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Full Research Article

Effect of Biogas Poultry Manure on Soil Fertility in Cereal-Legume based Cropping System

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Abstract

A field experiment was conducted during *kharif* and *rabi*, 2006-08 at All India Coordinated Research Project on Forage Crops, Livestock Research Institute, Rajendranagar, Hyderabad to study the effect of biogas poultry manure (BPM) on soil fertility in cereal-legume based cropping system. Application of 50, 75 and 100% N through biogas poultry manure (BPM) and poultry manure resulted in a significant increase in cob and Stover yield of maize. The highest cob yields were recorded in the treatment where 100% of N was substituted by BPM, recording 55.6 q ha^{-1} of cob yields and was significantly superior to all other treatments. Better yields in biogas poultry manure compared to that of poultry manure could be due to the fact that biogas poultry manure contains all the nutrients in more mineralized form compared to that of poultry manure as it had already passed through a part of decomposition in the biogas unit. The C:N ration of BPM is less than that of PM. The green fodder yields of cowpea which was grown on residual fertility were significantly influenced by poultry manure and biogas poultry manure. The soil fertility status of available major nutrients (N, P_2O_5 and K_2O) was found to be significantly higher in the treatments that received N through biogas poultry manure or poultry manure. The highest buildup of available nitrogen in poultry manure treated plots might be due to less mineralization during crop growth period resulting in more accumulation in soil. Effect on the soil physico-chemical properties was non-significant.

1. Introduction

Generating power from renewable energy resources has become increasingly important in the world. One of the main renewable energy resources is biogas. People have been using biogas for over 200 years. Biogas is a resource of energy that is environment-friendly and manure. In many parts of the world, biogas is used to heat and light homes and cook (Tatlidil et al., 2009). Biogas contains agricultural waste such as manure and plant waste. In order to protect environment, the usage of biogas should be increased. There are several biogas plants in Turkey. The main aim of this study is to determine the potential of biogas production produced by livestock and poultry waste in Turkey. According to livestock and poultry population, agricultural sector has an important resource for biogas production. Biogas potential will be calculated in compliance with type of livestock and poultry.

With emphasis on conventional sources of energy, the poultry manure is often used for biogas production in the poultry industry. Biogas thus produced is utilised in brooders, incinerators, generators and flame gun which are essential equipment in poultry industry. The use of poultry manure for biogas production is gaining popularity owing to the fact that poultry manure yields 1.4 times more biogas as compared to cattle dung in conventional biogas digesters. This biogas thus produced is often rich in methane, which is used as fuel. The by-product of such biogas unit i.e., the slurry from the unit is applied as organic manure for various crops. Trehan (2000) reported that the amount of N mineralized from the organic fraction of slurry in one year was 49.1% of the organic N in slurry (organic N in slurry=28.9 mg kg^{-1} dry slurry) and net mineralization was 26.3% of the organic N in slurry.

Indian poultry industry is the biggest in the world with 96 million tonnes (Ministry of Agriculture, 2007) of poultry production. In the production of poultry manure India nevertheless occupies the same position. Singh et al. (2005) observed that application of biogas (cow dung based) increased grain yield of maize and a maximum yield of 2.9 t ha^{-1} was obtained when slurry was applied at 10 t ha^{-1}. Similarly results were also reported by Basavaraj and Manjunathaiah (2003) in maize. The biogas poultry manure slurry in dried form could be used as organic manure for production of crops that have importance as poultry feed like maize, cowpea, etc. and thus used in a cyclic way in poultry industry. To utilize this biogas poultry manure slurry there is a need to conduct studies on its use efficiency by crop. If it is found beneficial, this biogas poultry manure powder could be commercially marketed like vermi-compost, neem cake etc. However, the actual benefits of BPM (Biogas Poultry Manure) in crop yields and its effects on soil properties or its residual effects if any, were less studied.

