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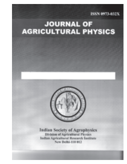

Research Article

Effect of Biogas Slurry and Urea on Soil Health

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ABSTRACT

The aim of this study was to appraise the influence of different combinations of biogas slurry (BGS) on soil (0-30 cm) physical and biological properties. The BGS from cattle dung based field biogas plant with different combinations of urea were applied to baby corn crop (*Zea mays* L.) in 2013-14, at farm soils of IARI. Soil bulk density and porosity were measured as indices of physical properties and soil enzyme activity (urease, dehydrogenase, protease and acid phosphatase) were measured as indices of biological activity. Besides these, some soil chemical parameters, such as pH, electrical conductivity, organic carbon, available N, P, K and micronutrients were also measured. The BGS @ 7 t ha^{-1} as amendments reduced bulk density and increased porosity. The BGS also increased available N (0.24 to 1.21%), phosphorus (0.35 to 6.39%) and potassium (0.51 to 2.06%) contents at 0-15 cm soil layer. Biogas slurry may be used as soil amendments with 50% fertilizers for obtaining short- and long-term benefits in terms of production increments and soil amelioration.

Key words: biogas slurry, bulk density, baby corn, porosity, fertilizer

Introduction

Continuous decomposition of organic matter in cultivated soils of arid and semiarid regions may lead to soil degradation, with an effect on the sustainability of production. Application of organic wastes, and particularly biogas slurry (BGS) could be a way. This has two aspects, the waste disposal and the improvement of organic matter content of cultivated soils. Using BGS in agriculture is an economical disposal of manure, and is ecologically important as it helps in reducing waste load to the environment. India has 529.7 million of livestock population, making it the first in the world. The potential of BGS generation in India is 292Mt in 2012-13. Due to propagation of biogas plants in many Asian countries including India, the amount of slurry to be disposed has drastically increased. The BGS is a good source of plant nutrients and is reported to improve crop yield and soil properties (Smith and Elliot, 1990; Prasad and Power, 1991; Pathak *et al.*, 1992).

In agricultural systems, soil quality includes soil reaction (pH), supply of mineral nutrient elements, water content, composition of soil atmosphere and biotic factors. Digested BGS when added to soil, directly affects all of these factors. In many countries of the world, major benefits derived from BGS result from improved soil physical properties. The increase in total porosity has been attributed to increased numbers of pores in the 30-50 and 50-500 μm size ranges and a decrease in number of pores greater than 500 μm (Pagliai *et al.,* 1981).

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Soil microbial biomass, activity, and community structure respond to agricultural management practices. Soil microbial properties have a strong correlation with soil health. The BGS contains an enormous community of micro-organisms. Thus, application of slurry adds organic matter and nutrients and living organisms. This acts as a nutrient source for indigenous soil micro-organisms, which significantly increased over a 12-month period in a soil treated with BGS (Beffa *et al.,* 1995). Soil enzymatic activity is generally related to soil microbial population and it is positively influenced by the amount of pores ranging from 30 to 200 µm (Pagliai and De Nobili, 1993). Despite the fact that BGS has potential to improve soil quality, results under field studies are limited. Hence, the aim of this study was to assess soil enzyme activities and change in soil bulk density and porosity in response to mineral fertilizers and BGS under field conditions, using baby corn as a test crop.

Materials and Methods

Experimental site and design

A field experiment was conducted at the experimental farm of the ICAR-Indian Agricultural Research Institute, New Delhi under irrigated condition during *zaid, kharif and rabi* seasons of 2013-14. The size of the individual plots was 20 m^2. The experimental soil is sandy loam and is grouped under Inceptisols (Mahapatra *et al.,* 2000).

