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Impact of Long-Term Nutrient Management on Carbon Dynamics under Cluster Bean-Wheat Cropping System in Western Rajasthan, India

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Authors' contributions

This work was carried out in collaboration among all authors. Author SK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SRY, PSS and YS managed the analyses of the study. Authors SK and BY managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was started in 2008 under All India Co-ordinated Research Project- Soil Test Crop Response in western Rajasthan to study the long-term effects of nutrient management strategy using Soil Test Crop Response (STCR) approach on cluster bean– wheat cropping system. The present investigation indicated effects of organic compost and inorganic fertilizer as per soil test crop response approach basis on soil carbon dynamics. The treatments consisted of general recommended dose, target yield 15 q ha^{-1}, target yield 15 q ha^{-1} with Integrated Plant Nutrient System (IPNS), target yield 20 q ha^{-1} and target yield 20 q ha^{-1} without Integrated Plant Nutrient System. The soil organic pools were studied after 9 years and it was found that the total C and its different pools of soil increased significantly under target yield 20 q ha^{-1} with IPNS. Active and passive pools (AP and PP) of carbon of soil increased significantly under target yield 20 q ha^{-1} with IPNS as compared to the target yield 15 and 20 q ha^{-1} treatments without IPNS and at par with target yield 15 q ha^{-1} with IPNS. Carbon management index (CMI) and carbon stock (CS) increased significantly under target yield 20 q ha^{-1} with IPNS. It can be concluded that combined application of organic and inorganic nutrient in long term basis significantly enhance carbon sequestration rate, consequently soil quality.

Keywords: STCR; carbon fractions; carbon management index; long-term fertilization.

1. INTRODUCTION

Soil organic carbon (SOC), the major component of soil organic matter, is important in all soil processes. The term "Soil Organic Matter" embraces the non-mineral fractions of soil is essentially derived from residual plant and animal material, synthesized and decomposed by microbes under the influence of temperature, moisture and ambient soil conditions. It plays an important role in maintaining soil quality and eco-system functionality [23,24,25]. “Land use and agricultural practices such as tillage, irrigation and fertilization, all influence the storage of SOC” [29,30,34,51,55]. “It is a direct source of plant nutrient elements, the release of which depends upon microbial activity by affecting the cation exchange capacity, organic matter is directly involved in availability of nutrient elements” [15,18,42].

Soil organic carbon (SOC) is a very crucial element in soil fertility and productivity [5, 65]. It is found in the soil in the forms of labile and non-labile [36]. Addition of crop residue in soil significantly enhanced soil carbon content [39]. “The labile form contains three fractions that are frac1 (very labile carbon), frac2 (labile carbon) and frac3 (less labile carbon), and frac4 of the carbon is non-labile” [9,15]. “These forms of carbon help in maintaining soil health” [54,11,57,68,43]. “The labile C pool belongs to SOC with rapid turnover rates, which serves as an energy source for soil food webs, and therefore increases nutrient cycling, quality and productivity of soil” [11,21,10,41]. “It is very crucial in long-term carbon storage” [35,1]. “Labile Carbon pool determined by chemical-extraction techniques is considered an early indicator of management induced change in quality and composition of soil organic matter” [7]. [71] offered “a method for measuring the C content of soil” and [17] improved “the Walkley-Black method to divide SOC into four fractions with different labilities and oxidizabilities which are very labile carbon (C_{VLC}), labile carbon (C_{LC}), less labile carbon (C_{LLC}), and recalcitrant carbon or non-labile carbon (C_{NLC})”. “The VLC and LC fractions are the most readily Oxidizable fractions and mainly composed of polysaccharides, decaying young organic matter, fungal hyphae, and other microbial products, which contribute to the formation of macro aggregates and availability of nutrients” [48,44]. “The LLC and NLC fractions are related to compounds of high chemical stability and are slowly decomposed by soil microbe” [64]. “The pool being readily accessible to microorganisms directly impact plant nutrient supply” [33,62]. “This pool is also sensitive to land management changes. The highly recalcitrant or passive pool is on the other hand, changed only very slowly by microbial activities and hence hardly serves as a good indicator for assessing 2 soil quality and productivity” [50,8,57]. “Some of the important labile pools of SOC currently used as indicators of soil quality are microbial biomass C, mineralizable C, oxidizable organic C fractions and light-fraction. The vertical distribution of Soil Organic Carbon (SOC) in the soil profile is, though unclear. In the subsoil below 30cm depth, Soil Organic Carbon (SOC) stocks fluxes are critical for the soil functions. Aside from strong soil inorganic carbon and Soil Organic Carbon (SOC), the subsoil contributes to the cycling of elements with the consequence, e.g. plant nutrients" [58,60,63]. "Despite lesser concentration, the subsoil is probable also an important factor for the long-term storage of SOC, as the radiocarbon age and turnover time of OM increased with a decreased in soil depth. Thus, the Organic Matter in the subsoil can impact the mitigation of atmospheric increases in CO_2 by SOC sequestration" [47].

