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Effect of Soil Drying and Rewetting on Nitrogen Mineralization from Soil Amended with Organic Matters

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ABSTRACT

Decomposition rate of various organic matters in soil depends on their intrinsic qualities, environmental condition specially temperature and moisture as well as size, diversity and activity of soil microorganisms. Soil water content variation caused by drying and rewetting events constitute an environmental factor that may have an important effect on N mineralization. In the future, many regions of the globe may experience higher mean annual temperatures and greater intra-annual variability in the timing of precipitation events. Under these scenarios, surface soils may experience more frequent drying and rewetting events. However, limited data are available on the effect that drying and rewetting may have on N mineralization from added organic matter. With this background the present study was undertaken with the specific objective to study the effect of drying and wetting of soil on nitrogen mineralization of organic matters under laboratory condition. After 10 days of drying that nitrogen mineralization for all the organics were significantly less as compared to constant moisture treatment. The difference of net nitrogen mineralization was more in tannery waste than other two. After second drying also nitrogen mineralization were more in constant moisture treatment for all the organics. It was also revealed that reduction of net mineralization was more after second drying.

Keywords: Drying, Rewetting, N-Mineralization, Organic matter

Decomposition rate of various organic matters in soil depends on their intrinsic qualities, environmental condition specially temperature and moisture as well as size, diversity and activity of soil microorganisms. Soil water content variation caused by drying and rewetting events constitute another environmental factor that may have an important effect on N mineralization. In the future, many regions of the globe may experience higher mean annual temperatures and greater intra-annual variability in the timing of precipitation events (Barrow and Hulme, 1996; Waggoner, 1989). Under these scenarios, surface soils may experience more frequent drying and rewetting events. In many environmental conditions, where rainfall events are infrequent and soils are often dry, the rewetting CO_2 pulse may constitute a significant proportion of the total annual CO_2 flux from surface soils.

Drying and rewetting effects on N mineralization from soil organic matter have been extensively studied (Cabrera, 1993; Van Gestel *et al.* 1996). Dry-wet cycles can stimulate microbial activity and increase mineralization of soil organic matter (SOM) (West *et al*. 1992; Denef *et al*. 2001a, b). The increase in mineralization of SOM can be partly attributed to microbial death upon rewetting of dry soil (Cabrera, 1993; Magid *et al.* 1999), and partly to the increased exposure or organic residues (Van Gestel *et al.* 1993; Appel, 1998). Both microbial biomass and organic residue can be simultaneously involved in enhanced mineralization (Van Gestel *et al*. 1993: Pulleman and Tietema, 1999). However, limited data are available on the effect that drying and rewetting may have on N mineralization from added organic matter (Clein and Schimel, 1993; Magid *et al.* 1999; Kruse *et al.* 2004).

With this background the present study was undertaken with the following specific objectives to study the effect of drying and wetting of soil on nitrogen mineralization of organic matters under laboratory condition.

MATERIALS AND METHODS

N-mineralization influenced by drying and rewetting

For this experiment university farm soil was air dried and sieved through 2mm sieve. Silica gel (self indicating) was used to dry the wet soil (Mikha *et al*. 2005). Before starting the wet dry experiment, an initial experiment was performed to determine the time required to dry the soil from 36% moisture (0.7 KPa) to approximately 2.7 to 5.7% moisture content. Gravimetric soil moisture content was determined by weight loss at 105 ˚C for 24 hrs.

Initial Drying Experiment

Air dried soil was mixed thoroughly with de-ionized water to raise the moisture content to 36%. After rewetting 100gm of soil (oven dry basis) was added to an air dried tight glass jar (1.5 litre). A polypropylene cup, containing 50 gm blue colored silica gel desiccant and attached to the lid of the glass jar, was held above the soil. Two holes (3 cm diameter) were made on the side of the cup to facilitate the absorption of moisture and the change of desiccant. The apparatus was closed tightly and incubated at 25 ˚C for the drying period. The silica gel was changed periodically by observing the change of the colour (from blue to colorless) and the desiccant was changed five times (two days interval) for drying period of 10 days (change of moisture from 36% to 2.5 –5.7%). Desiccant was changed after every 48 hrs and it was changed for five times.

