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Nitrogen mineralization kinetics in Typic camborthid soil amended with spent mushroom composts and farm yard manure

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Abstract
A laboratory experiment was carried out in completely randomized design with three replications under controlled conditions (25±1 °C) as an incubation study for 12 weeks. Bulk surface soil samples (0–15 cm) of sandy loam (Typic camborthids) was air-dried, ground, passed through a 2mm sieve, and mixed homogeneously. The required amount of organic amendments *viz.* White button spent mushroom compost (WB-SMC), Dhingari spent mushroom compost (D-SMC), and farm yard manure (FYM) @ 0.75% on dry weight basis were added in 500 g soil. After thorough mixing the soil and organic amendments, triplicate samples of (20 g) for each treatment and twelve incubation periods were transferred to 125 ml wide mouth plastic bottles. A control treatment without any organic amendment was also run. The containers were incubated in BOD incubator for 12 weeks and moisture content at field capacity was maintained throughout the incubation period with double distilled water by weighing the containers on alternate days. On completion of each incubation period i.e. 1, 2, 3, 4, 5, 6, 7, 8, 10 and 12 weeks, triplicate samples of each treatment were removed from the incubator and extracted immediately with 2 M KCl solution for determination of mineral-N. The cumulative amounts of mineral N in control soil as well as organic amendments treated soil increased with increase in incubation period. Among organic amendments, WB-SMC accumulated higher amounts of mineral N in soil followed by FYM and D-SMC. The lower accumulation of mineral N under D-SMC treatment as compared to WB-SMC or FYM was presumably due to immobilization of native mineral N by increased soil micro-organism activity.

Keywords: N mineralization, spent mushroom composts, FYM, Typic camborthid soil

Introduction
Mineralization of nitrogen from organic amendment varies with N content and C: N ratio (Frankenberger and Abdelmagid, 1985; Constantinides and Fowens, 1994; Pathak and Sarkar, 1994; Cabrera *et al.*, 2005) [1-4]. Unlike mineral fertilizer, organic amendments undergo mineralization before N become available to growing crop. Variations in chemical composition of organic amendment affect the mineralization and N release pattern. Organic amendment consist of many complex compounds and it is expected that no single characteristic will control N mineralization through out. Several other factors like organic-N content of amendment, temperature, soil composition, level of other nutrients also affect the N mineralization rate from added organic substance. The amount of N mineralized was significantly positively correlated to total N content and negatively with C: N ratio (Singh and Kumar, 1996; Pathak and Sarkar, 1994) [5, 6].

Mushroom substrate for growing mushroom is an organic material made from a blend of natural products that can include straw bedded horse manure, poultry manure, wheat straw, paddy straw, brassica straw, field hay, crushed corn cobs, cotton seed hulls, cocoa bean hulls, gypsum and water etc. In addition to these bulk ingredients, composters add a variety of protein concentrates like cotton seed meal, soybean meal *etc.* to enhance the nitrogen content of the finished compost. It is formulated by adding N, P and K containing fertilizers and then composted under controlled conditions. The fungal mycelia derive their nutrition from this medium and produce the fruiting bodies. Three to four week later, the initial harvest (first break) occurs followed by two or three weekly breaks (flushes) of mushrooms that are harvested. When a farmer decides that input costs exceed the potential value of additional harvests or when an economical crop is no longer being produced, the mushroom substrate become waste and declared "Spent" (Wuest and Fahy, 1991) [7]. Thus, spent mushroom compost is a waste product of the mushroom industry, which has traditionally been discarded as useless wastes, creating an environmental nuisance. The re-use of Spent Mushroom Composts (SMCs) has become the focus of attention due to its nutrient content and ability

to reduce the use of non-renewable resources (Lou *et al.*, 2017) [8].

In recent years, the world production of mushroom has increased dramatically with more than 30-fold increase since 1978 (Royse *et al.*, 2017) [9]. The annual production of mushrooms is estimated to be over 4.1 million tons worldwide (Levanon and Danai, 1995) [10] and the mushroom industry needs to dispose off more than 50 million tons of used mushroom compost each year (Fox and Chorover, 1999) [11]. About five kilograms of fresh compost are needed to produce one kilogram of mushrooms (Sample *et al.*, 2001) [12].

