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Sugarcane Productivity and Fertility in Plant Ratoon System under Treated Distillery Effluent and Inorganic Fertilizers Management

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ABSTRACT

Treated Distillery Effluent (TDE) generated through biomethanated distillery effluent was applied to arable land for augmenting agricultural production. The TDE contains considerable amount of organic matter and salt besides its high plant nutrients content. With this background, an attempt was made. Field experiments were conducted to study the long term effect of TDE and inorganic fertilizers on soil properties and yield of sugarcane in sandy loam soil during 2010-2011 and 2011-2012. The main plot treatments viz., TDE was applied at the rate of 1.25, 2.5, 3.75 and 5.0 lakh litres ha^{-1} for treatments were compared with control and the sub-plots viz., N, NP, NK, PK, NPK for fertilizer treatments were compared with control (no fertilizer). The results revealed that the application of TDE had significantly increased the cane yield and had left significantly higher organic carbon, alkaline $KMnO_4$-N, 0.5 M $NaHCO_3$-P and neutral normal ammonium acetate-K content (211, 21.6 and 414 kg ha^{-1}) and exchangeable cations in the post harvest soil after the crop uptake. The TDE applied @ 3.75 lakh L ha^{-1} along with NP (106.3 t ha^{-1}) has resulted in higher yield without any adverse effect on soil properties.

Key words: TDE, inorganic fertilizers, soil properties, sugarcane yield

INTRODUCTION

India is basically an agricultural country. It occupies second position in the sugarcane production in the world. In Tamil Nadu, there are 35 sugar factories and distilleries with a total installed capacity of 2.4 lakh kiloliters of alcohol. Distillery effluent, a liquid waste from the distillery industry is of plant origin contains large quantities of soluble organic matter and plant nutrients. In the distillery industry, for every liter of alcohol produced, about 15 L of spentwash is released as waste water. So there is a possibility of getting 48 billion litres of spentwash (Distillery spentwash) from distillery industries in India. The sugarcane crop irrigated with Treated Distillery Effluent (TDE) did not contain any toxic elements/compounds. The estimated potential of 48 billion liters of spentwash will be 1,44,000 tonnes of K, 12,200 tonnes of N and 2000 tonnes of P per annum. The proper use of TDE application could produce 85,000 tonnes of biomass annually. Different doses of TDE have been tried in combination with different fertilizers in agricultural fields by Joshi *et al.* (1996) and they had recommended post sown irrigation with 50% NPK treatment for better performance in sugarcane. Under sugarcane cultivation, the soils are getting depleted of nutrients. So, replenishment of soil nutrients and maintenance of soil health by organic source are required. The TDE can play a prime role in bridging the wide gap of depletion and repletion of nutrients. The present study was carried out in sandy loam soil to assess the nutrient supplying potential of TDE to sugarcane crop with different combination of fertilizers. The effect of such application on the cane yield and physico-chemical properties were also assessed.

MATERIALS AND METHODS

The field experiment was undertaken up to study the long term effect of TDE and fertilizers on sugarcane yield at cane farm, EID Parry (India) Ltd., Cuddalore district, Tamil Nadu. The TDE was obtained from EID Parry (India) Ltd., Distillery, Nellikuppam and was characterized for its various physico-chemical properties (Table 1). The initial soil (0-15 cm depth) was low in organic carbon (0.37%) and alkaline $KMnO_4$-N (123 kg ha^{-1}) and medium in Olsens's P (15.1 kg ha^{-1}) and Neutral normal ammonium acetate-K (212 kg ha^{-1}), having pH (8.38) and EC of 0.10 dsm^{-1} (Table 2). The experiments were laid out in split-plot design with graded doses of TDE as main-plots and nutrient combinations as sub-plots with three replications. The main-plot treatments viz., TDE was applied @ 1.25, 2.5, 3.75 and 5 lakh litres per ha for M_2, M_3, M_4, M_5 treatments and were compared with control and the sub-plots viz., N, NP, NK, PK, NPK for S_2, S_3, S_4, S_5, S_6 fertilizer treatments and were compared with control (no fertilizer). The TDE was applied as pre-planting

Table 1: Physico-chemical properties and chemical composition of the treated distillery effluent

Parameters	Content	Parameters (ppm)	Content
Colour	Dark brown	Nitrogen	1,350
pH	7.3	Phosphorus	550
EC (dS m^{-1})	29.5	Potassium	9,500
BOD	4,500	Zinc	11
COD	48,000	Copper	65
Total solids	85,000	Iron	4.3
Organic carbon (%)	27.4	Manganese	5.4

