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Effect of INM on Soil Carbon Pools in Rice - Oil Seed Cropping System under Temperate Conditions of Kashmir Valley

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ABSTRACT

Integrated nutrient management system (INMS) gained importance not only in increased yield of crops but also in maintaining the soil health and fertility. Keeping these in views a field experiment was conducted at Mountain research centre for field crops Khudwani (SKUAST-Kashmir) during 2013 (in progress since march 2008) to study the Effect of INM on soil carbon pools in rice-brown sarson cropping system with different treatment combinations. Significant build-up in SOC pools namely, total organic carbon (TOC), Walkley and Black organic carbon (WBC), labile organic carbon (LBC) and microbial biomass carbon (MBC) were maintained under FYM and integrated nutrient management involving FYM and NPK than unfertilized control plot in 0-15 and 15-30 cm soil depths. Results showed that application of NPK+ FYM significantly increased soil organic matter. These results conclude that for sustainable crop production and maintaining soil quality, input of organic manure like FYM is of major importance and should be advocated in the nutrient management of intensive cropping system for improving soil fertility and biological properties of soils.

Key words: *Carbon, Carbon Pools, Nutrient, Rice, Soil Organic Matter.*

INTRODUCTION

India is second largest rice producer accounting for 20% of global rice production. The crop plays a significant role in livelihood of the people of Jammu and Kashmir State. Although area under rice is very small (0.27 m ha), it plays an important role in the state economy (DRR Hyderabad). The total annual rice production of the state is more than 0.59 million metric tonnes, but continuous rice planting has a negative impact on soil properties, such as reduced soil nitrogen supply and organic carbon content[10]. Furthermore, because of long-term submergence and mineral fertilizer application, these soils experience degradation of soil quality, such as breakdown of stable aggregation and deterioration of soil organic matter (SOM), which negatively affects agricultural sustainability[29].

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On the other hand, *brown sarson* is a dominant oilseed crop in Jammu and Kashmir, often grown after rice in rotation. It is popular with the farming community of valley as it fits well on rice-oilseed rotation under temperate climatic conditions.

Maintenance and management of soil fertility is the core for development of sustainable food production systems[11]. Soil is an essential element of agriculture and the soil fauna, its intrinsic component, obviously affects its agricultural value[17]. INM, which entails the maintenance/adjustment of soil fertility to an optimum level for crop productivity to obtain the maximum benefit from all possible sources of plant nutrients both organics as well as inorganics in an integrated manner[1], is an essential step to address the twin concerns of nutrient excess and nutrient depletion. INM is also important for marginal farmers who cannot afford to supply crop nutrients through costly chemical fertilizers only. Agricultural soil is a potential sink for atmospheric C as soil organic C (SOC), which contributes to the productivity and quality of soils[18]. Dynamics of organic C storage in agricultural soils strongly affects global climatic change and crop productivity and yield[24]. The benefits of using organic manure and straw in maintaining soil quality have been increasingly recognised[8]. Soil microorganisms and the processes that they control are essential for the long-term sustainability of agricultural systems[48] and are important factors in soil formation and nutrient cycling. It has been frequently reported that soil microbial biomass and activity is an important aspect of soil quality[40]. Research has shown that soil microbial biomass and activity responds to crop and soil management practices such as organic manure and inorganic fertilizers application[25].

Furthermore, soil organic carbon (SOC) is an important component playing key multifunctional roles in soil quality and determining many soil physical and biological properties[41]. Sustaining SOC is of primary importance in terms of cycling plant nutrients and improving the soils' physical, chemical and biological properties. SOC is an important index of soil quality because of its relationship with crop productivity[21]. A decrease in SOC leads to a decrease in soil's structural stability[7]. Also restoration of SOC in arable lands represents a potential sink for atmospheric CO_2[23]. Agricultural utilization of organic materials, particularly farmyard manure (FYM) has been a rather common traditional practice[42] as it enhances the SOC level, which has direct and indirect effect on soil physical properties[20]. In general, application of organic fertilizers and especially manure, either alone or in combination with inorganic fertilizers, increases SOC concentration[35]. There is a critical need for the development of best management practices that enhance SOC sequestration. Changes in SOC due to management practices are difficult to quantify as these changes occur slowly and are relatively small compared to the vast SOC pool size, and vary both spatially and temporally. The application of inorganic fertilizers has been widely observed to increase the crop yields. The inorganic fertilizers affect soil physical environment by increasing the above ground and root biomass due to immediate supply of plant nutrients in sufficient quantities[26]. This in turn increases the soil organic matter content[4]. Thus, regular additions of organic materials to soil are required to improve and maintain SOC pools and to help in governing nutrient fluxes, microbial biomass and their activities and improvement in soil physical properties[27]. Labile organic carbon is sensitive to soil management practices and thus provides the better management of carbon dynamics in short-term to medium-term effect than total carbon alone. Soil organic carbon refers to the sum total of different heterogeneous organic substances, which may be simply divided into stable and labile organic carbon fractions[47]. Stable SOC fractions are relatively resistant to decompose, take longer time to turn-over and do not take part in several nutrient cycling. However, labile SOC fractions are readily accessible source of microorganisms, turn-over rapidly (weeks or months) and have an impact on plant nutrient supply. Labile SOC fractions could indicate changes in soil quality due to management practices more rapidly than measuring changes in the magnitude of total SOC[9]. Some of the important labile pools of SOC currently used as indicators of soil quality are microbial biomass carbon (MBC), mineralizable organic carbon (Cmin), particulate organic carbon (POC) and KMnO4-oxidizable labile organic carbon (LBC). Highly recalcitrant or passive pool of SOC is very slowly altered by microbial activities and hence hardly serves as a good indicator for judging soil quality. It is now widely recognized that SOC plays an important role in soil biological (provision of substrate and nutrients for microbes), chemical (buffering and pH changes) and physical (stabilization of soil structure) properties. Reeves[37] noted that "SOC is the most often reported attribute from long-term agricultural studies and is chosen as the most important indicator of soil quality and agronomic sustainability because of its impact on other physical, chemical and biological indicators of soil quality.

