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UTILIZATION OF POST METHANATION DISTILLERY EFFLUENT FOR SUSTAINABLE SUGARCANE CULTIV ATION AND ITS IMPACT ON SOIL PROPERTIES

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ABSTRACT

Post methanation effluent (PME) generated through biomethanation of distillery effluent was characterized with high biological oxygen demand, chemical oxygen demand and soluble salt content. In spite of this, PME also contains considerable amount of organic matter and high plant nutrient content and its was being applied to arable land for augmenting agriculture production. The present investigation was conducted during 2004 – 05 on sugarcane to evaluate the impact of graded levels of post methanation effluent (PME) with different combinations of major nutrients on soil properties and crop productivity in sandy loam soil. The main plot treatments *viz*., M_2 – 1.25, M_3 - 2.50, M_4 – 3.75, M_5 – 5.0 lakh litres ha^{-1} of PME application were compared with control (no PME application) and the sub plots, *viz*., S_2 - N, S_3 – NP, S_4 – NK, S_5 – PK, S_6 – NPK fertilizer treatments were compared with control (no fertilizer treatment). The fertilizer treatments received only 75 % of recommended dose of fertilizers (206, 45, and 84 kg of N, P_2O_5 and K_2O). The application of PME has significantly increased the cane yield and has left significantly higher soil organic carbon, available NPK, exchangeable cations and available micronutrients in the post harvest soil after the crop uptake. The PME applied at 1.25 lakh litres per ha has resulted in higher cane yield without any adverse effect on the soil properties. The PME has substituted 25 % of inorganic N and P fertilizer and 100% of inorganic K fertilizer. Thus application PME to arable land, as an amendment could be considered as a valuable substitute for inorganic fertilizers as well as a viable option for safe disposal of this industrial waste.

INTRODUCTION

Distilleries are one of the 17 most polluting industries listed by the Central Pollution Control Board (CPCB). At present, there are 319 distilleries in India with an installed capacity of 3.25 billion litres of alcohol. For every litre of alcohol produced, molasses based distilleries generate 8-15 L of wastewater characterized by high BOD (45-60 000 mg L^{-1}), high COD (80-160 000 mg L^{-1}) and dark color (Uppal, 2004). In order to reduce high bio-chemical oxygen demand (BOD) and chemical oxygen demand, it is passed through biomethanation digester, and the end product thus obtained is known as post methanation ef-

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fluent (PME). The PME even after biomethanation contains considerable amount of organic matter (BOD 4.0 g l^{-1}, COD 39.2 g l^{-1}) and salt (EC 25.1 dSm^{-1}). The PME contains organic and inorganic nutrients have been reported to have beneficial effects on crop yields (Pathak *et al.* 1999, Ramana *et al.* 2002). The estimated potential of PME are 2,44,000 tonnes of potassium (K), 12,200 tonnes of nitrogen (N) and 2000 tons of phosphorus (P) per annum and if PME is used carefully for irrigation of agricultural crops can produce more than 85000 tonnes of biomass annually (Kumar *et al.* 2000).

Land application of distillery effluent has become a common practice these days because proper treatment of the nutrient rich wastes involves large expenditure to bring down the high levels of BOD from about 50,000 mg l^{-1} to the permissible limits of 30 mg l^{-1} (CPCB, 1998). However, it is not desirable to use the lands simply to dispose off the wastewater. Rather, emphasize should be laid on exploring the possibilities of utilizing the wastewater for its organic matter and nutrients, which could be useful for growing crops or vegetables (Ajmal and Khan, 1984; Joshi *et al.* 1996; Ramana *et al.* 2002). Different doses of distillery wastes have been tried in combination with different types of fertilizers in agricultural fields and their or reports are both positive and negative impacts. Joshi *et al.* (1998) recommended post sown irrigations with diluted PME in combination with 50% NPK treatment for best performance results.

The bio-methanated distillery effluent (PME) when used carefully can play a prime role in bridging the wide gap of depletion and repletion of nutrients in intensive agricultural lands. Keeping abreast the scenario of disposal of PME and depleted status of agricultural lands an attempt was made for effective utilization of PME for sustainable sugarcane production and to study the impact of PME on the cane yield and soil properties.