This experiment aims at studying utilization of biogas poultry manure (BPM) in production of crops that are essential ingredients of poultry feed i.e., maize and cowpea. The biogas slurry which is a byproduct of poultry manure based biogas units is confounded to be enriched with plant nutrients with much more nutrient content than FYM, which is commonly used organic manure. Maize, (Zea mays L.) the sole cultivated member of genus Zea, ranks as one of the important cereal crops in the world after wheat and rice. (Devi et al., 2013).The maize seed is very important ingredient of poultry feed while cowpea being a legume can be fed to poultry as leaf meal. Thus in a cyclic way the BPM could be used in production of crops in poultry industry. Poultry feed with maize+cowpea leaf meal→Poultry manure with biogas production→Biogas Poultry Manure→Maize and cowpea crop production with BPM for feed→poultry manure. In this study BPM is compared with the best alternative from poultry industry i.e., poultry manure (PM).

2. Material and Methods

Field experiment was conducted at fields of AICRP on Forage Crops located at Livestock Research Station, Rajendranagar. The field is at 17 20 35′ N and 780 24 414′ E latitude and 1700 m above mean sea level. Experiment was conducted for two consecutive years during both *kharif* and *rabi* on sandy loam soil (pH 7.98, EC 0.08 dS m^{-1} (Jackson, 1973), organic carbon 0.5% (Walkley and Black, 1934), alkaline permanganate N 204.70 kg ha^{-1}, Olsen's-P 33.80 kg ha^{-1}, neutral normal NH_4OAC K 202 kg ha^{-1} (Piper, 1966) at the farm of AICRP on forage crops, LRI, Rajendranagar, to evaluate the effect of biogas poultry manure (BPM) on the yield of maize and its residual effect on *rabi* cowpea. The cereal crop maize (a hybrid-DeKalb super 900) was grown as *kharif* crop. Eight treatments involving T_1-state recommended dose of fertilizers (120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1}), T_2-50% N through biogas poultry manure (BPM), T_3-75% N through BPM, T_4-100% N through BPM, T_5-50% N through poultry manure(PM), T_6-75% N through PM, T_7-100% N through PM and T_8-absolute control were imposed in maize. The experimental design followed was randomized block design with three replications in plot size of 5.0×3.0 m^2. Biogas poultry manure (BPM) contained 3.06% N, 3.16% P, 3.05% K, 4105.50 ppm Fe, 450.20 ppm Mn, 43.00 ppm Cu and 74.80 ppm Zn; poultry manure (PM) contained 3.36% N, 1.88% P, 1.86% K, 3486 Fe, 220.50 Mn, 20.30 Cu and 64 ppm Zn. Both the poultry manure and biogas poultry manure were air dried, powdered to fineness and applied to fields. An amount of 19.6, 29.4 and 39.2 q ha^{-1} of BPM was applied to treatments receiving 50%, 75% and 100% N through biogas poultry manure. On the contrary, poultry manure of 17.85, 26.78 and 35.7 q ha^{-1} was applied for 50%, 75% and 100% replacement of N, respectively.

A uniform dose of P and K at 60 kg P_2O_5 and 40 kg K_2O ha^{-1} in the form of single superphosphate and muriate of potash were applied before sowing in RDF and all organic manure applied plots expect absolute control. Biogas poultry manure and poultry manure were applied 7 days before sowing. In RDF treatment N applied in the form of urea applied in 3 splits 1/3 each at basal, at knee height and at tasselling stages which corresponded to 30 and 55 days after sowing, respectively. The crop was harvested at maturity. Data on cob, and stover yields were recorded and samples of the same along with those of soil at end of two years of experimentation were collected and analyzed for magnitude of N, P and K besides, soil reaction and conductivity.

Forage cowpea (var. COFC-8) was grown after maize on residual fertility for purpose of leaf meal for poultry. This crop is harvested at flowering dried and powdered for leaf meal for poultry. During the two years of study an amount of 525.5 and 518.7 mm of rainfall was received during crop growth period in 41 and 43 days, respectively.