However, Janzen *et al*[15]., pointed out that the relationship between soil quality indicators (e.g. SOC) and soil functions does not always comply to a simple relationship increasing linearly with magnitude of the indicator and that therefore "bigger is not necessarily better". Some of the soil C fractions, such as microbial biomass C (MBC)[31], particulate organic C (POC) and potentially mineralizable C[5,33], and $KMnO_4$ oxidizable C[3] are likely to be more sensitive to management practices than the total SOC[6]. A good farming practice can decrease CO_2 evolution from soil into the atmosphere and enhance soil fertility and thus productivity. Studies have shown that such an increase in SOC levels is directly linked to the amount and quantity of organic residues return to the soils[36]. Increased sequestration of C in agricultural soils has the potential to mitigate the increase in atmospheric greenhouse gases[39]. Optimum levels of soil organic matter can be managed through crop rotation, fertility maintenance including use of inorganic fertilizers and organic manures, tillage methods, and other cropping system components[35]. Among these, management practices like proper cropping systems and balanced fertilization are believed to offer the greatest potential for increasing SOC storage in agricultural soils[22]. For studies on soil quality, the evaluation of long term soil fertility experiments provides a good base that cannot be accomplished with the results of typical short-term experiments[16]. Long-term experiments provide the best means of studying changes in soil properties and processes over time, and these experiments are important for obtaining information on long term sustainability of agricultural systems to formulate future strategies for maintaining soil health[45].

With this backdrop the proposed study shall be undertaken to evaluate the long term effect of fertilizers along with organics on soil carbon pools in *rice-brown sarson* cropping system under temperate conditions.

MATERIALS AND METHODS

Experimental site

The experiment was carried out during *rabi* season of 2013 at Mountain Research Centre for Field Crops, Khudwani *of* Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir in a long term experiment initiated in march 2008.It is located at a latitude of $33^o43.260'$ N and longitude of $75^005.803$ 'E with an altitude of 1650 m above mean sea level.

Experimental design and treatments

The field experiment on rice- brown sarson cropping system consisted of eleven treatments along with a control in a randomized block design with four replications. The treatments selected for this study consisted of:

Treatment	Rice (SR-1)	Brown sarson (KS-101)
T_1	Control	Control
T_2	50% NPK	50% NPK
T_3	50% NPK	100% NPK
T_4	75% NPK	75% NPK
T_5	100% NPK	100% NPK
T_6	50% NPK + 50% FYM	100% NPK
T_7	50% NPK + 50% FYM	50% NPK
T_8	75% NPK + 25% FYM	75% NPK
T_9	50% NPK + 50% N (Rice straw)	100% NPK
T_{10}	50% NPK + 25% N (Rice straw)	75% NPK
T_{11}	Farmers practice (60-80 kg N+30-40 kg P_2O_5+5-10 t FYM)	Farmers practice (30-40 kg N+40 P_2O_5+5t FYM)

The NPK dose was applied through urea, DAP and MOP. FYM and rice straw applied were 36.6 and 46% total carbon. On an average farmyard manure contained 0.60% N, 0.15% P and 0.54% K.

Soil sampling

Composite soil samples were collected from surface (0-15 cm) and sub surface (15-30 cm) after harvesting of oilseed and before transplantation of rice (May, 2013). The soil samples were collected by core sampler of diameter 10 cm and all the samples were weighed. The samples were brought to the laboratory, air dried and crushed to pass through 2.0 mm mesh sieve. The processed samples were subjected to appropriate mechanical and chemical analyses to estimate its effect on carbon pools. The soil is silty clay loam in nature.

