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Assessment of different pools of organic carbon for better C management in cotton-growing shrink-swell soils of Jalgaon district, Maharashtra

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ABSTRACT

Information on dynamics of soil organic carbon (SOC) in agricultural soils is important for sustained crop productivity, maintenance of soil health and alleviating the climate related stress. Researchers have found that oxidizable soil organic carbon (SOC) fractions are more important in maintaining the soil quality than total organic carbon (TOC). The SOC measured by Walkley and Black method is not sensitive to assess soil quality, but labile fractions of TOC is directly related to the soil productivity and quality. It is therefore, imperative to find out its quantum of SOC and fractions of TOC for better C management and carbon sequestration. In such an endeavour, a case study on carbon dynamics was undertaken for cotton-growing shrink-swell soils of Jalgaon district, Maharashtra, to quantify the SOC and its fractions in TOC and their interrelation with the crop yield. The surface (0-30 cm) soil samples (75) were collected from dominant cotton-growing shrink- swell soils in 2011-12 and analyzed for SOC, very labile carbon (VLC), labile carbon (LC), less labile C (LLC) and non-labile C (NLC). Factorial relationship between SOC with TOC and their relationship with crop yield was worked out. The result indicated that VLC, LC, LLC and NLC contributed to the tune of 15.33%, 11.85%, 51.15% and 21.07% of the TOC, respectively. The dichromate oxidizable SOC (y) was found linearly related to the TOC (x) by the equation, $y = 0.782x + 0.025$ ($R^2 = 0.932$), indicating that oxidizable SOC comprised 78.2 % of the TOC, in other words, a correction factor of 1.278 (inverse of the slope of linear regression line) may be used to convert SOC values in shrink-swell soils of Jalgaon. The crop yield was closely related to the SOC ($r = 0.642$) compared to TOC ($r = 0.610$). Considering the maximum and minimum cotton yield, the threshold value and maximum value of SOC were worked out to be 5.688 and 8.312 g C/kg, respectively, reflecting the carbon sequestrations potential of soils. Among the different fractions, VLC was found to be well correlated ($r = 0.512$) with the crop productivity. The computed threshold and maximum value for VLC were 0.547 and 2.147 g C/ kg, respectively. The study thus establishes that only 27.18 % of active carbon (VLC+LC) are important for the crop production in cotton- growing shrink-swell soils.

Key words: Optimum and threshold value, Oxidizable soil organic carbon, Shrink-swell soils, Soil organic carbon fractions, Total soil organic carbon

The study of soil carbon dynamics in sub-tropical soils is important as it determines the agro-ecosystem functions, influences soil fertility, water holding capacity and maintenance of physical, chemical and biological properties. (Lal 2005, Franchini *et al*. 2007, Bayer and Mielniczuk 2008). Lal (2004) reported that the enrichment of soil organic carbon would minimize the effect of global warming. As such soil organic carbon is considered the most important soil quality and sustainability indicator (Brejda *et al*. 2000; Murage *et al*. 2000). Several research findings suggested that certain fractions of organic matter are most important in maintaining soil quality and thus could be important indicator to assess the impact of management practices (Chan 1997). The conventional methods used to determine soil organic carbon were developed to maximize oxidation and recovery of carbon (Walkley and Black 1934, Nelson and Sommers 1996). As such, total organic carbon (TOC) measurement may not be a sensitive indicator which can represent the soil quality parameters for management purpose, only labile form of organic carbon might be more useful to find out the influence of different management practices on TOC (Chivane and Bhattacharya 2010). The influence of different management practices on TOC will dictate the quantum of organic carbon to be oxidized. The labile carbon pool of TOC have the rapid turn-over rates and it is the main sources of nutrients which affect the quality and productivity of soils (Chan *et al*. 2001, Majumdar *et al*. 2008, Mandal *et al*. 2008). Several workers have fractionated TOC for tropical and sub-tropical soils. Using different concentration of

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H_2SO_4, Chan *et al.* (2001) differentiated total SOC into four pools, namely, Very labile C, Labile C, Less labile C and Non-labile C and showed that the amount of organic C oxidizable by a modified Walkley and Black method. The most widely used technique for delineation of soil organic carbon (SOC) is wet dichromate oxidation method of Walkley and Black (1934) which is mostly used by all soil testing laboratories as a standard method because of its simplicity, minimal time and equipment requirement (Nelson and Sommens 1996). Swarup *et al*. (2000) reported variable proportion of SOC is determined by this method depending upon soil type, depth and nature of SOC in different climatic zones. Researchers have proposed a correlation factor ranging from 1.19 to 1.35 may be used to account for total SOC from the values for oxidizable SOC obtained by the dichromatic oxidation method (De Vos *et al.* 2007, Ghosh *et al.* 2001). Thus, the relationship between oxidizable SOC (Walkley and Black 1934) and total SOC (by dry combustion method) has implication in SOC related research, especially pertinent to SOC stocks estimation for Indian soils. Number of studies were conducted to find out the relative share of active (labile form of TOC) and passive (stable or resistant form of TOC) pools. Most of such studies have either been conducted in temperate soils or on soils of Indo-Gangetic alluvial plains (IGP) but not in central India having shrink-swell soils.