3. Results and Discussion

3.1. *Effect on cob and stover yields of maize*

The cob yields (Table 1) of maize increased significantly due to application of biogas poultry manure and poultry manure at different levels of application. The highest cob yields were recorded in the treatment where 100% of N was substituted by BPM, recording 55.6 q $ha^{-1}$of cob yieldsand this was significantly superior to all other treatments. The treatment that received 50% and 75% N through BPM and PM recorded on par yields. The increase in cob yield in best performing treatment was 30.2% more than that of the state recommended fertilizer treatment. The stalk yields of maize too were significantly influenced by the application of N through BPM. All the BPM receiving treatments irrespective of percent replacement along with 50% PM recorded on par stalk yields. Among the PM receiving treatments, 50% N receiving treatment proved better than 75% and 100% PM receiving treatments. It is interesting to observe that BPM and PM receiving treatments showed considerable yield increase over state RDF and absolute control with regard to both cob and stalk yields. The treatments receiving 50% and 75% replacement of N were on par with each other irrespective of source of replacement. However, the difference between the mean cob yields of the three BPM and PM receiving treatments and 48.2 q ha^{-1}, respectively and mean stalk yields 39.8 and 36.1 q ha^{-1}, respectively indicates superiority of BPM over PM and also of the two manures over the RDF (42.7 q ha^{-1} cob yields) and 34.6 q ha^{-1}-stalks and absolute control (38.6 and 29.7 q ha^{-1}, respectively).

Better yields in biogas poultry manure compared to that of poultry manure could be due to the fact that biogas poultry manure contains all the nutrients in more mineralized form compared to that of poultry manure as it had already passed through a part of decomposition in the biogas unit. The C:N ratio of the BPM is comparatively low than that of poultry manure and have the nutrients in readily available state. Godhole (1987) opined that biogas slurry contains reduced quanity of carbon component, more of protein, phosphorus and therefore, is a source of mineralizable nitrogen in rhizosphere resulting in better crop growth. This increased dry matter production provides a better source sink relationship (Evans, 1980) enhancing greater synthesis and translocation of metabolites to reproductive organs, leading to improved seed yields. Higher grain yields with organic (FYM based) biogas slurry application were also reported by Lavanya and Manickam (1991), Singh and Totawat (2002), Singh et al. (2005), Abera et al. (2005), in maize. These results are also in confirmation to that reported by Madhavi et al. (1995), Poongothai and Mathan, (2002). Channabasavanna et al. (2002) also reported similar maize yield increases with 1 t ha^{-1} of PM; they further reported that performance of PM being more than that of FYM (Channabasavanna et al., 2007).

This indicated that inorganic N with BPM at any % of replacement gave the highest stover yields (50% N through BPM-40.1, 75% N replacement-39.2 and 100% N replacement-40.1 q ha^{-1}, respectively). The increase in stover yields could be due to improved soil physical properties (Prasad and Singh, 1980) enhanced microbial activity (Singh and Bhattacharya, 1989) and improvement in availability of micronutrients (Mann et al., 1977). These changes in soil properties have influenced the early vigor of the plant and, in turn, the yields and yield components. Another reason for the increased stover yields could be the high phosphorus content in the biogas poultry manure. High P in the slurry causes boot root elongation and thereby high dry matter production owing to higher root surface area and this could be one of the important reasons for increase in Stover yield.

3.2. Residual effect of BPM on forage cowpea

The green fodder yields of cowpea were significantly affected by the replacement of N by BPM or PM. Though highest green fodder yields of cowpea were observed in 100% BPM i.e., 41.8 q ha$^{-1,}$ the treatments receiving 50%, 75% and 100% N replacement through poultry manure recorded GFY of 40.5, 39.6 and 39.3 q ha^{-1}, respectively. This indicates that the PM has long lasting effect compared to BPM owing to its slow decomposition due to high C:N ratio.

3.3. Effect on soil fertility status

3.3.1. Physico-chemical properties

The studies on physico-chemical properties like pH, E.C. and OC content in soil indicated that there was no significant increase with the addition of manures (Table 3), either BPM or PM at harvest of cowpea at the end of 2nd year of study. The

Table 1: Effect of BPM on yields of *kharif* maize and *rabi* cowpea grown on residual fertility

