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Carbon dynamics under long term integrated nutrient management

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Abstract
The effect of integrated nutrient management (INM) on carbon pools of soil organic carbon (SOC) under Rice-wheat cropping sequence of a calcareous soil was studied in a long-term field experiment initiated during *Rabi* 1988 at Pusa, Bihar. Effect of varying doses of NPK with compost, crop residue, compost+ crop residue after 28th year of Rice-wheat crop sequence was studied. All the levels of fertilizers significantly affected the $KMnO_4$-C content of soil. The maximum $KMnO_4$-C (0.86 g kg^{-1}) was found to be in the treatment receiving both compost and crop residue which was 45.76% higher than that no manure application The maximum carbon management index (155.68%), obtained in the treatment receiving 150% NPK, was 4.71, 15.10 and 26.09% higher than the treatments receiving 100%, 50% and No NPK, respectively. Addition of manure increased the both labile and non- labile pools of carbon but, increment is higher in non-labile pool than labile pool. Integrated nutrient management resulting in enhanced carbon management index indicated favorable impact of integrated nutrient management on carbon stabilization in soil.

Keywords: Carbon dynamics, long term integrated, nutrient management

Introduction
The labile C pool is the fraction of SOC with the most rapid turnover rate. On oxidation, this pool of SOC adds to the loading of CO_2 to the atmosphere to accentuate the process of global warming. At the same time, this pool is important from the point of view of crop production. It fuels the soil food web and, therefore, greatly influences nutrient cycling for maintaining soil quality and its productivity (Chan *et al*., 2001; Majumder, 2007) [2, 4].
This pool is also sensitive to land management changes. The highly recalcitrant or passive pool is, on the other hand, altered only very slowly by microbial activities and hence hardly serves as a good indicator for assessing soil quality and productivity (Weil *et al*., 2003; Sherrod *et al*., 2005) [9, 8]. Some of the important labile pools of SOC currently used as indicators of soil quality are microbial biomass C (Cmic), mineralizable C (Cmin), oxidizable organic C fractions, and light-fraction C.
Cropping systems and management practices that ensure greater amounts of crop residues returned to the soil are expected to cause a net buildup of the SOC stock. Identifying such systems or practices is a priority for sustaining crop productivity. Law of restitution given by Justus von Leibig (1940) that whatever is being taken from the soil needs to be restored to maintain nutrient supplying capacity of soil is the backbone principle of soil fertility and is still valid for sustainable agriculture. To better understand the mechanisms by which C is lost or stabilized in soil, the SOC stock is separated into a labile or actively cycling pool, a slow pool, and a stable or passive, recalcitrant pool with varying residence times (Parton and Rasmussen, 1994) [5].
Application of graded doses of NPK from 50% to 150% of recommended dose in the maize-wheat-cowpea cropping system in semiarid. The sub-tropical India brought significant increase in POC and $KMnO_4$-C fractions in soil. Prakash *et al.* (2016) [6] reported higher concentration of non-labile C in the treatments involving FYM application shows the stabilization of organic C in soil. This could be due to the application of already stabilized material in soil through FYM.

Material & Methods
A study was conducted in an ongoing field experiment under AICRP on Soil Test Crop Response Correlation, started in *Rabi*, 1988-89 in light textured calcareous soil at 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. Different fractions of carbon was determined by following methods.-

Potassium permanganate oxidizable organic carbon or labile carbon: The 0.02 M $KMnO_4$ solution was produced according to Blair *et al.* (1995) [1] and Weil *et al.* (2003) [9].

Non-Labile carbon
Total organic carbon – Labile carbon

Lability of carbon
Carbon oxidized by $KMnO_4$ **/** Non-labile C

Lability index (LI)
LI = Lability of C in cultivated soil **/** Lability of C in uncultivated soil

Carbon management index (CMI)
Carbon management index (CMI) was calculated as per the procedure describe by Blair *et al.* (1995) [1]
CMI = CPI x LI x 100
Where, CPI is the C Pool index and LI is the liability index.