Table 2: Characteristics of experimental soil

Parameter	Values
Soil series	Vadalapakkam
Soil taxonomy	Typic Haplustalf
Texture	Sandy loam
Bulk density (Mg m^{-3})	1.32
Particle density (Mg m^{-3})	2.33
Pore space (%)	30.20
Water holding capacity (%)	36.40
pH	8.38
EC (dsm^{-1})	0.10
CEC (cmol p(+) kg^{-1})	15.60
Organic carbon (%)	0.37
Available N (kg ha^{-1})	123.00
Available P (kg ha^{-1})	15.10
Available K (kg ha^{-1})	212.00
Exchangeable calcium (cmol (p+) kg^{-1})	7.40
Exchangeable magnesium (cmol (p+) kg^{-1})	3.50
Exchangeable sodium (cmol (p+) kg^{-1})	1.52
Exchangeable potassium (cmol (p+) kg^{-1})	0.25
ESP (%)	12.00

dose in the fallow land as per the treatments and allowed for natural oxidation. The natural oxidation was to narrow down the BOD and COD of the TDE. The soil was then thoroughly mixed and sugarcane planting (Variety CO 86032) was taken up after 45 days of TDE application. The N, P and K fertilizers were applied at 75% of the recommended doses viz., 206, 45 and 84 kg of N, P_2O_5 and K_2O per ha. The crop was managed by adopting standard package of practices. Cane yield data were recorded at the age of 12 months from the plots and were converted to yield ha. The initial and post harvest soil samples were collected from 10 spots at random from each experimental plot (0-30 cm depth) and a composite sample of each plot was used for estimation of soil physico-chemical properties by standard procedures. The data were statistically scrutinized (Gomez and Gomez, 1984).

RESULTS

pH: The application of TDE at graded levels continuously for 10 years declined the pH nearer to neutral range (M_1: Control, M_2: 1.25 lakh L ha^{-1}; M_3: 2.5 lakh L ha^{-1}, M_4: 3.75 lakh L ha^{-1} and M_5 : 5.0 lakh L ha^{-1}), S_1: control, S_2: N alone, S_3: NP, S_4: NK, S_5: PK and S6: NPK). The pH were recorded 8.06 in the plots which received TDE @ 5.0 lakh L ha^{-1}, whereas, control plots recorded the value of 8.32. The sub-plots and interaction were found to be non-significant (Table 3).

EC: The increasing rate of TDE significantly increased the soil EC at post harvest stage over 10 years. The highest value of EC (0.15 dS m^{-1}) was recorded at 5.0 lakh L ha^{-1} (M_5) while the control plot had 0.11 dS m^{-1}. The effects of sub-plots and interaction were also non-significant (Table 3).

Organic carbon: The application of TDE in long term at increased level registered higher organic carbon content at harvest stage. Among the treatments, the application of TDE @ 5.0 lakh L ha^{-1} (M_5) recorded the highest (0.92%) organic carbon content, whereas the lowest (0.39%) in control plot. The influence of fertilizers and combination of TDE and fertilizers were also found to be non-significant (Table 3).

Table 3: Effect of TDE and fertilizers on pH, EC and organic carbon of post harvest soil (pooled data of 2 crop cycles)

	pH							EC (dS m^{-1})							Organic carbon (%)						
Treatments	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean
M_1	8.34	8.33	8.31	8.31	8.33	8.32	8.32	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.35	0.36	0.39	0.38	0.41	0.45	0.39
M_2	8.19	8.11	8.17	8.10	8.13	8.11	8.14	0.12	0.11	0.12	0.11	0.12	0.12	0.12	0.75	0.74	0.77	0.79	0.78	0.79	0.77
M_3	8.16	8.13	8.13	8.07	8.03	8.08	8.10	0.12	0.12	0.12	0.13	0.14	0.14	0.13	0.80	0.82	0.83	0.81	0.83	0.85	0.82
M_4	8.09	8.10	8.05	8.08	8.06	8.08	8.08	0.13	0.13	0.14	0.14	0.13	0.14	0.14	0.86	0.88	0.89	0.89	0.90	0.89	0.89
M_5	8.02	8.07	8.10	8.06	8.02	8.06	8.06	0.14	0.15	0.15	0.15	0.15	0.16	0.15	0.90	0.90	0.91	0.94	0.92	0.96	0.92
Mean	8.16	8.14	8.15	8.12	8.11	8.13		0.12	0.12	0.13	0.13	0.13	0.13		0.73	0.74	0.76	0.76	0.77	0.79	