The experiment was carried out using a randomized complete block design with six treatments and four replications (plot size 4 m × 5 m). Treatments were:

T0 – Control (where no urea/BGS applied); T1 – 100% N by recommended dose of fertilizer (Urea); T2 – 25% N by BGS + 75% N by RDF; T3 – 50% N by BGS + 50% N by RDF; T4 - 75% N by BGS + 25% N by RDF; T5 - 100% N by BGS. The crop was baby corn (cultivar G-5414) with spacing of 60 cm x 20 cm. The slurry was applied 1 week before the sowing. The recommended dose of fertilizer was 150: 60: 60 N-P-K (kg ha^{-1}).

Physicochemical analysis

Liquid BGS was collected in pre-treated and marked cans from BGS pit. Soil samples from selected plots were collected in polythene bags. The liquid biogas slurry samples were characterized for pH, total N, P and K, and micronutrients (Fe, Cu, Zn, Mn). Soil samples were also analyzed for the same parameters in addition to electrical conductivity (EC$_w$), organic C, bulk density and porosity. Conductivity and pH of BGS were analyzed within 2h of sampling using a digital conductivity and pH meter. The slurry samples were oven-dried at 60^{o}C for 48 h. After drying and grinding, samples were analyzed for total N, P and K contents by Kjeldahl's method, vanadomolybdate phosphoric yellow colour method (Jackson, 1973) and neutral normal ammonium acetate method (Jackson, 1973), respectively. Micronutrients of Zn, Fe, Cu and Mn were estimated using an Atomic Absorption Spectrophotometer (AAS) (Lindsay and Norvell, 1978). Each analysis was done in triplicate and the mean values were taken.

Soil (0-15 and 15-30 cm) samples were collected after one year of baby corn grown continuously in three seasons. The collected samples were analyzed for oxidizable organic C (Walkley and Black, 1934), available N (alkaline permanganate oxidation method; Subbaiah and Asija, 1956), P (Olsen's method using a spectrophotometer; Jackson, 1973), K (neutral normal ammonium acetate method using a flame photometer) and micronutrients (Fe, Cu, Mn, Zn using an AAS; Lindsay and Norvell, 1978). Bulk density of the soil was determined using a core sampler (Dastane, 1967). Each analysis was done in triplicate and the mean values were taken. The analytical data quality was ensured through careful standardization, procedural blank measurements and duplicate sample.

Biological analysis

Soil samples were collected from 0-15 cm soil layer at silk emergence stage (45-50 days after sowing) of baby corn. Plants were excavated at four randomly selected locations at a distance of 0.5 m row length from each plot. Loose soil was

Table 1. Physicochemical composition of biogas slurry collected from the biogas plant

Parameters	Range	Average ± SE
pH	7.80-8.10	7.90±0.16
Total nitrogen (%)	1.94-2.26	2.10±0.16
Total phosphorus (%)	0.98-1.14	1.10±0.07
Potassium (%)	0.88-1.10	0.98 ±0.13
Fe (ppm)	2750-2845	2797±67
Cu (ppm)	19.66-22.54	20.33±2.13
Mn (ppm)	200-218	209±12
Zn (ppm)	18.66-22.12	20.44±2.12

shaken off the roots. The soil adhered strongly to the roots was carefully brushed from the roots and collected. Four such rhizosphere samples from each plot were combined, passed through a 2-mm sieve and stored at 4 °C until analysis.

The microbial biomass C (MBC) was determined by chloroform fumigation extraction method (Joergensen *et al.,* 1990). Biomass C was determined using the formula: MBC = (C in treated soil - C in untreated soil)/k, where k = 0.45. Each sample had duplicates, and results were expressed on a moisture-free basis. Protease activity was determined according to Kandeler *et al.* (1996). Acid phosphatase enzymes activity was determined according to Mandal *et al.* (2007). Urease activity was measured as per Nannipieri *et al.* (1974). Dehydrogenase activity was determined by the reduction of tri-phenyl tetrazolium chloride (TTC) to tri-phenyl formazan (TPF) as described by Serra-Wittling *et al.* (1995). All enzyme activities values were calculated based on of oven-dry (105 °C) weight of soil.