Soil organic C fractions

Organic carbon content was determined by wet oxidation method of Walkley and Black[46]. The Walkley and Black method is based on oxidation of organic matter by $K_2Cr_2O_7$ with H_2SO_4 heat of dilution. Some-what less of the total organic matter is oxidized by this method, because the heating obtained by the H_2SO_4 dilution is less and thus Walkley–Black method tends to underestimate SOC concentrations. A correction factor 1.33 was applied to results to adjust the organic carbon recovery. Total organic carbon in the soil was determined by the wet oxidation method[43] (Snyder and Trofymow, 1984). For this purpose, 1.0 gm of soil (passed through 1 mm sieve) was pretreated with 3.0 ml of 2N HCl to remove carbonates. Then soil was oxidized with $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and H_3PO_4 in a ratio of 3**:**2 by heating on digestion block for 2 hrs. Thus evolved CO_2 was trapped in 2N NaOH and amount of CO_2 (trapped) was measured by back titration with 0.5N HCl using phenolphthalein indicator. Total organic carbon content was computed based on amount of CO_2 evolved.

The amount of oxidizable carbon by $KMnO_4$ (labile carbon) in soil was determined by following the procedure of Blair *et al*[3]. For this purpose, 2.0 g of soil was taken in a centrifuge tube and oxidized, with 25 ml of 33M $KMnO_4$ by shaking on a mechanical shaker for 1 hr. The tube was centrifuged for 5 minute at 4000 r.p.m. and 1.0 ml of superannuated solution was diluted to 250 mL with double distilled water (DDW). The concentration of $KMnO_4$ was measured at 565 nm wavelength using spectrophotometer. The change in concentration of $KMnO_4$ was used to estimate the amount of carbon oxidized assuming that 1.0 mL of MnO_4^- is consumed in the oxidation of 0.7 mM (9.0 mg) of carbon. Particulate organic matter (POM) was separated from 2-mm soil following the method described by Camberdella and Elliot[5]. The C content in POM wasdetermined following the method of Snyder and Trofymow[43].

Microbial biomass carbon (MBC) was estimated by the chloroform-fumigation incubation method of Jenkinson and Powlson. Sample of soil (10.0 g) rewetted to 40-60 % WHC (water holding capacity) was fumigated with ethanol-free chloro-form ($CHCl_3$) in a vacuum desiccator. Following fumigant removal, the soil was extracted with 0.5 M K_2SO_4 (soil:solution ratio of 1:2.5) through 30 min horizontal shaking at 200 rpm and filtered. A duplicate soil sample without fumigation (unfumigated) was also extracted with 0.5 M K_2SO_4 in a similar fashion. Both the extracts of fumigated and unfumigated soil were subjected to wet oxida-tion separately with potassium persulphate and 0.02N H_2SO_4 by heating on a digestion block at 120 ± 1 ◦C for 2 h. Evolved CO_2 was then trapped in 0.1N NaOH solution. The amount of CO_2 evolved was determined by back titration with 0.05N HCl. The MBC was computed by subtracting the amount of CO_2 evolved in fumigated soil from that of unfumigated one. A sub-sample of soil was drawn for moisture determination so as to express the data on oven dry weight basis. The amount of the MBC in soil was calculated as follows:

Microbial biomass carbon (MBC) = OCF - OCUF/KEC

Where, OCF and OCUF are the organic carbon extracted from fumigated and unfumigated soil, respectively (expressed on oven dry basis), and KEC is the efficiency of extraction. A value of 0.45 is considered as a general KEC value for microbial extraction efficiency and used for calculation.

Statistical analysis

For statistical analysis of data, Microsoft Excel (Microsoft Cor-poration, USA) and CPCS1 window version 32.0 were used. Analysis of variance (ANOVA) The ANOVA is based on three replicate plots per treatment. 1984). The significant differences between treatments were compared with the least significance (LSD) at 5% level of probability.

