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NITROGEN MINERALIZATION KINETICS IN SOILS INCUBATED AT DIFFERENT TEMPERATURES AMENDED WITH ORGANIC AND INORGANIC FERTILIZERS

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ABSTRACT

Nitrogen mineralization of five soils consisting of control, recommended fertilizer (RF), RF plus 200 kg N ha^{-1} from FYM (INM2), 300 kg N ha^{-1} from FYM and 400 kg N ha^{-1} from FYM treatments at three temperatures was studied in a laboratory incubation experiment of 126 days. Triplicate samples were incubated at 15, 25 and 35°C for 0, 3, 5, 7, 14, 28, 42, 56, 70, 98, 126 days and analyzed for mineral N (NH_4-N + NO_3-N) at each incubation interval. Potentially mineralizable nitrogen (N_o) increased with time of incubation and increase in temperature andat 15, 25 and 35°C ranged from 100.5 to 146.6 mg kg^{-1}, 113.2 to 195.7 mg kg^{-1}, and 129.7 to 222.9, respectively in different soils. The N_o and N_t in different treatment soils followed the order, 400 kg N FYM > 300 kg N FYM > INM2 > RF > control. Rate constant (k) ranged from 0.197 to 0.261,0.196 to 0.290 d^{-1} and 0.195 to 0.346 d^{-1} at 15, 25 and 35°C, respectively the value being highest in INM2 treatment soil (INM2 > 400 kg N FYM > 300 kg N FYM > RF > control). The R^2 values increased from 0.44, 0.277 and 0.005 to 0.786, 0.761 and 0.664 in INM2, 300 and 400 kg N ha^{-1} from FYM treated soils, respectively with the increase in temperature from 15 to 35°C. The increase in value of R^2 indicates that the model gives a significantly better fit at 35°C than 25 and 15°C in amended soils than the unamended control soil.

KEY WORDS
Nitrogen mineralization
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INTRODUCTION

The depletion of organic matter content of soils by use of high analysis fertilizers has lead to the deficiency of macronutrient elements particularly nitrogen. Nitrogen is the most important nutrient from crop production point of view than the other nutrients, but its efficiency is low compared to other macronutrients. Soil nitrogen mineralization which implies the conversion of soil organic nitrogen to plant usable inorganic nitrogen (ammonical, NH_4^+ and nitrate, NO_3^-) forms is an important contributor of N to plant uptake. An increase in soil organic matter content helps in reversing the degradation and often increases soil fertility and crop production (Magdoff, 2009). Soil organic matter can be managed to release or conserve soil N to increase short term productivity or increase long-term conservation (Franzluebbers *et al.*, 1999). When organic manures are supplemented with nitrogen fertilizer under different management practices, it is difficult to predict nitrogen availability during the growing period of a crop. The knowledge of such availability is essential to ensure the release of adequate amount of nitrogen as well as to minimize its losses. Understanding the rates of transformation and fate of nitrogen in organic manure amended soil is important to ensure that the amount of organic manure applied provide sufficient available nitrogen for plant growth, but do not liberate amounts of NO_3 in excess of plant needs.

When N is added to the soil through organic sources it exhibits a very high resistance to mineralization, as usually only 1-3% of it is being mineralized during a growing season (Baker and Herson, 1994). Therefore, to supplement N, inorganic fertilizers are added extensively and continuously along with the organic sources, stimulating the mineralization and immobilization, so affecting the biological transformation of N in soil (Duhan *et al.*, 2005). It has been found that when farm yard manure (FYM) is added along with the inorganic nitrogenous fertilizers there is increase increases the nitrogen mineralization potential and rate over the use of inorganic fertilizers alone. The cumulative N mineralized increases linearly with the incubation time and with the amount of incorporated organic wastes (Isirimah and Keeney, 1972). Lodhi *et al.* (2009) reported that net mineralization of N increase with the time of incubation and temperature, being higher at 40ºC than 20 and 30ºC.A temperature coefficient of mineralization (Q_{10}) of about two from 15 to 35ºC has been found by Stanford *et al.* (1973) with maximum mineralization occurring at 35ºC. Mishra *et al.* (2011) studied the effect of organic amendments andearthworm inoculation on some important quality parameters of iron mine spoil over on incubation period of 28 days and reported that FYM treatedspoil with worm indicated the highest (297 ± 14.3 cfu/g) bacterial count and heterotrophic soil respiration (29.8 ± 1.6 mg/m2/hr), thus enhanced, % organic C, P, N and K followed by poultry manure. When FYM is used either alone or in combination with chemical fertilizers, it is difficult to predict the N availability to crops, thus it is important to understand the N mineralization kinetics in soils and informationavailable oninorganic (plant available) nitrogen release pattern under basmati-wheat cropping sequence when treated with FYM is sparse. Therefore the present study was therefore undertaken to study the N mineralization kinetics in soil using first order kinetic model of Stanford and Smith (1972).