This method could be the applied for finding out different subfractions of soil organic matter *i.e.* very labile (C_{VLC}), labile carbon (C_{LC}), less labile carbon (C_{LLC}) and non-labile ·carbon (C_{NLC}) may help to understand the soil quality and health in terms of their capacity to store active and passive pools of soil organic matter.

2. MATERIALS AND METHODS

A field experiment was started in 2008 under All India Co-ordinated Research Project- Soil Test Crop Response (STCR) in western Rajasthan to study the long-term effects of nutrient management strategy using Soil Test Crop Response approach on cluster bean- wheat cropping system. The present investigation indicated effects of organic compost and inorganic fertilizer as per soil test crop response approach basis on soil carbon dynamics. After 11 years (2018), soil samples were collected from experimental field in Agroclimatic zone Ic (Hyper arid partially irrigated western plain) of Rajasthan comprising canal irrigated North-Western plains of Bikaner located between $28^0 10'$ N latitude, $73^0 18'$ E longitude. The climate is characterized as hyper arid with monsoonal influence. Annual bimodal rainfall ranges between 220 and 230 mm. The maximum and minimum temperature ranged between 35°C to 39.5°C and 16.7°C to 26.9°C during crop growing season. July–October).

The experiment was laid out in a Randomized Block Design with five treatment combinations and four replications. Details of treatments with their symbol given in Table 1. In this experiment on treatment is general recommended dose and in the pair treatments same target yield but nutrient applied with or without IPNS according to STCR recommended equation. These requirements were calculated following the equation.

Organic compost- Treatments with IPNS, nutrient applied as per the prescription based nutrient recommendation Kg compost plot^{-1}. Chemical composition of compost was nitrogen (0.68 %), phosphorus (0.35 %) and potassium (0.62%)

Fertilizer Application - Urea as nitrogen source, single super phosphate for phosphorus and muriate of potash for potassium were applied in different treatments.

Soil Sampling - Soil samples from each treatment plot taken with the help soil samples were taken with a soil core sampler (inner diameter 7 cm) by boring randomly at four places after the harvest of the crop at 0-7.5 and 7.5-15 cm soil depths. Collected soil samples were air dried, ground in wooden pestle and mortar, passed through 2 mm sieve and preserved in cloth bags for the subsequent analysis for different chemical properties. The soil samples from each replicate subplot were brought back to the laboratory, immediately sieved through a 2-mm sieve and stored at 4^0C until used for the various tests. Total organic carbon – A wet oxidation diffusion procedure was used to determine total organic carbon in the soil sample [66]. Permanganate Oxidizable Carbon- The permanganate-oxidizable organic carbon (PmOC) was determined following the procedure of [69]. Different soil organic carbon pools- The content of oxidizable organic carbon and its different fractions in the soil were determined following the [71] method as modified by [17] using 5, 10 and 20 ml of concentrated (18.0 mol l^{-1}) H_2SO_4 and $K_2Cr_2O_7$ solution. This resulted in three acid-aqueous solution ratios of 0.5:1, 1:1 and 2:1 that corresponded to 6.0, 9.0 and 12.0 mol L^{-1} H_2SO_4, respectively, and produced different amounts of heat of reaction to bring about oxidation of SOC of varying oxidizability. The amounts of oxidizable organic carbon thus determined allowed separation of TOC into the following four fractions of decreasing oxidizability as defined by [17]:

