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Effect of Bio-Methanated Distillery Effluent on Soil Physico-Chemical Properties, Cane Yield and Uptake of Nutrients in Calcareous Soil of Bihar

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ABSTRACT

Field study on effect of bio-methanated distillery effluent on soil properties, cane yield and uptake of nutrients under sugarcane crop was conducted during 2011-12 in calcareous soil of Bihar. Seven treatments of bio-methanated distillery effluent and different dose of nutrients were tried in randomized block design. Results revealed that the integrated application of BMDE and different dose of NPK nutrient significantly improved the physico-chemical properties of soil in 0-30 cm soil depth, number of millable cane, cane yield and uptake of NPK nutrients as compared to control. Treatment combination BMDE+100% NPK (T_3) recorded 129.4% higher cane yield which was closely followed by BMDE+75%NPK (T_4) over control (T_7).

Key words: *Sugarcane, BMDE, Yield, Uptake, Soil properties.*

INTRODUCTION

Distillery effluent, a waste water of distillery industry is of purely plant origin and contains large quantities of soluble organic matter and plant nutrients. It does not contain any toxic elements or compounds. Therefore, its application in agricultural fields as such is considered beneficial for crop production. The spent wash is subjected to bio-methenation treatment to decrease biological oxygen (BOD) demand and chemical oxygen demand (COD) and the product obtained is known as bio-methanated distillery effluent (BMDE). BMDE can be used as a source of nutrients as well as soil amendment which simultaneously serves as a source of water to crops. 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). The manurial value of the effluents can profitably be used as supplement to fertilizer and organic matter[11]. This will solve a twin problem of disposal and also substitute some quantity of fertilizers and organic matter.

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% [18]. Bio-methanated distillery effluents are rich in plant nutrients and contain easily biodegradable organic carbon.

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The proper management of sugar industry wastes *viz*. pressmud and BMDE will reduce the cost of fertilizer and will be helpful in improving cane yield and for maintaining soil health[3]. The integrated use of organic manures had beneficial effect on sustaining sugarcane productivity and also in economizing fertilizer nitrogen. Application of BMDE significantly increased the EC, organic carbon, available N, P, K, Ca, Mg and micronutrient status of soil[5]. It contains large amount of organic carbon, K, Ca, Mg, Cl and SO_4 and moderate amount of N and P and traces of Zn, Cu, Fe and Mn [16].

Application of nutrient enriched distillery effluents without dilution affected plant growth parameters and quality of cane juice at significant level, but improved these parameters when combined with freshwater at various levels. Alternate application of distillery effluent and freshwater gave the highest cane yield (133.8 t ha^{-1}) with sugar concentration (18.5 t ha^{-1}). It also improved other growth parameters, nutrient contents and overall fertility status of soil. Plant nutrient loaded distillery effluent of sugar industries with high organic matter (soluble) content is thus proved a good irrigation source and soil amendment[22]. This study evaluated the feasibility of using distillery effluents to contribute towards sugar security and sustainable agriculture. Therefore, the aim of the study was to evaluate the effect bio-methanated distillery effluent on soil physico-chemical properties, yield and uptake of nutrients.