MATERIALS AND METHODS

The soil samples for laboratory incubation study on nitrogen mineralization were collected from the Department of Soil Science, PAU, Ludhiana (30º- 56´ N, 75º - 52´E and 247m above sea level) farm where the long-term experiment on effect of organic and inorganic sources of nutrition on soil properties and crop yield under basmati-wheat sequence is in progress, since rabi 2006-07.The surface soil samples (0-15cm) were collected before application of fertilizer treatments to wheat crop sown in November 2011 from following treatments:

Control	:	Unfertilized Recommended fertilizers (RF)
INM2	:	RF + 200 kg N ha^{-1} from FYM
FYM 300 N	:	300 kg N ha^{-1} from FYM
FYM 400 N	:	400 kg N ha^{-1} from FYM

Details of incubation study

Number of soils	:	5
Incubation temperature	:	Three (15, 25 and 35ºC)
	:	Incubation time 11 (0, 3, 5, 7, 14, 28, 42, 56, 70, 98 and 126 days)
Replication	:	3

Mineralization of nitrogen from five soils was studied in laboratory by conducting aerobic incubation under controlled conditions.Ten gram of fresh soil was placed in plastic containers (120 ml capacity). The soils were wetted to field capacity (moisture held at 0.33 bars potential), the mouth of container was covered with perforated plastic to maintain a constant air supply. The soil moisture was maintained throughout the incubation period at field capacity by frequently weighing containers and adding water whenever necessary. Triplicate samples were incubated at 15, 25 and 35ºC for 0, 3, 5, 7, 14, 28, 42, 56, 70, 98, 126 days and analyzed for mineral N (NH_4-N + NO_3-N) at each incubation interval. To avoid soil disturbance due to sampling, independent sets were run concurrently for each incubation period.

At the end of each incubation period, NH_4 and NO_3-N from soil samples were extracted with 2M KCl. The method involved shaking of incubated soil samples (10 g) with 50 ml of 2M KCl (ratio 1:5) for one hour. The NH_4-N and NO_3-N in the extract were analyzed by steam distillation method (Keeney, 1982).

Cumulative N mineralized in a soil at a given time was calculated by subtracting mineral-N content of the soil at the start of incubation i.e. zero day time and then the mineral N data was fitted to first order kinetic model to work out the nitrogen mineralization potential.

First order kinetic model; (Stanford and Smith, 1972)

N_t	=	Cumulative N mineralized (mg N kg^{-1} soil) at time't' (days)
N_0	=	Nirogen mineralization potential (mg N kg^{-1} soil)
K	=	First order rate constant (day^{-1})

RESULTS AND DISCUSSION

Cumulative N mineralized at 15ºC

The cumulative N mineralized at 3 days ranged from 17.5 mg kg^{-1} to 19 mg kg^{-1}(Fig1) in different treatment soils. It was highest in soil treated with RF alone and RF in combination with 200kg N ha^{-1} from FYM (INM2) at 3 days than control and organically treated soils. The time course of cumulative N mineralized showed that N mineralization was faster in initial few weeks of incubation followed by a slow increase.Rapid cumulative N production in initial intervals of incubation followed by low rate has also been reported by Broadbent (1979). In control and RF treated soils the cumulative N was higher than the soils receiving organic manures either alone or in combination with chemical fertilizer up to 56 days. This indicated slow N mineralization in organically treated soils. The cumulative N mineralized was more in organically treated soils as compared to control and RF alone treated and at the end of 126 days of incubation. It was 86.2, 84.7, 81.6, 79.6 and 75.8 mg kg^{-1} in 400 kg N ha^{-1} from FYM, 300 kg N ha^{-1} from FYM, INM2, control and RF treatment, respectively.