Pool I	**Very labile (C_{VL})**	**Organic carbon oxidised by 12 N H_2SO_4**
Pool II	labile carbon (C_L)	Difference in carbon oxidised between 18 N and that 12 N H_2SO_4 (18 N – 12 N H_2SO_4)
Pool III	less labile (C_{LL})	Difference in carbon oxidised between 24 N and 18 N H_2SO_4
Pool IV	Recalcitrant (C_{RC})	Difference in organic C extracted with 24 N H_2SO_4 and TOC determined by CHN analyzer (TOC–24 N H_2SO_4).

Table 1. Details of treatments with their symbols

Treatment symbols		Treatment details
T_1-General recommended dose	:	General recommended dose (20 Kg Nitrogen ha^{-1} 32 Kg $P_2O_5 ha^{-1}$)
T_2-Target yield 15 q ha^{-1}	:	Soil test crop response recommendation dose for target 15 q ha^{-1}
T_3-Target yield 15 q ha^{-1} with IPNS	:	Soil test crop response recommendation under integrated plant nutrient system (IPNS)dose for target 15 q ha^{-1}
T_4-Target yield 20 q ha^{-1}	:	Soil test crop response recommendation dose for target 20 q ha^{-1}
T_5-Target yield 20 q ha^{-1} with IPNS	:	Soil test crop response recommendation under integrated plant nutrient system dose for target 20 q ha^{-1}

For Nitrogen (T_2 and T_4) = 6.70 T - 0.37 N***

For Nitrogen (T_3 and T_5) = 6.70 T - 0.37 N** – 0.65 O***N*

For Phosphorus (T_2 and T_4) = 9.90 T - 2.15 P_2O_5***

For Phosphorus (T_3 and T_5) = 9.90 T - 2.15 P_2O_5 **–2.05 X 50 O*** P_2O_5*

For potassium (T_2 and T_4) = 6.78 T – 0.23 K_2O***

For potassium (T_3 and T_5) = 6.78 T – 0.23 K_2O** – 0.62 O*** K_2O*

*target yield ** amount of available nutrient present in soil ***Nutrient % in compost

Active pool (AP) and passive pool (PP) of organic carbon - Active pool of organic carbon was computed by adding fraction I and fraction II, whereas, passive pool of organic carbon was determined as addition of fraction 3 and fraction 4. Active pool of organic carbon represents amount of organic carbon present in easily oxidisable form in soil. Whereas, passive pool of organic carbon is resistant to decomposition, thus, it has higher mean residence time in soil. Hence, from soil carbon sequestration point of view storing more carbon in passive pool is important

“Soil organic carbon and soil organic carbon stocks - SOC content was determined using the rapid titration method (wet combustion method) as described by [71]. The soil carbon stocks were calculated from the SOC content measured at different depth intervals by multiplying them with the respective bulk density and the thickness of the corresponding soil layer; and expressed as Mg ha^{-1}. Soil carbon management index-The CMI was calculated based on the method of” [13]. “The CMI = CPI× LI× 100.The CPI was determined as follows: CPI = (Total organic C content in sample soil) / (Total organic C content in reference soil). The liability index (LI) was calculated as follows: LI = (liability of C in sample soil) / (liabiality of C in reference soil). Statistical analysis by using SPSS (Statistical Package for the Social Science), software developed by three PhD students at the University of Stanford (Norman H. Nie, C. Hadlai (Tex) Hull and Dale H. Bent), after graduation N”. [78].

