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RESEARCH ARTICLE

Integrated Effect of Bio-methanated Distillery Effluent and Bio-compost on Soil Properties, Juice Quality and Yield of Sugarcane in Entisol

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Abstract The integrated effect of bio-methanated distillery effluent (BMDE), bio-compost and FYM as a source of plant nutrients and their effect on soil properties, nutrient uptake, juice quality and sugarcane yield were investigated. The BMDE, bio-compost and FYM were characterized. The treatments consisted of substitution of K_2O through bio-methanated distillery effluent @ 0, 25, 50, 75 and 100 % of BMDE, bio-compost and FYM (@ 20 t ha^{-1}) with recommended dose of inorganic fertilizer. The cane yield increased significantly 2.6, 6.4, 20.4, 23.3, 17.2, 9.8 %, respectively with the application of BMDE, bio-compost and FYM over control. The uptake of nutrient, viz., N, P and K followed the similar trend of cane yield. The highest cane yield (BO 137) was recorded (72.13 t ha^{-1}) in treatment receiving 100 % K_2O replacement through BMDE and lowest (58.50 t ha^{-1}) in control. The result also indicated that integrated use of BMDE along with inorganic potassium was superior to other treatments improving cane yield. The quality of juice, viz., sucrose and purity remains unaffected. However, commercial cane sugar significantly increased in all the treatments over control. The application of different doses of BMDE and bio-compost @ 20 t ha^{-1} significantly increased the EC, organic carbon and available N, P_2O_5 and K_2O content of soil over control (recommended dose). They also enriched the soil organic matter which improved the physical properties of soil especially the water transmission characteristic of soil. Hydraulic conductivity, infiltration and soil aggregation increased significantly due to application of bio-compost and BMDE. The soil aggregation increased and bulk density decreased with increasing levels of BMDE. The K content of post harvest soil increased substantially in BMDE and bio-compost treated plots. The application of BMDE and bio-compost brings remarkable changes in the properties of soil and thus enhance the fertility of soil and productivity of sugarcane significantly.

Keywords BMDE · Bio-compost · Sugarcane · Soil properties · Juice quality · Nutrient uptake · Yield

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Introduction

The disposal of wastes from industrial sources is becoming a serious problem throughout the world. A large network of distilleries (about 300) has been established in India to utilize the molasses, which are recognized as one of the most polluting agro-based industries emitting huge quantities (940 billion l) of highly foul smelling raw spent wash. However, its direct use in agricultural fields is generally not considered safe because of its high biological oxygen demand (BOD) (40,000–50,000 mg l^{-1}) and chemical oxygen demand (COD) (9,000–100,000 mg l^{-1}) (Pathak et al. 1998). Alternatively, the raw spent wash is subjected to bio-methanation treatment to decrease BOD and COD and the product obtained is known as bio-methanated spent wash (BMDE). Distillery effluents contain organic and inorganic nutrients and have been reported to be beneficial in increasing the crop yields. The application of bio-methanated distillery effluent @ 150 m^3 ha^{-1} can reduce fertilizer requirement especially N by 75 %, P_2O_5 by 20 % and K_2O by 100 % (More et al. 2008). Bio-menthanated distillery effluent is rich in potassium (K), sulphur (S), nitrogen (N), phosphorus (P) as well as easily biodegradable organic matter and its application to soil has been reported to be beneficial to increase sugarcane production. Apart from above mentioned nutrient elements, high values of a few micronutrient, viz. Zn, Fe, Cu and Mn have also been observed. Since this effluent is an organic nutrients and it has wide spectrum of utility. On an average, 1 m^3 of spent wash supplies 1.0 kg N, 0.2 kg P_2O_5 and 10.0 kg K_2O (AIDA 2007).

Bio-composting is an eco-friendly approach for bio-conversion into value added products which may be utilized as plant nutrients. It also reduces the disposal and pollution problems arising from spent wash. Davamani et al. (2006) also reported that bio-compost significantly enhanced the yield and yield components and juice quality of sugarcane. Bhalerao et al. (2006) and Jadhav et al. (1992) observed that increased nutrient uptake by sugarcane is due to use of spent wash and pressmud compost. Thus, bio-composting not only solves the disposal problems but also helps in saving the cost on chemical fertilizers. Many workers have studied the effect of spent wash as a source of plant nutrients; however, very little information is available on the use of BMDE and bio-compost in sugarcane.