MATERIALS AND METHODS

The experiment was taken up to study the effect of PME with fertilizers on sugarcane yield and soil properties on a deep sandy loam soil (Typic Haplustalf) at Edayanveli, Cuddalore District, and Tamil Nadu. The surface soil (0 - 15cm depth) was low in organic C (0.48%) and available N (135 kg ha^{-1}), and medium in available P (17.5 kg ha^{-1}) and available K (235 kg ha^{-1}), having pH 8.43 and a EC of 0.09 dSm^{-1}. The experiments were laid out in split plot design with graded dose of PME as main plots and nutrient combinations as subplots with three replications. The four PME treatments *viz*., M_2 – 1.25, M_3 - 2.50, M_4 – 3.75, M_5 – 5.0 lakh litres per ha were compared with control (no PME application) in the main plot and the five fertilizer treatments, *viz*., S_2 - N, S_3 – NP, S_4 – NK, S_5 – PK, S_6 – NPK were compared with control (no fertilizer treatment) in the sub plot.

The post bio-methanated distillery effluent (PME) was obtained from EID PARRY (I) LTD., Distillery, Nellikuppam and was characterized for its physico-chemical properties (Table 1). The PME was applied as pre-planting 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 PME, the soil was then thoroughly mixed and sugarcane planting (variety CO-86032) was taken up after 45 days of PME application. The fertilizer treatments received only 75 % of recommended dose of fertilizers (206, 45, and 84 kg of N, P_2O_5, and K_2O). The crop was managed by adopting standard package of practices. Cane yield data was recorded at the age of twelve months from the plots and were converted to yield per ha. The initial and post harvest soil samples were collected from ten spots at random from each experimental plot (0-30cm) and a composite sample of each plot was used for estimation of soil physico-chemical properties by standard procedures (Sparks, 1996). The data were statistically scrutinized (Gomez and Gomez, 2000).

RESULTS AND DISCUSSION

Sugarcane yield

The graded levels of PME application have significantly increased the cane yield over the control. The effect of different doses of PME and different levels of fertilizer treatments on sugarcane yield is given in the Table 2 and Figure 1. Though there is a gradual increase in the cane yield for the increasing doses of PME, the cane yield @ 1.25 lakh litres ha^{-1} with NP fertilizers was found to be optimal to give the higher yield *ie.*, 15 tonnes increase in yield over the control. The increase in yield may be attributed to the pronounced effect of distillery effluent on growth, dry matter production, chlorophyll content and increased uptake of nutrients (Patil and Shinde, 1995 and Ramana *et al.* 2002) and better soil physical properties (Hati *et al.* 2004).

The inorganic fertilizers significantly increased the yield of sugarcane over no fertilizer. Though significant response was observed for N and P fertilizers, differences between applications of N & NK and NP & NPK fertilizers were not significant. Irrespective of the quantity of PME applied there was no yield difference between N & NK and NP & NPK, indicating that the supply of K through PME is sufficient. Baskar *et al.* (2004) has reported that the PME has supplied entire K requirement of the sugarcane crop and has also significantly substituted for inorganic N and P. Thus the PME has substituted for 25% of recommended dose of N and P fertilizer and 100% of K fertilizer.

Soil properties

Soil reaction and electrical conductivity

Application of PME altered the soil pH to near neutral (Table.3). The pH has declined from 8.42 (Control) to 8.19 (M_5). The decrease in pH might be attributed to the Ca^{++}, Mg^{++} and H^+ ions released during the decomposition of organic matter supplied by the distillery effluent. The applied PME influence on the soil pH has a positive correlation with the availability of the nutrients. The soluble salt content of the soil measured by the EC of the soil has marginally increased with the increase in doses of PME. The soluble salts present in the distillery effluent might be responsible for the increase in electrical conductivity of the post harvest soil. However, the increase in EC was not significant in the plots which received the distillery effluent @ 1.25 lakh litres per ha (M_2). Similar findings of increase in EC at higher doses due to high salt load (25.1 dSm^{-1}) of the PME was earlier reported by

Table 1. Physico chemical properties and chemical composition of the post methanation effluent (PME) obtained from EID Parry (I) Ltd., Nellikuppam, Tamil Nadu.

