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Soil Microbial Dynamics as Influenced by Organic Amendments in Alluvium Soil of Indo-Gangetic Plains, India

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An incubation study was carried out during 2009-2010 in net house at BHU, Varanasi on alluvial soils, to investigation the consequences of enriching the soil with different organic amendments viz. FYM, sludge, poultry manure, fresh cow dung and Lantana Camera on microbial inhabitant, CO_2 evolution, Soil microbial biomass carbon (SMBC) and C: N ratio of soil at 15,30 and 45 days of incubation (DAI).The results indicated a significant rise in microbial inhabitant, CO_2 evolution, Soil microbial biomass carbon (SMBC) and C: N ratio. Microbial inhabitant under the sludge application (45 DAI) was significantly higher than that gained under other organic materials, while CO_2 evolution, SMBC and C: N ratio was significantly higher under FYM application (45 DAI).Highest soil respiration was reported with FYM followed by sludge and fresh cow dung with increasing incubation periods. Highest value of CO_2 evolution was observed in FYM (28 mg CO_2) at 45 DAI. A marked increase in SMBC was recorded with application of FYM followed by sludge and fresh cow dung. Maximum SMBC occurred (392 μg g^{-1} soil) at 45 DAI. Treatment with FYM application found to be efficient in increasing C: N ratio and showed superior over all treatments.

Keywords: Organic amendments; Soil microbial inhabitant; CO_2 evolution; Soil microbial biomass carbon; C: N ratio; Incubation period.

Use of organic amendments is an integral part of sustainable agriculture[1]. Organic amendments supply nutrients and replenish the soil organic matter (OM) pool. According to several studies, organic materials improve soil chemical, physical and biological properties and thereby contribute to the maintenance of overall soil fertility and productivity[2, 3]. Addition of organic amendments is a suitable strategy to achieve soil recuperation in semi-arid areas, where the organic matter (OM) content and biological quality are low[4]. Applications of organic amendments can cause changes in the physical, chemical, and biological properties of soils. Applying organic amendments has been shown to increase soil microbial activity[5], microbial diversity[6], and bacterial densities[7]. Soil microbial communities are extremely diverse, and the relation between their diversity and function influences soil stability, productivity and resilience; on the other hand, organic matter, water activity, soil fertility, physical and chemical properties influence microbial biomass in soils[8].

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Organic amendments are materials that have ever been alive either as plant or animal added to a soil to improve its physical properties, such as water & nutrient retention, permeability, water infiltration, drainage, aeration, & structure. The goal is to provide a better environment for roots**.** Organic amendments are an eco-friendly in nature which can maintain the soil health in terms of soil biological fertility and productivity besides producing quality produce. Microbial biomass and microbial activity are closely related to soil organic matter content; they are positively influenced by organic amendment.

It is well established that microbial life only occupies a minor volume of soil localized in the hot spots such as the rhizosphere soil[9] where microflora has continuous access to a flow of low- and high-molecular-weight organic substrates derived from roots. The rhizosphere is the soil volume surrounding the rhizoplane, and the term was first coined by Hiltner in 1904[10]. The soil is the habitat of both fungi and bacteria, which have positive and negative effects on the growth and development of plants[11]. Microorganisms are largely responsible for the cycles of the elements within a soil and are involved in the decomposition of the organic matter at the ecosystem level via a variety of enzymes. In this sense, the addition of different organic amendments, such as solid organic wastes, sewage sludge, agricultural wastes, and animal manures, is a method of replenishing degraded soil quality through improvement of the biological status of the soil, which usually implies an increase in both microbial and enzyme activity[12]. This study was undertaken (i) to determine effect of organic amendments on microbial inhabitant, (ii) to investigate the effect of organic amendments on CO_2 evolution, (iii) to evaluate effect of organic amendments on Soil microbial biomass carbon (SMBC) and (iv) to examine effect of organic amendments on C: N ratio of soil.