In India, distillery generates approximately 40 billion liters of waste water of spent wash annually during the production of alcohol, which can provide 40,000,000 t ha^{-1} N, 8,000,000 t ha^{-1} P_2O_5 and 400,000,000 t ha^{-1} K_2O annually. If two crops are taken in a year, the manurial value of 1 year's can meet the nitrogen, phosphorus and potassium requirement of about 0.25, 0.20 and 3 million hectare of land, respectively. In Bihar, presently about 500,000 M^3 spent wash generated annually from four distilleries having capacity of 185 KLD. Thus the manurial value of this spent wash can meet about 500 t N, 100 t P_2O_5 and 5,000 t K_2O ha^{-1} annually. Thus, keeping in view the above facts, a field experiment was conducted to study the integrated effect of different doses of BMDE and substitution through chemical fertilizers on soil properties, growth, yield and quality of sugarcane in entisol.

Materials and Methods

A long term field experiment is in progress since 2008–2009 at Sugarcane Research Farm, Bihar, Pusa using BMDE and bio-compost under ad-hoc project was financed by new Swadeshi Sugar Mills Narkatiaganj, West Champaran (Bihar) with sugarcane–sugarcane ratoon rotation. The BMDE was used as source of fertilizer-K and compared with bio-compost and FYM. Treatment consisted of T_1 recommended dose (RD), T_2 RD + FYM @ 20 t ha^{-1}, T_3 RD + bio-compost @ 20 t ha^{-1}, T_4 N, P_2O_5 (RD) + 75 % K_2O through inorganic fertilizer + 25 % K_2O through BMDE, T_5 N, P_2O_5 (RD) + 50 % K_2O through inorganic fertilizer + 50 % K_2O through BMDE, T_6 N, P_2O_5 (RD) + 25 % K_2O through inorganic fertilizer + 75 % K_2O through BMDE, T_7 N, P_2O_5 (RD) + 100 % K_2O through BMDE. The sugarcane variety BO 137 was planted after 1 month of application of BMDE & Bio-compost. The above experiments were conducted with four replications in R.B.D. The plot size was 9.21 m × 5.40 m. The experimental soils (0–30 cm depth) collected at the end of 2nd rotation and were analyzed for various physico-chemical properties using standard procedures. Whole plant samples were also analyzed for nutrients uptake. Soil samples were analyzed for pH and EC in 1:2 soil suspension ratios. The organic carbon was estimated by Walkey and Black (1934) method. The available N was determined by using alkaline permanganate method (Subbiah and Asijia 1956), available P was analyzed by method described by Olsen et al. (1954) and available K was determined by flame photometrically as described by Jackson (1967). The soil physical properties were analyzed by method described by Black (1965). The cane juice quality was determined using procedure outlined by Spencer and Meade (1964) and commercial cane sugar (CCS) was calculated. The data obtained on chemical properties of soil, uptake of nutrients by plant, quality of juice and yield of sugarcane were analyzed statistically.

Results and Discussion

Characterization of Distillery Effluent, Bio-compost and FYM

The raw spent wash acidic (pH 3.04–4.30) and loaded with organic and inorganic salts, resulting in high EC (30–45 dS m^{-1}) with high BOD and COD. The raw spent wash was unsafe and not fit for agricultural use. The BMDE has low BOD (5,000–6,000 ppm) and COD value (30,000–35,000 ppm). It contains 1.20 % N, 0.40 % P, 0.82 % S and 9.20 % K on oven dry basis and loaded with high amount of organic carbon (20.09 %) (Table 1). The TDS of BMDE ranges from 40,000 to 45,000 ppm. The bio-compost is also characterized with neutral pH (6.85), EC value of 15.06 dS $m^{-1}$and rich in plant nutrients and organic matter with C:N ratio of 17:1.

Soil Properties

Organic Carbon

Organic carbon content of the surface soil increased significantly with incorporation of 100 % BMDE, bio-compost and FYM @ 20 t ha^{-1} over control. The highest build up (13.0 %) of organic carbon was in soil with the application of RD of NP + 100 % K_2O through BMDE. Bio-compost and FYM increased the organic carbon by 10.9 and 6.5 %, respectively over control (Table 2).