RESULTS AND DISCUSSION

Soil organic C

Walkley and Black method mostly determines both labile and small part of non-labile organic carbon which is the readily accessible source of carbon to micro-organisms and have direct impact on plant nutrient supply. Soil organic C contents changed significantly across the fertilizer treatments (Table). The plots that received 50% NPK + 50% FYM (1.76g kg^{-1}) and 50% NPK +50% rice straw (1.62 g kg^{-1}) had significantly higher build-up in WBC over 100% NPK treated (1.54 g kg^{-1}), farmers practice (1.55 g kg^{-1}) and unfertilized control plots (1.21 g kg^{-1}) in the surface soil. The increase in build-up in WBC was 31.2% over control. In case of sub-surface soil, the build-up in WBC under plots receiving 50% NPK+50% FYM fertilizer (1.16 g kg^{-1}) and 50% NPK +50% rice straw (0.99 g kg^{-1} was higher than in the plots receiving only 100% NPK fertilizer (0.87 g kg^{-1}), farmers practice (0.88g kg^{-1}) and in the control (0.58 g kg^{-1}). In general, the values of WBC in sub-surface soils were low compared to surface soil. The organic carbon of soil was significantly affected by nutrient management practices. Under organic and integrated nutrient management practices, there was significant build up of organic carbon as compared to initial values. This might be because of continuous use of organic manures. Manure applications sustain a significantly increasing trend in SOC, not only in the humid and semi-humid warm temperate areas with the double cropping system, but also in arid and semi-arid areas with the mono-cropping systems, which is widely documented all over the world[12,42]. Apparently, manure application is one way to offset the depletion of SOC due to soil organic matter decomposition especially for the dry areas The significantly greater SOC in the fertilized plots over the control may be explained by the greater yield and associated greater amount of root residues and stubbles of all the crops added to the soil[13]. Greater SOC under complete doses of NPK fertilizer as compared to unfertilized soil has also been reported in long-term studies[44]. Kundu *et al*[19]., reported that SOC content improved in fertilized plots as compared to the unfertilized plots due to C addition through the roots and crop residues, higher humification rate constant, and lower decay rate. Similarly, in a long-term experiment, Masto *et al*[28]., observed that the SOC was considerably greater in soils receiving FYM or straw along with NPK fertilizer than in plots receiving merely NPK fertilizer. In this study, the combination of organic and inorganic fertilization enhanced the accumulation of SOC which is consistent with many other studies[2,14]. Significant increase in SOC in FYM and straw treated plots over control was also reported by Zhang *et al*[49]., and Moharana *et al*[30].

Total organic carbon

Application of FYM in combination with NPK resulted in considerable accumulation of total soil organic carbon in 0-15 cm soil layer than unfertilized control plots (Table). Soils under the FYM + NPK treated plots resulted in higher total soil organic carbon in the 0-15 cm and 15-30 cm soil layer over those under the NPK treated plots. The TOC in surface soil were in the order of 75% NPK + 25% FYM (4.63 g kg^{-1}) > farmers practice (4.59 g kg^{-1}) > 50% NPK+ 50% RS (8.50 g kg^{-1}) > 100% NPK (4.33 g kg^{-1}) > unfertilized control (2.75 g kg^{-1}). However, increase in TOC was more in surface as compared to sub-surface soil, which indicate that higher accumulation of organic carbon due to application of FYM was confined to surface soil. The increase in total organic carbon in 75% NPK + 25% FYM treatments in surface layer was 40% greater over unfertilized control. Continuous application of FYM in combination with NPK resulted in considerable accumulation of total SOC in surface as well as sub surface soil layer than unfertilized control plots However, increase in TOC was more in surface as compared to sub-surface soil, which indicate that higher accumulation of organic carbon due to application of FYM was confined to surface soil. This might be due to more turn-over of root biomass in FYM + NPK treatment because of better growth and higher average yields obtained during the study period of both the crops in FYM + NPK treatment. Increase in TOC in optimal and balanced application of NPK is because of greater input of root biomass due to better crop growth. It was supported by the data published by Moharana *et al*[30]., who noted. Similar effects of manure and inorganic fertilizer applications on soil organic C has also been reported by Rudrappa *et al*[38].

Labile organic carbon

High fertility significantly increased labile carbon fraction in both surface and sub surface soils (Table). The plots that received 50% NPK +50% FYM treatments showed significant increase in LBC over 100% NPK and unfertilized control treatments in both surface and sub-surface soil depth. However, the highest value of 10.42 mg g^{-1} was observed in 75% NPK +25% FYM treatment in surface soil. The labile carbon in surface soils were in order of 75% NPK+ 25% FYM (10.42mg g^{-1}) > 50% NPK+50% RS (9.28 mg g^{-1}) > farmers practice (8.47mg g^{-1}) > 100% NPK (8.45 mg g^{-1}) > unfertilized control (7.28 mg g^{-1}). Similar trend occurs in sub surface soil depth. The increase in LBC in 75%NPK +25% FYM was 30.7% greater over unfertilized control. Labile soil organic carbon pool is considered as the readily accessible source of microorganisms which turns over rapidly and has direct impact on nutrient supply. Labile soil organic carbon pool generally includes light faction of organic matter, microbial biomass and mineralizable organic matter. The labile organic carbon (LBC) pool or $KMnO_4$ oxidizable carbon is considered as a useful approach for the characterization of SOC resulting from different soil management practices including cropping systems and application of organic and inorganic sources of nutrients. The plots that received with FYM + NPK treatments showed significant increase in LBC over NPK and unfertilized control treatments in both surface and sub-surface soil depth. This may be due to the application of FYM as well as higher turn-over of root biomass because of better growth and yield of rice and rapeseesd crops under combined application of FYM + NPK. Greater increase in LBC in combined application of 75% NPK + 25% FYM fertilizer indicate that this pool of soil organic C is more sensitive to change due to manuring and fertilization. Higher turn-over of root biomass under integrated nutrient management (FYM + NPK) also might have attributed to higher increase in this pool as compared to other treatments. Our results are in agreement with the values reported by Rudrappa *et al*[38]., Purakayastha *et al*[35]., Moharana *et al*[30].