Statistical analysis

Data were analyzed by a one-way ANOVA using Fishers' PLSD-test (protected least significant difference) at the 0.05 level of probability. Microsoft Excel 2003 and SPSS 13.0 (SPSS Inc., Chicago IL) were used for statistical analysis.

Results and Discussion

Physicochemical characteristics of biogas slurry

Before sowing of baby corn, liquid BGS sample was collected from the biogas plant, located at IARI farm near the experimental plots.

Table 2. Physico-chemical parameters of soil before sowing

Parameters	Range	Average±SE
A. Physical		
Bulk density (Mg m^{-3})		
0-15 cm	1.43-1.49	1.47±0.02
15-30 cm	1.54-1.59	31.57±0.019
Porosity (%)		
0-15 cm	44.25-44.74	44.45±0.828
15-30 cm	39.74-41.86	40.75±0.737
B. Chemical		
Available N (kg ha^{-1})	213.2-271.8	241.7±27.4
Available P_2O_5 (kg ha^{-1})	39.9-48.7	43.7±4.5
Available K_2O (kg ha^{-1})	249.7-254.4	251.5±5.5
Oxidizable organic C (%)	0.41-0.46	0.43±0.038
Soil pH (1:2.5 soil: water)	7.8-8.0	7.9±0.139
Electrical conductivity (dS m^{-1})	0.48-0.57	0.51±0.037
DTPA Extractable micronutrients		
Zn (mg kg^{-1})	1.98-3.20	2.66±0.442
Cu (mg kg^{-1})	1.32-1.46	1.42±1.16
Mn (mg kg^{-1})	18.9-19.6	19.25±0.280
Fe (mg kg^{-1})	5.09-7.10	6.27±0.739

The pH of the biogas slurry was 7.9, and total N, P, K were 2.1, 1.1, and 0.98, respectively (Table 1). The Fe, Cu, Mn, and Zn content were 2797, 20.33, 209 and 20.44 ppm, respectively. Values were in conformity with those reported by Gupta (1991) and Tripathi (1993).

Physicochemical characteristics of soil

Before land preparation and sowing of baby corn, bulk density of soil at 0-15 cm and 15-30 cm layers was 1.47 and 1.57 Mg m^{-3} respectively, indicating 44.5 and 40.8% porosity in these layers (Table 2). The pH of the soil was 7.9 with the EC value of 0.51 dS m^{-1}. Oxidizable organic C, available N, P and K were 0.43%; 241.67, 43.66 and 251.54 kg ha^{-1}, respectively. Micronutrients Fe, Cu, Mn, and Zn contents were 6.27, 2.66, 19.25 and 2.66 ppm, respectively. Initial values indicated that the selected site was deficient in organic matter and N but was sufficient in available P and adequate in extractable K and micronutrients. Soil was mildly alkaline with low EC and had favourable BD and porosity.

Physical properties

The bulk density of 0-15 and 15-30 cm soil layers after harvest of baby corn are presented in Fig. 1. Bulk density decreased at both the layers in all BGS applied treatments. Maximum decrease in BD was found in T5 treatment where 100% BGS was applied. Thus, the porosity of the soil increased. Maximum bulk density was found in T0 (1.47, 1.57) and the minimum was in T5 (1.39, 1.52 g cm^{-3}) at both the depths. Maximum porosity was observed in T5 (47.54, 42.64%) and minimum in T0 and T1 (44.45, 40.75%) at 0-15 cm and 15-30 cm layers, respectively. Although the effect is short-term, data implies soil physical properties is likely to improve through application of biogas slurry.

Application of BGS at 15 Mg ha^{-1} (SH) decreased the bulk density by 0.12 Mg m^{-3} over the control (C), whereas flyash treatments (FL, FM and FH) and application of slurry at 4 Mg ha^{-1} (SL) had no significant effect on bulk density of surface soil (Garg *et al.,* 2005).

