



Long-term effect of fertilization and manuring on soil aggregate carbon mineralization

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ABSTRACT

The 32 years impact of manuring and fertilization on carbon mineralization in macro- and micro-aggregates in major soil groups of India was studied. Mollisol, Inceptisol, Vertisol, and Alfisol samples were collected (0–15 cm soil depth) from the treatments comprising of control, 100% NPK, 50%NPK+50% N-FYM, 50%NPK+50%N-WR (Wheat residue), 50% NPK + 50% N-GM (Green manure) in the year 2015. The results showed that the mineralizable C pool was significantly higher in treatments applied with 50%NPK+50%N-GM in Mollisol and Vertisol. In Alfisol and Inceptisol, 50% NPK+50% N-FYM and 50% NPK+50% N-GM were significantly higher in both macro-aggregates and micro-aggregates protected carbon. Supplementation of fertilizer N either through FYM or various green manuring crops like *Sesbania* (*Sesbania aculeata* L. in Inceptisol), greengram (*Vigna radiata* L. in Mollisol), sunhemp (*Crotalaria juncea* L. in Vertisol) and *karanj* (*Pongamia pinnata* L. in Alfisol) significantly improved mineralizable carbon pool signifying their potential contributions to nutrient cycling and thereby nutrient availability to various crops in the cropping systems in the above soils.

Keywords: Carbon mineralization, FYM, Macro-aggregates, Micro-aggregates, Soil organic matter, Soil organic carbon

Soil organic matter (SOM) can be observed as a potentially imperative C sink, mitigating global warming by sequestering C removed from the atmosphere by plants. Equally, soils can be a source of CO₂, with microbes and other soil organisms annually releasing 50–75 Pg of CO₂-C to the atmosphere (Iturbide *et al.* 2020). Carbon is stabilized in soil by various physical and chemical mechanisms. The C that is physically protected inside macro-aggregates is transient in nature and this type of protection is largely controlled by tillage, fertilization and manuring, and other management practices. On the

otherhand, microaggregate carbon is not affected by tillage management practices. Carbon inputs to the system also may be increased indirectly by fertilization or irrigation treatments that increase crop productivity, biomass and root production (Yadav *et al.* 2017). Optimum levels of SOM can be managed through crop rotation, fertility maintenance including use of inorganic fertilizers and organic manures, tillage methods, and other cropping system components (Purakayastha *et al.* 2008). Stability of aggregate protected carbon may be measured by long-term carbon mineralization (C_{min}). Measured C_{min} rates ranged from less than 0.007 to 35.6% of total soil C using varying incubation times (12–800 days) and soil temperature and moisture conditions (Yadav *et al.* 2017). There is a paucity of information available on the long-term effect of manuring and fertilization on the stability of aggregate protected carbon in diverse soil groups.

With this background the All India Coordinated Research Project on Integrated Farming System located in Pantnagar (Mollisols), Ludhiana (Inceptisols), Jabalpur (Vertisols) and Ranchi (Alfisols) with rice-wheat cropping system was used for the present study. In this study we attempted to address the issues of long-term impact of manuring and fertilization on stability of as assessed by

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long-term carbon mineralization in four major soil groups of India.

MATERIALS AND METHODS

Field experiments: Soil samples were collected during 2015 to a depth of 0-15 cm from the All India Coordinated Project on Integrated Farming Systems coordinated by Indian Institute of Farming System Research (IIFSR), Modipuram continuing in Inceptisol (Ludhiana), Vertisol (Jabalpur), Alfisol (Ranchi) and Mollisol (Pantnagar) under rice-wheat cropping systems excepting Alfisol having maize-wheat cropping system since the year 1983. The soils collected from Ludhiana, Punjab belonged to Typic Ustochrept-Ustipsamment with sandy loam in texture, while the soils of Pantnagar, Uttarakhand was an Aquic Hapludoll with silty clay loam texture and neutral in reaction. The soils collected from Jabalpur, Madhya Pradesh belonged to Typic Haplustert with clay texture and neutral in reaction. The soils collected from Ranchi, Jharkhand belonged to Typic Haplustalf with sandy clay loam in texture and acidic in reaction. In rice, the full recommended levels of N, P and K and 50% of N were supplemented through FYM, crop residue (wheat straw in Ludhiana, Pantnagar and Jabalpur and paddy straw in Ranchi) and green manuring crops like *sesbania* (*Sesbania aculeata* L. in Ludhiana), greengram (*Vigna radiata* L. in Pantnagar)/sunhemp (*Crotalaria juncea* L. in Jabalpur)/karanj (*Pongamia pinnata* L. in Ranchi). The wheat did not receive any organic sources of nutrients but received N-P-K fertilizers as per recommended dose. The experiment was laid out in a randomized block design with three replications.