Statistical analysis	M	S	M×S	S×M	M	S	M×S	S×M	M	S	M×S	S×M
SEd	0.06	0.03	0.10	0.08	0.002	0.002	0.004	0.004	0.02	0.01	0.03	0.03
CD (0.05)	0.13	NS	NS	NS	0.005	NS	NS	NS	0.04	NS	NS	NS

M1: Control, M2: 1.25 lakh L ha^{-1}, M3: 2.5 lakh L ha^{-1}, M4: 3.75 lakh L ha^{-1} and M5: 5.0 lakh L ha^{-1}, S1: Control, S2: N alone, S3: NP, S4: NK, S5: PK and S6: NPK, NS: Not significant

Table 4: Effect of TDE and fertilizers on available nutrients of post harvest soil (pooled data of 2 crop cycles)

	Available nitrogen (kg ha^{-1})							Available phosphorus (kg ha^{-1})							Available potassium (kg ha^{-1})						
Treatments	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean
M_1	126	138	135	140	124	142	134	15.1	15.8	17.3	15.8	19.6	18.0	16.9	208	205	203	230	228	224	216
M_2	173	179	180	182	173	186	179	16.9	17.3	18.2	16.5	18.7	18.8	17.7	316	316	317	330	328	326	322
M_3	187	190	190	195	186	196	191	18.3	17.8	18.2	17.7	19.8	19.4	18.5	353	352	347	382	377	372	364
M_4	196	198	200	203	197	206	200	19.4	19.2	19.3	18.5	20.1	19.5	19.3	384	359	370	412	409	406	390
M_5	200	209	204	210	201	211	206	19.1	18.5	20.4	19.3	21.6	20.4	20.1	404	384	395	414	412	410	403
Mean	176	183	182	186	176	188		17.8	17.9	18.7	17.6	19.9	19.2		333	323	326	354	351	348	

Statistical analysis	M	S	M×S	S×M	M	S	M×S	S×M	M	S	M×S	S×M
SE d	3.0	2.0	5.0	5.0	0.3	0.6	1.2	1.3	5.0	4.0	9.0	8.0
CD (0.05)	8.0	4.0	NS	NS	0.7	1.2	NS	NS	11.0	7.0	NS	NS

M1: Control, M2: 1.25 lakh L ha^{-1}, M3: 2.5 lakh L ha^{-1}, M4: 3.75 lakh L ha^{-1} and M5: 5.0 lakh L ha^{-1}, S1: Control, S2: N alone, S3: NP, S4: NK, S5: PK and S6: NPK, NS: Not significant

Available nutrients: Graded levels of TDE application increased the alkaline $KMnO_4$-N, 0.5 M $NaHCO_3$-P and neutral normal ammonium acetate-K content (Table 4). The application of TDE @ 5.0 lakh L ha^{-1} recorded the highest alkaline $KMnO_4$-N (211 kg ha^{-1}) and control recorded the least value (126 kg ha^{-1}). Comparing the sub-plot treatments, application of NPK (S_6) was found to record the highest soil alkaline KMnO4-N (188 kg ha^{-1}) and lowest (176 kg ha^{-1}) was recorded in control plot. The interaction effect of TDE and fertilizers on soil alkaline $KMnO_4$-N were also found to be significant. Considering the 0.5 M $NaHCO_3$-P status at post-harvest stage, the highest 0.5 M $NaHCO_3$-P was recorded in the treatment TDE @ 5.0 lakh L ha^{-1} (M_5) and in control (16.94 kg ha^{-1}). Among the sub-plot treatments, the 0.5 M $NaHCO_3$-P content of the soil was found to be higher (21.6 kg ha^{-1}) in the plots which received PK (S_5) when compared to control. Similarly, the interaction of TDE and fertilizers effects also significantly influenced. Among the main-plot treatments, the application of TDE @ 5.0 lakh L ha^{-1} registered the highest neutral normal ammonium acetate-K (403 kg ha^{-1}) when compared to control (216 kg ha^{-1}). The sub-plot treatments were found to be significant and application of NK fertilizers recorded the highest neutral normal ammonium acetate-K (354 kg ha^{-1}) when compared to control (323 kg ha^{-1}). The interaction effect of TDE and fertilizers had created favourable influence on neutral normal ammonium acetate-K at post-harvest stage for more than 10 years.

