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HB Kalbhor
Assistant Professor of Soil Science and Agricultural Chemistry, MPKV, Rahuri, Ahmednagar, Maharashtra, India

SR Patil
Associate Professor of Soil Science and Agricultural Chemistry, MPKV, Rahuri, Ahmednagar, Maharashtra, India

MC Manna
Head Dept. of Soil Biology, Indian Institute of Soil Science, Bhopal, India

BD Tamboli
Associate Professor of Soil Science and Agricultural Chemistry, MPKV, Rahuri, Ahmednagar, Maharashtra, India

CA Nimbalkar
Associate Professor of Statistickas, MPKV, Rahuri, Dist. Ahmednagar, Maharashtra, State, India

AL Pharande
Dean, Faculty of Agriculture, MPKV, Rahuri Dist. Ahmednagar, Maharashtra, State, India

Corresponding Author:
HB Kalbhor
Assistant Professor of Soil Science and Agricultural Chemistry, MPKV, Rahuri, Ahmednagar, Maharashtra, India

Influence of long term tillage and nutrient management practices on carbon fractions in soil

HB Kalbhor, SR Patil, MC Manna, BD Tamboli, CA Nimbalkar and AL Pharande

Abstract
The long term effect of various tillage and nutrient management practices and their interactions were found significant on various soil organic carbon fractions of experimental Vertisol soil under rainfed *rabi* sorghum grown on a fixed site for the nine years during 2005-06 to 2014-15.
Among the various tillage practices, the low tillage (LT) practice significantly improved labile carbon fractions *viz.* WSC, POSC, and POMC over the period of nine years at all three soil depths as compared to medium tillage (MT) and conventional tillage (CT) with the exception of POSC at a depth of 30-45 cm, where tillage effects were non-significant. Whereas, the tillage effects were non-significant for SMBC at all three soil depths Similarly, among nutrient management practices, the exclusive organic treatment (N1) wherein the total nitrogen requirement of (50 kg N ha^{-1}) rainfed *rabi* sorghum was met through crop residues (byre waste) plus green *leucaena* loppings, significantly improved WSC, POSC, POMC, at all three soil depths as compared to INM treatment (N2) and exclusive chemical fertilizer treatment N3. The SMBC was significantly increased due to N2 as compared to N1 and N3 treatments.
The interaction between low tillage and nutrient management through organics (LT N1) was the best interaction for WSC, POSC, and POMC at all three depths of soil.
In general, the concentration of all carbon fractions was higher at the surface soil layer and gradually decreased with increase in soil depth. The lowest values of WSC, POSC, POMC, SMBC, were observed in control treatment at all the three soil depths.

Keywords: WSC, POSC, POMC, INM and tillage

Introduction
Soil carbon sequestration is one of the very important strategies towards mitigation of climate change and improving the soil fertility and productivity with sustainability. Since the SOC concentration is a key indicator of soil quality and productivity, restoring quality of degraded soils necessitates increasing SOC concentration in the root zone. The potential of cropping systems can be divided in to that of soil carbon sequestration and sequestration into vegetation. The term “Soil C sequestration” implies the removal of atmospheric CO_2 by plants through photosynthesis and transfer of the biomass C into soil as humus. The strategy is to increase SOC density, improve depth distribution of SOC and stabilize SOC by encapsulating it within stable micro-aggregates so that C is protected from microbial processes and has a long mean residence time (MRT).
Tillage is a primary essential land preparation activity which consumes most of the energy input in the farming practices. Conservation agriculture (CA) practices are likely to address the soil-related constraints faced by rainfed agriculture, if adopted on a long-term basis. Conservation agriculture is generally referred to a way of practicing agriculture that primarily includes low tillage, incorporation of crop residues and follow-up of better crop rotations. However, there are many other management practices that qualify the definition of CA.
The farmers of the scarcity zone of Maharashtra and adjoining areas are growing *rabi* sorghum as the predominant crop as a monocropping system. Due to poor economic condition, scarcity of organic manures and lack of technical knowledge, farmers apply a little or no organic and nitrogenous fertilizers, which affect *rabi* sorghum production. On the other hand the conventional tillage causes severe SOC depletion which also leads to soil quality deterioration and yield reduction as a result of exposure of tilled soils to intense heat and solar radiations prevailing in semi-arid conditions which accelerates surface SOC decomposition rate and

enhanced CO_2 fluxes to atmosphere. Hence, in order to improve *rabi s*orghum productivity with sustainability, along with integrated nutrient management (INM) suitable conservation tillage practices such as minimum or low tillage should be practiced which will reduce the CO_2 emission from soil, improve SOC level and ultimately soil fertility and productivity along with sustainability.