Table 1: Kinetic parameters for single compartment first-order (FO) model [$N_t = N_0 (1 - e^{-kt})$] for N mineralization of different treatment soils

Treatments	Temperature								
	15ºC	25ºC	35ºC						
	No (mg kg^{-1})	k (per day)	R^2	No (mg kg^{-1})	k (per day)	R^2	No (mg kg^{-1})	k (per day)	R^2
Control	100.5(4.18)	0.197(0.037)	0.864	113.2(4.70)	0.196 (0.037)	0.868	129.7(5.15)	0.195(0.035)	0.881
RF	107.8(6.33)	0.197(0.052)	0.665	124.6(7.38)	0.212 (0.058)	0.678	144.2(6.18)	0.271(0.058)	0.809
INM2	119.9(8.04)	0.261(0.086)	0.440	149.4(7.24)	0.287 (0.071)	0.714	168.4(6.864)	0.346(0.08)	0.786
300 kg N FYM	135.0(10.47)	0.214(0.076)	0.277	176.7(9.79)	0.29 (0.083)	0.610	204.5(8.73)	0.321(0.075)	0.761
400 kg N FYM	146.6(12.37)	0.226(0.089)	0.005	195.7(12.17)	0.284 (0.09)	0.488	222.9(10.80)	0.323(0.085)	0.664

Figures in parentheses indicate standard error; N_t = Cumulative N mineralized (mg kg^{-1}); N_0 = N mineralization potential (mg kg^{-1}); k = First-order rate coefficient (per day); R^2 = Coefficient of determination

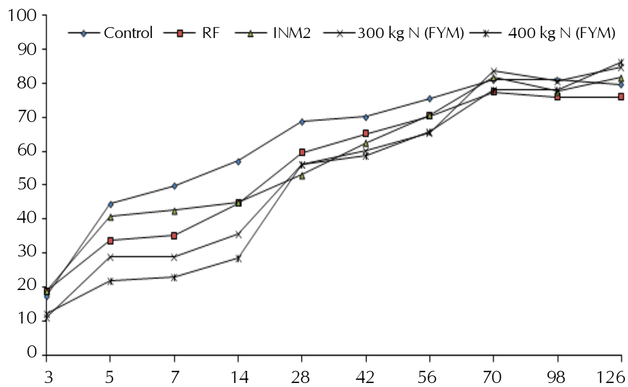

Figure 1: Effect of incubation time on cumulative net N mineralized (mg kg^{-1}) in different soils at 15°C

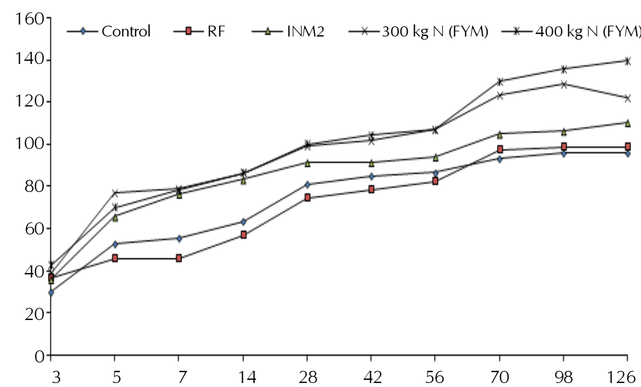

Figure 2: Effect of incubation time on cumulative net N mineralized (mg kg^{-1}) in different soils at 25°C

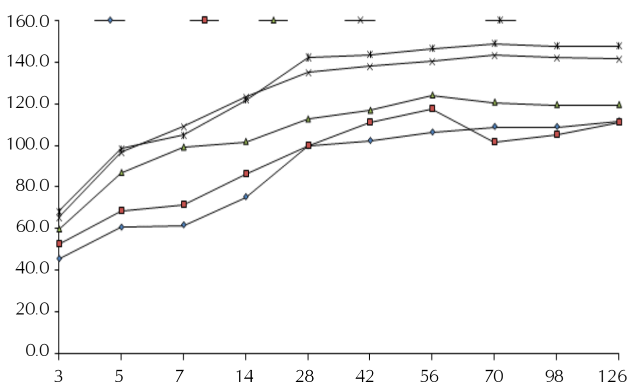

Figure 3: Effect of incubation time on cumulative net N mineralized (mg kg^{-1}) in different soils at 35°C

