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Nutrient Mineralization During the Application of Poultry Manure

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ABSTRACT

Among the different organic sources which can be used as manure, poultry litter is important as it is rich in major plant nutrients. A laboratory incubation experiment was conducted to study the rate of carbon and nitrogen mineralization in soil due to the application of various doses of solid and liquid fermented poultry manure application. The study revealed that the highest carbon dioxide evolution (68.0 mg kg^{-1}) and available nitrogen content (63 mg kg^{-1}) were present in the soil that received solid fermented poultry manure @ 680 kg ha^{-1}. The mineralization of carbon (72.8 mg kg^{-1}) and the nitrogen content (64.5 mg kg^{-1}) were maximum at 90th day of incubation. The poultry manure not only added valuable plant nutrients to the soil, but also enhanced the mineralization of nutrients. The present laboratory study confirmed the increased rate of nutrient mineralization in the soil due to the application of various doses of solid and liquid fermented poultry manure.

INTRODUCTION

The excessive use of agrochemicals for the last 50 years, though helped in achieving commendable progress in agriculture, the least attention to ecological principles resulted in widespread soil and groundwater pollution. In this context, a keen awareness has to be created on the adoption of organic farming as a remedy to manure the ill effects from chemical farming. Organic manure in agriculture adds much needed organic and mineral matter to the soil. Organic materials hold a great promise due to their local availability, as a source of multiple nutrients and ability to improve soil characteristics and crop yield. Nowadays, variety of organic sources are available which can be effectively utilized in organic agriculture. Among the different sources, poultry waste is the important one for its rich nutrient content. Mineralization is an important process which can provide mineral nutrients for plants and microorganisms by means of the biochemical degradation of soil organic matter. The conversion of organic nitrogen to inorganic nitrogen is critical to provide available forms of nitrogen to plants. Predicting the rate and amount of plant available nitrogen produced in poultry waste amended soil is necessary for providing proper plant nutrition and to protect the quality of groundwater and surface water (Weil & Kroontje 1979). Poultry manure has been found to have a higher mineralization rate than other types of animal manure (Serna & Pomares 1991). The present investigation is to assess the mineralization of nutrients due to application of fermented poultry manure.

MATERIALS AND METHODS

Production of solid and liquid fermented poultry manure: Subhashri Bioenergies Pvt. Ltd., located in Goundampalayam, Thiruchengode, produces organic manures from poultry litter by the following process: First step is the anaerobic digestion of poultry litter. The slurry from anaerobic digesters after biomethanation is dewatered, then the solids are composted aerobically and enriched with microbial inoculum. The product thus obtained is a solid fermented poultry manure and the liquid obtained through dewatering of slurry was enriched with the microbial inoculum and humic acid and used as liquid fermented poultry manure.

Incubation experiment to assess the effect of solid and liquid fermented poultry manure on nutrient mineralization: The effect of different levels of solid and liquid fermented poultry manure application on carbon and nitrogen mineralization was studied through a laboratory incubation experiment. The soil used for incubation study was collected from a groundnut grown field. Therefore, the dose of poultry manure application was fixed as per the nutrient requirement of groundnut crop.

Treatment details:

T_1 - Recommended dose of fertilizer (17:34:54 kg of NPK / ha)

T_2 - 80% N through solid fermented poultry manure (544 kg ha^{-1}) + 20% N through liquid fermented poultry manure (170 L ha^{-1})

T_3 - 50% N through solid fermented poultry manure (340 kg ha^{-1}) + 50% N through inorganic fertilizers

T_4 - 75% N through solid fermented poultry manure (510 kg ha^{-1}) + 25% N through inorganic fertilizers

T_5 - 90% N through solid fermented poultry manure (612 kg ha^{-1}) + 10% N through inorganic fertilizers

T_6 - 100% N through solid fermented poultry manure (680 kg ha^{-1})

Carbon mineralization: One hundred grams of air dried soil (< 2 mm) was weighed in 250 mL respirometer flask. Based on the treatments, different quantities of solid and liquid fermented poultry manures were added to the soil and thoroughly mixed. All the treatments were in quadruplicate and the flasks were incubated at room temperature for 90 days. Moisture content of 60 per cent was corrected at weekly intervals and maintained throughout the incubation period by adding required quantity of distilled water. The rate of mineralization of organic carbon was determined in terms of CO_2 evolution per 100 g of soil, by absorbing the evolved CO_2 in sodium hydroxide solution and back titrating with hydrochloric acid (Pramer & Schmidt 1966).