Parameters	Content	Parameters	Content
Color	Dark brown	Ex.Ca (ppm)	2300
pH	7.8	Ex.Mg (ppm)	2150
EC (dS m^{-1})	28.5	SO_4 – S (ppm)	4500
BOD (mg l^{-1})	4500	Ex.Na (ppm)	450
COD (mg l^{-1})	48,000	Cl (ppm)	7500
Total Solids	85,000	Zn (ppm)	10
Organic Carbon % (DW)	27.5	Fe (ppm)	65
Available N (ppm)	1350	Cu (ppm)	4.2
Available P (ppm)	550	Mn (ppm)	5.5
Available K (ppm)	9500		

Table 2. Effect of PME and fertilizers on sugarcane yield (t ha^{-1}) in Sandy loam soil

Treatments	No fert.	N	NP	NK	PK	NPK	Mean
Control	44	62	78	71	60	95	68
1.25 lakh L ha^{-1}	60	77	98	75	70	100	80
2.5 lakh L ha^{-1}	72	88	109	86	82	106	91
3.75 lakh L ha^{-1}	81	96	113	94	91	112	98
5.0 lakh L ha^{-1}	89	104	116	102	99	117	105
Mean	69	85	103	86	80	106	
CD (0.05)	M	S	SXM	MXS			
	6	11	21	23			

Table 3. Effect of PME on soil physico-chemical properties, organic carbon (%) and available NPK (kg ha^{-1}) of post harvest soils

Treatment	pH	EC (dSm^{-1})	OC	Av. N	Av. P	Av. K
Control	8.42	0.095	0.47	135	16.8	230
1.25 lakh L ha^{-1}	8.35	0.099	0.52	151	18.6	287
2.5 lakh L ha^{-1}	8.32	0.107	0.53	159	19.6	323
3.75 lakh L ha^{-1}	8.23	0.115	0.58	165	20.9	344
5.0 lakh L ha^{-1}	8.19	0.139	0.60	170	21.8	371
CD (0.05)	0.14	0.012	0.02	6	0.9	13

Table 4. Effect of PME on exchangeable Ca and Mg [cmol (p+) $kg^{-}1$] and exchangeable sodium percentage of post harvest soils

Treatment	Ex. Ca	Ex. Mg	ESP
Control	7.35	3.64	11.6
1.25 lakh L ha^{-1}	7.73	3.92	10.9
2.5 lakh L ha^{-1}	7.87	4.13	10.7
3.75 lakh L ha^{-1}	8.09	4.35	10.3
5.0 lakh L ha^{-1}	8.41	4.62	9.9
CD (0.05)	0.31	0.19	1.1

Table 5. Effect of PME on available micronutrients (mg kg^{-1}) of post harvest soils

Treatment	Av. Zn	Av. Fe	Av. Cu	Av. Mn
Control	2.10	9.2	2.01	13.6
1.25 lakh L ha^{-1}	2.31	10.6	2.21	15.9
2.5 lakh L ha^{-1}	2.40	11.4	2.42	16.4
3.75 lakh L ha^{-1}	2.51	12.3	2.52	17.1
5.0 lakh L ha^{-1}	2.63	13.4	2.70	17.4
CD (0.05)	0.13	0.62	0.06	0.57

Pathak *et al.* (1999) and Jadhav and Savant (1975). However the sugarcane crop, which receives 35 - 40 irrigations, has significantly decreased the influence of these soluble salts on the crop growth.

Organic carbon

Application of PME increased the organic C content of the surface soil. (Table 3). Maximum organic C was recorded in M_5 treatment (0.60%) where maximum dose of PME was applied. Addition of organic matter through effluent, better crop growth with concomitant higher root-biomass generation could be the probable reasons for improvement in organic C content particularly in high PME treated plots. Zalawadia and Raman (1994) and Hati *et al.* (2004) also reported similar results.

Available N, P and K

The post harvest soil analysis for the available NPK has revealed a significant increase in the soil nutrient status even after the crop uptake. The increase in the available NPK positively correlates with the graded levels of PME application confirming the increased supply of available nutrients by the PME. In line with the above findings Kaushik *et al.* (2005) has reported increase in total kjeldahl nitrogen, PO_4 and exchangeable K on PME application.

