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Carbon and nitrogen mineralization kinetics as influenced by diversified cropping systems and residue incorporation in Inceptisols of eastern Indo-Gangetic Plain

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ABSTRACT

Carbon (C) and nitrogen (N) mineralization process is a key indicator of soil quality which regulate nutrient availability and supply to the crops. To provide insight on C and N mineralization in soil of diversified cropping systems, an experiment was initiated in split-plot design with five diversified jute-rice based cropping system under four nutrient and crop residue management practices (NCRM) during 2012–13. The five cropping system viz., fallow-rice-rice (F-R-R), jute-rice-wheat (J-R-W), jute-rice-baby corn (J-R-Bc), jute-rice-gardenpea (J-R-Gp), jute-rice-mustard-mung bean/green gram (J-R-M-Mu) were taken in main plot and four (NCRM) practices *viz.* 75% recommended doses of fertilizers (RDF) to all crops without crop residue (F_1R_0), 75% RDF with crop residues (F_1R_1) (Residue of rice, wheat and corn at 4 t/ha and garden pea and mung bean at 2 t/ha incorporated into soil with their respective cropping), 100% RDF without crop residues (F_2R_0) and 100% RDF with crop residue (F_2R_1) were taken in sub plot with three replication. Soil samples (0–15 cm) were collected after four year completion of crop cycles in 2016 to measure C and N accumulation and to estimate potentially mineralizable C (C_0) and N (N_0) using first order kinetic model. The highest C mineralization was recorded in J-R-M-Mu (1280 mg CO_2/kg soil) followed by J-R-Gp (1235 mg CO_2/kg soil) and J-R-Bc (1235 mg CO_2/kg soil) cropping system under F_2R_1. N mineralization was also higher in J-R-M-Mu (63.3 mg N/kg soil) followed by J-R-Gp (55 mg N/kg soil) and J-R-Bc (52 mg N/kg soil) cropping systems under F_2R_1.Significantly higher ($P < 0.05$) rate constant for C and N mineralization (k_C and k_N) were in J-R-M-Mu under F_2R_1 compared to other cropping systems and NCRM practices. Hence, our findings indicate that cropping systems with 100% RDF with mungbean residue at 2 t/ha had higher C and N mineralization. This cropping system had also higher C and N kinetic due to presence of more labile or decomposed SOC. Application of mineral fertilizers with crop residues had positive effect on C and N mineralization and their kinetics.

1. Introduction

Soil organic carbon (SOC) plays an important role in the long-term sustainable productivity of agro-ecosystems due to direct effects on physical, chemical, and biological properties of soil (Tian et al., 2013). Intensive tillage and cropping practices with removal of crop residue decrease SOC content and soil aggregate stability and thereby soil quality (Raiesi, 2006; Marinari et al., 2010). Moreover, SOC mineralization process while providing mineral nutrients for plants and energy for micro-organisms efflux CO_2 to the atmosphere and lowered the SOC content. However, easily mineralizable pool of organic C is mainly responsible for CO_2 fluxes from the soil to environment (Iqbal et al., 2009). Nevertheless, there is need to maintain balance between soil carbon decomposition and sequestration by selecting crop rotations, applying manures, by adopting conservation tillage, managing higher quality crop residue, proper water management, soil erosion control etc. (Lal, 2004; Janzen 2006; Frasier et al. 2016). Because, mineralization of organic N is the key process for N nutrition in many arable crops and their in-situ turn over potential is considered as a quality indicator of fertility (Mikha et al., 2006). Carbon mineralization has strong relationship with N mineralization in soil through the activity of microbial pool and C:N ratio of substrate. These processes regulate N supply in soil which influences growth and development of crops. A positive relationship between SOC status and N supplying capacity of soil has been well documented (Benbi and Chand, 2007). Soil has the ability to partially supply the N requirement of crop through SOC

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mineralization that has immense economic and environmental importance (Li et al., 2011). The turnover rate of different fractions of soil organic carbon determines the potential carbon storage and its losses in the soil. A better understanding about SOC and N mineralization in soils is necessary to improve soil fertility through management practices which helps in sustainable food production and mitigation of climate change (Cai et al., 2016).