Treatments	Maize cob yields (q ha^{-1})			Maize stalk yields (q ha^{-1})			Cowpea GFY (q ha^{-1})		
	Istyr	IIndyr	Pooled	Istyr	IIndyr	Pooled	Istyr	IIndyr	Pooled
Recommended NPK	47.2	38.2	42.7	35	34.1	34.6	32.5	31.3	34.8
50% N through BPM	54.3	40.4	47.3	40.8	39.4	40.1	36.0	34.6	37.5
75% N Through BPM	55.9	42.8	49.3	40	38.3	39.2	32.5	31.2	37.1
100% N through BPM	60.9	50.3	55.6	40.7	39.5	40.1	34.5	33.2	41.8
50% N through PM	55.4	45.9	50.6	40.8	40.1	40.4	36.5	35.1	40.5
75% N through PM	53.9	45.5	49.7	35.8	34.6	35.2	35.0	33.7	39.6
100% N through PM	45.0	43.7	44.4	33.3	32.1	32.7	37.0	35.6	39.7
Absolute control	42.7	34.5	38.6	30	29.3	29.7	30.5	29.3	31.9
Mean	51.9	42.7	47.3	37.1	35.9	36.5	34.3	33.0	37.9
SEm±			1.42			1.58			1.23
CD (p=0.05)			4.09			4.57			3.56

pH which was 7.98 before crop was 8.07 at harvest of cowpea at end of two years of study. Though the effect of BPM and PM was not significant on the soil organic carbon content, a slight increase in OC with addition of poultry manure was also observed compared to that of absolute control at end of maize. Kumar et al. (1995) reported similar trends in rice-wheat cropping system. Increase in organic carbon content of soil was also reported by Basak et al. (2012 and 2013). Besides, a slight increase in OC after harvesting of maize crop could be also due to high organic carbon content in the manure under study. Similar results were reported by Mathur et al. (1998).

This slight increase in the organic carbon content of the soil in the treatments that had received manures and fertilizers can also be attributed to the presence of yet un decomposed components of poultry manure and biogas poultry manure besides supply of organic matter through root biomass of maize, etc. Similar results were reported by Toor et al. (1995).

3.3.2. Major nutrients

The studies on available N, P_2O_5 and K_2O status of soil at harvest of maize are presented in table 4.The status of available nitrogen and phosphorus were significantly the highest in the treatment that received 100% 'N' through PM, i.e., 257.8 kg N ha^{-1}, accounting for 30.33% increase over the absolute control. This treatment was on par with 75% N through PM and 100% N through BPM in case of both nitrogen and phosphorus. However treatments receiving 75% and 100% N through PM were on par in this regard recording 240.0 and 257.8 kg N ha^{-1}. The status of available phosphorus at the end of two year study also indicated similar results i.e., the soil status of PM receiving treatments is higher than that of BPM or completely inorganic fertilizers receiving treatments. However, with regard to available potassium all the BPM and PM receiving treatments were on par with each other and significantly superior over that of state recommended treatment dose.

This increase could be attributed to the direct addition of slow release of N, P and K through organic manures i.e., BPM (biogas poultry manure) and PM (poultry manure). The highest buildup of available nitrogen in poultry manure treated plots might be due to less mineralization during crop growth period resulting in more accumulation in soil. Vasanthi and Kumaraswamy (2000) observed that apart from yield, the soil fertility status, and the content and uptake of N, P and K were significantly higher in the treatments that received poultry manure or sheep-goat manure at 10 t ha^{-1} with 50% of the recommended NPK schedule than the yields in the treatment that had received NPK alone. Reddy and Reddy (1999) also made similar observation in maize-soybean cropping system. They reported that the available macro nutrients (N, P, and K) were significantly increased with the integrated use of manures and fertilizers viz., vermicompost, Poultry manure, biogas slurry and FYM. Sharma et al. (2001) reported that the highest available phosphorus recorded in manure treated pots might be due to the organic acids, which were released during the microbial decomposition of organic matter, which helped in the solubility of native insoluble phosphates, thus increasing the available phosphorus content in soil. Besides this, appreciable quantities of carbon dioxide released during the decomposition of organic matter might be formed into carbonic acid, which might have enhanced the solubility of phosphates.