Material and Methods

The AICRP for the Dryland Agriculture had initiated and planned a long-term field experiment during 2005-06 entitled "Tillage and Nutrient Management in Vertisols of semi-arid tropics", located at the Dry Farming Research Station (DFRS), Solapur (MS) in consultation with CRIDA, Hyderabad so as to develop low tillage and judicious INM farming technology for sustainable *rabi* sorghum productivity.

The present investigation is the part of above ongoing long-term field experiment which was planned and studied after completion of nine years of long-term experiment during 2014-15.

The soils of the experimental site were medium black and classified as *Vertic Ustochrept* (Vertisol), clay in texture. The initial soil properties of experimental soil before start of experiment (2005-06) were analyzed at DFRS, Solapur.

Treatment comprisedof T1: LT.N1 Low Tillage + Organics, T2: LT.N2 Low Tillage + Organics + Chemical fertilizersT3: LT.N3 Low Tillage + Fertilizers (RDF),T4: MT.N1 Medium tillage + Organics,T5: MT.N2 Medium tillage + Organics + Chemical fertilizers,T6: MT.N3 Medium tillage + Fertilizers (RDF),T7: CT.N1Conventional tillage + Organics,T8: CT.N2Conventional tillage + Organics + Chemical fertilizers,T9: CT.N3 Conventional tillage + Fertilizers (RDF), and T10: Ab.C Absolute Control The crop residues (Byre waste and green *Leucaena* loppings) were applied as per treatments as a source of nitrogen.

Table 1: Nutrient content and quantity of organic sources applied

Organic source applied	Total Nitrogen (%)	Carbon (%)	C:N ratio	Moisture (%)	Quantity added for Supply of 25 kg N kg ha^{-1}	
Crop residues-byre waste *	0.56	42.25	75.45	-	14.46	4464
Leucaena loppings **	2.92	36.00	12.33	75	11.10	3424

Soil sampling

The soil samples were collected from each treatment at 0-15, 15-30 and 30-45 cm depth. The composite and representative soil samples were prepared by drying samples in shade on paper sheet, gently ground, mixed and sieved through 2 mm sieve for further analysis for physico-chemical properties. The soil analysis was carried out for different carbon fractions.

1. Water Soluble Carbon (WSC) The WSC in soil was extracted by hot water extraction as described by Mc Gill *et al.* (1986) [10].
2. Permanganate Oxidizable Soil Carbon (POSC) (Labile Carbon) The alkaline permanganate oxidizable labile carbon in soil sample was determined by 20 mM $KMnO_4$ (pH 7.2) method as outlined by Blair *et al.* (1995) [2].
3. Soil Microbial Biomass Carbon (SMBC) The soil microbial biomass carbon from soil was determined by the fumigation-extraction technique in incubated soil samples at 27^0C as described by Brooks *et al.* (1985).
4. Particulate Organic Matter Carbon (POMC) Particulate organic matter carbon was determined by wet digestion method outlined by Camberdella and Elliott (1992)

Results and Discussion

Effect of long term tillage, nutrient management and their interactions on soil organic carbon fractions.

Water soluble carbon (WSC) (Table 2)