Particulate organic carbon

The INM treatment significantly influenced the POC contents in 0-15 cm soil depth (Table). The highest value of 5.39 mg kg^{-1} was observed in 75% NPK + 25% FYM treatment in surface soil. The particulate organic carbon in surface soils were in order of 75%NPK + 25% FYM (5.39 mg kg^{-1}) > farmers practice (4.40mg kg^{-1}) > 50% NPK + 50% RS (4.20 mg kg^{-1}) > 100% NPK (4.17 mg kg^{-1}) > unfertilized control (3.58 mg kg^{-1}). Similar trend was recorded in sub surface soil depth. There was 33.5% increase in particulate organic carbon over control due to integrated nutrient management. Particulate organic C makes up a large portion of the light fractions of SOC[5].

Table: Long Term Effect of Inm on Soil Carbon Pools

Treatments	SOC	TOC	LBC	POC	MBC
0-15cm depth					
T_1	1.21	2.75	7.28	3.58	208.1
T_2	1.31	3.17	8.20	3.81	214.9
T_3	1.33	3.56	8.22	3.84	218.6
T_4	1.38	3.72	8.31	4.00	221.3
T_5	1.54	4.33	8.45	4.17	226.5
T_6	1.76	4.59	10.07	5.27	228.0
T_7	1.73	4.34	9.82	5.27	228.0
T_8	1.75	4.63	10.42	5.39	230.3
T_9	1.62	4.22	9.28	4.18	219.7
T_{10}	1.57	4.09	8.45	4.20	219.3
T_{11}	1.55	4.59	8.29	4.40	224.0
C.D	0.22	0.27	0.40	0.29	8.93
15-30cm depth					
T_1	0.58	2.22	7.02	3.16	206.3
T_2	0.63	3.03	7.85	3.21	208.0
T_3	0.69	3.32	7.83	3.42	210.6
T_4	0.75	3.60	8.09	3.83	216.0
T_5	0.87	3.90	8.19	3.89	217.3
T_6	1.16	4.19	9.13	4.59	225.3
T_7	1.02	4.09	9.11	4.56	224.0
T_8	1.14	4.36	9.46	4.77	225.3
T_9	0.99	4.04	8.62	3.97	219.3
T_{10}	0.89	3.83	8.29	3.86	217.6
T_{11}	0.88	4.32	8.29	4.04	217.3
C.D	**0.19**	**0.09**	**0.18**	**0.17**	**11.29**

The POM is often separated densimetrically and is comprised of plant residues as well as microbial and micro faunal debris including fungal hyphae and spores[15]. Therefore, POC is composed of a large proportion of relatively labile organic materials, often of recent origin. Application of FYM along with N-P-K (NPK + FYM) resulted in a significant positive built up of POC over NPK at different locations at all soil depths. Similarly, substitution of 50% N through CR or GM to rice also recorded significantly higher POC concentration over NPK at all locations in 0-15 and 15-30 cm soil depths only. The increase in POC in fertilized plot was mainly being due to increased yield trend in this treatment over past years. The additional amounts of organic C input from organics in the treatments received NPK along with organics further enhanced the POC contents in these treatments. The main source of POC in this study was mainly the left over root biomass and increased microbial biomass debris. Our results corroborate the findings reported by Purakayastha *et al*[35]., and Nayak *et al*[32].

Microbial biomass carbon

It is evident that the MBC contents in both surface and sub-surface soil were significantly higher in plots receiving 75%NPK + 25%FYM compared to 100% NPK fertilizer and unfertilized control plots (Table). The values of MBC in surface soil varied from 208.1 mg kg^{-1} in unfertilized control plot to 230 mg kg^{-1} in integrated nutrient use of 75%NPK+ 25% FYM plots, respectively; while it varied from 206 mg kg^{-1} (control) to 225 mg kg^{-1} (75%NPK + 25%FYM) in sub-surface soil. There was 10.4% increase in MBC in 75%NPK+ 25%FYM treatment over unfertilized control. The microbial biomass carbon (MBC) is an important component of the SOM that regulates the transformation and storage of nutrients. The soil MBC regulates all SOM transformations and is considered to be the chief component of the active SOM pool. It is evident that the MBC contents in both surface and sub-surface soil were significantly higher in plots receiving 75% NPK+ 25% FYM and FYM treated plots compared to NPK fertilizer and unfertilized control plots Continuous application of FYM along with N-P-K (NPK + FYM) resulted in a significantly higher soil MBC over control. In our study, MBC was highest in the FYM plus inorganic fertilizer treatment. The increase of MBC under FYM amended soils could be attributed to several factors, such as higher moisture content, greater soil aggregation and higher SOC content. The FYM amended plots provided a steady source of organic C to support the microbial community compared to NPK treated plots. Generally, FYM applied to soil has long been employed to enhance favourable soil conditions. Decomposition of manure in soil releases essential nutrients such as N, P and S that are required by microorganisms. The highest value of MBC due to integrated use of FYM and NPK fertilizer might be due to higher turn-over of root biomass produced under FYM + NPK treatment. Similar increases in integrated nutrient management with manure + fertilizer have been reported by others[30,32]. In a long-term field experiments in Denmark, Powlson *et al*[34]., showed that straw manure could increase MBC up to 45%.

