting process is being carried out by mechanized open windrow system with the use of treated distillery effluent and bioinoculants for about 70 – 80 days. The product is then sun dried, ground and sieved by mechanical separator and finally enriched with bio-fertilizers. The results of bio-compost analysis indicated that it was neutral in reaction (pH 7.56) with considerable amount of salt (EC 6.74 dSm^{-1}). It was rich in organic carbon (21.86 per cent), N (1.58 per cent), P (2.32 per cent), K (4.56 per cent), Ca (2.78 per cent), Mg (1.62 per cent), Na (1.76 per cent) and had traces of micronutrients *viz*., Zn, Fe, Cu and Mn with a favourable C: N ratio of 20.4 and considerable amount of enzyme activity and microbial population. Gururaj Hunsigi (2000) also reported that bio-compost prepared from distillery effluent have a neutral pH 6.5 to7.5.

The TDE was dark brown in colour imparted by melanoidin and had unpleasant odour which may be due to skatole, indole and other sulphur compounds. It was neutral in reaction (pH 7.71), but loaded with high organic and inorganic salts recording high EC (34.6 dS m^{-1}). The total solids, suspended solids and dissolved solids content of the TDE were 51200, 5610 and 45590 mg L^{-1}, respectively. Being originated from plant sources, the TDE was rich in organic carbon (28,500 mg L^{-1}), K (12,650 mg L^{-1} as K_2O), Ca (2,250 mg L^{-1}), Mg (1,560 mg L^{-1}) with considerable amount of N (2,000 mg L^{-1}), low in P (246 mg L^{-1}), and had relatively small amounts of micronutrients in the order of Fe>Mn> Zn > Cu. The TDE contained large amounts of bases, whose concentration followed the order of Ca>Mg>Na. The BOD and COD of TDE used for land application were 7,890 and 38,562 mg L^{-1}, respectively. The TDE had appreciable counts of fungi, bacteria and actinomycetes. Sodium adsorption ratio, residual sodium carbonate and soluble sodium percentage were below the critical limits, whereas the potential salinity exceeded the critical level as per the irrigation water quality standards.

3. RESULTS AND DISCUSSION

3.1. Soil Organic Carbon as influenced by different levels of TDE and biocompost

In this study, significant increase in soil organic carbon status was observed in the TDE applied treatments compared to control plot at all the stages of observation in both soils. The highest mean organic carbon content was recorded (42.06 per cent increase over control) in treatment which received the application of TDE at 1.5 lakh litres ha^{-1}. The increase in organic carbon content of the soil might be due to the decomposition and humification of organic matter supplied through distillery effluent. The organic carbon status of soil was declined with advancement of crop growth. Similar findings were opined by Maheswari (2011) and Dinesh (2011).

The TDE with high organic carbon (2.4%) content enriched the soil with organic matter which in turn increased the soil organic carbon. During crop growth period, the organic carbon content was found to decrease particularly towards the harvest stage (Table 1). It could be due to the organic matter decomposition. The effectiveness of TDE in increasing the organic carbon content was also reported by many workers (Sridharan, 2007; and Janaki, 2008).

3.2. Soil available Nitrogen as influenced by different levels of TDE and biocompost

The available N content was significantly influenced by the application of TDE and BC. Among the different treatments, application of TDE @ 1.5 lakh litres ha^{-1} (M4) recorded the highest available N to a tune of 267 kg ha^{-1} which contributed to an increase of 37 % over the absolute control (Table 2). The higher rate of mineralization and release of N from soil, fertilizers and TDE could have contributed for the increase in the available N in the soil.

Among the subplot treatments, S6 (application of 75% N as urea+ 25% N as compost) recorded high available N status which contributed to an increase of 10% over check. It was being on par with S7 (37.5 %N as urea + 37.5 % N as biocompost) contributing an increase of 9.6% increase over the control. The effect of biocompost almost at all the stages of observations was found superior to control. This increase could be attributed to release of N upon sustained mineralization of organic manures (Suganya, (2008) and Dinesh (2011).