The water soluble carbon is a labile fraction of SOM with the shortest turnover time and may be used as a sensitive indicator of management of SOM. The water soluble carbon content under various tillage practices ranged from 15.4 to 16.9 mg kg^{-1}, 10.5 to 14.2 mg kg^{-1} and 4.4 to 7.5 mg kg^{-1} at 0-15, 15-30 and 30-45 cm soil depths, respectively. The low tillage practice recorded significantly higher content of WSC at 0-15, 15-30 and 30-45 cm soil depth (16.9, 14.2 and 7.5 mg kg^{-1}; respectively) over the medium tillage (MT) and conventional tillage (CT).This might be associated with minimum disturbance of soil in low tillage. The minimum tillage and conventional tillage were found statistically on par with each other for their WSC content at 0-15 cm depth (15.9 and 15.4 mg kg^{-1}), 15-30 cm (10.9 and 10.5 mg kg^{-1}). Lower WSC contents in MT and CT as compared to LT may be because of extensive tillage operation which caused exposure of soil to atmospheric conditions in SAT resulting in increasing in C oxidation and thereby its depletion. These results are in conformity with the results obtained by Kandelier and Mirer (1993) [5] and Blair *et al.* (1995) [2] who reported that the soil disturbance especially through tillage operations like ploughing and cropping of pasture soils resulted in rapid decrease in carbon, particularly more in labile fractions.

The conventional tillage recorded the least amount of WSC (4.4 mg kg^{-1}) at 30-45 cm depth. The WSC content was considerably decreased in all tillage practices with increased soil depth. Similar results with respect to depth wise trend of WSC content have been recorded by Kaiser and Guggenberger (2000) [6] and Hassouna *et al.* (2010) [4] who reported that the rapid decline in pool size of water extractable carbon with soil depth is due to its decomposition and particularly, sorption to mineral components.

The long-term nutrient management to *rabi* sorghum significantly influenced the WSC at 0-15, 15-30 and 30-45 cm soil depths. It was significantly the

highest in the 100 per cent organics treatment N1 (50 kg N through organics) i.e. 25 kg N ha^{-1} through crop residue (CR-byre waste) + 25 kg N ha^{-1} through green *Luecaena* loppings (GLL) without phosphorus application (20.2, 16.0 and 9.8 mg kg^{-1}; respectively) than the INM treatment N2 (25 kg N ha^{-1} through Urea + 25 kg N ha^{-1} through organics [50% CR + 50% GLL] + 12.5 kg P_2O_5 ha^{-1} through SSP) (14.7, 11.2 and 4.5 mg kg^{-1} respectively) and nutrient management only through chemical fertilizer as 50 kg ha^{-1} N through urea + 25 kg P_2O_5 ha^{-1} through SSP (13.3, 8.5 and 3.1 mg kg^{-1}; respectively). These results clearly indicated that the 9 years addition of nitrogen to the rainfed *rabi* sorghum through organics was found beneficial for increasing water soluble carbon content in soil at various soil depths. This might be due to the addition of nitrogen through organics *viz*; byre waste and green *Leucaena loppings* which might have released the carbon in soil and resulted into increased content of water soluble carbon in soil in N1 treatment. Khambalkar *et al.* (2013) [7] and Liu *et al.* (2013) [9] reported similar results as in the present study and reported that the long-term addition of organics as a source of N resulted into increase in WSC. The treatments N2 (50% N through urea + 50% through organics) and N3 (100% N through Urea) have also recorded significantly superior WSC over control. In the present study, the significant improvement of water soluble carbon (labile pool) observed in N1 and N2 over N3 acted as a source of bio-energy which is evidenced by better improvement of soil microbial biomass C in N1 and N2 over N3.The rapid decline in pool size of water extractable carbon with an increase in soil depth in all treatments is due to its decomposition and particularly, sorption to mineral components as also reported by earlier researchers Kaiser and Guggenberger (2000) [6] and Hassouna *et al.* (2010) [4].