Dry-Wet Experiment

Two dry-wet (DW) cycles were done during the experimental period (40 days). Each cycles contained two periods, 10 days drying followed by 10 days, incubation after rewetting at 25 ˚C. For this experiment soil was mixed with organic matter @ 100mg organic nitrogen kg^{-1} soil (dry weight basis) and deionized water was added to raise moisture content to 36%**.** Three replications of four treatments (i.e. Soil, Soil+FYM, Soil+FM and Soil+TW) were maintained for two sets, one for constant water content (CWC) treatment and other for DW treatment. After 10 days of incubation soils from both CWC and DW treatments were analysed for mineral (NO_3^-+NH_4^+) nitrogen. After drying (after 10 days) soils of DW treatments were rewetted to 36% moisture. Again soil samples were analysed for mineral nitrogen at 2, 4, 6, 8 and 10 days after rewetting of dry soils. Simultaneously, soils from CWC treatments were also analyzed (at 2, 4, 6, 8 and 10 days) for mineral nitrogen to compare the results of two sets of treatments.

With the progress of the experiment the amount of soil in glass jar was decreased and hence the quantity of desiccant was also reduced accordingly to maintain the same soil and desiccant ratio throughout the experimental period. Mineral nitrogen content was expressed on oven dry weight basis for both sets of treatments.

RESULTS AND DISCUSSION

Properties of Organic matters

In the present investigation seven different types of organic matters viz. vermicompost (VC), raw cow dung (RCD), farm yard manure (FYM), poultry manure (PM), fish meal (FM), tannery waste (TW) and mustard cake (MC) were used. Among these organics VC, FYM, PM were decomposed, whereas RCD, FM, TW and MC were un-decomposed. Some of the essential quality parameters were analyzed. Nitrogen content of various organic matters, used under study, varied from 0.83% to 9.29% (Table 1). On the basis of nitrogen content organics can be categorized as (a) low nitrogen containing organic matters i.e. vermicompost (0.83%), FYM (0.95%), raw cow dung (1.1%) and poultry manure (2.29%), and (b) high nitrogen containing organics i.e. Mustard cake (6.95%), fish meal (8.85%), and tannery Waste (9.29%). Total mineral nitrogen of VC, RCD, FYM and PM varied from 1071 to 3705 mg N per kg of organics, whereas FM, TW and PM had 4023, 6495 and 573 mg mineral N/kg organics. Total organic nitrogen of various organic matters, which was derived by subtracting the mineral nitrogen from total nitrogen, varied in the decreasing order of TW> FM> MC> PM> FYM> RCD> VC. Total organic nitrogen is very important parameter so far nitrogen mineralization is concerned. Although the

Table 1: Net-nitrogen mineralization (mg N/kg) of organic amendments as influenced by dry-wet cycle and constant moisture

Organic amendments	1st DW cycle						2nd DW cycle					
	Days after drying	Days after rewetting					Days after drying	Days after rewetting				
	10 days	2 days	4 days	6 days	8 days	10 days	10 days	2 days	4 days	6 days	8 days	10 days
Dry-Wet treatments												
FM-DW	27.55	32.86	32.86	40.64	48.41	54.63	33.30	46.86	49.97	53.08	60.86	59.30
FYM-DW	-2.36	3.99	7.10	11.76	10.99	12.54	1.58	14.10	17.21	27.31	28.87	25.76
TW-DW	6.41	18.87	32.09	29.75	33.64	28.20	8.96	25.09	34.42	40.64	42.20	43.75
Constant Moisture Treatments												
FM-CMC	39.86	53.08	53.08	51.52	59.30	62.41	62.27	73.29	62.41	65.52	62.41	71.74
FYM-CMC	7.88	8.65	12.54	24.98	29.65	24.98	26.50	26.54	27.31	31.20	34.32	35.87
TW-CMC	40.64	42.97	43.75	45.30	51.52	58.52	52.42	45.30	54.63	58.52	60.86	67.08
S.Em(±)	1.93	2.06	1.23	1.09	0.95	1.31	0.96	1.23	0.84	1.09	1.19	0.84
C.D.(5%)	5.86	6.34	3.79	3.39	2.93	4.03	3.00	3.79	2.59	3.39	3.66	2.59