The eastern part of the Indo-Gangetic Plain (IGP) is one of the world's most important agricultural eco-regions (Timsina and Connor, 2001) practiced under intensive rice based cropping systems viz. rice-rice, rice-potato, jute-rice-potato, jute-rice-wheat and jute-rice-mustard (Biswas et al., 2006; Kumar et al., 2014). Indiscriminate and imbalance use of inorganic fertilizers in various intensive cropping systems ofthis region causes nutrient imbalances which tend to gradually changes soil fertility. Biswas et al. (2006) reported a decline in soil organic matter under continuous jute–rice–wheat cropping. Continuous declining trend in SOC content in the region has a serious concern regarding crop productivity. Therefore, attempts should be made to raise the productivity while maintaining soil fertility using efficient management practices (Hobbs and Gupta, 2003; Bhattacharyya et al., 2009; Ramesh et al., 2009). Management practices like crop rotation, conservation tillage, balanced fertilization, return/incorporation of crop residues and/or manures are known to increase soil organic carbon and improve agricultural sustainability (Yang and Kay, 2001; Li et al., 2012). Diversified cropping systems that rely on crop rotation benefits the soil by spatial and temporal placement of organic matter inputs of varying quantity and quality, which, therefore, influenced the decay of SOC through alter physical and biochemical factors in soil (Govaerts et al.,2009). Many researchers (Islam and Weil, 2000; Mikhailova et al., 2000; Lobe et al., 2001) have reported that soil tillage and crop residue management affected microbial population, its activity and biomass, soil moisture content, bulk density, porosity, nutrient distribution and structure stability. These changes may decrease or increase C and N dynamics and have an influence on nutrient uptake by plants. Application of chemical fertilizers, especially N, for improving nutrient availability may also have an effect on C and N mineralization process (Kanchikerimath and Singh, 2001; Raiesi, 2006). However, nitrogen fertilization and its interaction with different crop residues addition can prompt C mineralization or immobilization depends on soil type (Sakala et al., 2000; Muhammad et al., 2011). Increases in C mineralization caused by nitrogen fertilization have been positively related to labile C concentration (Ding et al., 2010). Besides, soil and residue management may interactively influence soil nutrient concentrations that would further affect mineralization of C and N in the soil (Salinas-García et al., 2002). Residue incorporation in soils with high levels of SOC or high C:N ratio may increase C mineralization and have positive priming which accelerate native SOC decomposition (Zhang et al., 2013). Greater understanding of how soil under different crop rotation and crop residue incorporation influence soil response to C and N mineralization needed to help us manage the soil C cycle to mitigate climate change (Cai et al., 2016). Therefore, we had plan to provide insight on C and N mineralization kinetics under diversified jute-rice cropping systems under nutrients and crop residue incorporation in Inceptisols of Indo-Gangetic Plain. The main objectives of this study were: i) to assess the effect of different cropping systems on C and N dynamics. ii) to assess the effect of different crop residue incorporation and application of mineral fertilizers (N, P and K) on C and N dynamics in soils. iii) to assess whether kinetics of C and N mineralization would be altered with growing of different crops in jute-rice cropping system under nutrients and crop residues incorporated soil. We hypothesized that C and N mineralization kinetics of diversified cropping systems would be differed under different nutrients and crop residue incorporated soil.

2. Materials and methods

2.1. Experimental site

Field experiment was initiated during 2012–13 at Central Research Institute for Jute and Allied Fibre Barrackpore, India (22°45′N, 88°26′E, 9.0 ms l)) on new alluvial soil (Inceptisols) in the hot humid sub tropic of eastern India. The soil texture was a loam (sand, silt and clay were 54% 34% and 12%, respectively) (hyperthermic, typic Utrochrept) with pH 7.1, bulk density 1.43 Mg/m^3 and cation exchange capacity 16.4 cmol (p +)/kg. The initial value of organic carbon, N, P and K in soil were 0.68%, 265 kg/ha, 35 kg/ha and 216 kg/ha, respectively. The experimental site received an annual rainfall of 1434, 1810 and 1337 mm 1682 mm in 2012-13, 2013-14 2014-15, and 2015-16, respectively. Maximum rainfall was received during June to August in each year of experimentation. Mean annual minimum temperature varied from 20.7 to 21.1 °C and maximum temperatures varied from 30.7 to 31.4 °C, variation in minimum relative humidity (RH) of 58 to 63.4%and maximum RH of 92.2 to 93.65% during experimental years.

2.2. Experimental details

The experiment was laid out in a split-plot design with five cropping systems (CS) *viz.,* fallow-rice (*Oryza sativa* L.)-rice (F-R-R), jute (*Corchorus olitorius* L.)-rice-wheat (*Triticum aestivum* L.) (J-R-W), jute-rice-baby corn (Zea mays L.) (J-R-Bc), jute-rice-gardenpea (*Pisum sativum* L.) (J-R-Gp), jute-rice-mustard (*Brassica juncea* L.)-mungbean/green gram (*Vigna radiata*) (J-R-M-Mu) in main plot and four levels of nutrients and crop residue management practices (NCRM) *viz.* 75% recommended doses of fertilizers (RDF) to all crops without crop residue (F_1R_0), 75% RDF with crop residue (rice, wheat and corn at 4 t/ha; garden pea and mung bean at 2 t/ha incorporated into soil with their respective cropping sequences once in a year) (F_1R_1), 100% RDF without crop residues (F_2R_0) and 100% RDF with crop residue(F_2R_1) were superimposed as sub plot. All these treatments were replicated thrice. Mustard and mung bean were sown on zero tillage in J-R-M-Mu cropping system a day after harvest of previous crop to save the time required in tillage and accommodate four crops in sequence. The crop residue incorporated by tractor drawn Disc harrow followed by rotavator before sowing of jute once in a year. Details of quantity of crop residue and nutrients applied for each cropping system are mentioned in Table 1.

Table 1
Total nutrients applied in different cropping systems and nutrient and crop residue management practices.

Cropping systems	Nutrients applied in 75% of recommended doses of fertilizer			Nutrient applied 100% of recommended doses of fertilizer			Crop residue (t/ha)
	N (kg/ha/year)	P (kg/ha/year)	K (kg/ha/year)	N (kg/ha/year)	P (kg/ha/year)	K (kg/ha/year)	
F-R-R	150	32.7	62.28	200	43.6	83	4.0 (Rice)
J-R-W	210	45.8	74.7	280	61.0	99.6	4.0 (Wheat)
J-R-Bc	185	45.8	74.7	260	61.0	99.6	4.0 (Corn)
J-R-Gp	150	45.8	74.7	200	61.0	99.6	2.0 (Garden pea)
J-R-M#-Mu#	184	55.37	93.37	245	74.1	124.5	2.0 (Mung bean)

F-Fallow, J-Jute, R-Rice, W-Wheat, Bc-Baby corn; Gp: Garden pea ; M-Mustard, Mu-mung bean (Green gram); # crop was sown on zero tillage.