MATERIALS AND METHODS

A one year of field experiment was conducted during 2013-2014 at the experimental farm of Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar (Formerly Rajendra Agricultural University, Pusa). The soil belongs to order Entisol, suborder Fluvents, great group Ustifluvent, and sandy loam in texture. Salient physical and chemical properties of the experimental soil of 0-30 cm depth were bulk density 1.40 g cm^{-3}, pore space 47.0%, infiltration rate 0.27 cm hr^{-1}, pH 8.15, organic carbon 4.2 g kg^{-1}, free $CaCO_3$ 34.0%, available N 230 kg ha^{-1}, P_2O_5 20 kg ha^{-1}, and K_2O 133 kg ha^{-1}, SO_4^{2-}S 10.0 mg kg^{-1}, Fe 9.58 mg kg^{-1}, Mn 3.10 mg kg^{-1}, Cu 1.25 mg kg^{-1}, and Zn 0.65 mg kg^{-1}. The average maximum and minimum temperature during experimentation (February 2013-January 2014) were 35.4°C and 7.3°C, respectively; average annual rainfall was 79.8 mm, most of which was received between May to October. The experiment was laid out in randomized block design, replicated four times within a block and involved seven treatments *viz*. T_1: 100% NPK; T_2: 150 m^3 ha^{-1} (BMDE); T_3: T_2+100% NPK; T_4 : T_2+75% NPK; T_5: T_2+50% NPK; T_6: T_2+25% NPK; and T_7: Control. BO 141 (mid-late) cultivar of sugarcane crop was planted in well prepared field on 24th February 2013 in plot size of 9.41 m × 5.21 m. The recommended dose of N, P_2O_5 and K_2O is 150 kg ha^{-1}, 85 kg ha^{-1} and 60 kg ha^{-1}, respectively. N was applied in the form of calcium ammonium nitrate, P_2O_5 as single super-phosphate and K_2O as muriate of potash. Half dose of NPK was applied at the time of planting, and remaining dose of NPK applied at earthing up. The applied BMDE with pH 7.31 contains organic carbon 140.9 g kg^{-1}, available N 0.40%, available P 0.082%, available K 9.25%, available S 0.82%, available Fe 7.0 mg l^{-1}, available Zn 6.5 mg l^{-1}, available Cu 4.6 mg l^{-1}, and available Mn 4.1 mg l^{-1}. Three representative soil samples from 0-30 cm depth were collected before crop planting and after crop harvest from each plot for analysis of physical and chemical properties following standard procedures. Soil bulk density of the surface layer (0-30 cm) was determined using the core method[6]. In the laboratory, sample of bulk density were carefully trimmed and dried at 105°C to a constant weight. The pore space (PS) of the 0-30 cm soil layer was determined from data on bulk density (BD) using the relationship: PS = (1 - BD / PD) ×100 [where PS = total pore space (%), BD = bulk density (Mg m^{-3}), and PD = particle density (assuming the value of 2.65 Mg m^{-3}). The infiltration behavior of the soil was studied using double ring infiltrometers[8]. pH and EC of soil were measured with the help of a pH and EC meter, respectively, maintaining the soil-water ratio of 1:2.5 as described by Jackson[10]. The organic carbon content in soil samples was estimated by chromic acid titration method as given by Walkely and Black[30]. Available N of soil was measured by alkaline permanganate methods as described by Subbijah and Asija[25]. Available P was determined by the ascorbic acid procedure using a blue filter (660 mµ) as suggested by Olsen *et al*.[19]. Available K was estimated with 1N NH_4OAc (pH 7.0) reagent using flame photometer[17]. The soil available sulphur was estimated by 0.15% $CaCl_2$ solutions as per method suggested by Williams and Steinbergs[31] and described as turbidimetric method given by Chesnin and Yein[9]. The DTPA extractable micronutrients (Fe, Mn, Cu and Zn) were determined by Atomic Absorption Spectro-photometer (model; A Analyst 200) as described by Lindsay and Norvell[15]. The crop was managed by adopting standard package of practices. Number of millable cane (NMC) was recorded in each plot and converted to thousand per hectare (000 ha^{-1}). Cane yield data were recorded at the age of 12 months from the plots and were converted to yield t ha^{-1}. The nutrient uptake by the crop was calculated by multiplying the nutrient content with dry matter yield. The nutrient content in crop was determined as per the standard procedure[27]. Statistical analysis was performed using the SPSS statistical package.

RESULTS AND DISCUSSION

Soil physical properties

The integrated uses of bio-methanated distillery effluent (BMDE) in sugarcane crop significantly (P=0.05) modified the soil physical properties (Table 1) *viz*. bulk density (BD), pore space (PS), and infiltration rate (IR). An integration of BMDE and 100% recommended dose of NPK (T_3) reduced the BD maximum (by 3.76%) as compared to application of BMDE alone (T_2). The order for different combination of nutrients in moderating the soil BD in sugarcane crop after one year is $T_3 < T_4$, $T_5 < T_6 < T_7 < T_2 < T_1$. In contrast, the soil pore space and infiltration rate were improved by 4.38% and 15.15%, respectively under treatment T_3 over T_2. The reduction in BD and improvement in PS and IR were due to integrated use of organic and inorganic sources of nutrients which promoted more root biomass and microbial activity. These findings are in accordance with those of Bokhtiar *et al*.[7], and Jha *et al.*[12].

