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Effect of long-term integrated nutrient management on soil pH and carbon mineralization in calcareous soil of North Bihar

M Alam, SN Suman, V Kumar, SK Singh, A Kumar and MM Nand

M Alam
PG Student Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, India

SN Suman
Assistant Professor Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, India

V Kumar
Assistant Professor Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, India

SK Singh
Assistant Professor Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, India

A Kumar
PG Student Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, India

MM Nand
PG Student, Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, India

Correspondence
M Alam
PG Student, Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, India

Abstract
A laboratory study was conducted in an ongoing field experiment started during *Rabi* 1988-89 in calcareous soil at Research Farm of Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar. The experimental design was split-plot with four fertilizer levels (0, 50, 100 & 150% NPK) in main plots and four levels of manures (no manures, compost @ 10 t ha^{-1}, crop residues and compost @10 t ha^{-1} plus crop residues) in sub-plots. The present investigation was undertaken with objectives to investigate the effect of combined use of NPK and different organics (compost and crop residues) on Soil pH and Carbon Mineralization under rice–wheat-cropping system. Continuous application of compost @ 10 t ha^{-1} plus crop residues, reduces the pH of soil by 3.66% than no manure application. Cumulative carbon mineralization significantly increased in treatments having both organic and inorganic fertilizers than of treatments having only inorganic fertilizers. Rate of mineralization increased in initial days of incubation after that it decreases.

Keywords: Carbon mineralization, crop residues, soil organic carbon, calcareous soil

Introduction
Rice-wheat cropping system is one of the largest agricultural production systems of the world, occupying 13.5 million ha (Mha) of cultivated land in the Indo-Gangetic Plains (IGP) in South Asia. Soil pH is a dominant factor that regulates soil nutrient bioavailability. The changes in soil pH widely depends on soil type, climate, vegetation (Robson *et al.*, 1989) [10], way and time of management and soil water content (Troch and Thompson, 2005) [14]. Soil pH was generally elevated significantly by addition of all organic amendments in acid soil (Naramabuye and Haynes, 2006) [8]. Benbi and Brar (2009) [2] reported that soil pH in Punjab soils has declined by 0.8 units after 25 years of rice-wheat cropping. Soil organic carbon (SOC) mineralization, is one of the most important processes in the ecosystem carbon cycle (Bahn *et al.*, 2008). Changes in SOC storage significantly influence atmospheric CO_2 concentrations and the global carbon cycle (wang *et al.*, 2013) [15]. The differences in the rate of carbon mineralized are indicative of variable amounts of labile organic carbon accumulated in soils (Campbell *et al.*, 1992) [4]. Long-term experiments are essential to understand the effects of cropping systems, tillage, manuring,
and fertilization practices on soil physical and chemical properties. Therefore, evaluation of SOC mineralization dynamics in long-term experiment (25 years) is important to study the terrestrial ecosystem carbon cycle.

Materials and Methods
A study was conducted in an ongoing field experiment under AICRP on Soil Test Crop Response Correlation, initiated in *Rabi*, 1988-89 in light textured highly calcareous soil at Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, India, having 25^0 94' N latitude, 85^0 67' E longitude and an altitude of 52.00 meter above mean sea level. The climate is sub-tropical having average annual rainfall 1135 mm. The experimental design was split-plot with four fertilizer levels (0, 50, 100 & 150% NPK) in main plots and four levels of manures (no manures, compost @10 t ha^{-1}, crop residues and compost @10 t ha^{-1} plus crop residues) in sub-plots. The soil of experimental area having texture sandy loam, pH 8.5, organic carbon 5.02 g/kg and $CaCO_3$ content 36.6%. Rice and wheat crops are being grown continuously under rice-wheat system during *Kharif* and *Rabi* seasons respectively.