CONCLUSION

The positive effects of balanced fertilization with N, P and K and organic manures on SOC were clearly demonstrated in this long-term fertilizer experiment Moreover, higher addition rates of organic manure benefited more prominent increase in the total SOC and its various C fractions. Manure and straw application had beneficial effects on SOC, LBC, POC, MBC concentration, total SOC stocks.

REFERENCES

1. Aulakh, M.S. and Grant, C.A., Integrated Nutrient Management for Sustainable Crop Production. The Haworth Press, Taylor and Francis Group**:** New York. (2008).
2. Banger, K., Kukal, S.S., Toor, G., Sudhir, K. and Hanumanthraju, T.H., Impact of long term additions of chemical fertilizers and farmyard manure on carbon and nitrogen sequestration under rice-cowpea cropping system in semi-arid tropics. *Plant and Soil*, **318:** 27-35 (2009).
3. Blair, G.J., Lefroy, R.D.B. and Lise, L., Soil carbon fractions based on their degree of oxidation and the development of a carbon management index for agricultural systems. *Australian Journal of Agriculture Research*, **46:** 1459-14661 (1995).
4. Bostick, W.M.N., Bado, V.B., Bationo, A., Solar, C.T., Hoogenboom, G. and Jones, J.W., Soil carbon dynamics and crop residue yields of cropping systems in the Northern Guinea Savanna of Burkina Faso. *Soil and Tillage Research*, **93:** 138-151 (2007).
5. Camberdella, C.A. and Elliott, E.T., Particulate soil organic matter across grassland cultivation sequence. *Soil Science Society America Journal,* **56:** 777-783 (1992).

6. Campbell, C.A., Janzen, H.H. and Juma, N.G., Case studies of soil quality in the Canadian prairies**:** long-term field experiments. **In:** *Soil quality for crop production* (Eds. E.G. Gregorich and M.R. Carter). Elsevier Science Publishers, Amsterdam, The Castro Filho, C., Lourenco, A., de F. Guimaraes, M. and Fonseca, I.C.B. 2002. Aggregate stability under different soil management systems in a red latosol in the state of Parana, Brazil. *Soil and Tillage Research*, **65:** 45-51 (1997).
7. Castro Filho, C., Lourenco, A., de F. Guimaraes, M. and Fonseca, I.C.B., Aggregate stability under different soil management systems in a red latosol in the state of Parana, Brazil. *Soil and Tillage Research*, **65:** 45-51 (2002).
8. Chander, K., Goyal, S., Mundra, M.C. and Kapoor, K.K., Organic matter, microbial biomass and enzyme activity of soils under different crop rotations in the tropics. *Biology and Fertility of Soils*, **24:** 306-310 (1997).
9. Ding, G.W., Liu, X.B., Herbert, S., Novak, J., Amarasiriwardena, D. and Xing, B.H., Effect of cover crop management on soil organic matter. *Geoderma*, **130:** 229-239 (2006).
10. Dobermans, A. and Witt, C., The potential impact of crop intensification on carbon and nitrogen cycling in intensive rice systems. **In :** *Carbon and Nitrogen Dynamics in Flooded Soils* (Eds. G.D. Kirk and D. Olk). Laguna, Philippines**:** International Rice Research Institute, pp. 1-25 (2000).
11. Doran, J.W., Fraser, D.G., Culik, M.N. and Liebhardt, W.C., Influence of alternative and conventional agricultural management on soil microbial process and nitrogen availability. *American Journal of Alternative Agriculture*, **2:** 99-106 (1988).
12. Galantini, J. and Rosell, R., Long-term fertilization effects on soil organic matter quality and dynamics under different production systems in semiarid pampean soils. *Soil and Tillage Research*, **87:** 72-79 (2006).
13. Ghosh, P.K., Dayal, D., Mandal, K.G., Wanjari, R.H. and Hati, K.M., Optimization of fertilizer schedules in fallow and groundnut-based cropping systems and an assessment of system sustainability. *Field Crops Research*, **80:** 83-98 (2003).
14. Hao, X.H., Liu, S.L., Wu, J.S., Hu, R.G., Tong, C.L. and Su, Y.Y., Effect of long-term application of inorganic fertilizer and organic amendments on soil organic matter and microbial biomass in three subtropical paddy soils. *Nutrient Cycling in Agroecosystems*, **81:** 17-24 (2008).
15. Janzen, H.H., Campbell, C.A., Brandt, S.A., Lafond, G.P. and Townley-Smith, L., Light fraction organic matter in soils from long-term crop rotations. *Soil Science Society of America Journal*, **56:** 1799-1806 (1992).
16. Jordan, D., Kremer, R.J., Bergfield, W.A., Kim, K.Y. and Cacino, V.N., Evaluation of microbial methods as potential indicators of soil quality in historical agricultural fields. *Biology and Fertility of Soils*, **19:** 297-302 (1995).
17. Keith, A.M., Boots, B., Hazard, C., Niechoj, R., Arroyo, J., Bending, G.D., Bolger, T., Breen, J., Clipson, N., Doohan, F.M., Griffin, C.T. and Schmidt, O., Crox-taxa congruence, indicators and environmental gradients in soil under agricultural and extensive land management. *European Journal of Soil Biology*, **49:** 55-62 (2012).
18. Kundu, S., Bhattacharyya, R., Prakash, V., Ghosh, B.N. and Gupta, H.S., Carbon sequestration and relationship between carbon addition and storage under rainfed soybean-wheat rotation in a sandy loam soil of the Indian Himalayas. *Soil and Tillage Research*, **92:** 87-95 (2007).
19. Kundu, S., Prakash, V., Ghosh, B.N., Singh, R.D. and Srivastva, A.K., Quantitative relationship between annual carbon inputs and soil organic carbon build-up in soybean (*Glycine max*)-wheat (*Triticum aestivum*) cropping sequence. **In**: 2nd International Agronomy Congress.