Among the treatment combinations, application of TDE @ 1.0 lakh litres per hectare (M3) along with 37.5% N as urea + 37.5 % N as biocompost (S7) registered high available nitrogen and was found to be comparable with the application of TDE @ 1.5 lakh litres ha^{-1} (M4) along with 37.5% N as urea + 37.5 % N as biocompost (S7) recording 278 kg $ha^{-1.}$ Higher N availability in soil could be due to the direct contribution of nitrogen supply as well as increased microbial activity due to the added organic matter and partial pressure of carbon dioxide in the effluent treated soil resulting in an enhanced availability of N in soil. Similar results were reported by Subash Chandra Bose *et al*. (2002b) and Sridharan (2007). Significant and positive correlation observed between the available N and yield ($r = 0.802^{**}$) also supported the above findings. A marked decline in the available N in the soil was observed with the advancement of crop growth which might be due to the continuous removal of N by the crop, losses due to transformation. However, during the crop growth the reduction in the soil available N could be due to the uptake by growing crop.

3.3. Soil available Phosphorus as influenced by different levels of TDE and biocompost

Application of TDE and biocompost remarkably increased the available P in soil. Among the different treatments, application of TDE @ 1.5 lakh litres ha^{-1}(M4) had recorded the highest available P to the tune of 21.36 kg P ha^{-1} which contributed to an increase of 24% over the absolute control (Table 3). The increase in available P may be due to the application of TDE applied as well as the consequent dissolution of soil mineral P (apatite P). Though TDE was not acidic, its decomposition released organic acids which might have solubilised the soil native P and thus increased the $NaHCO_3$-P. Similar results were reported by Murugaraghavan (2002), Maheswari (2011) and Dinesh (2011).

Among the sub plot treatments, application of 75% N as urea +25% N as biocompost (S6) recorded higher phosphorus availability of 20.19 kg ha^{-1} being comparable with 37.5% N as urea +37.5% N as biocompost (S7) registering 20.05 kg ha^{-1}, both of which contributed to an increase of 10.9 % and 10.4% increase over the check.

Application of TDE @ 1.0 lakh litres ha^{-1} along with 37.5% N as urea + 37.5% N as biocompost (M3S7) or 75% N as urea +25% N as biocompost (M3S6) being on par with the application of TDE @ 1.5 lakh litres ha^{-1} along with 37.5% N as urea +37.5% N as biocompost (M4S7). The effect of biocompost almost at all the stages of observations was found superior to check. These results are in line with the findings of Singh *et al*. (2002). The decomposition processes of easily degradable organics might have reduced the binding energy and P sorption capacity of the soil, favouring higher P availability in the soil. Significant and positive correlation observed between the available P and yield ($r = 0.869^{**}$) also supported the above findings. The decline in available phosphorus at harvest stage could be due to crop uptake, physico-chemical transformations of phosphorus (adsorption, precipitation) into insoluble forms or due to microbial immobilization.

3.4. Soil available Potassium as influenced by different levels of TDE and biocompost

The available K in the soils was significantly influenced by the application of TDE and biocompost. Among the main plot treatments, application of TDE@ 1.5 lakh litres ha^{-1} (M4) registered significantly higher K availability (404 kg ha^{-1}) compared to the other main plot treatments which contributed to an increase of 53.7% over control. The reason attributed to this was due to the high potassium content of TDE (12,650 ppm). Increase in the available K content of the surface soil was sustained even after the harvest. These results also agreed with the findings of Murugaragavan (2002) and Janaki (2008) who observed that the available K in the soil increased due to the application of effluent.

Among the subplot treatments, application of 75% N as urea+ 25% N as compost, 37.5 %N as urea + 37.5 % N as bio-compost, 100% N as urea and 75 % N as urea being comparable among themselves registered higher available potassium content of 337 kg ha^{-1}, 333 kg ha^{-1}, 331 kg ha^{-1} and 329 kg ha^{-1} respectively in the soil over the rest of the treatments which contributed an increase of 10.4%, 9.3% and 8.8% increase over control (Table 4).