MATERIALS AND METHODS

Description of experiment and site

During 2009-2010 pot culture experiment was conducted in net house at Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (25.26º N latitude and 82.99º E longitude and 128.93 m above sea level) located in India. The area receives an average of 1100 mm of annual rainfall. For experiment, Agricultural Research Farm, Banaras Hindu University soil was used. The soil in the study area is an alluvial soil. Alluvial soil is formed by accumulated sediments transferred by the rivers and rapids, thus, it is amongst the most fertile soils. Alluvial soils are rich in potash, phosphoric acid, lime and organic matter but deficient in nitrogen and humus contents. The soils used in this experiment were collected after 15, 30 and 45 days of incubation (DAI) for laboratory analysis. The experiment was set up using complete randomized design with 6 treatments viz. control, FYM, poultry manure, fresh cow dung, sludge, *Lantana camara* replicated four times. Soil was amended with different organic amendments @10 tha-^{1}.

Isolation and Counting of Microorganisms

The serial dilution plate technique[13] was employed to enumerate the rhizosphere soil bacteria, actinomycetes and fungi. Thornton's Medium[14], Kenknight & Munaier's medium[15] and Martins Rose-Bengal-Streptomycin-Agar medium were used for isolation of total bacterial, Actinomycetes and fungal counts, respectively. After the incubation period, the colony-forming units were counted and expressed as cfu×10^6 g^{-1} of soil.

CO_2 evolution

CO_2 evolution was determined using 0.1 N KOH by Zibilske method[16]. The amount of CO_2 evolution was calculated by using the following formula:

$$CO_2\,(mg) = (B\text{-}V) \times (N \times E)$$

Where, B= Volume (ml) of standard acid needed to titrate the trap solution from the empty flask (blank); V= Volume of HCl required to titrate sample reading; N= Normality of the acid in milli equivalents mL^{-1}; E= 22 if the data is to be expressed as CO_2 (i.e. mg CO_2)

Soil Microbial biomass carbon (SMBC)

SMBC was measured by chloroform fumigation extraction[17]. Soil MBC was estimated from the relationship between C_{org} extracted from fumigated and subtracted from non-fumigated soil samples by using following formula:

$$MBC\,(\mu g\ g^{-1} soil) = \frac{(ECF - ECNF)}{KEC}$$

Where, ECF = Extractible carbon in

fumigated soil samples; ECNF = Extractible carbon in non-fumigated soil samples; KEC = 0.25 ± 0.05

C: N ratio

The soil C_{org} was analysed by wet-oxidation technique using by potassium dichromate, sulfuric acid and phosphoric acid[18]. N_{Total} in soil was estimated by modified Kjeldahl method using alkaline potassium permanganate[19].

$$C : N\ ratio = \frac{Organic\ carbon\,(\%)}{Total\ nitrogen\,(\%)}$$

Statistical Analysis

The data thus recorded were subjected to statistical analysis by adopting appropriate method of "Analysis of variance" by C.R.D. (Completely Randomized Design) as detailed by Chandel[20]. The significance of the treatment effects was judged with the help of "F" (variance ratio) test.

RESULTS AND DISCUSSION

Microbial Inhabitant

The microbial counts were significantly influenced by application of organic material. The application of sludge, microbial population was recorded 83, 89 and 97 cfu×10^6 g^{-1} soil at 15, 30 and 45 DAI, respectively followed by FYM, Fresh cow dung, Poultry manure and Lantana. While, minimum microbial count was recorded 50, 49 and 52 cfu×10^6 g^{-1} soil at 15, 30 and 45 DAI in control, respectively (Fig. 1). Krishnakumar *et al.* observed that among all the treatments FYM had significantly more influence on the microbial population[21]. The attributed reason could be the enhanced C_{org} content of the soil as a result of organic material application.

In microbial inhabitant, the maximum account was obtained by bacteria (> 50%) except sludge followed by actinomycetes and fungi in all treatments. The maximum bacterial count observed under FYM followed by sludge, fresh cow dung, poultry manure, *Lantana camara* and control during all incubation period (Fig. 2). Whereas, the maximum actinomycetes and fungal population recorded in sludge followed by FYM, fresh cow dung, poultry manure, *Lantana camara* and control during all incubation period. Cwalina-Ambroziak *et al.* found that the application of sludge increased fungal colony as compare to other organic and inorganic amendment[22].

Evolution of carbon dioxide

Soil respiration is considered to reflect the availability of carbon for microbial maintenance. The maximum respiratory activity was recorded 16, 21 and 28 mg CO_2 at 15, 30 and 45 DAI in FYM amendment, respectively (Fig. 3). The CO_2 evolution significantly higher recorded in all treatment at 15 DAI whereas, During 30 and 45 DAI, *Lantana camara* was not significantly as compare to control and rest other treatment was significantly higher. Jaruhar stated that CO_2 evaluation was higher with application of FYM amended due to be improves the physicochemical properties of soil and availability of substrate carbon[23].