Held at New Delhi, India, November 26-30, 2002, pp. 108-110 (2002).

20. Lado, M., Paz, A. and Ben-Hur, M., Organic matter and aggregate-size interactions in saturated hydraulic conductivity. *Soil Science Society of America Journal*, 68**:** 234-242 (2004).
21. Lal, R., Residue management, conservation tillage and soil restoration for mitigating greenhouse effect by CO_2-enrichment. *Soil and Tillage Research*, **43:** 81-107 (1997).
22. Lal, R., Soil carbon sequestration in China through agricultural intensification, and restoration of degraded and desertified ecosystems. *Land Degradation and Development*, **13(6):** 469-478 (2002).
23. Lal, R. and Kimble, J.R., Conservation tillage for carbon sequestration. *Nutrient Cycling in Agroecosystems*, **49:** 243-253 (1997).
24. Li, J.T. and Zhang, B., Paddy soil stability and mechanical properties as affected by long term application of chemical fertilizer and animal manure in subtropical China. *Pedosphere*, **17(5):** 568-579 (2007).
25. Livia, B., Uwe, L. and Frank, B., Microbial biomass, enzyme activities and microbial community structure in two European long-term field experiments. *Agric-Ecosystem and Environment*, **109:** 141-152 (2005).
26. Lopez-perez, A., Casanova, E., Chacon, L.A., Paz, P.M. and Guerrero, J.R., Residual effect of three phosphate rocks from Tachina (Venezuela) in a greenhouse experiment with maize (*Zea mays* L.) as indicator plant. *Revista-Cientifica-UNET*, **4(1-2):** 29-48 (1990).
27. Marinari, B., Masciandara, G., Ceccanti, B. and Grego, S., Influence of organic and mineral fertilizers on soil biological and physical properties. *Bioresource Technology*, **72:** 9-17 (2000).
28. Masto, R.E., Chhonkar, P.K., Singh, D. and Patra, A.K., Changes in soil biological and biochemical characteristics in a long-term field trial on a sub-tropical Inceptisol. *Soil Biological Chemistry*, **38:** 1577-1582 (2006).
29. Mohanty, M. and Painuli, D.K., Land preparatory tillage effect on soil physical environment and growth and yield of rice in a Vertisol. *Journal of the Indian Society of Soil Science*, **51(3):** 223-228 (2004).
30. Moharana, P.C., Sharma, B.M., Biswas, D.R., Dwivedi, B.S. and Singh, R.V., Long-term effect of nutrient management on soil fertility and soil organic carbon pools under a 6-year-old pearl millet-wheat cropping system in an Inceptisol of subtropical India. *Field Crops Research*, **136:** 32-41 (2012).
31. Nannipieri, P., Greco, S. and Ceccanti, B., Ecological significance of the biological activity in soil. **In :** *Soil Biochemistry* (Eds. J.M. Bollag and G. Stozky), **6:** 293-354 (1990).
32. Nayak, A.K., Gangwa, B.R., Shukla, A.K., Mazumda, S.P.R., Kumar, A., Raja, R., Kumar, A., Kumar, V., Rai, P.K. and Mohan, U., Long-term effect of different integrated nutrient management on soil organic carbon and its fractions a sustainability of rice-wheat system in Indo Gangetic Plains of India. *Field Crops Research*, **127:** 129-139 (2012).
33. Powlson, D.S. and Jenkinson, D.S., A comparison of the organic matter, adenosine triphosphate, and mineralizable nitrogen contents of ploughed and direct-drilled soils. *Journal of Agricultural Science* (Cambridge), **97:**713-721 (1981).
34. Powlson, D.S., Brookes, P.C. and Christensen, B.T., Measurement of soil microbial biomass provides an early indication of changes in total soil organic matter due to straw incorporation. *Soil Biological Chemistry*, **19:** 159-164 (1987).
35. Purakayastha, T.J., Huggins, D.R. and Smith, J.L., Carbon sequestration in native prairie, perennial grass, No-Tilled and Cultivated Palouse Silt Loam. *Soil Science Society America Journal*, **72:** 25-30 (2008).
36. Rasmussen, P.E., Allmaras, R.R., Rohde, C.R. and Roager, N.C. Jr., Crop residue influences on soil carbon and nitrogen in a