The interactions between tillage and nutrient management to *rabi* sorghum in long term experiment showed significant variations in WSC content in soil at 0-15, 15-30 and 30-45 cm soil depth. The interaction of nutrient management (N1) as 50 kg ha^{-1} N through organics: 25 kg ha^{-1} N-byre waste + 25 kg ha^{-1} N-green *Leucaena* lopping with low tillage (LT N1), minimum tillage (MT N1) and conventional tillage (CT N1) recorded significantly higher WSC at 0-15 cm soil depth (21.4, 19.7 and 19.6 mg kg^{-1}; respectively) followed by 15-30 cm soil depth (20.9, 13.8 and 13.2 mg kg^{-1}; respectively) and 30-45 cm soil depth (13.6, 8.9 and 6.8 mg kg^{-1}; respectively) than the interactions of remaining two nutrient management (N_2 + N_3) with tillage practices. The interactions between tillage practices and nutrient management showed the decreasing trend for WSC content with an increased soil depth. Similarly, the interactions of recommended dose of fertilizer (50 kg N and 25 P_2O_5 kg ha^{-1} through urea and sIngale superphosphate) and conventional tillage (CT N3) recorded less amount of WSC at 0-15, 15-30 and 30-45 cm (12.3, 8.1 and 2.7 mg kg^{-1}; respectively). Thus, the treatment combination LT N1 for *rabi* sorghum was found beneficial for WSC content in soils (21.4, 20.9 and 13.6 mg kg^{-1}) over the rest of the treatments at all three soil depths under dryland conditions. The improvement in WSC in LT N1 may be due to addition of substantial quantity of organic sources i.e. crop residues (byre waste) and green *Leucaena* lopping over the period of nine years for supply of 50 kg N ha^{-1} per year as well as due to slow decomposition rate in low tillage due to paucity of aeration and moisture. The supporting observations on WSC were also reported by Shokati and Ahangar (2014) wherein they explained that conservation tillage practices such as no-tillage results in an increase in carbon retention and accumulation in the soil because of slow oxidation process.

Table 2: Effect of tillage, nutrient management and their interactions on depth wise water soluble carbon at harvest of rainfed rabi sorghum

Treatment	**Water soluble carbon (mg kg^{-1})**											
	0-15 cm				**15-30 cm**				**30-45 cm**			
Tillage	**LT**	**MT**	**CT**	**Mean**	**LT**	**MT**	**CT**	**Mean**	**LT**	**MT**	**CT**	**Mean**
Nutrient management												
N_1	21.4	19.7	19.6	20.2	20.9	13.8	13.2	16.0	13.6	8.9	6.8	9.8
N_2	15.3	14.5	14.2	14.7	12.8	10.5	10.2	11.2	5.4	4.3	3.8	4.5
N_3	14.1	13.6	12.3	13.3	9.0	8.3	8.1	8.5	3.4	3.1	2.7	3.1
Mean	16.9	15.9	15.4	16.1	14.2	10.9	10.5	11.9	7.5	5.4	4.4	5.8
	SE(m) ±		CD at 5%		SE(m) ±		CD at 5%		SE(m) ±		CD at 5%	
Tillage	0.10		0.40		0.20		0.60		0.10		0.30	
Nutrient management	0.10		0.40		0.20		0.60		0.10		0.30	
T x N interactions	0.20		0.70		0.40		1.00		0.20		0.40	
Treatment	0-15 cm				15-30 cm				30-45 cm			
Treated mean	16.1				11.87				5.8			
Control	9.0				7.0				2.1			
Grand Mean	15.4				11.38				5.4			
Treated x Control												
S.Em. ±	0.2				0.4				0.2			
CD at 5%	0.7				1.1				0.5			

Soil microbial biomass carbon (SMBC) (Table 3)

The SMBC, the most active and dynamic fraction of the SOC which acts as transient nutrients sinks and is responsible for releasing nutrients from organic matter for use of plants.

The pattern of variation of SMBC in soil over the nine years revealed that tillage practices did not influence the soil microbial biomass carbon at all soil depths (0-15, 15-30 and 30-45 cm respectively). However, it was numerically higher in minimum tillage practice at 0-15, 15-30 and 30-45 cm (676.80, 311.44 and 279.95 mg kg^{-1}; respectively). Alvaro-Fuentes *et al.* (2013) [1] studied soil biochemical properties in a semiarid Mediterranean agroecosystem as affected by long-term tillage and N fertilization at four soil depths (i.e., 0-5, 5-10, 10-25 and 25-50 cm) and they observed that in the soil surface layer (0-5 cm), SMBC levels in CT were about 50% (254 mg C kg^{-1} dry soil) of the levels in the NT plots. Similarly in the present study SMBC level at 0-15 cm soil depth in CT were 9.75 per cent less as compared to LT and 19.84 per cent less than MT treatment.