Nitrogen mineralization: Two hundred and fifty gram of air dried soil were weighed in plastic containers and incubated in the laboratory at room temperature for 90 days. The solid and liquid fermented poultry manures were added to the soil based on the treatments fixed above and thoroughly mixed with soil. They were covered with polythene sheets having small pin sized hole to permit aeration. Based on the weight loss, distilled water was added to the container to maintain the moisture content of 60 per cent throughout the incubation period. At the end of 30, 60 and 90 days, samples were collected from each replication and the mineral nitrogen contents were analysed (Bremner 1965). Subsequently, the microbial population in the soil was also characterized as per the standard methods described (Waksman & Fred 1922).

RESULTS AND DISCUSSION

The important physical, chemical and biological characteristics of solid and liquid fermented poultry manure samples are presented in Table 1.

The colour of the solid fermented poultry manure was dark brown and liquid fermented poultry manure was black in colour. There was no odour present in solid and liquid fermented poultry manure. The moisture content, bulk density and particle density of the solid fermented poultry manure were 23 per cent, 0.74 Mg m^{-3} and 1.11 Mg m^{-3}, respectively. The pH of the solid and liquid fermented poultry manure was 7.30 and 7.60, respectively. The electrical conductivity of the solid and liquid fermented poultry manure was 1.31 and 1.39 dS m^{-1}, respectively. The organic carbon content was 17.4 and 16.8 per cent for solid and liquid fermented poultry manure. The total N, P and K content of the solid fermented poultry manure was 2.5, 2.0 and 2.0 per cent, and the liquid fermented poultry manure was 2.0, 1.5 and 1.5 percent, respectively.

Effect of Solid and Liquid Fermented Poultry Manure on Nutrient Mineralization

Nitrogen and carbon mineralization: The effect of various doses of solid and liquid fermented poultry manure application on N mineralization is presented in the Table 2. From the Table, it is evident that the application of different doses of solid and liquid fermented poultry manure significantly influenced the soil available N. The available N content was maximum in the treatment that received solid fermented poultry manure @680 kg ha^{-1} (63 mg kg^{-1}) followed by T_2, which received solid fermented poultry manure @544 kg ha^{-1} along with liquid fermented poultry manure @170 L ha^{-1} (60.5 mg kg^{-1}). Control recorded the lowest available N content of 117 kg ha^{-1}.

The soil samples taken at 90th day after incubation recorded the highest available N content (64.5 mg kg^{-1}), followed by 120th day after incubation (62.5 mg kg^{-1}). The interaction effect between various treatments and the incubation period were found to be significant. The highest interaction effect in available N content was observed at 90th day after incubation period (67 mg kg^{-1}) in T_6 (solid fermented poultry manure @680 kg ha^{-1}) followed by the T_2 which received solid fermented poultry manure @544 kg ha^{-1} along with liquid fermented poultry manure @170 L ha^{-1} (64.5 mg kg^{-1}), whereas the lowest available nitrogen was recorded in control at the initial stage (54 mg kg^{-1}).

The effect of different doses of solid and liquid fermented poultry manure application on carbon mineralization is pre-

Table 1: Initial characteristics of solid and liquid fermented poultry manure.

Characteristics	Solid fermented poultry manure	Liquid fermented poultry manure
Colour	Dark brown	Black
Odour	No odour	No odour
Moisture content (%)	23.0	-
Bulk density (mg m^{-3})	0.74	-
Particle density(mg m^{-3})	1.11	-
pH	7.30	7.60
EC(dS m^{-1})	1.31	1.39
C:N ratio	6.96	8.40
Organic carbon (%)	17.4	16.8
Total nitrogen (%)	2.50	2.00
Total phosphorus (%)	2.00	1.50
Total potassium (%)	2.00	1.50

sented in the Table 3. From the Table, it is evident that the application of different doses of solid and liquid fermented poultry manure significantly influenced the carbon dioxide evolution. The CO_2 evolution was maximum (68.0 mg kg^{-1}) in the treatment (T_6) that received solid fermented poultry manure @680 kg ha^{-1} followed by T_2 which received solid fermented poultry manure @544 kg ha^{-1} along with liquid fermented poultry manure @170 L ha^{-1} (63.5 mg kg^{-1}). Control recorded the lowest CO_2 evolution of 44.5 mg kg^{-1}.

The evolution of carbon dioxide at different incubation periods shows that, 90th day after incubation recorded the highest CO_2 evolution (72.8 mg kg^{-1}), followed by 120th day after incubation (78.0 mg kg^{-1}), while the least CO_2 evolution of 35.0 mg kg^{-1} was recorded at 30th day after incubation. The interaction effect between various treatments and the incubation period was found to be significant. The highest interaction effect was observed (84.0 mg kg^{-1}) in T_6, which received solid fermented poultry manure

Table 2: Effect of solid and liquid fermented poultry manure on available nitrogen (mg kg^{-1}) in soil.