Soil chemical properties

Application of BMDE in combination with different dose of nutrient levels produced beneficial effect on chemical properties of 0-30 cm soil layer (P=0.05) (Table 2). Soil reaction was reduced not significantly, but numerically (0.08-0.14 units) by the combined application of 150 m^3 ha^{-1} (BMDE) and 100% NPK in comparison with BMDE alone and control. In contrast soluble salts were significantly improved (0.15-0.21 units) by the integration of BMDE and different sources of NPK nutrients because of high value of EC in distillery effluent. However, increases in EC value of the soils due to distillery effluent was within permissible and safe limits. These results are in conformity with the findings of Alam *et al.*[2], Jha *et al.*[13], and Sinha *et al*.[23].

Soil organic carbon (SOC) and available nutrients *viz*. nitrogen, phosphorus, potassium and sulphur were significantly (P=0.05) affected by the combined soil application of BMDE and 100% recommended dose of NPK (Table 2) in 0-30 cm soil depth. SOC improved by 65.7% with the combined application of BMDE and 100% NPK nutrients (T_3), and by 14.3% due to BMDE alone (T_2) over control (T_7). The improvement in SOC in these treatments might be due to addition of organic matter through application of bio-methaneted distillery effluent as it is rich source of organic matter with low C: N ratio. Sinha *et al*.[23] reported that the combination of organic matter and fertilizer was effective for the SOC enrichment. These results are in close conformity with the findings of Alam *et al.*[2], Jha *et al.*[13] and Sinha *et al*.[23].

Similarly, available soil N, P, K and S were improved by 24.5%, 46.5%, 52.8%, and 15.6%, respectively in treatment T_3 as compared to control (T_7). This may be due to higher organic matter content in treatment T_3, and interaction of organic and inorganic sources of nutrients. The maximum availability of nitrogen may be attributed to the steady mineralization of N from the stable N components of organic matter during the decomposition process[24,29]. The improvement in available phosphorus may be due to solubilizing effect on native soil phosphorus and consequent contribution to labile pool, and increased mineralization of organic P due to greater microbial action[2,18]. The improvement in available K content may be ascribed to the reduction in K fixation and release of K due to interaction of organic matter[2,29]. The enhancement in available S might be due to addition of sulphitation BMDE and interaction of organic and inorganic fertilizers[28].

The availability of Fe, Mn, Cu, and Zn was also significantly (P=0.05) influenced with the combined as well as alone application of BMDE and NPK nutrients (Table 2) in 0-30 cm soil depth as compared to control. The highest increment in available Fe, Mn, Cu and Zn was recorded by 5.4%, 76.6%, 22.1% and 33.8%, respectively with the application of 150 m^3 ha^{-1} BMDE (T_2) over control (T_7) and it was statistically at par with combined application of BMDE and 100% NPK (T_3). This might be due to chelating effect of BMDE which is a rich source of micronutrients as well. These results are in close conformity with the findings of Anandakrishan *et al.*[4] and Umesh *et al*.[28].

NMC and cane yield

Bio-methanated distillery effluent and different dose of NPK nutrients produced significant (P=0.05) effects on number of millable cane (NMC) and cane yield (Figure 1). The maximum number of millable cane (87.6×10^3 ha^{-1}) was recorded with combined application of BMDE+100% NPK (T_3) which was statistically at par with BMDE+75% NPK (T_4). This might be due to reduction in plant mortality and favorable condition produced by BMDE for conversing tillers into millable cane. The separate application of BMDE (T_2) and 100% NPK (T_1) had produced statistically similar values of NMC. The results are supported by Selvamurugan *et al.*[21] and Umesh *et al.*[28]. Similarly, the highest cane yield of 92.0 t ha^{-1} was obtained in treatment T_3 and was statistically at par with treatment T_4 (86.9 t ha^{-1}). Treatments, T_1 and T_2 produced statistical similar effects on cane yield. Overall, the percent increment of NMC and cane yield under treatment T_3 was 63.7% and 129.4%, respectively over control. The results are in conformity with the findings of Tamilselvan and Jayabal[26] and Sekar[20] who reported that the cane yield observed the positive impact of availability of individual plant nutrients from BMDE, and balanced supplement of NPK through inorganic fertilizers might have induced cell division, expansion of cell wall, meristematic activity, photosynthetic efficiency and regulation of water intake into cells, resulting in the enhancement of cane yield.