Chemical properties

The pH of the soil differed marginally before and after the experiment. The soil pH (before the experiment) was alkaline (7.9). Even on the soil from the plot treated with different dose of manure, slight improvement on the soil reaction was observed.

The organic C content was improved by use of biogas slurry (Fig. 2). The increase in organic C in T2, T3, T4 and T5 were 7.3, 12.1, 14.3 and 16.6%, respectively over the control. Subtle improvement was also recorded in available N, P and K contents (Figs. 3 & 4). The increase in available N in T2, T3, T4 and T5 were 0.2, 1.0, 1.1 and 1.21%, respectively over the control. Increase in available P and K in T2, T3, T4 and T5 were 4.1, 4.4, 5.6 and 6.4%; and 1.2, 1.4, 1.8

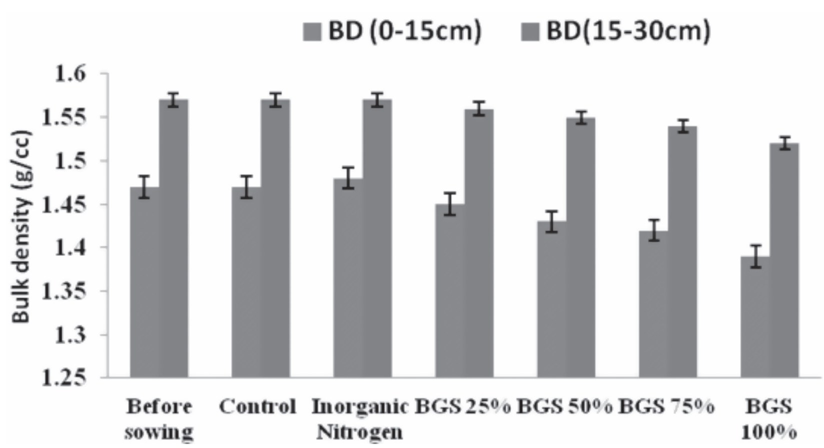

Fig. 1. Effect of biogas slurry on bulk density of soil

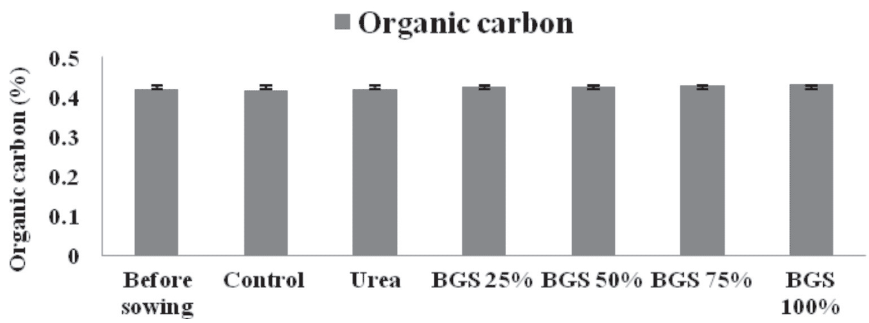

Fig 2. Effect of biogas slurry on organic C content in soil

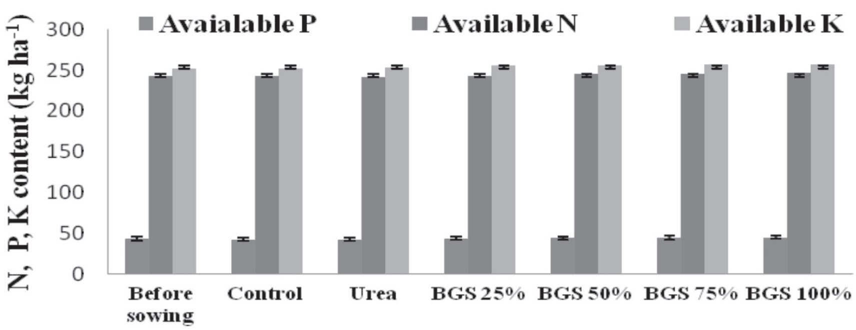

Fig. 3. Effect of biogas slurry on N, P and K contents in soil

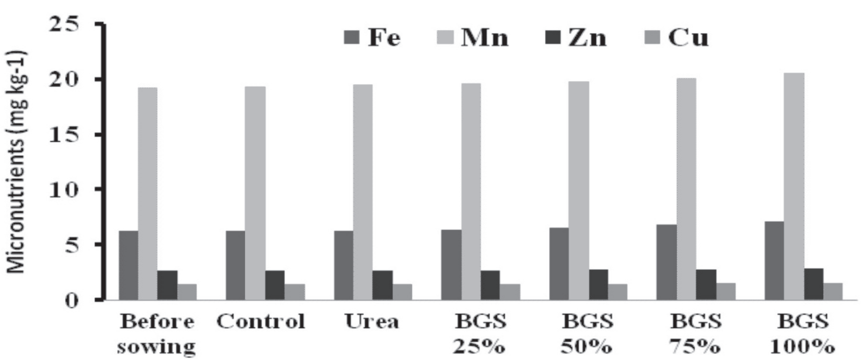

Fig 4. Effect of biogas slurry on Cu, Zn, Fe and Mn contents in soil

and 2.1% over the control. Micronutrients content also increased marginally (Fig. 5). Higher nutrient concentrations of biochar and cattle manure treated plots compared to control is suggestive of the positive contribution of organic amendments to improve soil nutrient availability. However, to sustain these positive effects, cattle manure should be applied every planting season, whereas a single application of biochar can maintain these positive attributes for a longer period of time (Islami *et al.,* 2011).

Biological properties

Pattern of variation of MBC in the soil during three seasons in one years of study were similar. Addition of BGS significantly ($p < 0.05$) increased the soil microbial biomass C (MBC) in comparison to the chemical fertilizer and the control. Higher levels of MBC in biogas slurry treated soil could be due to greater amounts of biogenic materials like, water soluble C, mineralizable N and carbohydrates. Integrated use of chemical fertilizers and BGS (T2, T3, T4 and