Treatments	Available nitrogen of soil (mg kg^{-1})					
	Initial	P_1	P_2	P_3	P_4	Mean
T_1	54.0	56.5	58.5	63.0	61.0	58.5
T_2	56.0	59.0	61.0	64.5	63.0	60.5
T_3	54.5	56.5	59.0	63.5	61.5	59.0
T_4	55.0	58.0	60.0	64.0	62.5	60.0
T_5	55.0	58.5	60.5	64.5	62.5	60.0
T_6	57.5	61.0	63.5	67.0	65.5	63.0
Mean	55.5	58.5	60.5	64.5	62.5	60.0
		SEd		CD (0.05)		
		0.824		1.637		

P_1 - 30 days of incubation; P_2 - 60 days of incubation; P_3 - 90 days of incubation; P_4 - 120 days of incubation

Table 3: Effect of solid and liquid fermented poultry manure on carbon dioxide evolution (mg kg^{-1}) in soil.

Treatments	Carbon dioxide evolution (mg kg^{-1})				
	P_1	P_2	P_3	P_4	Mean
T_1	26.0	42.0	58.0	52.0	44.5
T_2	40.0	62.0	79.0	73.0	63.5
T_3	30.0	49.0	68.0	64.0	52.8
T_4	34.0	51.0	72.0	68.0	56.3
T_5	38.0	59.0	76.0	71.0	61.0
T_6	42.0	68.0	84.0	78.0	68.0
Mean	35.0	55.2	72.8	67.7	57.7
		SEd		CD (0.05)	
		0.458		0.913	

P_1 - 30 days of incubation; P_2 - 60 days of incubation; P_3 - 90 days of incubation; P_4 - 120 days of incubation

Table 4: Effect of solid and liquid fermented poultry manure on soil bacterial population at various stages of incubation.

Treatment	Bacteria (× 10^6 CFU g^{-1} of soil)				
	P_1	P_2	P_3	P_4	Mean
T_1	14.5	16.4	13.4	12.7	14.3
T_2	25.1	26.4	23.1	20.1	23.7
T_3	15.4	16.3	14.1	13.4	14.8
T_4	20.4	21.3	18.4	18.1	19.6
T_5	24.4	25.1	21.7	19.4	22.7
T_6	29.2	30.4	25.3	22.1	26.8
Mean	21.5	22.7	19.3	17.6	20.3
		SEd		CD (0.05)	
		0.079		0.158	

P_1 - 30 days of incubation; P_2 - 60 days of incubation; P_3 - 90 days of incubation; P_4 - 120 days of incubation

Table 5: Effect of solid and liquid fermented poultry manure on soil fungal population at various stages of incubation.

Treatment	Fungi (× 10^3 CFU g^{-1})				
	P_1	P_2	P_3	P_4	Mean
T_1	10.8	11.2	10.3	9.5	10.5
T_2	20.3	22.1	18.4	15.4	19.1
T_3	13.4	15.7	15.3	12.2	14.2
T_4	18.7	19.5	16.3	13.3	17.0
T_5	19.2	20.4	17.3	14.2	17.8
T_6	20.7	23.3	18.1	15.3	19.4
Mean	17.2	18.7	16.0	13.3	16.3
		SEd		CD (0.05)	
		0.063		0.126	

P_1 - 30 days of incubation; P_2 - 60 days of incubation; P_3 - 90 days of incubation; P_4 - 120 days of incubation

Table 6: Effect of solid and liquid fermented poultry manure on soil actinomycetes population at various stages of incubation.

Treatment	Actinomycetes (× 10^2 CFU g^{-1} of soil)				
	P_1	P_2	P_3	P_4	Mean
T_1	6.30	8.00	5.40	4.80	6.13
T_2	10.30	11.40	8.80	8.40	9.73
T_3	6.20	11.10	8.20	6.50	8.00
T_4	9.00	10.00	7.00	6.40	8.10
T_5	9.00	10.90	8.50	8.30	9.18
T_6	10.20	11.70	8.90	8.60	9.85
Mean	8.50	10.52	7.80	7.17	8.50
	SEd	CD (0.05)			
	0.033	0.065			

P_1 - 30 days of incubation; P_2 - 60 days of incubation; P_3 - 90 days of incubation; P_4 - 120 days of incubation

@680 kg ha^{-1} at 90^{th} day after incubation, while the lowest CO_2 evolution of 26.0 mg kg^{-1} was observed in control at 30^{th} day after incubation.