The nutrient management to *rabi* sorghum under rainfed condition significantly varied the SMBC at three depths of soil. The SMBC values were the highest in integrated nutrient management to rainfed *rabi* sorghum as N2 (i.e. 25 kg N ha^{-1} through urea + 25 kg ha^{-1} through organics [12.5 kg N-CR + 12.5 kg N-GLL ha^{-1}] + 12.5 kg ha^{-1} P_2O_5 through SSP) at 0-15 cm (762.67 mg kg^{-1}), 15-30 cm (372.80 mg kg^{-1}) and 30-45 cm (346.80 mg kg^{-1}) soil depth; respectively. These results are in accordance with the results of Liu *et al.* (2013) [9] who reported that organic manure plus inorganic fertilizer application increased the average concentration of SMBC by 74.7 to 99.4 per cent in 0-60 cm soil depth.

The enhancement in SMBC in MT over CT might be because of minimum disturbance in physical structure of soil with slight improvement in soil aeration. The shifts in microbial community structure to occur due to temporal increase in microbial niche, water retention or reduced physical disturbance with medium tillage. Malviya (2014) [11] who assessed the effect of conservation agricultural practices on carbon pools in black soils of central India and observed that SMBC was significantly higher in RT compared to CT under both the soil depths (0-5 and 5-15 cm). The result trend on SMBC from present study is in close conformity with results of Malviya (2014) [11].

The interactions between tillage and nutrient management to *rabi* sorghum under rainfed condition were statistically non significant for soil microbial biomass carbon. However, it was numerically higher in surface layer (0-15 cm) followed by 15-30 and 30-45 cm; respectively. Numerically, it was the highest in interactions between MT and nutrient management as N_2 (25 kg N ha^{-1} through urea + 25 kg N ha^{-1} through organics [50% CR + 50% GLL] + 12.5 kg ha^{-1} P_2O_5 through SSP at all the depths of soil (785.70, 409.77 and 388.34 mg kg^{-1}; respectively).

The results of the present study also revealed that in all treatments the SMB-C values decreased with an increase in soil depth. These results are in conformity with the earlier results of Shao-shan *et al.* (2009) [13] who reported that soil microbial biomass carbon (Cmic) increased under revegetated grass communities as compared to cropland and overgrazed pastures and were higher in surface layers (0-10 cm) than in the subsurface (10-20 cm) layer.

Thus, the medium tillage, nutrient management through organics and chemical fertilizers (MT N2) and their interactions were found beneficial for enhancing soil microbial biomass carbon in *rabi* sorghum growth under rainfed condition.

Table 3: Effect of tillage, nutrient management and their interactions on depth wise soil microbial biomass carbon at harvest of rainfed *rabi* sorghum

Treatment	**Soil microbial biomass carbon (mg kg^{-1})**											
	0-15 cm				**15-30 cm**				**30-45 cm**			
Tillage	**LT**	**MT**	**CT**	**Mean**	**LT**	**MT**	**CT**	**Mean**	**LT**	**MT**	**CT**	**Mean**
Nutrient management												
N_1	659.38	676.68	610.43	648.83	270.09	319.75	239.69	276.51	222.39	281.83	179.46	227.90
N_2	760.98	785.70	741.32	762.67	379.53	409.77	329.12	372.80	351.56	388.34	300.51	346.80
N_3	438.95	568.01	342.45	449.80	175.32	204.80	145.71	175.27	120.62	169.66	90.13	126.80
Mean	619.77	676.80	564.73	620.43	274.98	311.44	238.17	274.86	231.52	279.95	190.03	233.83
	SE(m) ±		CD at 5%		SE(m) ±		CD at 5%		SE(m) ±		CD at 5%	
Tillage	50.50		NS		36.27		NS		30.55		NS	
Nutrient management	50.50		145.46		36.27		104.49		30.55		87.99	
T x N interactions	87.46		NS		62.83		NS		52.91		NS	
Treatment	0-15 cm				15-30 cm				30-45 cm			
Treated mean	620.43				274.86				233.83			
Control	185.12				124.53				81.54			
Grand Mean	576.90				259.83				218.60			
Treated x Control												
S.Em. ±	92.19				66.22				55.77			
CD at 5%	265.57				190.77				160.65			

Permangnate oxidizable carbon (Table 4)

The tillage practices to rainfed sorghum significantly influenced the permanganate oxidisable carbon at 0-15, 15-30 and 30-45 cm soil depths. It was significantly the highest in low tillage at all the three soil depths (1313, 1161 and 1117 mg kg^{-1} at 0-15, 15-30 and 30-45 cm; respectively) as compared to medium and conventional tillage. The low tillage consist of sowing with seed drill and light harrowing after sowing which leads to minimum disturbance to soil physical structure and exposure to atmospheric condition *viz*., sun light, wind which may conserve soil moisture and SOC by reducing oxidation of soil carbon due to minimum exposure to atmospheric temperature. This might be the reason for higher content of permanganate oxidizable carbon content in soils in low tillage treatment.