Nutrients uptake

Uptake of N, P and K nutrients was significantly (P=0.05) influenced with the application of BMDE and different dose of NPK nutrients (Figure 2). Treatments recording higher yield reflected in higher uptake of these nutrients. The increment in uptake of N, P and K nutrients over control in treatments comprising application of BMDE alone as well as combination of BMDE and different dose of NPK (T_1, T_2, T_3, T_4, T_5 and T_6) varied from 5.6-52.2%, 22.5-67.5% and 9.6-58.2%, respectively. The highest uptake was recorded in treatment consisting combinations of BMDE and 100% NPK nutrients (T_3). This might be due to more absorption of nutrients by the crop, supplied through nutrient rich distillery effluent which is also rich source of organics, beneficial to micro flora, besides acting as slow nutrient releaser. These findings are in accordance with the findings of Lalha *et al*.[14], Venkatakrishnan *et al*.[29] and Sinha *et al*.[24].

Table 1: Effect of bio-methanated distillery effluent on soil physical properties in 0-30 cm soil depth after crop harvest

Treatment	Bulk density (Mg m^{-3})	Pore space (%)	Infiltration rate (cm hr^{-1})
T_1: 100% NPK	1.39	47.64	0.28
T_2 : 150 m^3 ha^{-1} (BMDE)	1.38	47.73	0.33
T_3 : T_2+100% NPK	1.33	49.81	0.38
T_4 : T_2+75% NPK	1.34	49.43	0.37
T_5: T_2+50% NPK	1.34	49.43	0.35
T_6: T_2+25% NPK	1.36	48.67	0.34
T_7: Control	1.42	46.32	0.23
SEm ±	0.01	0.42	0.01
$LSD_{(0.05)}$	0.03	1.13	0.03
CV (%)	1.88	3.92	5.48

Table 2: Effect of bio-methanated distillery effluent on soil chemical properties in 0-30 cm soil depth after crop harvest

Table 2: Effect of bio-methanated distillery effluent on soil chemical properties in 0-30 cm soil depth after crop harvest

Treatment	pH	EC (dSm^{-1})	OC (%)	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	S (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})
T_1: 100% NPK	8.22	0.24	0.39	243.75	22.81	136.00	10.40	9.26	3.22	1.38	0.64
T_2 : 150 m^3 ha^{-1} (BMDE)	8.18	0.26	0.40	261.00	23.30	136.89	10.54	13.61	5.14	1.60	0.83
T_3 : T_2+100% NPK	8.10	0.41	0.58	282.53	28.93	198.08	11.40	12.91	4.98	1.54	0.79
T_4 : T_2+75% NPK	8.11	0.39	0.57	272.42	26.78	190.00	11.05	12.42	4.68	1.50	0.75
T_5: T_2+50% NPK	8.11	0.36	0.51	266.00	25.95	181.00	11.00	11.20	4.07	1.47	0.70
T_6: T_2+25% NPK	8.14	0.30	0.44	264.00	24.90	144.63	10.61	9.76	3.44	1.42	0.66
T_7: Control	8.24	0.20	0.35	227.00	19.75	129.64	9.86	9.13	2.91	1.31	0.62
SEm ±	0.12	0.02	0.04	7.37	1.04	3.06	0.17	0.41	0.36	0.03	0.02
$LSD_{(0.05)}$	NS	0.07	0.11	18.45	3.04	9.00	0.49	1.19	1.03	0.08	0.05
CV (%)	1.02	2.50	3.42	5.68	5.84	3.85	3.12	4.65	4.00	3.75	2.56