The interaction effect of M x S was also significant wherein the application of TDE @ 1.0 lakh litres ha^{-1} along with 37.5% N as urea +37.5% N as biocompost (M3S7) or 75% N as urea +25% N as biocompost (M3S6) being on par with the application of TDE @ 1.5 lakh litres ha^{-1} along with 37.5% N as urea +37.5% N as biocompost (M4S7). The increase may be attributed to the release of mineral K and addition of K rich manures led to the release of K into the soil solution. The present findings fall in line with that of Sivasamy (2004), Venkatakrishnan and Ravichandran (2007) and Dinesh (2011). Significant and positive correlation observed between the available K and yield (r =0.748**) also supported the above findings. The availability of K in the soil got decreased as the crop growth advanced which could be attributed to the uptake of K by the crop.

3.5. Soil microbial population as influenced by different levels of TDE and biocompost

Microbial activity had a direct impact on the plant nutrient availability as well as other properties related to soil productivity. Microbial activity is dependent on adequate energy supply from organic C, inorganic ion availability and numerous environmental conditions. The impact of TDE and biocompost as well as the different levels of fertilizers on the population of soil bacteria, fungi and actinomycetes was very well pronounced.

The highest population of bacteria, fungi and actinomycetes were observed in the treatment receiving TDE @ 1.0 lakh litres ha^{-1} along with 37.5% N as urea + 37.5% N as biocompost (M3S7) (Table 5, 6 and 7). Being rich in nutrients and organic material, particularly easily oxidizable and soluble organic carbon, the TDE might have favoured the proliferation of microbial population throughout the crop growth by the steady supply of nutrients and build up of organic matter in both soils. This was in line with the findings of Maheswari (2011) and Dinesh (2011).

4. SUMMARY AND CONCLUSION

In general the effect of TDE application on higher N, P, K and microbial availability might be ascribed to several reasons which are as follows:

- Contribution of huge amounts of K and organic matter and considerable amount of N and P through the addition of TDE.
- Increased microbial population and enzymatic activities.
- Low volatilization loss of NH_3 and accumulation of organic N.
- Solubilization of native soil P through acid forming effect

The application of TDE @ 1.0 lakh litres ha^{-1}(M3) or TDE @ 1.5 lakh litres ha^{-1} (M4) along with 37.5% N as urea + 37.5 % N as biocompost (S7) recorded the highest availability of soil available nutrients and microbial population in the soil.

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Table 1. Soil organic carbon (g kg^{-1}) as influenced by different levels of TDE and bioc

Treatments	Active Tillering Stage (Stage 1)					Panicle Initiation Stage (Stage 2)					
	M1	M2	M3	M4	Mean	M1	M2	M3	M4	Mean	M1
S1	3.65	4.54	5.70	5.81	**4.92**	3.35	4.20	5.56	5.99	**4.77**	2.98
S2	3.79	4.72	5.93	6.28	**5.18**	3.54	4.35	5.68	6.13	**4.93**	3.12
S3	3.77	4.68	5.94	6.26	**5.16**	3.53	4.32	5.70	3.11	**4.16**	3.10
S4	3.71	4.61	5.89	6.20	**5.10**	3.44	4.26	5.66	6.07	**4.86**	3.06
S5	3.69	4.59	5.87	6.15	**5.07**	3.43	4.24	5.64	6.05	**4.84**	3.04
S6	3.82	4.75	5.97	6.39	**5.23**	3.61	4.39	5.75	6.17	**4.98**	3.17
S7	3.75	4.64	5.99	6.43	**5.20**	3.46	4.29	5.78	6.20	**4.93**	3.08
Mean	**3.74**	**4.65**	**5.90**	**6.21**	**5.12**	**3.48**	**4.29**	**5.68**	**5.67**	**4.78**	**3.08**

Treatments	Pooled mean (Stages)				
	M1	M2	M3	M4	Mean
S1	3.33	4.22	5.59	5.82	**4.74**
S2	3.48	4.38	5.75	6.11	**4.93**
S3	3.47	4.35	5.77	5.08	**4.67**
S4	3.40	4.29	5.71	6.04	**4.86**
S5	3.38	4.27	5.69	6.00	**4.84**
S6	3.53	4.42	5.80	6.18	**4.98**
S7	3.43	4.32	5.82	6.21	**4.94**
Mean	**3.43**	**4.32**	**5.73**	**5.92**	**4.85**