The nutrient management to rainfed *rabi* sorghum showed the significantly highest content of permanganate oxidizable carbon in N1 treatment receiving 50 kg ha^{-1} nitrogen through only organics (25 kg N ha^{-1} through crop residue i.e. byre waste + 25 kg N ha^{-1} through green *Leucaena* loppings) at 0-15, 15-30 and 30-45 cm soil depth (1338, 1184 and 1135 mg kg^{-1} respectively). It was followed by remaining treatments of nutrient management. In all nutrient management treatments the POSC decreased with an increased depth of soil and it was the least in N3 (50 kg N ha^{-1} through urea) *viz*., 1215, 1101 and 1054 mg kg^{-1} at 0-15, 15-30 and 30-45 cm soil depth, respectively. The higher content of permanganate oxidizable carbon content in nutrient management only through organics (crop residues (byre waste) + green *Leucaena* loppings) attributes to mineralization of carbon in soil like labile C which are readily oxidizable by potassium permanganate. Kharche *et al.* (2013) [8] reported the similar

observations that the integrated use of organics with chemical fertilizers recorded the highest permanganate oxidizable carbon ($KMnO_4$-C) as a result of more carbon sequestration from added organic manures and increased root residues which enhanced soil quality.

The interaction effect of tillage and nutrient management were significant at 0-15 and 15-30 cm soil depth. However, they were non-significant at 30-45 cm soil depth. Treatment LTN1 recorded significantly highest POSC (1380 and 1229 mg kg^{-1}) at 0-15 and 15-30 cm soil depth respectively. The next best treatment was MTN1 (1320 and 1165 mg kg^{-1}) followed by CTN1 (1314 and 1158 mg kg^{-1}).

Table 4 : Effect of tillage, nutrient management and their interactions on depth wise permanganate oxidizable carbon at harvest of rainfed *rabi* sorghum

Treatment	Permangnate oxidizable carbon (mg kg^{1-})											
	0-15 cm				15-30 cm				30-45 cm			
Tillage Nutrient management	LT	MT	CT	Mean	LT	MT	CT	Mean	LT	MT	CT	Mean
N_1	1380	1320	1314	1338	1229	1165	1158	1184	1168	1120	1118	1135
N_2	1295	1280	1273	1283	1144	1137	1134	1138	1117	1104	1103	1108
N_3	1263	1213	1168	1215	1111	1097	1095	1101	1066	1054	1042	1054
Mean	1313	1271	1252	1278	1161	1133	1129	1141	1117	1093	1088	1099
	SE(m) ±		CD at 5%		SE(m) ±		CD at 5%		SE(m) ±		CD at 5%	
Tillage	0.72		2.07		15.72		NS		2.00		7.00	
Nutrient management	0.72		2.07		15.72		45.28		2.00		7.00	
T x N interactions	1.24		3.58		27.23		NS		4.00		12.00	
Treatment	0-15 cm				15-30 cm				30-45 cm			
Treated mean	1278				1141				1099			
Control	1095				966				1002			
Grand Mean	1260				1124				1089			
Treated x Control												
S.Em. ±	1				5				29			
CD at 5%	4				13				83			

Particulate organic matter carbon (POMC) (Table 5.)