Higher mineralization of N in soils amended with N-rich plant residues had been observed by Seneviratne(2000) and Eriksen and Jensen (2001). A slight decrease in cumulative N was observed in control and RF at the end of incubation, it may be due to lesser amount of residual organic nitrogen in these treatment soils. The data showed that up to 28th day of incubation 86, 78, 65, 66, 65 per cent of N was mineralized in control, RF, INM2, 300 kg N FYM and 400 kg N FYM treated soils, respectively. This suggests that with increased incubation period, recalcitrant organic N fraction with slower rate of decomposition started contributing towards N mineralization.

Cumulative N mineralized at 25°C

The data on cumulative N mineralized at 25°C revealed that increase in temperature from 15 to 25°C resulted in increase in total amount of N mineralized from different sources. It was observed that cumulative N mineralized was higher in organically treated soils as compared control, RF and INM2 treated soils throughout the incubation, it may be due to mineralization of N from organic pools of nitrogen. The cumulative N mineralized ranged from 29.7 to 95.8 mg kg^{-1}, 36.6 to 98.8 mg kg^{-1}, 35.4 to 110.1 mg kg^{-1}, 38.4 to 121.6 mg kg^{-1} and 42.4 to 139.5 mg kg^{-1} in control, RF, INM2, 300 and 400 kg N ha^{-1} from FYM treatment soils, respectively at different incubation time intervals (Fig. 2).Vimlesh and Giri (2009) also observed an increase in the cumulative N release with the increase in incubation time and organic manures at 30°C than 20°C during their investigation on nitrogen mineralization in soil amended with crop residues.The higher mineral N release in organic treatment soils may be due to the fact that organic matter addition results in higher microbial activity leading to higher mineralization (Pansu and Thuries, 2013). Amount of cumulative N mineralized was higher in first few weeks of incubation, as from 3rd to 28th day cumulative mineralized N increased from 29.7, 36.6, 35.4, 38.4 and 42.4 mg kg^{-1} to 80.9, 74.4, 91.1, 99.0 and 99.9 mg kg^{-1} under control, RF, INM2, 300 and 400 kg N ha^{-1} from FYM treated soils, respectively. This is the stage of peak microbial activity probably caused by easily metabolizing carbon, organic N and rapid growth of microbial organisms. Statistical analysis showed that N mineralization increased almost linearly with the time of incubation. The results are in conformity with the findings of Garau*et al* (1986). Higher cumulative N mineralized at 25°C as compared to 15°C may be due to faster turnover of N from SOM at higher temperature subsequently increasing the rate of N mineralization. An increase in net mineralization rate with temperature during laboratory incubations has also been found by Wang *et al.* (2006).

Cumulative N mineralized at 35°C

At 35°C higher amount of cumulative N mineralized was recorded as compared to 15 and 25°C. It ranged from 45.9-68.4 mg kg^{-1} at 3 days of incubation. It was found that cumulative N mineralized increased with the period of incubation in all soils, but the increase was again faster during the first few weeks of incubation.These results may be due to increase in bacterial population density, its wet weight and biomass up to 21 days and thereafter a declining patternas reported by Kumari *et al.* (2009). At the end of incubation the cumulative N mineralized ranged from 111.0 to 147.7 mg kg^{-1} under different treatment soils (Fig 3). It was observed that cumulative N mineralized in organically treated soils was higher than soils receiving 200 kg N ha^{-1} from FYM along with RF dose (INM2), which was in turn higher than control and RF treated soils. The higher cumulative N mineralized in organically treated soils is due to the higher turnover rate of organic materials. The higher amount of cumulative N mineralized at 35°C than 15 and 25°C could be attributed to the slower mineralization and turnover of N from organic matter pool at low temperatures, while at higher temperature, the organic matter has a very fast turn-over of N and hence more release of NH_4-N (Javier and Tabien, 2004).A temperature coefficient of mineralization (Q_{10}) of about two has been found with maximum mineralization occurring at 35°C (Stanford *et al.*, 1973). Similar results had also been reported by Ellert and Bettany (1992) who found higher mineralization rate at 35°C than at 5, 15 and 25°C. Similarly Lodhi *et al.*, (2009) reported higher mineralization at 40°C than 20 and 30°C.