	Stage	M	S	M at St	S at M	S at St	S at St
SEd	0.06	0.07	0.09	0.12	0.18	0.15	0.30
CD(5%)	0.11	0.13	NS	NS	NS	NS	NS

Table 2. Soil available nitrogen (kg ha^{-1}) as influenced by different levels of TDE and bi

Treatments	Active Tillering Stage (Stage 1)					Panicle Initiation stage (Stage 2)					
	M1	M2	M3	M4	Mean	M1	M2	M3	M4	Mean	M1
S1	160	221	248	259	**222**	154	215	244	257	**217**	142
S2	177	232	270	275	**238**	173	231	268	268	**235**	170
S3	175	234	267	277	**238**	171	230	265	270	**234**	168
S4	171	227	258	269	**231**	167	226	256	265	**228**	163
S5	169	225	254	265	**228**	163	225	252	262	**225**	162
S6	179	240	275	279	**243**	177	233	273	275	**239**	175
S7	173	229	288	283	**243**	169	228	282	280	**240**	165
Mean	**172**	**230**	**265**	**272**	**235**	**168**	**227**	**263**	**268**	**231**	**163**

Treatments	Pooled Mean				
	M1	M2	M3	M4	Mean
S1	152	212	243	255	**215**
S2	173	230	268	267	**234**
S3	171	230	264	270	**233**
S4	167	224	255	263	**227**
S5	165	222	252	260	**224**
S6	177	234	273	274	**239**
S7	169	227	282	278	**238**
Mean	**168**	**225**	**262**	**267**	**230**

	Stage	M	S	M at St	S at M	S at St	S at St x M
SEd	3	4	5	6	9	8	16
CD(5%)	6	7	9	12	18	NS	NS

Table 3. Soil available phosphorus (kg ha^{-1}) as influenced by different levels of TDE and l

Treatments	Active Tillering Stage (Stage 1)					Panicle Initiation Stage (Stage 2)					
	M1	M2	M3	M4	Mean	M1	M2	M3	M4	Mean	M1
S1	15.35	17.55	20.30	19.90	**18.28**	15.17	17.16	20.20	20.00	**18.13**	14.11
S2	17.20	19.30	21.30	21.40	**19.80**	16.89	19.11	21.09	22.28	**19.84**	16.70
S3	16.70	19.20	21.70	21.20	**19.70**	16.51	19.01	21.59	22.07	**19.80**	16.41
S4	16.15	18.80	20.80	20.60	**19.09**	15.93	18.43	20.69	21.68	**19.19**	15.74
S5	15.95	18.60	20.50	20.40	**18.86**	15.74	17.94	20.40	21.48	**18.89**	15.45
S6	17.45	19.40	22.20	22.30	**20.34**	17.28	19.21	21.89	22.47	**20.21**	17.09
S7	16.50	19.00	22.70	22.85	**20.26**	16.32	18.72	22.39	22.67	**20.02**	16.13
Mean	**16.47**	**18.84**	**21.36**	**21.24**	**19.48**	**16.27**	**18.51**	**21.18**	**21.81**	**19.44**	**15.95**

Treatments	Pooled mean (Stages)				
	M1	M2	M3	M4	Mean
S1	14.88	17.03	20.13	19.83	**17.97**
S2	16.93	19.11	21.13	21.65	**19.71**
S3	16.54	19.01	21.56	21.45	**19.64**
S4	15.94	18.46	20.66	20.89	**18.99**
S5	15.72	18.06	20.40	20.69	**18.72**
S6	17.27	19.21	21.96	22.32	**20.19**
S7	16.32	18.75	22.46	22.67	**20.05**
Mean	**16.23**	**18.52**	**21.19**	**21.36**	**19.32**

	Stage	M	S	M at St	S at M	S at St	S at St
SEd	0.06	0.07	0.09	0.12	0.18	0.16	0.32
CD(5%)	0.12	0.14	0.18	0.24	0.37	NS	NS

Table 4. Soil available potassium (kg ha^{-1}) as influenced by different levels of TDE and b