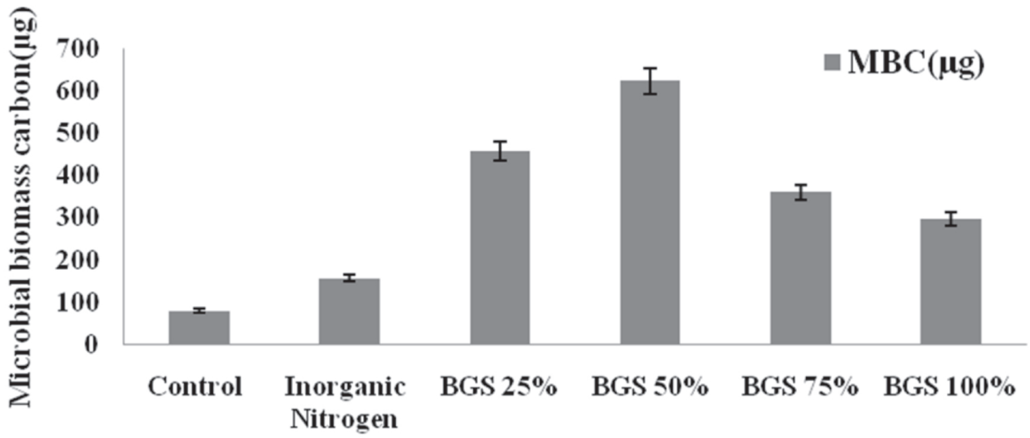

Fig. 5. Effect of biogas slurry on microbial biomass carbon in soil

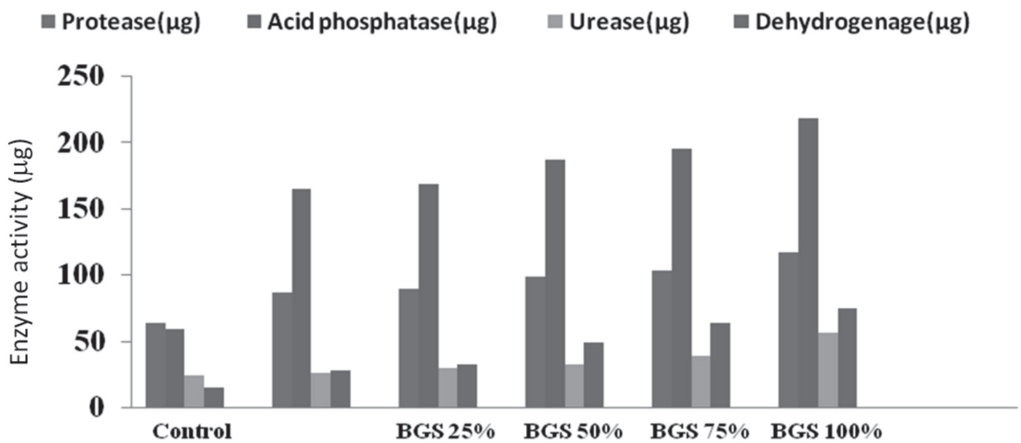

Fig. 6. Effect of biogas slurry on enzyme activity in soil

T5) resulted in higher MBC in soil compared to the single application (Fig. 5). Maximum MBC content was found in T3 (662.6 µg) followed by T2 (456.1µg), T4 (360.2µg), T5 (296.5µg), T1 (156.6µg) and T0 (79.3µg). Similar observations were recorded by Leita *et al*. (1999). Fertilizers may meet up the demand of mineral nutrition required by the microbes but not that of C, which is a major component of microbial cells. Integrated application of organic and inorganic materials provides a balanced supply of mineral nutrients as well as C.

Activities of all enzymes varied significantly in different treatments. Activities of all enzymes were higher in T5, T4, T3 and T2 treatments than in the control and chemical fertilizer treatments. The protease acid phosphatase, dehydrogenase, urease activities were maximum in T5 (116.4, 217.7, 56.2, 74.8µg) followed by T4 (102.6, 194.9, 38.963.4µg), T3 (98.3, 186.2, 32.4, 48.6 µg), T2 (89.3, 168.3, 29.1. 32.6 µg), T1 (86.5, 164.6, 25.6, 27.3 µg) and T0 (63.1, 58.4, 24.3, 14.6 µg) respectively. As shown in Fig. 6, acid phosphatase generally increased with BGS application. Increased phosphatase activity could be responsible for hydrolysis of organically bound phosphate into free ions, which were taken up by the plants. Tarafdar and Marschner (1994) reported that plants can utilize organic P fractions from the soil by phosphatase activity enriched in the soil– root interface. The increase in enzymatic activities due to organic fertilizers amendments are in accordance with previous studies. Martens *et al*. (1992) reported that addition of organic matter maintained high levels of phosphatase activity in soil. Giusquiani *et al*. (1994) reported that phosphatase activities increased when compost was added at rates of up to 90 t ha^{-1} and the phosphatases continued to show a linear increase with compost rates up to 270 t ha^{-1} in a field experiment. Application of nitrogen fertilizers significantly decreased urease activity while addition of BGS increased the activity.

Conclusions

We observed that 100% inorganic N and 75% BGS had nearly similar effect. Soil physical, chemical and biological properties improved, although marginally. The duration of the experiment was short, and a significant improvement could not be expected. However, changes in soil properties indicate that on long run, BGS can considerably improve the soil parameters, bringing positive impact on the crop growth and yield. Results also demonstrate that microbial biomass and soil enzyme activity is sensitive in discriminating between organic fertilizers and inorganic fertilizer application on a short-term basis. Further research work is needed for developing cost-effective and efficient use of BGS along with inorganic fertilizers for different crops.

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