Carbon mineralization (C_{min}): The soil micro- and macro-aggregates in soil was separated from soil by Yodder apparatus (Yodder 1936). In a BOD incubator (30°C), the carbon mineralization from micro- and macro-aggregates was measured periodically (15, 30, 60, and 90 days) by trapping evolved CO_2 in alkali for three months (Anderson, 1982). Twenty gram of wet soil (field capacity) was taken in a 50 ml beaker kept in 500 ml capacity respiration with 5 mjar to trap the evolved CO_2 and the jar was closed with the help of a lid. The 0.5 N NaOH traps were taken out of the jar during sampling day and was back titrated with standard 0.5 N HCl with the help of phenolphthalein indicator.

RESULTS AND DISCUSSION

Carbon mineralization from soil macro-aggregates: Long term manuring and fertilization significantly influenced the cumulative carbon mineralization from macroaggregates over 90 days period across various soil groups

Table 1 Long-term effects of fertilization and manuring on cumulative carbon mineralization from macro-aggregates

Treatments	Mollisol	Inceptisol	Vertisol	Alfisol
Control	0.42d§	0.34 d	0.36c	0.32d
100%NPK	0.74c	0.61c	0.71b	0.66c
50%NPK+50%N-FYM	1.10b	1.84a	1.03a	1.04a
50%NPK+ 50% N-WR	1.12ab	1.03b	1.06a	0.69bc
50%NPK+ 50% N-GM	1.18a	1.21b	1.10a	0.77b

§The values followed by different lowercase letters are significant according to Duncan's Multiple Range Test at $P = 0.05$, FYM –Farmyard Manure, WR-Wheat Residue, GM- Green Manure.

(Table 1 and Fig 1). The cumulative C mineralization in Mollisol varied from 0.42 mg/g in 50% NPK+50% N-GM to 1.18 mg/g in control. 50% NPK+50% N-GM being at par with 50% NPK+50% N-WR showed the highest carbon mineralization. The cumulative C mineralization from macro-aggregates was recorded highest in 50% NPK+50% N-FYM followed by 50% NPK+50% N-GM and 50% NPK+50% N-WR in Inceptisol. The cumulative C mineralization from macro-aggregates was significantly higher in NPK treatments comprising of 50% of N supplemented with either FYM, or WR or GM in Vertisol. The cumulative C mineralization from macro-aggregates was recorded highest with 50% NPK+50% N-FYM followed by 50% NPK+50% N-WR and 50% NPK+50% N-GM. Overall, the cumulative carbon mineralization from 100% NPK was lower than the integrated treatments.

Carbon mineralization from micro-aggregates: The cumulative carbon mineralization from micro-aggregates varied significantly cross different treatments and soils (Table 2 and Fig 2). The cumulative C mineralization from