3. RESULTS AND DISCUSSION

3.1 Organic Carbon Fractions of Different Degrees of Oxidisability

Data showed that long term nutrient management strategies through IPNS and without IPNS organic carbon fractions at 0-7.5 cm and 7.5-15 cm soil depths have been presented in Table 2. Comparatively higher proportions off different oxidisable fractions were found in top 0 - 7.5 cm soil and decrease with increase depth. The magnitudes follow the order total organic carbon >recalcitrant carbon > less labile carbon > very labile carbon > labile carbon >permanganate oxidizable. It’s ranging from 1.92 to 3.69,1.01 to 1.70, 0.449 to 0.901, 0.289 to 0.673, 0.111 to 0.418 and 0.112 to 0.295 g C kg^{-1}, total organic carbon, recalcitrant carbon, less labile carbon, very labile carbon, labile carbon and permanganate oxidizable respectively. Significant variation was also obtained in active pool (AP) and passive pool (PP) under different treatments. Highest AP and PP SOC were recorded in 0-7.5 soil depth under the treatment target yield 20 q ha^{-1} with IPNS *i.e.,* AP SOC 1.09 g C kg^{-1} and PP SOC 2.60 g C kg^{-1}, similarly at 7.5-15 cm soil depth AP and PP SOC were recorded as 0.578 and 1.943, respectively under the treatment target yield 20 q ha^{-1} with IPNS (Table 3). “The close relationships between the various labile organic C fractions present in soil suggested that pathways between these different organic C fractions exist, which makes them interdependent. Manuring enhanced PmOC content in soils due to the presence of higher root exudates, which contained lingo-cellulose residues” [3,12]. “Decreased PmOC with increased soil depth might be due to slow and low translocation of leaf litter and applied compost. The increased labile C content with application of nutrient thorough with and without IPNS system could be because of the priming effect of applied nutrients on fresh organic materials in the soils. All these amendments stimulate the microbial activity helping SOC decomposition due to rapid excretion of the labile C” [75]. “The rise in recalcitrant C in target yield 20 q ha^{-1} with IPNS plots could be related to resistance induced by biochemical property of organic compounds present either in organic material or plant materials" [52,76]. "Studies showed that compost application increased lignin and lignin-like products, the main constituents of resistant C pools" [58,61,4]. "Besides higher organics inputs, the greater amounts of recalcitrant C under target yield 20 q ha^{-1} with IPNS than same yield target without IPNS might be due to increased decomposition of labile compounds and accumulation of recalcitrant materials over time with target yield 20 q ha^{-1} with IPNS" [46].

3.2 Soil Carbon Management Index

As C_{poc} provides useful information on the nature and turn-over rate of different organic carbon pools, carbon management index (CMI) was computed. Results indicate that CMI was significantly varied under different treatments in 0-7.5 cm and 7.5- 15 cm soil depth. It is ranged from 92.27 % to 129.2 % (Table 3). Highest CMI recorded under treatment yield 20 q ha^{-1} with integrated plant nutrient system *i.e.,* 129.2% which is 29.2% more than general recommended dose,33.59% more in same target yield without integrated plant nutrient system at 0-7.5 cm soil depth which is at par with target yield 15 q ha^{-1} with integrated plant nutrient system. "At second depth *i.e.,* 7.5-15 cm soil depth not influenced significantly carbon management index. The CMI provides an indication of changes in the C dynamics of soil systems, which has been used to assess the capacity of management practices to promote soil quality" [37,13] reported that "the actual CMI values were not important, but the differences reflect how different management practices impacted reference. In the present study, the CMI in soils at the two different depths (0–7.5 cm, and 7.5-15 cm) that received nutrient through IPNS showed higher CMI than without IPNS treatments". The result is in agreement with [13] who reported that "farmyard manure with chemical fertilizer significantly increased CMI compared with any other chemical fertilizer treatments in a long-term experiment started from 1843". "The reason might be that the increase in annual C addition and the changes in organic matter quality, thus modifying the lability of C to $KMnO_4$ oxidation" [69]. "In the present study, only compost additions significantly increased CMI in the 0–7.5 cm and 7.5-15 cm the reason may be that the larger amount of C entered into the soil from decomposed compost and increased the lability of C in cluster bean soils" [32]. "The CMI were higher in target yield 20 q ha-1 with IPNS treatment than that without IPNS treatment at 0–7.5 cm depth may be due to the decrease of labile carbon which to increase in the recalcitrant fraction of C in the surface layer" [31]. "But there was no significant difference (p> 0.05) in CMI 7.5-15 cm soil depth. The reason may be that it was strongly related to root C inputs, crop residues, and application of chemical fertilizer with soil tillage which often accumulated in the deep layer, higher residue recycling and other biological activities in these soil layers" [19]. "In addition, the CMI was correlated with soil bulk density in our study. These results reinforced the suitability of using labile C for calculating the CMI and the CMI as a reliable index to assess the quality of soil management systems". [78] The higher CMI of soil in compost return treatments than that of in without IPNS alone and with IPNS input treatments fit with our Hypothesis 2 that soil carbon management index would be higher in nutrient management through IPNS than that of in without IPNS condition.