The chopped straw of previous crops treated as crop residues. The source of N, P and K was urea, SSP, muriate of potash (MOP) and period of the investigation was the year 2017-18. The pH of the suspension of soil in water with a soil water ratio of 1:2 was determined with the help of glass electrode pH meter (Jackson, 1973) [6]. The electrical conductivity in the clear extract of soil with water in soil: water ratio of 1:2 was determined with the help of Electrical Conductivity Bridge (Bower and Wilcox, 1965) [3]. Carbon mineralization was studied in a laboratory incubation experiments at constant room temperature for 32 days. The soil moisture condition was adjusted at 60% of water holding capacity to simulate average field moisture condition and incubation was carried out in incubator or room temperature (25 ± 3 °C). Carbon mineralized was determined by titrimetric method as outlined by Parr and Smith (1969). A vial containing 10 ml of 2*M* NaOH was placed inside the flask containing known weight of soil (100g) with the help of thread, and flasks were sealed (air-tight) with wax. The vials were taken out on 3rd, 6th, 9th, 12th, 15th, 18th, 25th and 32nd days and titrated with standardized 0.5*M* HCl after addition of l ml of saturated $BaCl_2$ using phenolphthalein as visual indicator. The amount of CO_2 evolved were calculated by using the formula:

CO_2 evolved (mg kg^{-1}) = (A-B) x N x22

Where, A and B are the volume of HCl consumed for titrating 10 ml of 0.5*M* NaOH in control and soil, respectively and *N* was the normality of HCl.

Results and Discussion

Effect on Soil pH

The pH in surface soil (0-15 cm) ranged from 8.23 to 8.35 (Table 1) with different levels of fertilizer treatments i.e. no NPK to 150% NPK. The soil pH minimum (8.23) was obtained in the treatment received 150% NPK. In different manure application, soil pH ranged 8.15 to 8.46. Minimum pH (8.15) was observed in treatment of compost @ 10 t ha^{-1} with crop residues which was 3.66% lower than no manure application. No interaction effect was found in different fertilizer levels and manure levels. The decrease in soil pH with compost @ 10 t ha^{-1} with crop residues application may be attributed to the production of organic acids and release of CO_2 during organic matter decomposition. The decrease in soil pH with the combined application compost @ 10 t ha^{-1} with crop residues has also been reported by Srikanth *et al*. (2000) [11]. Benbi and Brar (2009) [2] reported that soil pH in Punjab soils has declined by 0.8 units after 25 years of rice-wheat cropping. However, Hati *et al*. (2007) [5] reported that long-term application of fertilizer and organic manure did not influence pH of a clay soil significantly. This may be because of high buffering capacity of the clay soil and nominal presence of weak salts namely carbonates or bicarbonates, which on dissolution release free cations leading to buffering of soil reaction (Tembhare *et al*., 1998) [13].

Effect on Soil Electrical Conductivity

Electrical conductivity (EC) in surface soil (0-15 cm) under different NPK treatments ranged between 0.24 dS m^{-1} and 0.34 dS m^{-1} (Table 1). The EC values in all the treatments were less than 0.5 dS m^{-1}, which is considered safe for growth of all crops. The electrical conductivity of soil was not significantly influenced by different treatments i.e. manure and fertilizers levels. Electrical conductivity was maximum (0.34 dS m^{-1}) in the treatment receiving 150% NPK and treatments receiving compost @ 10 t ha^{-1} (0.29 dS m^{-1}). Stalin *et al*. (2006) [12] also found that electrical conductivity of soil was not influenced by long-term continuous application of manure.

Table 1: Effect of Long-term Integrated Nutrient management on Soil pH and EC

Fertilizer Level (kg ha^{-1})	pH	EC (dS m^{-1})	Manure Level	pH	EC (dS m^{-1})
NO NPK	8.35	0.24	No Manure	8.46	0.28
50% NPK	8.31	0.25	Compost @ 10 t ha^{-1}	8.24	0.29
100% NPK	8.27	0.28	Crop Residue	8.30	0.27
150% NPK	8.23	0.34	Compost @ 10 t ha^{-1}+ Crop Residue	8.15	0.28
SEm±	0.02	0.023	SEm±	0.01	0.011
CD (P=0.05)	0.07	NS	CD (P=0.05)	0.04	NS