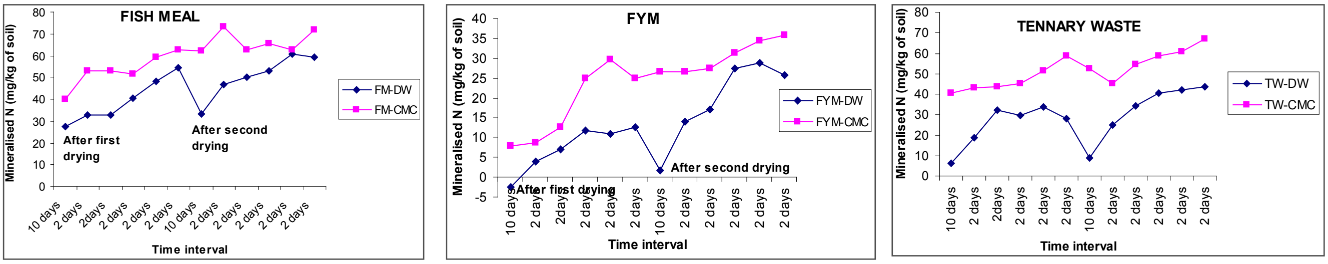

Fig. 1: Net nitrogen mineralization of organic matter influenced by drying and wetting.

total nitrogen content and organic nitrogen content of TW, FM and MC are high, these materials have less percentage distribution of mineral nitrogen as compared to VC, RCD, FYM and PM (Fig. 1).

Higher mineral nitrogen content of VC, FYM and PM may be attributed to the process of decomposition, however, RCD being un-decomposed contained the highest percentage of mineral nitrogen (20.22% NH_4^+ and 13.46% NO_3^-). Total organic carbon varied from 18.5% (FYM) to 44.84% (MC). The decomposed products, VC, FYM and PM contained 18.5, 27.24 and 29.13% TOC, whereas, the un-decomposed products i.e. RCD, FM, TW and MC contained 42.65, 36.92, 36.02 and 44.84% TOC, respectively. Organics C: N ratios, which were dependent on total organic carbon and total nitrogen, varied from 3.8 to 38.8. High nitrogen containing matter have C: N ratios of 3.8 (TW), 4.2 (FM) and 7.7 (MC), whereas, the bulky organic matter (contain less nitrogen percentage) have this ratios of 22.0 (VC), 38.8 (RCD), 28.6 (FYM) and 12.7 (PM).

Water soluble organic carbon (WSOC) and hot water soluble organic carbon (HWSOC) were also analyzed. There was a distinct trend in WSOC content and it was revealed that high nitrogen containing organics i.e. FM, TW and MC contained higher WSOC (5254 to 7398 mg C /kg organics) as compared to VC, RCD, FYM and PM (728 to 1380 mg). After the extraction of WSOC, hot water soluble organic carbon (HWSOC) were also extracted from the same sample and it was observed that decomposed organic matters i.e. VC, FYM and PM had less HWSOC (2990 to 3987 mg C per kg matter), whereas un-decomposed matters contained 4830 (TW) to 6900 mg C (RCD). Intrinsic properties of various organics have direct bearing with the decomposition rate and nutrient release pattern from these materials.

A C to N ratio of <12 has been suggested to indicate a mature compost product (Bernal *et al.* 1998b); by this standard TW, FM, MC should all behave in a similar manner, as "mature" amendments. While

VC, FYM behaved as a mature amendment, the others did not, indicating that the total C to N ratio did not always predict the behavior of the organic amendments in soil. This is supported by other studies that suggest it is the quality of C and N rather than the total amounts that have the greatest influence on decomposition(Kogel-Knaber, 2002; Vigil and Kissel, 1995; Wang *et al.* 2004b).