The tillage practices over the 9 years significantly influenced the POMC at 0-15, 15-30 and 30-45 cm soil depth at harvest of *rabi* sorghum under rainfed condition. It was significantly the highest in low tillage (SSDH) in 0-15, 15-30 and 30-45 cm soil depth (1.13, 0.77 and 0.38 g kg^{-1}, respectively). It was followed by medium tillage (0.83, 0.74 and 0.34 g kg^{-1}; respectively) and conventional tillage (0.73, 0.58 and 0.29 g kg^{-1}; respectively). The POMC content was found to be decreased with an increase in soil depth and it was numerically the highest in surface soil depth (0-15 cm). Thus, long term conservation tillage practices like medium or low tillage significantly increased the SOC fraction in the form of POMC and thereby improve the soil aggregation, saturated hydraulic conductivity and reduced the bulk density, soil compaction, erosion and run-off losses and facilitate the biological activities in the rhizosphere. Camberdella and Elliot (1992) reported that proper land use management and conservation tillage practices like minimum or low tillage primarily controlled POM disruption rate by improving soil aggregation. This accumulation of POMC also provided opportunity for carbon sequestration in soil and created nutrient rich environment in plant rhizosphere.

The nutrient management of *rabi* sorghum under rainfed conditions through N1 (100% N only through organics, i.e. 25 kg ha^{-1} N through CR + 25 kg ha^{-1} N through GLL) significantly enhanced the POMC in 0-15, 15-30 and 30-45 cm soil depths at harvest of sorghum (1.39, 0.91 and 0.44 g kg^{-1} respectively). The POMC was significantly reduced (43.24, 20.25 and 18.88% reduced at 0-15, 15-30 and 30-45 cm soil depth) in the INM treatment N2 where equal quantities of N were applied through organics + chemical fertilizer as compared to N1 (100% N through only organics) treatment. The higher POMC content of soil in nitrogen management through organic (N1) might be because of 9 years addition of organic matter *viz*., crop residues (Byre waste) and green *Leucana* loppings which might have improved the soil organic carbon fraction in the form of POMC. Similar result on POMC were recorded by Srinivasarao *et al.* (2009) [14] who reported the improvement of POMC concentrations by regular addition of organics irrespective of the cropping systems.

The interactions of tillage practices and nitrogen management to rainfed *rabi* sorghum were also significant for POMC content in soil at harvest at all the soil depths. The POMC was significantly the highest in interaction between low tillage with nitrogen management only through organics (LT N1) at 0-15, 15-30 and 30-45 cm soil depth (1.98, 0.99 and 0.48 g kg^{-1}; respectively). This might be because of addition of nitrogen through organic which might have developed POMC pool in soil with low tillage operations. Low tillage also significantly reduced the bulk density and that enhanced the organic carbon in rhizosphere. Thus, the POMC content of soil was significantly enhanced by the low tillage practice with the nitrogen management through organics to *rabi* sorghum under rainfed condition. Nayak *et al.* (2012) [12] also recorded the similar result on POMC improvement, who reported that application of FYM along with NPK resulted in significantly positive build up of POMC over only NPK at different locations at 0-15, 15-30and 30-45 soil depths.

Table 5: Effect of tillage, nutrient management and their interactions on depth wise particulate organic matter carbon at harvest of rainfed *rabi* sorghum

Treatment	Particulate organic matter carbon (g kg^{-1})											
	0-15 cm				15-30 cm				30-45 cm			
Tillage Nutrient management	LT	MT	CT	Mean	LT	MT	CT	Mean	LT	MT	CT	Mean
N_1	1.98	1.15	1.02	1.39	0.99	0.96	0.79	0.91	0.48	0.43	0.40	0.44
N_2	0.82	0.79	0.75	0.79	0.79	0.74	0.66	0.73	0.39	0.35	0.33	0.36
N_3	0.60	0.54	0.41	0.52	0.52	0.52	0.30	0.45	0.26	0.25	0.15	0.22
Mean	1.13	0.83	0.73	0.90	0.77	0.74	0.58	0.70	0.38	0.34	0.29	0.34
	SE(m) ±		CD at 5%		SE(m) ±		CD at 5%		SE(m) ±		CD at 5%	
Tillage	0.02		0.05		0.005		0.015		0.004		0.012	
Nutrient management	0.02		0.05		0.005		0.015		0.004		0.012	

T x N interactions	0.03	0.08	0.01	0.03	0.01	0.02
Treatment	0-15 cm		15-30 cm		30-45 cm	
Treated mean	0.090		0.70		0.34	
Control	0.37		0.30		0.14	
Grand Mean	0.84		0.66		0.32	
Treated x Control						
S.Em. ±	0.03		0.01		0.01	
CD at 5%	0.08		0.03		0.02	

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