Statistical analysis
The data were statistically analyzed using analysis of variance technique (ANOVA) in split-plot design. The significance of the treatment means was tested at 5% ($P \leq 0.05$) level of probability.

Result & Discussion

Potassium permanganate oxidizable organic carbon ($KMNO_4$-C)
The $KMnO_4$ oxidizable C (KMnO4-C), which is considered as a labile C fraction in soil. The $KMnO_4$-C varied from 0.64 to 0.81 g kg^{-1} (Table 1) with increasing levels of fertilizer i.e. no NPK to 150% NPK. The value of $KMnO_4$-C was 0.81g kg^{-1} in the treatment receiving 150% NPK which was 5.19, 15.71 and 26.56% higher than treatments receiving 100%, 50% and no NPK, respectively. All the levels of fertilizers significantly improved the $KMnO_4$ oxidizable carbon content of soil. The $KMnO_4$ oxidizable carbon content after 28 years of continuous manure application increased from 0.59 to 0.86 g kg^{-1}. The maximum $KMnO_4$ oxidisable carbon content (0.86 g kg^{-1}) was found in the treatment receiving both compost and crop residue which was 45.76% higher than no manure application. All the manure levels significantly improved the $KMnO_4$ oxidizable carbon content. This might be due to the left over root biomass, rhizo deposition and root exudates. Similar result was reported by Rudrappa *et al*. (2006) [7].

Non-Labile organic carbon
Non labile organic carbon content varies from 10.39 to 11.32 with increasing level of fertilizer (Table 1) i.e. no NPK to 150% NPK. It increased with increase in fertilizer levels but increment was non-significant. The non-labile carbon content after 28 years of continuous manure application increased from 8.8 to 11.99 g kg^{-1}. The maximum $KMnO_4$ oxidisable carbon content (11.99 g kg^{-1}) was found in the treatment receiving both compost and crop residue which was 36.25% higher than no manure application. Graphical representation of $KMnO_4$ oxidisable carbon and non-labile carbon content is presented in figure 1. This shows that addition of manure increased the both labile and non- labile pools of carbon but, increment is higher in non-labile pool than labile pool.

Lability index (LI)
Lability index is the ratio of lability of carbon in cultivated soil and lability of carbon in uncultivated soil. Lability of carbon is a ratio of carbon oxidized by $KMnO_4$ and Non-labile carbon. The lability index increase from 1.063 to 1.234 (Table 2) with increasing levels of fertilizer i.e. no NPK to 150% NPK. The treatment receiving 150% NPK having maximum (1.23) lability index content was 1.65, 9.82 and 16.03% higher than treatments receiving 100%, 50% and no NPK, respectively. Treatment receiving 150% and 100% NPK are at par and significantly superior over 50% and no NPK treatment. In manure level, the lability index increased from 1.14 to 1.24. The maximum LI (1.24) was found in the treatment receiving both compost and crop residue which was 18.09, 4.20 and 8.77% higher than treatments receiving crop residue, compost @ 10 t ha^{-1} and no manure application, respectively. The interaction between fertilizer level and manures was also significant. The treatment receiving 150% NPK with compost + crop residue found highest lability index (1.61) which was significantly superior over treatment received no manure and no NPK.