Application of 100 % BMDE, bio-compost and FYM enhanced the available N content by 3.6, 4.0 and 2.6 %, respectively over control. Increase in available nitrogen with application of BMDE, bio-compost and FYM may be attributed to the incorporation of organic matter which enhanced multiplication of microbes by incorporation of different organic sources for the conversion of organically bound N to inorganic form. Significant build up of available P was recorded with RD of N, P and organic sources. The application of 100 % BMDE, bio-compost and FYM along with RD of N, P significantly increased P_2O_5 by 15.7, 18.3 and 9.1 %, respectively over control (Table 2).

Perusal of data in Table 2 revealed significant build up of available K due to addition of organic sources. BMDE, bio-compost and FYM addition increased the available K content significantly after harvest of sugarcane. Increase in available potassium due to BMDE, bio-compost and FYM application may be attributed to the direct addition of potassium to the available pool of the soil. Beneficial effect of organic sources on available K may also be attributed to the reduction of fixation and release of K due to interaction of organic matter with clay besides the direct effect of K addition on the available K pool of the soil (Santhy et al. 1998; Pannu et al. 2002).

The bulk density declined and infiltration rate, hydraulic conductivity and aggregation of soil improved significantly in the plots treated with BMDE and bio-compost over control of post harvest soil at 0–30 cm depth (Table 3). However, the infiltration rate, hydraulic conductivity and soil aggregation increased and the bulk density decreased with increasing levels of distillery effluent. The highest infiltration rate, hydraulic conductivity and soil aggregation were observed in treatment, receiving bio-compost @ 20 t ha^{-1} (T_3) and the lowest in control plot (T_1). The improvement in soil aggregation resulted in the increase of infiltration and hydraulic conductivity. However, the bulk density of effluent treated soil decreased with increasing level of distillery effluents. These results suggested that application of bio-compost and BMDE improved physical environment of soil. The beneficial effect of bio-compost on improvement of physical condition of soil may be attributed to improvement in organic matter status of effluent treated soil.

Table 1 Composition of bio-compost, bio-methanated distillery effluent (BMDE) and FYM

S. No.	Parameter	Bio-compost	BMDE	Farmyard manure
1.	pH	6.85	7.10	6.60
2.	EC (dS m^{-1})	12.00	15.06	3.42
3.	Organic carbon (%)	34.19	20.09	30.20
4.	Nitrogen (%)	2.00	1.20	0.91
5.	Phosphorus (%)	1.55	0.40	0.15
6.	Potash (%)	2.85	9.20	0.50

Effect on Yield and Yield Attributes

The cane yield increased significantly (Table 4) in bio-compost (T_3) and BMDE treated plots (T_6 & T_7) over control

Table 2 Integrated effect of bio-methanated distillery effluent and bio-compost on soil physic-chemical properties after harvest of sugarcane

Treatment	pH	EC (dS m^{-1})	Organic carbon (%)	Available nutrients (kg ha^{-1})		
				N	P	K
T_1	8.23	0.22	0.46	227.2	19.7	103.4
T_2	8.18	0.24	0.49	233.2	21.5	106.1
T_3	8.01	0.34	0.51	236.3	23.3	110.4
T_4	8.10	0.26	0.47	228.1	19.7	104.2
T_5	8.10	0.28	0.48	229.4	20.0	104.8
T_6	8.05	0.35	0.50	231.6	21.6	111.6
T_7	8.01	0.37	0.52	235.4	22.8	114.2
SE dm (±)	0.10	0.007	0.007	1.91	0.54	1.44
CD (0.05)	NS	0.021	0.022	5.70	1.64	4.43

Table 3 Integrated effects of bio-methanated distillery effluent and bio-compost on physical properties of soils after harvest of sugarcane

Treatments	Physical properties			
	Bulk density (g cm^{-3})	Infiltration (cm h^{-1})	Hydraulic conductivity (cm h^{-1})	Soil aggregation (%)
T_1	1.38	0.24	0.210	37.78
T_2	1.37	0.26	0.225	38.60
T_3	1.36	0.29	0.235	39.25
T_4	1.37	0.25	0.205	37.60
T_5	1.37	0.26	0.213	38.10
T_6	1.36	0.28	0.245	39.75
T_7	1.34	0.30	0.288	40.10
SE dm (±)	0.01	0.009	0.002	0.38
CD (0.05)	0.03	0.02	0.006	1.18