Modeling N mineralization kinetics

Nitrogen mineralization potential (N_o) and rate constant (k) as estimated by first-order kinetic (FO) single compartment model [$N_t = N_0 (1 - e^{-kt})$] for five soils at 15, 25 and 35°C temperatures are presented in Table 1. The N mineralization potentials for different treatment soils at 15°C ranged from 100.5 to 146.6 mg kg^{-1} and the rate constant (k) ranged from 0.197 to 0.261 per day. The potentially mineralizable N was higher in soils receiving organic manures either alone or in combination with chemical fertilizers than control and RF treated soil. The highest value of N_o (146.6 mg kg^{-1}) was observed in soil treated with 400 kg N ha^{-1} from FYM. The higher value of N_0 in organically treated soils may be due to presence of more residual organic N than control and RF treated soil. The highest value of rate constant (0.261 d^{-1}) was observed in the soil, which was treated with 200 kg N ha^{1} from FYM along with recommended dose of fertilizers (INM2). At 15°C, rate of N mineralization in different soils followed the order INM2 > 400 kg N FYM > 300 kg N FYM > RF > control. The higher values of R^2 at 15°C showed that the model gave a significantly better fit in control and RF treated soils compared to INM2 and organically treated soil.

Potentially mineralizable nitrogen (N_o) and rate constant were higher at 25ºC than 15ºC. The value of N_o ranged from 113.2 to 195.7 mg kg^{-1} in different soils. The highest value of N_o was again observed in the soil treated with 400 kg N ha^{-1} from FYM and lowest in control. The N mineralization potential of integrated nutrient management (INM2) soil was higher than control and RF treatment soils, but lower than organically treated soils. Nitrogen mineralization potential increased with the dose of N applied through FYM. The N mineralization rate constant (k) ranged from 0.196 to 0.290 d^{-1}; it was higher in soils treated either with organic manures alone or in combination with chemical fertilizers than control and RF treated soils. Nitrogen mineralization potential as well as the rate of mineralization was higher in soils where organic manures were used either alone or in combination with chemical fertilizers. The lower N mineralization potential in control and RF treated soils may be due to removal of easily mineralizable organic N by proceeding crop. In organically treated soils the residual organic N remained in the soil even after the harvest of rice crop, as the samples for analysis were taken before the application of fertilizer treatments to wheat. The value of R^2 in control and RF treated soils was almost similar at 25ºC as at 15ºC, but the R^2 value increased from 0.44 to 0.714, 0.277 to 0.61 and 0.005 to 0.488 in INM2, FYM 300 N and FYM 400 N treatment soils, indicating better fit of model at 25°C than at 15°C in these treatment soils.

Nitrogen mineralization potential (N_o) and rate constant (k d^{-1}) ranged from 129.7 to 222.9 mg kg^{-1} and 0.195 to 0.346 d^{-1}, respectively at 35°C. The nitrogen mineralization potential in all soils increased with the increase in temperature of incubation. The highest value of N_o was recorded in soils where FYM was applied to supply 400 kg N ha^{-1}, the potentially mineralizable N in different treatment soils followed the order, 400 kg N FYM > 300 kg N FYM > INM2 > RF > control. The value of k was highest (0.346 d^{-1}) in soil receiving 200 kg N ha^{-1} from FYM along with RF dose (INM2), indicating faster rate of N mineralization in INM2 treatment soil. In control the k value remained almost same at 15, 25 and 35°C, but it increased in the other treatment soils from 15 to 35°C. The values of rate constant were higher than those reported (0.054-0.058 per week) by Stanford and Smith (1972) at 35°C. This suggests higher N mineralization rate in the different treatment soils used for present study. The R^2 values ranged from 0.664 to 0.881 under different treatment soils at 35°C. The R^2 value doesn't increase much in control and RF treated soil with temperature, but the increase was higher in organically and INM2 treated soils. The R^2 values increased from 0.44, 0.277 and 0.005 to 0.786, 0.761 and 0.664 in INM2, 300 and 400 kg N ha^{-1} from FYM treated soils, respectively with the increase in temperature from 15 to 35°C. The increase in value of R^2 indicates that the model gives a significantly better fit at 35°C than 25 and 15°C in amended soils than the unamended control soil.

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