Treatments	Active Tillering Stage (Stage 1)					Panicle Initiation Stage (Stage 2)					
	M1	**M2**	**M3**	**M4**	**Mean**	**M1**	**M2**	**M3**	**M4**	**Mean**	**M1**
S1	200	322	392	385	**324**	182	294	374	370	**305**	137
S2	209	336	409	421	**344**	198	326	401	415	**335**	178
S3	206	333	413	419	**343**	194	322	403	412	**333**	173
S4	204	328	408	416	**339**	190	312	408	408	**330**	157
S5	202	326	403	414	**336**	187	310	405	405	**327**	154
S6	211	339	424	425	**350**	200	328	418	418	**341**	182
S7	205	332	427	428	**348**	192	316	420	420	**337**	165
Mean	**205**	**331**	**411**	**415**	**341**	**192**	**315**	**404**	**407**	**330**	**164**

Treatments	Pooled mean (Stages)				
	M1	**M2**	**M3**	**M4**	**Mean**
S1	173	293	372	370	**302**
S2	195	319	402	410	**331**
S3	191	316	402	409	**329**
S4	184	306	400	404	**324**
S5	181	303	397	402	**321**
S6	198	323	414	415	**337**
S7	188	312	416	417	**333**
Mean	**187**	**310**	**400**	**404**	**325**

	Stage	**M**	**S**	**M at St**	**S at M**	**S at St**	**S at S**
SEd	6	7	9	12	19	16	3
CD(5%)	12	14	19	24	37	NS	N

Table 5. Soil bacterial population as influenced by different levels of TDE and biocompost

Treatments	Bacterial Population (x 10^6 CFU g^{-1} of soil)							
	S1	S2	S3	S4	S5	S6	S7	Mean
M1	31.30	35.71	35.33	34.47	33.89	36.39	34.85	**34.56**
M2	44.37	48.07	48.07	46.90	46.41	48.95	47.39	**47.16**
M3	51.68	56.83	56.14	54.25	53.46	57.92	60.00	**55.75**
M4	54.43	56.62	57.71	56.12	55.42	58.41	59.30	**56.86**
Mean	**45.44**	**49.31**	**49.31**	**47.93**	**47.30**	**50.41**	**50.38**	**48.58**

	M	S	M at S	S at M
SEd	0.76	0.03	0.76	0.06
CD(5%)	2.43	0.06	2.43	0.12

Table 6. Soil fungal population as influenced by different levels of TDE and biocompost

Treatments	Fungi Population (x 10^4 CFU g^{-1} of soil)							
	S1	S2	S3	S4	S5	S6	S7	Mean
M1	6.94	7.92	7.84	7.64	7.53	8.08	7.73	**7.67**
M2	9.85	10.67	10.67	10.41	10.29	10.85	10.52	**10.46**
M3	11.45	12.63	12.47	12.04	11.86	12.85	13.28	**12.37**
M4	12.07	12.49	12.80	12.45	12.31	12.97	13.15	**12.60**
Mean	**10.08**	**10.92**	**10.94**	**10.63**	**10.50**	**11.19**	**11.17**	**10.78**

	M	S	M at S	S at M
SEd	0.17	0.01	0.17	0.01
CD(5%)	0.54	0.02	0.54	0.03

Table 7. Soil actinomycetes population as influenced by different levels of TDE and biocompost

Treatments	Actinomycetes population (x 10^2 CFU g^{-1} of soil)							
	S1	S2	S3	S4	S5	S6	S7	Mean
M1	3.32	3.79	3.76	3.66	3.60	3.87	3.71	**3.67**
M2	4.72	5.11	5.11	4.98	4.93	5.20	5.04	**5.01**
M3	5.49	6.04	5.97	5.76	5.69	6.16	6.35	**5.92**
M4	5.78	6.17	6.13	5.97	5.89	6.21	6.28	**6.06**
Mean	**4.83**	**5.28**	**5.24**	**5.09**	**5.03**	**5.36**	**5.34**	**5.17**

	M	S	M at S	S at M
SEd	0.08	0.01	0.08	0.01
CD(5%)	0.26	0.02	0.26	0.02