Table 4 Integrated effect of bio-methanated distillery bio-compost on juice quality, uptake of nutrients and cane yield

Treatment	Juice quality (%)			CCS (%)	CCS (t ha^{-1})	Cane yield (t ha^{-1})	Uptake of nutrients (kg ha^{-1})		
	Brix	Sucrose	Purity				N	P	K
T_1	18.8	16.70	88.83	11.37	8.77	58.50	138.12	15.33	178.45
T_2	19.1	17.05	89.26	11.84	7.60	64.23	144.79	17.50	210.20
T_3	19.4	17.10	88.14	11.81	8.10	68.59	152.45	21.25	235.30
T_4	18.9	16.90	89.41	11.75	7.05	60.02	140.20	16.10	180.50
T_5	19.4	17.02	87.73	11.73	7.30	62.23	141.40	17.10	184.20
T_6	19.6	17.20	87.75	12.22	8.60	70.45	157.50	19.75	240.30
T_7	20.1	17.43	88.40	12.03	8.68	72.13	163.20	20.20	238.58
SE dm (±)	0.35	0.28	0.90	0.41	0.24	1.71	4.1	1.31	5.2
CD (0.05)	1.05	NS	NS	NS	0.72	5.12	12.30	3.91	15.30

(T_1). The cane yield recorded in increasing order of T_7 (72.13 t ha^{-1}) > T_6 (70.45 t ha^{-1}) > T_3 (68.59 t ha^{-1}) > T_2 (64.23 t ha^{-1}) > T_5 (62.23 t ha^{-1}) > T_4 (60.02 t ha^{-1}) and lowest in control (58.50 t ha^{-1}). The highest cane yield (72.13 t ha^{-1}) was obtained in T_7 treatment receiving 100 % BMDE. However, treatment T_3, T_6 and T_2 were found at par with each other. The analysis of data revealed that integrated effect of fertilizer-K along with BMDE was superior in terms of cane yield. The treatment T_6 receiving 75 % BMDE + 25 % fertilizer-K was superior to other treatment in improving yield. It is interesting to observe that in absence of fertilizer-K, treatment T_7 recorded highest cane yield. Bio-methanated distillery effluent is rich in plant nutrients as well as easily biodegradable organic matter and its application to soil has been reported to be beneficial to increase sugarcane production. Davamani et al. (2006) also reported that bio-compost significantly enhanced the yield and yield components and juice quality of sugarcane.

Effect on Juice Quality, Sugar Yield and Nutrient Uptake

The juice quality parameters viz. brix. Pol and purity presented in Table 4 indicated that brix and pol % significantly increased in treatment T_7 receiving 100 % BMDE as fertilizer-K. However, the purity % remains unaffected. The CCS significantly increased in BMDE treated plots receiving 75 % BMDE as fertilizer-K (T_6) and receiving 100 % BMDE as fertilizer-K (T_7) indicating the beneficial role of potassium in sugar synthesis. The results are in conformity of the findings of Singh et al. (2007). The uptake of N, P and K significantly increased in the treatment T_2, T_3, T_6 and T_7 receiving FYM, Bio-compost, 75 % BMDE as fertilizer-K and 100 % BMDE as fertilizer-K, respectively. The highest uptake of nutrients were recorded in treatment T_7 (163.20 N, 20.20 P and 238.58 K ha^{-1}) and lowest in control (138.12 N, 15.33 P and 178.45 K ha^{-1}) (Table 4). Jadhav et al. (1992) and Bhalerao et al. (2006) also observed that increased nutrient uptake by sugarcane in due to use of spent wash and press mud compost.

Conclusions

On the basis of above findings, it may be concluded that BMDE can be used as a substitute of potassium fertilizer in particular and other source of plant nutrients in general. The application of bio-compost @ 20 t ha^{-1} along with RD of fertilizer gave similar yield performance as compared to treatments where 100 % K_2O was applied through BMDE. The bio-composting not only solves the disposal problems of effluent but also helps in saving the cost on chemical fertilizers for sustainable sugarcane production. The result also indicated that integrated use of BMDE along with inorganic potassium was superior in terms of improving cane yield. It also enriches the soil in terms of organic matter which improved the physical properties of soil especially the water transmission characteristic of soil. One time controlled land application of BMDE as liquid manure saved 100 % potassium fertilizer and also enriched soil fertility for obtaining profitable cane yield in calcareous soils.

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