Soil microbial biomass carbon (SMBC)

The soil microbial biomass is involved in the decomposition of organic materials and thus, the cycling of nutrients in soils. The SMBC was

Table 1. Effect of organic amendment on C_{org}, N_{total} and C: N ratio at different DAI

Organic	C_{org} (%)			N_{total} (%)			C: N ratio		
amendment	15 DAI	30 DAI	45 DAI	15 DAI	30 DAI	45 DAI	15 DAI	30 DAI	45 DAI
Control	0.30	0.33	0.34	0.17	0.19	0.20	1.60	1.71	1.77
FYM	0.35	0.39	0.41	0.20	0.22	0.23	1.72	1.84	1.87
Sludge	0.33	0.35	0.37	0.18	0.19	0.20	1.72	1.84	1.83
Poultry manure	0.31	0.35	0.36	0.19	0.19	0.21	1.64	1.71	1.78
Fresh cow dung	0.34	0.38	0.40	0.20	0.21	0.22	1.72	1.84	1.82
Lantana camara	0.31	0.34	0.36	0.20	0.21	0.21	1.54	1.64	1.70
SEm±	0.007	0.006	0.005	0.007	0.006	0.005	0.036	0.010	0.012
CD (P=0.05)	0.016	0.013	0.012	0.0150	0.014	0.012	0.075	0.021	0.025
CD (P=0.01)	0.020	0.017	0.010	0.020	0.017	0.014	0.10	0.028	0.034

largest in the FYM amended 376, 387 and 392 µg g^{-1} soil at 15, 30 and 45 DAI, respectively. At 15 DAI, SMBC of FYM amended was 1.60, 7.71, 15.16, 16.76 and 27.93% higher as compare to sludge, fresh cow dung, poultry manure, *Lantana camara* and control, respectively (Fig. 3). The SMBC recorded 373, 363, 330, 318 and 273 µg g^{-1} soil in sludge, fresh cow dung, poultry manure, *Lantana camara* and Control, respectively, at 30 DAI. At 45 DAI, the lowest SMBC found 274 µg g^{-1}soil in control, which was 13.42, 15.05, 21.90 and 26.76 % lower than *Lantana camara*, poultry manure, fresh cow dung and sludge, respectively. Soil treated with FYM, compost, and other organic manure showed a significant increase in total C_{org} and biomass C in response to the increasing amount of C_{org} added. Application of organic amendments increased the soil MBC[24]. There is evidence that increasing inputs

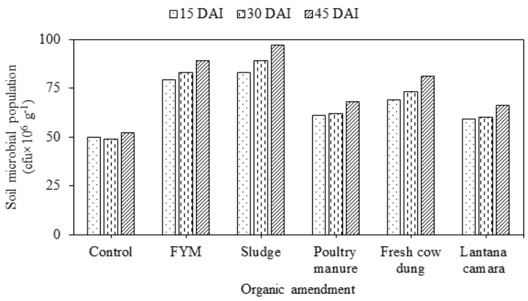

Fig. 1. Effect of organic amendments on soil microbial population (cfu×10^6 g^{-1}) at different days after incubation

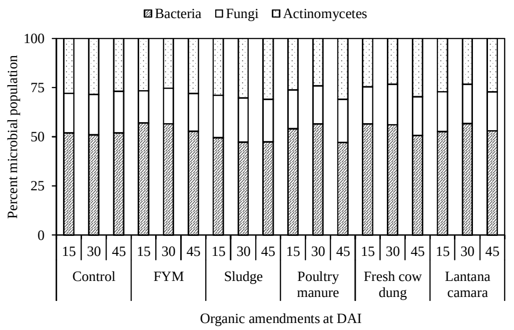

Fig. 2. Effect of organic amendments on percentage of different microbial population in soil at different days after incubation