3.3 Soil Organic Carbon Stock

Long term nutrient management strategies through integrated plant nutrient system and without integrated plant nutrient system were significantly influenced organic carbon stock in different depths in soil. Carbon stock varied from 15.20 Mg c ha^{-1} to 29.58 Mg c ha^{-1} in 0-7.5 cm and 7.5- 15 cm soil depth. Highest soil carbon stock 29.58 Mg c ha^{-1} and 23.68 Mg c ha^{-1} at 0.7.5 cm and 7.5-15 cm soil depths, respectively) was found under target yield 20 q ha^{-1} with integrated plant nutrient system treatment (Table 3). "It has been widely accepted that various management practices could increase the SOC content" [53,73]. "The content of SOC is determined by the balance between C inputs and decomposition losses" [45]. Consistent with our Hypothesis 1 that SOC content were increased under organic manure condition, the result showed that application of organic materials application generally increased organic carbon content in the different soil depths (0–7.5 cm, and 7.5-15 cm) as compared to the without IPNS, with the effectiveness being highest with organic manure additions was probably due to its lowest C/N ratio and organic manure fast decomposition [32], and thus causing greater potential for SOC sequestration and accumulation of carbon [26]. In the present study, the SOC in 0–7.5 cm layer were higher than that of the 7.5-15 cm with different fertilization treatments, the reason may be that

Table 2. Effect of STCR approach on soil carbon fractions of different soil depth

Treatments	0-7.5 cm soil depth						7.5-15 cm soil depth					
	C_{VLC}	C_{LC}	C_{LLC}	C_{RC}	C_{TOC}	C_{P0C}	C_{VLC}	C_{LC}	C_{LLC}	C_{RC}	C_{TOC}	C_{P0C}
T_1-General recommended dose	0.534	0.179	0.771	1.58	3.07	0.258	0.311	0.111	0.543	1.12	2.08	0.121
T_2-Target yield 15 q ha^{-1}	0.470	0.159	0.720	1.21	2.55	0.247	0.289	0.121	0.499	1.01	1.92	0.112
T_3-Target yield 15 q ha^{-1} with IPNS	0.652	0.359	0.850	1.59	3.45	0.282	0.423	0.132	0.588	1.23	2.37	0.127
T_4-Target yield 20 q ha^{-1}	0.531	0.170	0.723	1.39	2.81	0.251	0.307	0.119	0.467	1.08	1.97	0.119
T_5-Target yield 20 q ha^{-1} with IPNS	0.673	0.418	0.901	1.70	3.69	0.295	0.441	0.137	0.601	1.34	2.52	0.129
SEm±	0.042	0.009	0.019	0.087	0.123	0.011	0.033	0.005	0.022	0.06	0.089	0.004
Cd (P = 0.05)	0.129	0.027	0.059	0.27	0.38	0.033	0.102	0.016	0.067	0.18	0.27	0.012

**C_{VLC}- very labile carbon, C_{LC}–labile carbon, C_{LLC}–less labile carbon, C_{RC}–recalcitrant carbon, C_{TOC}– total organic carbon, C_{POC}–parmaganate oxidizable carbon*

Table 3. Effect of with IPNS and without IPNS approach on carbon stock (M g ha^{-1}), carbon management index (%), active pool (g C kg^{-1} soil) and passive pool (g C kg^{-1} soil) at 0-7.5 and 7.5-15 cm soil depth