The highest available NPK in the post harvest soil was recorded in the M_5 treatment, which received the highest PME dose. The available N content increased

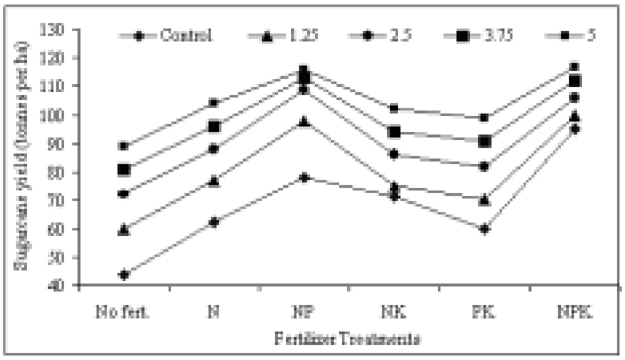

Fig. 1 Effect of PME and fertilizers on sugarcane yield (t ha^{-1}) in Sandy loam soil

to a tune of 16, 24, 30 and 35 kg ha^{-1} over the control in the M_2, M_3, M_4 and M_5 treatments respectively (Tables 3). The increased mineralization of the nitrogen in the PME applied has reflected in the increased available nitrogen content of the soil (Rajukkannu *et al.* 1996). The available P content increased to a tune of 1.8, 2.8, 4.1 and 5.0 kg ha^{-1} over the control in the M_2, M_3, M_4 and M_5 treatments respectively (Tables 3). With respect to available P, in addition to the P contributed by the effluent, HCO_3 content of distillery effluent and the organic acids produced during the decomposition of organic matter added through distillery effluent might have solubilised the native soil P and have resulted in higher available P (Baskar *et al.* 2004).

The available K content increased to a tune of 57,93,114 and 141 kg ha^{-1} over the control in the M_2, M_3, M_4 and M_5 treatments respectively (Tables 3). The PME with its high K content has significantly increased the available K content in all the treatments when compared to the control. The high available K content of PME has supplied all the K required by the sugarcane crop and thereby evidenced that there is no need of separate application of inorganic K fertilizer to the sugarcane crop. Distillery effluent as a rich source of K was reported earlier by Pathak *et al.* (1999) and Chandra *et al.* (2002).

Exchangeable cations and exchangeable sodium percentage

The exchangeable Ca and Mg in the post harvest soils have shown an increasing trend with the increase in doses of the PME and thus confirming the contribution of the exchangeable cations by the PME. The highest increase in exchangeable Ca and Mg *viz*., 1.06 and 0.98 cmol (p+) kg^{-1} respectively over the control was observed in the M_5 treatment, which received the maximum dose of PME (Tables 4). Similar increase in exchangeable cations on PME application was reported by Baskar *et al.* (2004).

The exchangeable sodium percent of the soil has shown a considerable decrease with the increase in the PME dose. The reduction in ESP was significant in M_4 and M_5 treatments (Tables 4). This might be attributed to the significant increase in exchangeable cations Ca and Mg supplied by the PME.

Available micronutrients

Application of graded doses of distillery effluent progressively increased the available micronutrient v*iz*., Zn, Fe, Cu and Mn contents of the post harvest soil. The highest availability was recorded by the M_5 treatment. This treatment had registered an increased available Zn, Fe, Cu and Mn contents to the tune of 0.53, 4.20, 0.69 and 1.20 mg kg^{-1} respectively over control (Table 5). The increased availability might be due to direct contribution from the effluent as well as solubilisation and chelation effect of organic matter supplied by the effluent. Slight depletion in available micronutrient contents was recorded in the treatments without effluent application. The built up of micronutrients in the post harvest soils of the PME long term experiments was reported by Anandakrishnan *et al.* (2007).

CONCLUSIONS

The use of post bio-methanated distillery effluent of sugar industries hence not only increased the crop yield but has also resulted in enriching nutrient status by adding up the organic carbon, macro and micronutrients to the soil nutrient pool. In addition, PME has substituted for 25 % of N and P fertilizers and 100 % of K fertilizer requirement of sugarcane crop and thereby reducing the fertilizer cost. Thus tapping the bio energy potential of distillery effluent could augment and sustain the sugarcane production and thereby will result in increased income to the farmers on a long-term basis as well as a viable option for safe disposal of this industrial waste.

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