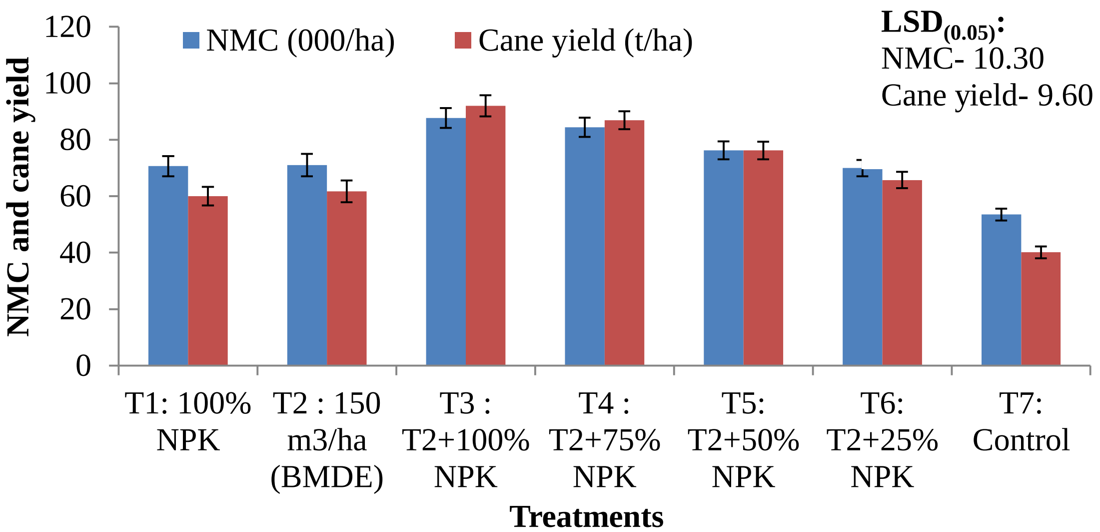

Fig. 1: Effect of bio-methanated distillery effluent on number of millable cane (NMC) and cane yield of sugarcane. Vertical bars indicate ± S.E. of mean of the observed values

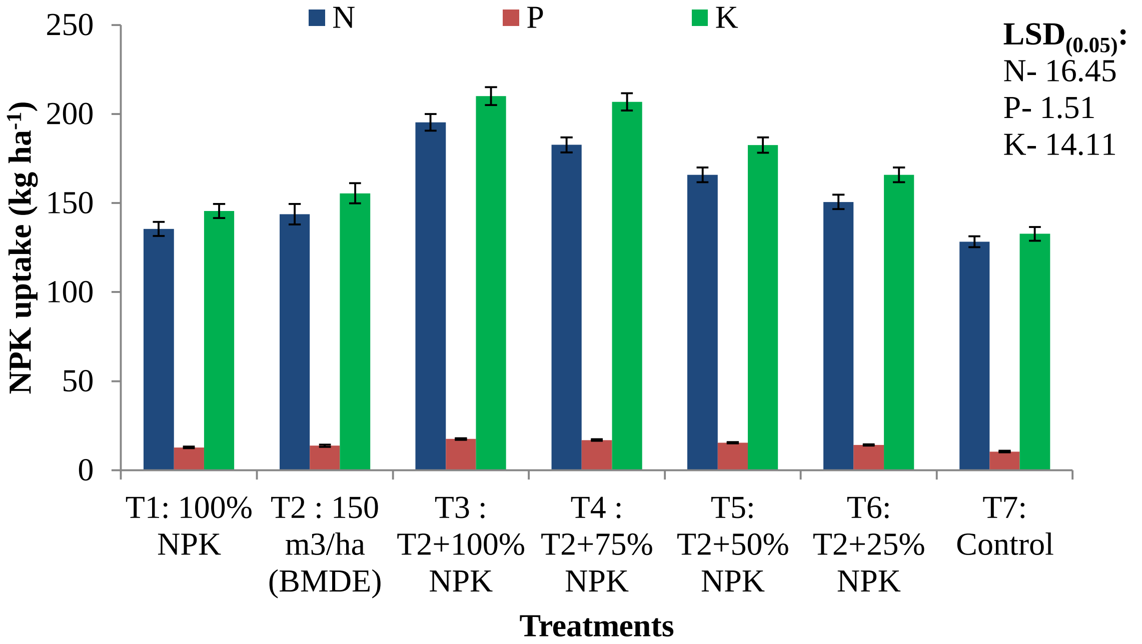

Fig. 2: Effect of bio-methanated distillery effluent on uptake of N, P, and K by sugarcane crops. Vertical bars indicate ± S.E. of mean of the observed values

CONCLUSION

The foregoing discussions lead to the conclusion that combined application of bio-methanated distillery effluent (BMDE) and NPK nutrients (150 m^3 ha^{-1} of BMDE + 100% and 75% NPK) is better than inorganic source of nutrients alone for achieving improved crop yield as well as soil environment.

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