During 2017, the total mushroom production in India was approximately 0.13 million tons. The mushroom industry in India has registered an average growth rate of 4.3 per cent per annum from 2010-2017. Out of the total mushroom produced, white button mushroom share is 73 per cent followed by oyster mushroom (16 per cent), paddy straw mushroom (7 per cent) and milky mushroom (3 per cent) (Sharma *et al.*, 2017) [13]. Indian mushroom growers generate huge amount of spent mushroom compost (SMC) each year and with the coming up of many new export-oriented high-tech farms, these farms are likely to produce more SMC annually in the next couple of years as a waste product. Mushroom growers all over the world are facing increasing pressure of environmental legislation, giving rise to the need for a more viable solution for the disposal of SMC. At the same time, there is an increasing demand for organic residues and composts, which could provide a great potential outlet for spent mushroom compost generating more income for the mushroom growers (Wuest and Fahy, 1992) [14] as it has the role of increasing the fertility of soils and productivity of crops (Wang *et al.*, 1984) [15].

Spent mushroom compost has been found to be a good reserve of plant nutrients with a C: N ratio of 16:1. These nutrients are made available in a phased manner contributing to substantial yields increase and nutrients uptake (Ranganathan and Selvaseelan, 1997) [16]. The nutrient value varies with different sources of SMC. As spent mushroom compost contains considerable amounts of nutrients and is generally not phytotoxic, thus the utilization of this waste seems to be a promising way to improve soil physical, chemical and biological properties and increase nutrient resources for crop production (Wang *et al.*, 1984) [17]. The suitability of organic amendments as source of N depends to a great extent on its mineralization of N in relation to crop demand. In SMC, most of the N is found in a stable organic form that must be mineralized by soil microbes before it is available for plant growth (Crohn, 2004) [18]. There is dearth of information on this aspect from SMCs in Typic camborthids soil, therefore, the present investigation was planned to study the nitrogen mineralization kinetics from SMCs and FYM.

Materials and methods

The bulk surface soil sample (0-15cm) of sandy loam (Typic camborthids) was collected from the experimental area of the Department of Soil Science, CCS Haryana Agricultural University, Hisar. The physico-chemical properties of the soil are shown in Table 1.

Table 1: Physico-chemical properties of soil used in the study

Properties	Value	Properties	Value
Sand	64.3	pH (1:2)	7.7
Silt	17.3	EC, dSm^{-1} (1:2)	1.2
Clay	18.4	Organic carbon (%)	0.6
Textural class	Sandy loam	CEC [Cmole (P^+) kg^{-1}]	11.6
Taxonomy	Typic camborthids	Available-N (kg ha^{-1})	116.00
Saturation %	39.0	Available-P (kg ha^{-1})	15.50
Field capacity (%)	17.0	Available-K (kg ha^{-1})	192.50

Organic amendments used in this study included White button spent mushroom compost (WB-SMC), Dhingari spent mushroom compost (D-SMC) and farmyard manure (FYM). WB-SMC refers to the compost previously used for cultivation of *Agaricus bisporus* and D-SMC refers to the compost previously used for cultivation of *Pleurotus* spp. The SMCs and FYM used in this study were collected from Mushroom Technology Laboratory and Live Stock Farm, CCS Haryana Agricultural University, Hisar, respectively. The SMCs and FYM were oven dried and ground to pass through 2 mm sieve and mixed thoroughly. The chemical analysis of the organic amendments used in this study is given in Table 2.

Table 2: Chemical composition of organic amendments used in the study

Nutrients	WB-SMC	D-SMC	FYM
O.C. %	32.00	38.00	22.00
N%	1.84	0.78	1.20
P%	0.90	0.19	0.88
K%	2.19	1.24	1.92
Ca%	5.10	1.21	1.48
Mg%	2.38	1.26	1.48
Zn (mg kg^{-1})	215.00	108.00	203.00
Cu (mg kg^{-1})	179.00	118.00	153.00
Fe (mg kg^{-1})	2200.00	1508.00	1800.00
Mn (mg kg^{-1})	1439.00	1153.00	1226.00

Mushroom substrate formulations used for preparing mushroom substrate are also presented in Table 3.