Nitrogen mineralization from organic matters under dry-wet cycle

An experiment was conducted under laboratory condition to study the effect of drying and rewetting of soils on nitrogen mineralization from fish meal, FYM and tannery waste. Two dry-wet cycles were given to each organics and simultaneously constant moisture treatments were also maintained. It was observed after 10 days of drying that nitrogen mineralization for all the organics were significantly less as compared to constant moisture treatment (Table 1 and Fig. 1). The difference of net nitrogen mineralization was more in tannery waste than other two. After second drying also nitrogen mineralization were more in constant moisture treatment for all the organics. It was also revealed that reduction of net mineralization was more after second drying. The reduction of mineralized nitrogen (mgN/kg soil) after first and second drying were 12.31 and 28.97 for FM, 10.24 and 24.92 for FYM and 34.23 and 43.04 for TW, respectively.

After 10 days of drying all dry-wet treatment were rewetted and mineralized nitrogen were estimated up to 10 days with 2 days interval. It was observed after 2 days of rewetting that all the organic matters increased nitrogen mineralization and these increments were more after second rewetting as compared to first. The increase in mineralized nitrogen (mgN/kg soil) for first and second cycle were 5.31(FM), 6.35(FYM), 12.46(TW) and 13.56(FM), 12.52(FYM), 16.13(TW), respectively. The incubation experiment was conducted for 40 days and for entire period the net nitrogen mineralization was more for constant moisture treatment for all the organic matters.

Kruse *et al.* (2004) found that cotton *(Gossypium hirslltum* L.) leaves decomposing in continuously moist soils for 185 days led to mineralization of 30% of theapplied N, whereas cotton leaves decomposing in soil subjected to a 14-d drying-rewetting cycle for 185 d led to minimal net N mineralization or net N immobilization. The authors hypothesized that this effect resulted from the effect of drying and rewetting on macrofauna populations that prey on bacterial populations. Clein and Schimel (1993) reported lower decomposition in dried and rewetted birch litter than in continuously moist litter.

They hypothesized that this reduction was caused by the drought sensitivity of a key microbial population in the litter. Similarly, Magid *et al.* (1999) found that drying and rewetting decreased the decomposition of added perennial ryegrass *(Lolium perenne* L.) shoot material. In the present study we also found less nitrogen mineralization of organic matters in drying-rewetting treatments.

Changes in soil water potential could cause the death of some portion of the microbial population (Kieft *et al.* 1987), and that may cause a shift in the active microbial population and their nitrogen needs. According to Franzluebbers *et al.* (1994), repeated dry wet cycles could cause a reduction in net nitrogen mineralization, either because of chemical reactions during the drying period, which reduce the amount of available N, or because of a change in species composition. Further, accumulation of N in a less-available portion of dead microbial biomass after each rewetting event could further reduce net N mineralization (Franzluebbers *et al.* 1994).

CONCLUSION

Decomposition rate of various organic matters in soil depends on their intrinsic qualities, environmental condition specially temperature and moisture as well as size, diversity and activity of soil microorganisms. Soil water content variation caused by drying and rewetting events constitute another environmental factor that may have an important effect on N mineralization. In the future, many regions of the globe may experience higher mean annual temperatures and greater intra-annual variability in the timing of precipitation events (Barrow and Hulme, 1996; Waggoner, 1989). Under these scenarios, surface soils may experience more frequent drying and rewetting events. However, limited data are available on the effect that drying and rewetting may have on N mineralization from added organic matter (Clein and Schimel, 1993; Magid *et al.* 1999; Kruse *et al.* 2004).

Finally it should be highlighted that farmers considering application of relatively unprocessed organic matters like fish meal, tannery waste, mustard cake and poultry manure, owing to their high N-mineralization capacity, need to know that it is likely to increase microbial biomass size and activity, and release large amounts of N into the soil system soon after application but not contribute to the long-term build-up of SOM. This is particularly true in high rainfall and warm environments, as those in North Bengal, which provide ideal microbial growth conditions. Thus the rate and timing of applications of these materials having high N-mineralizing capacity need to consider the N requirement of the given crop to ensure efficient use of N and minimize potential N leaching. Either these materials should be applied at low dose or after proper decomposition with some low nitrogen containing materials or these materials can be used as top dressing in the standing crop.

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