wheat-fallow system. *Soil Science Society of America Journal*, **44:** 596-600 (1980).

37. Reeves, D.W., The role of soil organic matter in maintaining soil quality in continuous cropping systems. *Soil and Tillage Research*, **43:** 131-167 (1997).
38. Rudrappa, L., Purakayastha, T.J., Singh, D. and Bhadraray, S., Long-term manuring and fertilization effects on soil organic carbon pools in a Typic haplustept of semi-arid sub-tropical India. *Soil and Tillage Research*, **88:** 180-192 (2006).
39. Sampson, R.N. and Scholes, R.J., Additional human-induced activities article 3.4. **In:** Land Use, Land-Use Change, and Forestry**:** A Special Report of the Intergovernmental Panel on Climate Change (Eds. Watson et al.). Cambridge University Press, New York, pp. 184-281 (2006).
40. Schloter, M., Dilly, O. and Munch, J.K., Indicators for evaluating soil quality. *Agriculture Ecosystem and Environment*, **98:** 255-262 (2003).
41. Shen, J., Li, R., Zhang, F., Fan, J., Tang, C. and Rengel, Z., Crop yields, soil fertility and phosphorus fractions in response to long-term fertilization under the rice monoculture system on a calcareous soil. *Field Crops Research*, **86:** 225-238 (2004).
42. Shen, M.X., Yang, L.Z., Yao, Y.M., Wu, D.D., Wang, J.G., Guo, R.L., and Yin, S.X., Long-term effects of fertilizer managements on crop yields and organic carbon storage of a typical rice-wheat agroecosystem of China. *Biology and Fertility of Soils*, **44:** 187-200 (2007).
43. Snyder, D. and Trofymow, J.A., Rapid accurate wet oxidation diffusion procedure for determining organic and inorganic carbon in plant and soil samples. *Communes Soil Science Plant Analytics*, **15:** 1587-1597 (1984).
44. Swarup, A. and Wanjari, R.H., Three Decades of All India Coordinated Research Long Term Fertilizer Experiments for Studying Changes in Fertility Crop Productivity and Sustainability. Indian Institute of Soil Science, Bhopal, India. (2000).
45. Swarup, A., Reddy, D. and Prasad, R.N., Long-term soil fertility management through integrated plant nutrient supply. Bhopal, India**:** Indian Institute of Soil Science, p. 335 (1998).
46. Walkley, A. and Black, I.A., An examination of the Degtjareff method for determining soil organic matter and a proposed medication of the chromicacid titration method. *Soil Science*, **37:** 29-38 (1934).
47. Wander, M., Soil organic matter fractions and their relevance to soil function. **In:** *Soil Organic Matter in Sustainable Agriculture*. [Eds. F.R. Magdoff and R.R. Weil] CRC, Boca Raton, pp. 67-102 (2004).
48. Wardle, D.A., Yeates, G.W., Nicholson, K.S., Bonner, K.I. and Watson, R.N., Response of soil microbial biomass dynamics, activity and plant litter decomposition to agricultural intensification over a seven-year period. *Soil Biology and Biochemistry* **31:** 1707-1720 (1999).
49. Zhang, W.J., Wang, X.J., Xu, M.G., Huang, S.M., Liu, H. and Peng, C., Soil organic carbon dynamics under long-term fertilizations in arable land of northern China. *Biogeosciences*, **7:** 409-425 (2010).