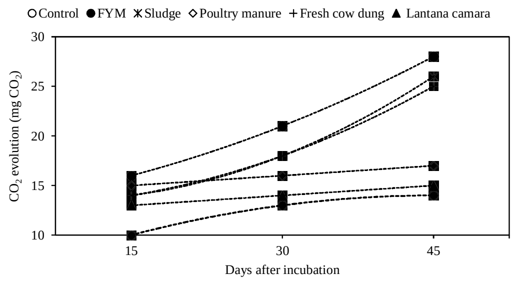

Fig. 3. Evolution of CO_2 through microbial community under different organic materials during incubation

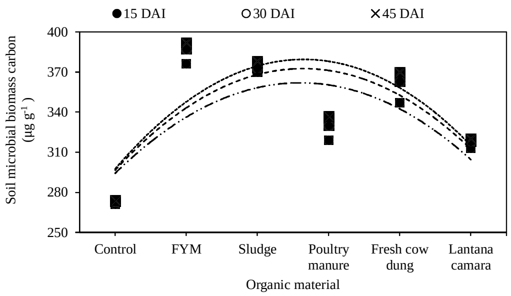

Fig. 4. Effect of organic materials on soil microbial biomass carbon (µg g^{-1} soil) at different days after incubation

of crop residues increase soil organic matter and microbial biomass.

C: N ratio

The maximum C_{org} was obtained FYM amended and significantly higher as compare to control at all incubation period. Maximum C_{org} content (0.35%) was recorded in FYM treatment followed by fresh cow dung which appeared significantly higher when compared with control (0.30%), poultry manure and *Lantana camara*. The similar trend was followed at 30 and 45 DAI. This finding was in accordance to the observation of Goyal *et al.*[25]. They concluded that highest amounts of both carbon and nitrogen were recorded in soils receiving farmyard manure.

At 15 DAI, N_{total} of soil significantly influenced by application of organic material. FYM, fresh cow dung and *Lantana camara* showed similar value (0.20%) of N_{total} which was found significant over control (0.17%). Poultry manure (0.19%) and sludge (0.18%) found to be non-significant over control. The highest N_{total} (0.22%)

was observed with FYM followed by fresh cow dung, *Lantana camara* and they showed significant increase in N_{total} over control, sludge, and poultry manure at 30 DAI. At 45 DAI, FYM amended recorded maximum N_{total} (0.23%), it was higher 4.55, 9.52 and 15.00 % in fresh cow dung, Poultry manure/*Lantana camara* and Sludge/ Control, respectively. Das and Dkhar elucidated the importance of soil C_{org}, N_{total}, and P_{avail}, which were found to be greater in manure amendments, with a significant effect on the composition and quantity of the microbial community in soybean rhizosphere[11].

The C: N ratio, which is an important tool of amendment evaluation, cannot explain all differences in nitrogen mineralization, since organic materials with similar C: N ratio may mineralize different amounts of nitrogen. C: N ratio increased significantly with application of organic material. At 15 DAI, FYM, sludge and fresh cow dung (1.72) caused increase in C: N ratio which was found non-significant over poultry manure (1.64) and control (1.60) but significant over *Lantana camara* (1.54). At 30 DAI, again FYM, sludge and fresh cow dung had similar C: N ratio (1.84) and was found to be significant over poultry manure or control (1.71) and *Lantana camara* (1.64). *Lantana camara* reported non-significant over control. FYM was recorded maximum C: N ratio (1.87) which showed its significant superiority to all rest treatment, followed by sludge (1.83), fresh cow dung (1.82), poultry manure (1.78), control (1.77) and *Lantana camara* (1.70) at 45 DAI. Treatment of soil with poultry manure and *Lantana camara* was found non-significant over control. Kirchner *et al.* also concluded that organic amendment increased the C_{org} of the soil, whereas C_{org} and C: N ratio significantly affect microbial community structure[26].

CONCLUSION

Our results showed that the enrichment of soil with organic amendments resulted in higher soil microbial activity measured by soil respiration, SMBC, C_{org} and N_{total}. This was caused by the higher inputs of C_{org} an energetic substrate for the present microbial communities that were activated to assure the turnover of indigenous nutrients. Among the amendments, FYM had more beneficial effects on soil respiration, SMBC and C: N ratio but only on when C_{org} was in the state of depletion to provide energy for the other soil microorganisms, which in turn increased soil respiration. Treatment of soil with sludge resulted in significant changes on microbial inhabitant. It was also observed that all parameters were much more dependent on incubation periods.

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