Table 3: Mushroom substrate formulations used for preparing mushroom substrate (Formulae given by CCS Haryana Agriculture University, Hisar)

Formulation:		
1.	Wheat straw	300 kg
2.	Wheat bran	30 kg
3.	Gypsum	2.5 kg
4.	Calcium ammonium nitrate	9 kg
5.	Urea	3.5 kg
6.	Murate of Potash	3 kg
7.	Single super phosphate	3 kg
8.	Molasses	5 kg

The experiment was conducted in a completely randomized design with three replications. The required amounts of organic amendments @ 0.75% on dry weight basis were added in 500 g sandy loam soil. After thorough mixing the soil and organic amendments, triplicate samples of (20 g) for each treatment and each incubation period were transferred to 125 ml wide mouth plastic bottles. The required amount of double distilled water was added to maintain moisture content at field capacity. A control treatment which received no organic amendments was also run. The plastic containers were covered with perforated Para film to prevent any appreciable loss of moisture due to evaporation. The containers were incubated at 25±1 °C in a BOD incubator for 12 weeks and moisture content at field capacity was maintained throughout the incubation period with double distilled water by weighing the containers on alternate days. After each incubation period i.e. 1, 2, 3, 4, 5, 6, 7, 8, 10 and 12 weeks triplicate samples of each treatment were removed from the incubator and then extracted immediately with 2 M KCl solution for determination of mineral-N. The extracts were analyzed for mineral-N (NH_4^+-N and NO_3^--N) by steam distillation (Keeney and Nelson, 1982) [19].

Results and discussion

The cumulative amounts of mineral-N in control as well as organic amendments treated soil increased with the increase in incubation period (Table 4). Among the organic amendments, WB-SMC accumulated higher amounts of mineral N in soil followed by FYM and D-SMC with their respective values of 79.9, 76.5 and 50.8 mg kg^{-1} in soil after 12 weeks incubation. Higher accumulation of mineral N by WB-SMC than FYM may be attributed to its higher total N content. The lower accumulation of mineral N under D-SMC treatment (having wider C:N ratio value) compared to WB-SMC or FYM was presumably due to immobilization of native N by increased soil micro-organism activity during decomposition (Norman *et al.,* 1990; Kaboneka *et al.,* 1997; Ebid *et al.,* 2007) [20-22]. These results also confirmed the earlier findings of Shields *et al*., (1973) [23] and Toor and Beri (1991) [24] who reported up to 98 per cent immobilization of nitrogen into microbial biomass under wide C: N ratio treatments.

Table 4: Cumulative amounts of mineral-N in soil treated with different organic amendments (mg kg^{-1} soil)

Incubation period (weeks)	Organic amendments			
	Control soil	WB-SMC	D-SMC	FYM
1	30.4	44.0	24.6	43.2
2	34.6	53.2	30.4	52.0
3	37.7	60.4	33.4	58.9
4	40.7	66.1	37.2	64.3
5	43.6	69.0	39.0	67.0
6	46.4	71.8	42.8	69.5
7	48.8	74.1	44.2	71.4
8	50.4	76.2	47.1	73.2
10	51.6	78.1	49.0	74.9
12	52.5	79.9	50.8	76.5

Relatively large amounts of mineral N were obtained during first four weeks of incubation in control as well as organic amendments treated soil. In general, the cumulative amounts of mineralized N increased in all the treatments but the magnitude of increase with successive incubation period decreased. Higher mineralizations during early period of incubation and gradually decreasing rates with time have also been reported by other investigators (Lindemann and Cardenas, 1984; Chae and Tabatabai, 1986; El Gharous *et al.,* 1990; Soni *et al.,* 1994; Dhull, 1995; Stewart *et al.,* 1998; Lou *et al.,* 2017) [25-31]. Stanford (1968) [32] and Crohn (2004) [33] reported the existence of two general pools of organic-N. The flush of mineral N and corresponding high mineralization rates during the initial period of incubation were attributed to the decomposition of very labile organic N. As the first pool (more labile organic N) disappears, the second pool of organic N predominates which is somewhat resistant to further rapid decomposition and contributes a small proportion of N-mineralization during short term incubation studies.

Conclusion

Crops can only assimilate inorganic forms of N, such as nitrate and ammonium. Much or most of manure N is applied in the organic form, however organic N remains in the soil until it mineralizes. Mineralization is a continuous process, but a number of factors influence the rate at which it occurs. In the present investigation, the higher accumulation of mineral N recorded by WB-SMC than FYM may be attributed to its higher total N content. The lower accumulation of mineral N under D-SMC treatment (having wider C: N ratio value) compared to WB-SMC or FYM was presumably due to immobilization of native N by increased soil micro-organism activity during decomposition. Hence, application of WB-SMC may be recommended to improve soil fertility in Typic camborthids soil.

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