Exchangeable cations: The exchangeable calcium and magnesium at post-harvest stage (Table 5) were found to be higher in 5.0 lakh L ha^{-1} (8.54 and 4.84 cmol p(+) per kg) of TDE applied plots than control (7.37 and 3.29 cmol p(+) per kg). The sub-plot treatments and their interaction were found to be non-significant. Similarly, there was no significant change due to application of TDE alone or fertilizer alone or in combination. The exchangeable sodium percentage of the soil had shown a considerable decrease with the increase in TDE dose. The reduction in ESP was significant in all the TDE treatments.

The graded doses of TDE applied plots had significantly increased the cane yield of sugarcane (Table 6). The highest cane yield of 100 t ha^{-1} was recorded in the treatment @ 5.0 lakh L ha^{-1} of TDE applied plots while the lowest cane yield of 63.3 t ha^{-1} was recorded in the control plot.

Table 5: Effect of TDE and fertilizers on exchangeable cations of post harvest soil (pooled data of 2 crop cycles)

	Exchangeable calcium (cmol p(+)kg)							Exchangeable magnesium (cmol p(+)kg)							Exchangeable sodium (cmol p(+)kg)						
Treatments	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean
M_1	7.57	7.29	7.32	7.35	7.32	7.35	7.37	3.20	3.22	3.29	3.23	3.34	3.45	3.29	1.35	1.42	1.41	1.40	1.37	1.41	1.39
M_2	8.20	8.06	8.20	8.16	8.17	8.15	8.16	4.10	4.19	4.14	4.18	4.14	4.20	4.16	1.39	1.39	1.40	1.39	1.39	1.39	1.39
M_3	8.18	8.16	8.24	8.23	8.27	8.28	8.23	4.22	4.18	4.20	4.22	4.23	4.25	4.22	1.37	1.41	1.39	1.40	1.40	1.37	1.39
M_4	8.32	8.36	8.43	8.25	8.41	8.31	8.35	4.30	4.36	4.38	4.50	4.51	4.53	4.43	1.36	1.39	1.41	1.42	1.43	1.39	1.40
M_5	8.51	8.60	8.55	8.62	8.60	8.35	8.54	4.74	4.88	4.83	4.81	4.90	4.88	4.84	1.40	1.40	1.42	1.48	1.47	1.41	1.43
Mean	8.16	8. 09	8.15	8.12	8.15	8.09		4.11	4.17	4.17	4.18	4.22	4.26		1.37	1.40	1.41	1.42	1.41	1.39	

Statistical analysis	M	S	M×S	S×M	M	S	M×S	S×M	M	S	M×S	S×M
SE d	0.23	0.20	0.15	0.10	0.09	0.04	0.12	0.08	0.02	0.04	0.09	0.09
CD (0.05)	0.52	NS	NS	NS	0.20	NS	NS	NS	NS	NS	NS	NS

M1: Control, M2: 1.25 lakh L ha^{-1}, M3: 2.5 lakh L ha^{-1}, M4: 3.75 lakh L ha^{-1} and M5: 5.0 lakh L ha^{-1}, S1: Control, S2: N alone, S3: NP, S4: NK, S5: PK and S6: NPK, NS: Not significant

Table 6: Effect of TDE and fertilizers on exchangeable cations, exchangeable sodium percentage and cane yield of post harvest soil (pooled data of 2 crop cycles)

	Exchangeable potassium (cmol p(+)kg^{-1})							Exchangeable sodium percentage							Cane yield (t ha^{-1})						
Treatments	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean
M_1	0.23	0.22	0.22	0.23	0.33	0.23	0.24	11.07	11.73	11.73	11.50	11.17	11.23	11.41	46.0	57.9	72.2	69.6	54.5	79.6	63.3
M_2	0.24	0.34	0.24	0.41	0.34	0.34	0.32	9.90	9.97	10.00	9.87	9.90	9.83	9.91	54.9	76.3	93.1	73.6	75.9	95.1	78.1
M_3	0.39	0.38	0.38	0.39	0.34	0.39	0.38	9.70	10.03	9.77	9.77	9.77	9.63	9.78	61.3	86.1	96.9	87.2	86.0	97.9	85.9
M_4	0.46	0.43	0.48	0.46	0.46	0.46	0.46	9.43	9.57	9.57	9.67	9.67	9.47	9.56	72.7	93.5	101.1	93.7	91.9	104.2	92.9
M_5	0.52	0.51	0.52	0.53	0.54	0.52	0.52	9.20	9.10	9.27	9.57	9.47	9.10	9.28	86.4	103.5	106.3	95.9	100.0	107.8	100.0
Mean	0.37	0.38	0.37	0.40	0.40	0.39		9.86	10.08	10.07	10.07	9.99	9.85		64.3	83.5	93.9	84.0	81.6	96.9	