Effect on Cumulative Carbon Mineralization

The cumulative carbon mineralization in 32 days of incubation, varied from 1002.81 to 1110.49 mg kg^{-1} of CO_2 (Table 2 and Figure 1) with increasing levels of fertilizer i.e. no NPK to 150% NPK. The treatment receiving 150% NPK had maximum (1110.49 mg kg^{-1} CO_2) carbon mineralization which was 10.73% higher than treatment receiving no NPK. All the levels of fertilizer significantly affected the evolution of carbon dioxide. In manure level, the carbon dioxide mineralization increased from 975.16 to 1136.26 mg kg^{-1}. The highest carbon mineralization (1136.26 mg kg^{-1} CO_2) was found in the treatment receiving both compost and crop residue which was 16.52% higher than treatment receiving no manure application. All the levels of manure has significant impact on evolution of carbon dioxide.

The interaction effect of fertilizer levels and manures are also significant. The CO_2 evolution in the treatment receiving 150% NPK and compost + crop residue was found 11.00% higher over no NPK along with compost + crop residue and was at par with treatment receiving 100% NPK with compost + crop residue. Carbon mineralization rate (mg kg^{-1} CO_2 day^{-1}) [Figure 2] increased in initial days of incubation (upto 12 days) but, after 12 days it decreased over time. The decrease in decomposition rate over time is probably due to rising concentrations of structural carbohydrates (Such as lignin and hemicelluloses) as a result of loss of other constituents (sugar and starches) in the detritus (Mfilinge *et al.* 2002) [7].

Table 2: Cumulative carbon mineralization in soil during 32 days of incubation at (25 ± 3 °C)

Fertilizer Level (kg ha^{-1})	Manure Level				
	No Manure	Compost @ 10 t ha^{-1}	Crop Residue	Compost @ 10 t ha^{-1}+ Crop Residue	Mean
	CO_2 mg kg^{-1}				
No NPK	940.01	1,029.03	972.76	1,069.44	1,002.81
50% NPK	956.21	1,069.82	1,004.97	1,110.00	1,035.25
100% NPK	997.49	1,139.16	1,042.06	1,178.43	1,089.29
150% NPK	1,006.94	1,155.32	1,092.51	1,187.16	1,110.49
Mean	975.16	1,098.33	1,028.08	1,136.26	
		SEm±		CD (P=0.05)	
Main plot		1.914		6.752	
Sub plot		1.433		4.207	
MxS		3.828		9.047	