Treatments	0-7.5 cm soil depth				7.5-15 cm soil depth			
	CS	CMI	AP	PP	CS	CMI	AP	PP
T_1-General recommended dose	21.38	100.0	0.713	2.35	17.24	100.00	0.421	1.663
T_2-Target yield 15 q ha^{-1}	19.59	97.62	0.628	1.93	16.08	92.77	0.409	1.512
T_3-Target yield 15 q ha^{-1} with IPNS	28.73	125.7	1.011	2.44	18.38	104.29	0.554	1.818
T_4-Target yield 20 q ha^{-1}	20.47	95.61	0.701	2.11	15.20	99.02	0.425	1.548
T_5-Target yield 20 q ha^{-1} with IPNS	29.58	129.2	1.091	2.60	23.68	105.75	0.578	1.943
SEm±	0.91	9.535	0.048	0.09	1.20	3.61	0.034	0.081
Cd (P = 0.05)	2.81	29.38	0.148	0.27	3.70	NS	0.105	0.249

**CS-carbon stock, CMI-carbon management index, AP- active pool and passive pool*

Table 4. Effect of with IPNS and without IPNS approach on different carbon stock (M g ha^{-1}) at 0-7.5 cm soil depth

Treatments	VLC Stock	LC Stock	LLC Stock	RC Stock	POC Stock	AP Stock	PP Stock
T_1-General recommended dose	0.603	0.203	0.874	1.793	0.293	0.806	2.269
T_2-Target yield 15 q ha^{-1}	0.553	0.187	0.848	1.421	0.292	0.740	2.667
T_3-Target yield 15 q ha^{-1} with IPNS	0.739	0.407	0.963	1.799	0.319	1.146	2.762
T_4-Target yield 20 q ha^{-1}	0.622	0.200	0.848	1.628	0.295	0.821	2.476
T_5-Target yield 20 q ha^{-1} with IPNS	0.748	0.466	1.003	1.885	0.328	1.214	2.889
SEm$\pm$	0.047	0.012	0.026	0.101	0.015	0.055	0.107
Cd (P = 0.05)	0.144	0.037	0.081	0.312	NS	0.170	0.330

** VLC- Very labile carbon stock, LC–labile carbon stock, LLC–less labile carbon stock, RC–Recalcitrant carbon stock, POC–Parmaganate oxidizable carbon stock, AP- Active pool stock and PP- Passive pool stock*

Table 5. Effect of with IPNS and without IPNS approach on different carbon stock (M g ha^{-1}) at 7.5-15 cm soil depth

Treatments	VLC Stock	LC Stock	LLC Stock	RC Stock	POC Stock	AP Stock	PP Stock
T_1-General recommended dose	0.755	0.268	2.718	1.319	0.294	1.023	4.036
T_2-Target yield 15 q ha^{-1}	0.706	0.294	2.476	1.221	0.274	1.000	3.696
T_3-Target yield 15 q ha^{-1} with IPNS	0.983	0.306	2.865	1.370	0.294	1.288	4.235
T_4-Target yield 20 q ha^{-1}	0.748	0.289	2.634	1.137	0.291	1.037	3.771
T_5-Target yield 20 q ha^{-1} with IPNS	1.018	0.317	3.100	1.388	0.297	1.335	4.488
SEm$\pm$	0.078	0.012	0.137	0.052	0.009	0.079	0.187
Cd (P = 0.05)	0.239	0.036	0.423	0.160	NS	0.245	0.576

** VLC- Very labile carbon stock, LC–labile carbon stock, LLC–less labile carbon stock, RC–Recalcitrant carbon stock, POC–Parmaganate oxidizable carbon stock, AP- Active pool stock and PP- Passive pool stock* the incorporation of compost into the surface soil through tillage [20]. On the other hand, higher SOC contents was observed in soil at 0–7.5 cm depth was probably due to promotes the cluster bean plant roots and soil microbial activities, which the aggregates cohesion and hydrophobicity, and soil aggregate stability were enhanced [72], and thus increasing the SOC.