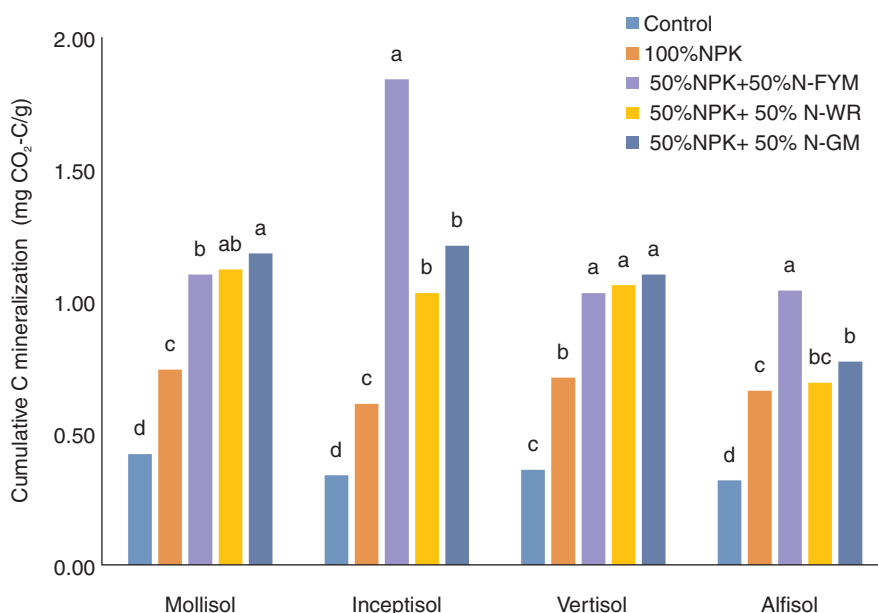


Fig 1 Long-term effects of fertilization and manuring on cumulative carbon mineralization from macro-aggregates

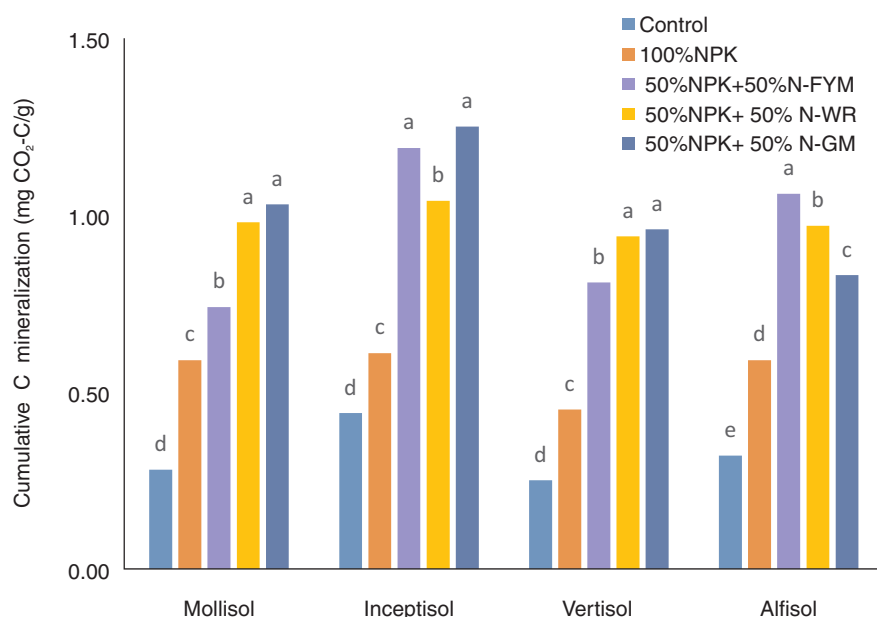


Fig 2 Long-term effects of fertilization and manuring on cumulative carbon mineralization from micro-aggregates.

Table 2 Long-term effects of fertilization and manuring on cumulative carbon mineralization from micro-aggregates

Treatments	Mollisol	Inceptisol	Vertisol	Alfisol
Control	0.28d§	0.44d	0.25d	0.32e
100%NPK	0.59c	0.61c	0.45c	0.59d
50%NPK+50%N-FYM	0.74b	1.19a	0.81b	1.06a
50%NPK+ 50% N-WR	0.98a	1.04b	0.94a	0.97b
50%NPK+ 50% N-GM	1.03a	1.25a	0.96a	0.83c

§The values followed by different lowercase letters are significant according to Duncan's Multiple Range Test at $P = 0.05$, FYM –Farmyard Manure, WR-Wheat Residue, GM- Green Manure.

micro-aggregate in Mollisol was recorded highest 50% NPK+50% N-GM though it was at par with 50% NPK+50% N-WR. However, in Inceptisol, it was recorded highest in 50% NPK+50% N-GM. The cumulative C mineralized under combined application of 50% NPK+50% N-FYM. In Vertisol, all the organic treatments (50% NPK+50% N-FYM 50% NPK+50% N-WR, 50% NPK+50% N-WR) being at par with each other showed higher carbon mineralization than 100% NPK treatment. In Alfisol, the cumulative C mineralization from micro-aggregates was recorded highest in 50% NPK+50%-N-FYM. Irrespective of the soil type, the cumulative carbon mineralization from micro-aggregates from 100% NPK was significantly lower than all the integrated nutrient management treatments.