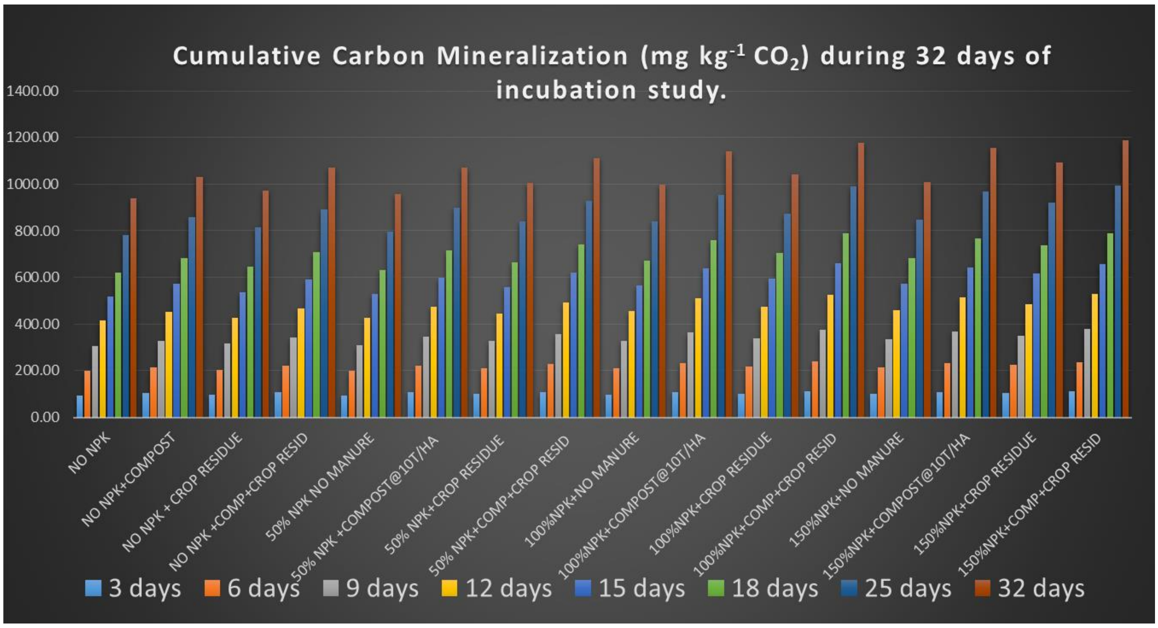

Fig 1: Cumulative Carbon Mineralization (mg kg^{-1} CO_2) during 32 days of incubation study.

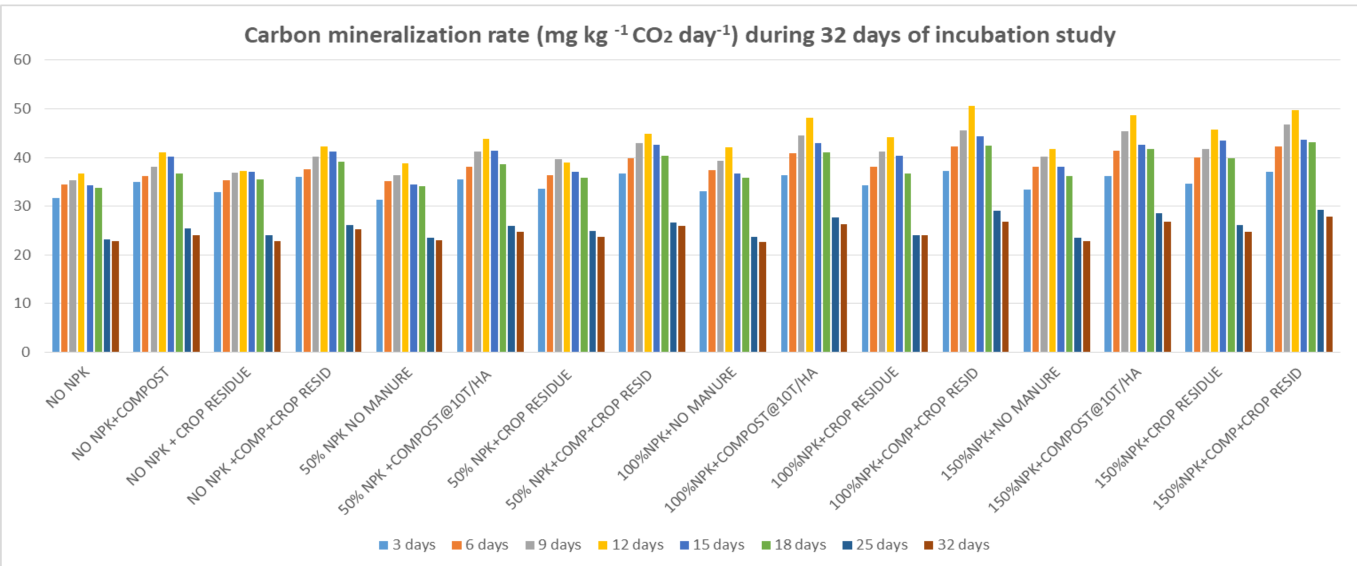

Fig 2: Carbon Mineralization rate (mg kg $^{-1}$ CO_2 day^{-1}) during 32 days of Incubation study

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