In incubation studies, the available nitrogen was increased rapidly up to 90 days of incubation and then started to decline gradually. It was same in the case of CO_2 evolution and microbial load. Hadas et al. (1983) reported that the 34 to 42 percent of the total N in the poultry manure was mineralized in the initial rapid phase. Sims (1987) stated that mineralization of manure nitrogen occurred in two phases. It could result in large accumulation of available nitrogen in the soil within 14 days. The NO_3-N content of the soil increased with increased level of poultry compost application with a maximum content in 60^{th} day of incubation (Prasanthrajan et al. 2011).

Singh et al. (2002) also stated that about 46 percent of the N from poultry litter was released after 60 days of incubation. Castellanos & Pratt (1981) observed N release of about 48% from poultry incubated for 10 weeks. Qafoju et al. (2001) reported a mean value of 51 per cent net N mineralization for poultry litter samples incubated for 112 days. Kessal et al. (2000) reported that 92 per cent of inorganic nitrogen in poultry manure was mineralized during aerobic incubation. These results corroborate with the findings of the present study.

Effect of solid and liquid fermented poultry manure on microbial population: The application of different doses of solid and liquid fermented poultry manure influenced the microbial population (Tables 4, 5, 6). The highest bacterial populations of 26.80 × 10^6 CFU g^{-1} of soil, 19.4 × 10^3 CFU g^{-1} of soil fungal population and 9.85 × 10^2 CFU g^{-1} of soil actinomycetes were observed in the treatment that received solid fermented poultry manure @680 kg ha^{-1} followed by T_2 (solid fermented poultry manure @544 kg ha^{-1} along with liquid fermented poultry manure @170 L ha^{-1}) which recorded the bacterial population of 23.7 × 10^6 CFU g^{-1} of soil, 19.1 × 10^3 CFU g^{-1} of soil fungal population and 9.73 × 10^2 CFU g^{-1} of soil actinomycetes population. The lowest bacterial population of 14.3 × 10^6 CFU g^{-1} of soil, 10.5 × 10^3 CFU g^{-1} of soil fungal populations and 6.13 × 10^2 CFU g^{-1} of soil actinomycetes were recorded in the control.

The soil sample taken at 60^{th} day after incubation recorded the highest bacterial population of 22.7 × 10^6 CFU g^{-1} of soil, 18.7 × 10^3 CFU g^{-1} of soil fungal population and 10.52 × 10^2 CFU g^{-1} of soil actinomycetes, while the least bacterial population of 17.6 × 10^6 CFU g^{-1} of soil, 13.3 × 10^3 CFU g^{-1} of soil fungal population and 7.17 × 10^2 CFU g^{-1} of soil actinomycetes were recorded at 120th day after incubation. The interaction effect between various treatments and the incubation period was found to be significant. The highest interaction effect was observed in the treatment which received solid fermented poultry manure @680 kg ha^{-1} at 60th day after incubation, which recorded soil bacterial population of 30.4 × 10^6 CFU g^{-1}, 23.3 × 10^3 CFU g^{-1} of soil fungal population and 11.7 × 10^2 CFU g^{-1} of soil actinomycetes, while the lowest bacterial population of 12.7 × 10^6 CFU g^{-1} of soil, 9.50 × 10^3 CFU g^{-1} of soil fungal population and 4.80 × 10^2 CFU g^{-1} of soil actinomycetes were observed in control at 120th day after incubation. The nitrogen mineralization potential showed a positive correlation with the carbon mineralization potential in soil. Compost contains a relatively large amount of microorganisms associated with organic nitrogen mineralization which can influence the chemical properties of soil (Prasanthrajan et al., 2011). Laboratory incubation studies can be important for evaluating N mineralization mechanism but relating incubation results in mineralization under actual field conditions can be difficult (Eghball et al., 2002). Nahm (2005) stated that a number of factors affect the amount of available N in soils including soil characteristics such as texture, structure, organic matter, rainfall, temperature patterns, farming practices such as tillage and rotations. Application rates of manure and method of application, as well as residue characteristics also influence the quantity of residual N that is available to crops. Eghball et al. (2002) reported that only 40% of the N is available in the year of application in corn field. Some of the residual N of 15% is available to plant in the second year. Nahm (2005) also reported that 60% of the organic N of poultry manure would be mineralized within 140 days after the application of manure.

CONCLUSION

Organic farming is a sustainable form of agriculture which uses only organic inputs for the supply of nutrients. Among the various organic sources, poultry litter contains rich amount of plant nutrients. However, the nutritional value of unprocessed poultry litter deteriorates rapidly. Therefore an investigation was undertaken to assess the possibility of utilizing the processed poultry litter through soil application, which could offer the double benefits of safe disposal of the waste and its effective recycling of nutrients for agricultural production. The present study suggests that the application of poultry manure enhanced the mineralization process which increased the availability of nutrients in the soil.

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