Carbon is physically as well as chemically stabilized inside the soil aggregates for carbon sequestration. The stabilization of aggregate protected carbon was studied in a long-term carbon mineralization study. Mineralization of soil carbon is a catabolic process which feed carbon and energy to the heterotrophic soil organisms. The

mineralizable part of soil organic carbon (SOC) is considered as labile part of SOC and, therefore, part of the SOC is easily mineralized in soil, while the resistant C pool is very slowly degraded with a time scale of hundreds to thousands of years (Oades 1993). Long-term manuring and fertilization significantly enhanced the labile part of the SOC inside the aggregates as humification process is extremely slow to make a sizeable change in recalcitrant part of SOC. The size of the mineralizable carbon in macro- and micro-aggregates under long-term manuring and fertilization in contrasting soil orders of our study varied widely. The differences in cumulative C mineralization patterns indicated that 50%NPK+50%N-FYM supported higher labile pool of carbon in macro-aggregates in all the soil

orders except Mollisol. However, 50%NPK+50%N-FYM were at par with 50%NPK+50%N-WS and 50%NPK+50%N-GM in Vertisol. The carbon mineralization pattern in micro-aggregates across different manuring and fertilization treatments and soil type almost followed similar trend as of macro-aggregate with little variation. 50%NPK+50%N-FYM supported higher labile pool of carbon in macro-aggregates in Inceptisol and Alfisol. However, 50%NPK+50%N-FYM were at par with 50%NPK+50%N-GN in Inceptisol. In both Mollisol and Vertisol, 50%NPK+50%N-WS and 50%NPK+50%N-GM showed higher pool of mineralizable carbon which is considered as labile. The role of rice straw, FYM on the formation of stable soil macroaggregates and aggregate associated C in sandy loam soil of Punjab (Benbi and Senapati 2010) and through FYM in clay soil of central India (Bandyopadhyay *et al.* 2010). The application of organic amendments, (farmyard manure, straw, green manure) tends to build up SOC in rice-based cropping systems (Ghosh *et al.* 2012; Mohanty *et al.* 2013). Our results on Alfisol corroborated the findings of Sharma *et al.* (1998) who reported that in a long-term experiment with maize–wheat, there was a 50% increase in SOC due to addition of FYM. The size of the mineralizable labile carbon pool in macro-aggregates was in general higher in Mollisol followed by Inceptisol, Vertisol and and Alfisol. Contrarily, the size of the mineralizable labile carbon in micro-aggregates was highest in Inceptisol. Vertisols and Mollisols of our study being richer in clay content as well as dominant in 2:1 type fine smectitic minerals (Gupta *et al.* 1999) might have played a major role in SOC stabilization which in turn enhanced the SOC to a greater extent than either Inceptisol and Alfisol which are poorer in clay content and dominated by illite and kaolinite.

Keeping in view of the experimental results discussed above, it may be concluded that supplementation of fertilizer

N through either FYM or various green manuring crops like *Sesbania* (*Sesbania aculeate* L. in Inceptisol), green gram (*Vigna radiata* L. in Mollisol), *Sunhemp* (*Crotalaria juncea* L. in Vertisol) and *Karanj* (*Pongamia pinnata* L. in Alfisol) emerged as promising management practices for accumulating good quality of organic matter in Mollisol, Inceptisol, and Vertisol under rice-wheat cropping system and in Alfisol under maize-wheat cropping system. The good quality organic matter is important for carbon and other nutrients cycling and thereby decreases the dependency on chemical fertilizers by increasing nutrient availability to crops. The carbon which is physically and or chemically protected in macro- and micro-aggregates can provide medium to long-term carbon sequestration in soils.

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