“The present results indicated that compared with and without IPNS, reduced SOC stability. The decomposed manure contained large amounts of labile organic C, which could be not only readily decomposed, but may promote microbial activity and thus increase the mineralization of inherent SOC” [70]. “Compared with the without IPNS significantly affect organic C stability at two different depths in the cluster bean soil. On the one hand, increases in N availability may promote the decomposition of crop residues and inherent SOC, as evidenced by the significant and positive correlation between cumulative C release per gram of soil C with the content of soil total N”. [16] “On the other hand, N addition is likely to reduce microbial biomass and thus C mineralization, particularly in the high-weathered and acid soil” [27]. “In addition, changes in enzyme activities and microbial community composition on SOC decomposition under different fertilizer treatments addition needed further investigation” [22,28]. “Soil is a potential C sink, and its capacity to store and sequester organic C is determined by a dynamical equilibrium between C inputs from primary biomass production and organic material application and C outputs by mineralization” [40]. “The higher C mineralization of the fertilized treatments represents higher losses of organic C and higher rates of organic matter turnover. In the present study, the SOC stocks cumulative of two depths nutrient management thorough with and without IPNS was 29.58 Mg ha^{-1} in target yield 20 q ha^{-1} with IPNS, 20.47 Mg ha^{-1} target yield 20 q ha^{-1} without IPNS treatments at 0-7.5 cm soil depth. This would have resulted in significantly higher C storage and sequestration in the with IPNS nutrient management system than those in the without IPNS nutrient management. The results indicated that without IPNS and with IPNS can maintain the SOC level, and if organic manure is applied, the SOC level can be significantly improved. A larger input over output of organic matter is the reason for the increase of SOC content in the without IPNS treatments. This implied that a high amount of organic material input through compost application is required for increasing the soil organic C pools. Therefore, higher SOC stocks in the cluster bean fields were attributed to both higher organic matter inputs and lower C decomposition rates” [38,40,2]. “In agreement with previous studies, organic manure and chemical fertilizer application could significantly enhance SOC stocks due to large additional C inputs in the cluster bean fields” [49,67,77,74].

3.4 Different forms of Carbon Stocks

Data presented in Tables 4 and 5 reflects that different carbon stock during experimental year as influenced by the integrated plant nutrient system. During experimental year, the very labile carbon stock ranged from 0.553 to 1.018 (M g ha^{-1}), labile carbon stock 0.187 to 0.317 (M g ha^{-1}), less labile carbon stock 0.848 to 3.100 (M g ha^{-1}), recalcitrant carbon stock 1.421 to 1.388 (M g ha^{-1}), parmaganate oxidizable carbon stock 0.292 to 0.297 (M g ha^{-1}), active pool stock 0.740 to 1.335 (M g ha^{-1}) and passive pool stock 2.269 to 4.488 (M g ha^{-1}) at both soil depths (0-7.5 cm and 7.5-15 cm) under T_2 *i.e.,* target yield 15 q ha^{-1} to T_5 *i.e.,* target yield 20 q ha^{-1} with IPNS. On the other hand, treatment T_5 *i.e.,* target yield 20 q ha^{-1} with IPNS not only registered highest different carbon stock at 0-7.5 cm and 7.5-15 cm (Very labile carbon stock 0.748 and 1.018 (M g ha^{-1}), labile carbon stock 0.466 and 0.317 (M g ha^{-1}), less labile carbon stock 1.003 and 3.100 (M g ha^{-1}), recalcitrant carbon stock 1.885 and 1.388 (M g ha^{-1}), parmaganate oxidizable carbon stock 0.328 and 0.297 (M g ha^{-1}), active pool stock 1.214 and 1.335 (M g ha^{-1}) and passive pool stock 2.889 and 4.488 (M g ha^{-1} at 0-7.5 cm and 7.5-15 cm soil depth, respectively) but also significantly superior to all the rest treatments. The lowest yield was recorded under T_2 *i.e.,* target yield 15 q ha^{-1}. Order of different treatments in influencing the different carbon stock was $T_5 > T_3 > T_4 > T_1 > T_2$.

4. CONCLUSION

Application of IPNS and without IPNS significantly influenced total C and its different pools, carbon management index, carbon stock, active and passive pools of carbon of soil. Result concluded that soil test crop response recommendation under integrated plant nutrient system dose for target 20 q ha^{-1} beneficial for the improvement in above mentioned parameters.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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