Statistical analysis	M	S	M×S	S×M	M	S	M×S	S×M	M	S	M×S	S x M
SE d	0.01	0.00	0.01	0.01	0.14	0.26	0.55	0.58	1.6	1.8	3.9	4.0
CD (0.05)	0.01	NS	NS	NS	0.31	NS	NS	NS	3.7	3.6	8.1	7.9

M1: Control, M2: 1.25 lakh L ha^{-1}, M3: 2.5 lakh L ha^{-1}, M4: 3.75 lakh L ha^{-1} and M5: 5.0 lakh L ha^{-1}, S1: Control, S2: N alone, S3: NP, S4: NK, S5: PK and S6: NPK, NS: Not significant

Irrespective of doses of TDE, the highest yield was recorded in NPK fertilizer plots while lowest in control. Among the interactions, the highest cane yield was recorded in TDE @ 5.0 lakh L ha^{-1} + NPK (107.8 t ha^{-1}) while lowest in control (63.3 t ha^{-1}).

DISCUSSION

The decrease in pH might be attributed to the H^+ ions released during the decomposition of organic matter supplied through TDE. This corroborates the results obtained by Anandakrishnan *et al*. (2008) and Maheswari (2011). The probable reason for reduction of EC might be that sugarcane crop which received 35-40 irrigations dilute the concentration of salts which had significantly decreased the influence of these soluble salts on the crop growth. The leaching of soluble salts is also due to sandy loam in texture of the experimental plot might have reduced the EC. Bose *et al*. (2002) also observed that one time application of TDE @ 6.25 lakh L ha^{-1} before planting of the crop did not raise the EC of the soil beyond 0.25 dS m^{-1} in TDE applied plots. The organic carbon content also increased due to continuous application of TDE for more than 10 years. The increase in organic carbon content might be due to decomposition and humification of organic matter in the soil supplied through TDE. Further, addition of organic matter through TDE, better crop growth with concomitant higher root biomass generation could be the probable reason for improvement in organic carbon. This is in line with Devarajan *et al.* (1996).

The contribution of N from TDE @ 1 lakh liter which supplies 135 kg N and increased microbial activity on the added organic matter might have increased the available nitrogen level of post-harvest soil Bose *et al.* (2002). The contribution of P from TDE, HCO_3 of TDE and organic acids produced during decomposition of organic matter might have solubilized the insoluble soil P and thus helped to increase the available P (0.5 M $NaHCO_3$-P) of the soil. Similar results were obtained by Anandakrishnan *et al.* (2008). Bertranon *et al.* (1989) opined that the available K was increased by 4 to 5 times due to TDE application which might be due to the contribution of K from the TDE itself. This is inline with Chandra *et al.* (2002).

Higher amount of Ca and higher Mg (2,435 and 2,406 mg L^{-1}) contents in the effluent might be the reason for the increase in exchangeable Ca and Mg. Similar findings were also reported by Bhaskar *et al.* (2007) and Kayalvizhi *et al.* (2001). The ESP of the soil slightly decreased due to exchangeable cations. This is in agreed with Maheswari (2011). The increase in cane yield may be attributed to the pronounced effect of TDE on growth, dry matter production, chlorophyll content and increased uptake of nutrients (Patil and Shinde, 1995; Ramana *et al.*, 2002). The increasing doses of TDE application increased the yield attributes and cane yield due to the enhanced supply of nutrients (Janaki, 2008).

CONCLUSION

Based on the above discussion, it can be concluded that the application of TDE @ 3.75 lakh L ha^{-1} along with NP fertilizer will be the best suitable combination for getting the highest yield in sugarcane in sandy loam soil. It is noteworthy that the application of inorganic fertilizers omitting 100% K and also 25% N and P in combination with 3.75 lakh L ha^{-1} of TDE gave higher yield as that of NPK combination leading to a saving of N, P and K fertilizers.

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