A better response of organic matter in improving the nutrient status of the soil can be ascribed to its decomposition, producing acids which in turn increase the nutrient availability through enhanced soil biological activities and release of nutrients from the exchange sites (Singh and Totawat, 2002). Similar results were also reported by Reddy and Reddy (1998) who stated that available major and micronutrients were influenced by the type and level of manure application. Bhardwaj and Omanwar (1994) too reported that the FYM treated plots had higher organic carbon and available N, P and K due to

Table 2: Effect of BPM on soil properties at harvest of crops during the two years of study

Treatments	pH			EC (dS m^{-1})			OC (%)		
	Istyr	IIndyr	Pooled	Istyr	IIndyr	Pooled	Istyr	IIndyr	Pooled
Recommended NPK	8.02	8.05	8.04	0.12	0.12	0.12	0.52	0.60	0.56
50% N through BPM	8.04	7.98	8.01	0.14	0.08	0.11	0.45	0.54	0.50
75% N Through BPM	8.10	8.03	8.07	0.10	0.08	0.09	0.48	0.56	0.52
100% N through BPM	8.12	8.09	8.11	0.10	0.11	0.11	0.55	0.61	0.58
50% N through PM	8.06	8.12	8.09	0.10	0.10	0.10	0.48	0.67	0.58
75% N through PM	8.10	8.07	8.09	0.09	0.10	0.10	0.48	0.62	0.55
100% N through PM	8.04	8.09	8.07	0.08	0.08	0.08	0.52	0.69	0.61
Absolute control	8.00	8.10	8.05	0.10	0.12	0.11	0.50	0.65	0.58
Mean	8.06	8.07	8.07	0.104	0.099	0.102	0.50	0.62	0.50
SEm±			0.04			0.004			0.04
CD (p=0.05)			NS			NS			NS

Table 3: Effect of BPM on available N, P and K at harvest of crops during the two years of study

Treatments	N (kg ha^{-1})			P (kg ha^{-1})			K (kg ha^{-1})		
	Istyr	IIndyr	Pooled	Istyr	IIndyr	Pooled	Istyr	IIndyr	Pooled
Recommended NPK	195.6	200.5	198.1	32.6	33.5	33.1	193.6	193.4	193.5
50% N through BPM	198.2	206.2	202.2	33.6	38.6	36.1	198.2	196.4	197.3
75% N Through BPM	199.6	217.3	208.5	35.6	39.7	37.7	208.6	219.2	213.9
100% N through BPM	220.4	238.3	229.4	38.8	45.3	42.1	220.6	228.1	224.4
50% N through PM	210.6	229.7	220.2	36.5	39.5	38.0	218.6	209.4	214.0
75% N through PM	226.4	254.0	240.2	37.2	44.6	40.9	216.3	218.8	217.6
100% N through PM	242.6	272.9	257.8	38.4	46.8	42.6	215.4	227.0	221.2
Absolute control	198.4	196.5	197.8	30.4	29.1	29.8	177.6	178.6	178.1
Mean	211.5	226.9	219.3	35.4	39.6	37.5	206.1	208.9	207.5
SEm±			7.3			1.11			5.3
CD (p=0.05)			21.21			3.195			15.31

manure application and attributed it to direct addition of N, P and K through FYM to available pool in soil.. The increase in available phosphorus might be due to the organic acids, which were released during microbial decomposition of organic matter. These helped in the solubility of native phosphates as a result of which increase in available P content occurred (Khan et al., 1984). Similar beneficial effects of organics on available K were reported earlier in case of vermicompost by Jhambhekar (1994).

Bitzer and Sims (1985) found that 40-60% of organic nitrogen in poultry manure was mineralized within 90 days and was made available to plants. On the other hand, NPK treatments with poultry manure either increased or retained the initial fertility status. Application of poultry manure is beneficial in two aspects. First, it decomposes at faster rate in hot climate, thereby releasing large amounts of plant nutrients into simple form. Secondarily, unlike inorganic fertilizers, poultry manure releases nutrients slowly over the entire growing season so that the nutrients, particularly N and K, from poultry manure are available for absorption by maize plants as compared to inorganic fertilizers which are subjected to leaching losses. The biogas poultry manure hence can be effectively used as bio manure for production of crops with beneficial effects on crop yields and soil conditions.

4. Conclusion

Utilization of biogas poultry manure or poultry manure applied to maize had showed significant impact on yields of maize and cowpea grown on residual fertility after two years of study. There was a significant effect on soil available N, P and K. The use of organic manures, those by-products of poultry industry can be commendably utilized for production of crop used as feed in poultry industry and can in a cyclic way fit into poultry industry viz., biogas production→biogas poultry manure→production of poultry feed crops.

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