Carbon management index (CMI)
CMI takes into account, changes in both labile and total carbon in agricultural soils relative to a reference site. Blair *et al.* (1995) [1] showed that, CMI as an indicator of soil C-rehabilitation, greater values indicate soil carbon rehabilitation, whereas smaller values suggest that C-molecules are being degraded. CMI is a multiplicative function of carbon pool index (CPI) and lability index (LI) as an indicator of the rate of change of soil organic matter in response to land management changes, relative to a more stable reference soil.
Carbon management index varied from 123.46 to 155.68% (Table 2 and Figure 2) with increasing levels of fertilizer i.e. no NPK to 150% NPK. The maximum carbon management index (155.68%) was obtained in the treatment receiving 150% NPK which was 4.71, 15.10 and 26.09% higher than treatments receiving 100%, 50% and no NPK, respectively. Treatment receiving 100% NPK was at par with treatment receiving 150% NPK. In manure levels, carbon management index varied from 113.04 to 165.8. The maximum CMI (165.88%) was found in the treatment receiving both compost and crop residue which was 25.49, 9.16 and 46.74% higher than treatments receiving crop residue, compost @ 10 t ha^{-1} and no manure application, respectively. Effect of different levels of NPK and manure on carbon management index was significant but their interaction effect was non-significant. This is in concurrence with the findings of Leite *et al.* (2007) [3]. Improvement in CMI under integrated application of fertilizers and manures is attributed to addition of organic carbon and other nutrients. In addition, higher crop productivity even under chemically fertilized plots generally leads to higher input of crop residues, which in turn in reach the soil with fresh organic matter.

Table 1: Effect of long-term Integrated Nutrient Management on $KMnO_4$ oxidisable carbon and Non-labile Soil organic carbon content

Fertilizer Level (kg ha^{-1})	Labile carbon (g kg^{-1})	Non-labile carbon (g kg^{-1})	Manure Level	Labile carbon (g kg^{-1})	Non labile carbon (g kg^{-1})
No NPK	0.64	10.39	No Manure	0.59	8.8
50% NPK	0.70	10.81	Compost @ 10 t ha^{-1}	0.79	11.54
100% NPK	0.77	11.12	Crop Residue	0.69	11.31
150% NPK	0.81	11.32	Compost @ 10 t ha^{-1}+ Crop Residue	0.86	11.99
SEm±	0.01	0.33	SEm±	0.01	0.08
CD (P=0.05)	0.03	NS	CD (P=0.05)	0.04	0.23

Table 2: Effect of long-term Integrated Nutrient Management on lability index and carbon management index

Fertilizer Level (kg ha^{-1})	carbon pool index	carbon management index	Manure Level	carbon pool index	carbon management index
No NPK	1.15	123.46	No Manure	0.99	113.04
50% NPK	1.20	135.25	Compost @ 10 t ha^{-1}	1.28	151.96
100% NPK	1.25	148.67	Crop Residue	1.26	132.18
150% NPK	1.27	155.68	Compost @ 10 t ha^{-1}+ Crop Residue	1.34	165.88
SEm±	0.02	2.03	SEm±	0.01	3.44
CD (P=0.05)	0.08	7.17	CD (P=0.05)	0.03	10.09

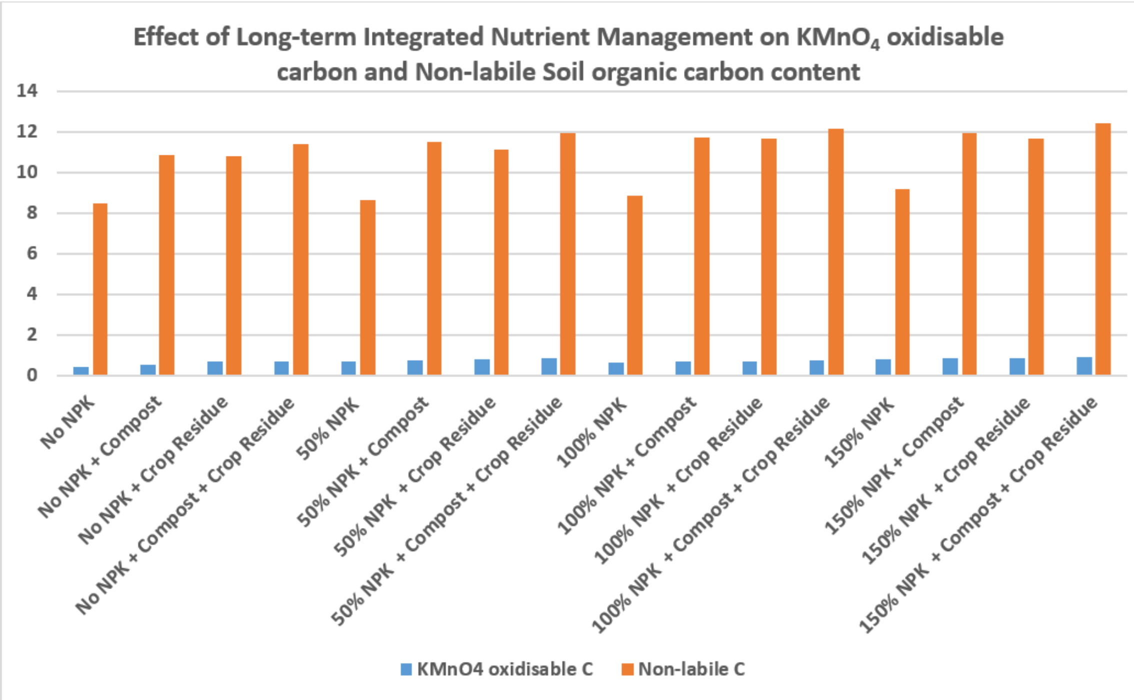

Fig 1: $KMnO_4$ oxidisable carbon and Non-labile Soil organic carbon content as Influenced by Long-term Integrated Nutrient Management

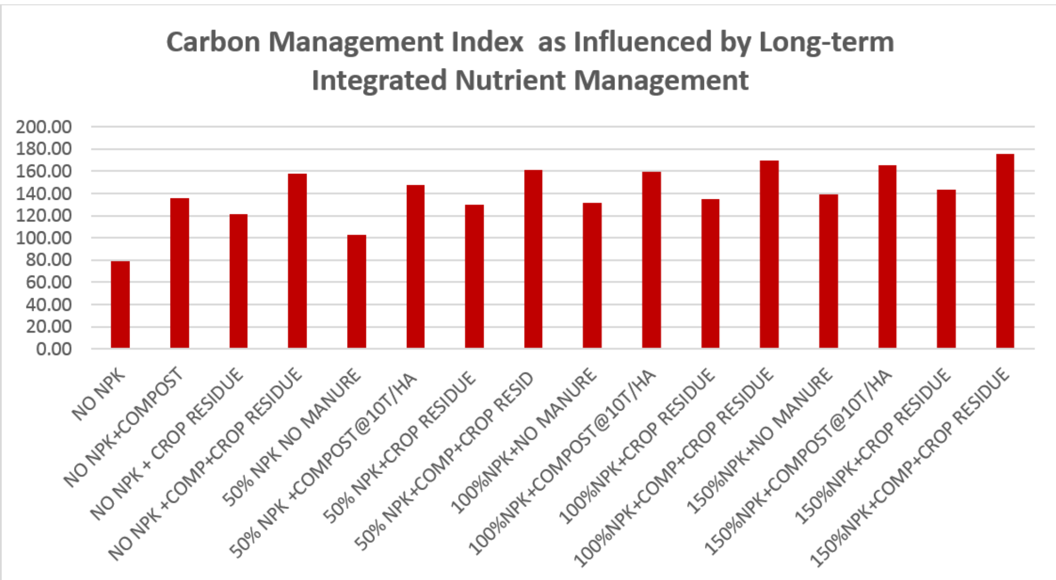

Fig 2: Carbon Management Index as Influenced by Long-term Integrated Nutrient Management

Conclusion

Application of fertilizers along with compost and crop residues resulted in significant buildup of both labile and non-labile soil organic carbon fractions. Integrated nutrient management resulted in increase in carbon management index indicating favorable impact of INM on carbon stabilization in soil.

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