An attempt was made to establish the relationship between SOC and TOC; to fractionate the oxidizable soil organic carbon and to find out the threshold and optimum values of SOC for organic carbon sequestration on cotton-growing shrink-swell soils of Jalgaon district of Maharashtra.

MATERIALS AND METHODS

The study area is located in Jalgaon district of Maharashtra (20° and 21° N, and 74° 55' and 76° 58' E). It is bounded by Satpuda and Satmala and Ajanta ranges in the north and south, respectively. The general elevation is 208.51 m above mean sea level (MSL). The river Tapti flows from east to west with most of its tributaries such as Purna, Girna and Bori flowing parallel to the river. The drainage pattern is dendritic. Seven distinct physiographic units namely hill ridges, table land, upper piedmont, lower piedmont, piedmont plain, river terrace and dissected flood plains were identified in the district.

Seventy five soil samples (0-15 cm) were collected from the cotton (Bt) growing shrink-swell soils of district in 2011-12 and processed. The soil samples were analyzed for oxidizable SOC by wet digestion method of Walkley and Black (1934) and total SOC by CHN – analyzer. The total SOC was apportioned into different pools by the modified Walkley and Black method as described by Chan *et al.* (2001) using 5, 10 and 20 ml of concentrated H_2SO_4 that resulted in 3 acid-aqueous solution ratio of 0.5:1, 1:1 and 2:1. The amount of C, thus determined, allowed the apportioning of total SOC into four fractions of decreasing oxidizability, i.e.

Fraction I (C_{VL}, Very labile C): Organic carbon oxidizible under 12 *N* H_2SO_4;

Fraction II (C_L, Labile soil C): The difference in oxidizible organic carbon extracted between 18 *N* and 12 *N* H_2SO_4;

Fraction III (C_{LL}, Less labile soil C): The difference in oxidizible organic carbon extracted between 24*N* and 18 *N* H_2SO_4 and

Fraction IV (C_{NL}, Non labile soil C): Residual organic carbon after reaction with 24 *N* H_2SO_4 when compared with the total carbon.

The yield data were collected and correlated with different fractions of SOC.

RESULTS AND DISCUSSION

The soils physical, chemical and biological data (Table 1) indicated that the sand, silt and clay content varied from 4.3 to 43.1, 13.9 to 34.3 and 34.5 to 69.5 %, respectively. The soils were neutral to slightly alkaline in reaction (7.1 to 8.7), CEC varied from 34.23 to 61.2 cmol (p^+)/kg. The DTPA-extractable micronutrient cations were 1.25 to 29.03 mg/ kg (Fe), 2.35 to 31.02 mg/kg (Mn), 0.14 to 1.91 mg/kg (Zn) and 0.52 to 6.43 mg/kg (Cu). The available N ranged from 125.48 to 244.95 kg/ha, P from 3.67 to 24.35 kg/ha, K from 435.68 to 954.12 kg/ha and available S was 4.12 to 14.67 kg/ha in the surface soils. The biological properties like soil microbial biomass carbon (SMBC) ranged from 158.7 to 227.5 mg/kg and dehydrogenase activity (DHA) from 36.4 to 56.4 µg TPF/g/ 24 h.

The fractions of SOC (Table 2) indicated that the total organic carbon (TOC) ranged from 5.40 to 12.80 g C/kg (8.93 g C/kg), whereas, oxidizable soil organic carbon (SOC) ranged from 4.40 to 9.80 g C/kg (7.01 g C/kg). The VLC, LC, LLC and NLC contributed 15.38%, 11.85%, 51.25% and 21.52% of the TOC, respectively. Mandal *et al.* (2008) observed that in a long-term field experiment (rice- based cropping) in an Inceptisol, the mean distribution of different pools of SOC, namely VLC, LC, LLC and NLC were

Table 1 Physical, chemical and biological properties of soils

Soil property	Range	Average
Sand (%)	4.3-43.1	23.2
Silt (%)	13.9-34.3	24.1
Clay (%)	34.5-69.5	52.6
pH	7.1-8.7	7.9
CEC (cmol (p^+)/kg)	34.23-61.2	47.5
DTPA-Fe (mg/kg)	1.25-29.03	12.5
DTPA-Mn (mg/kg)	2.35-31.02	15.7
DTPA- Zn (mg/kg)	0.14-1.91	0.6
DTPA-Cu (mg/kg)	0.52-6.43	3.2
Available N (kg/ha)	125.48-244.95	181.7
Available P (kg/ha)	3.67-24.35	12.9
Available K (kg/ha)	435.68-954.12	679.7
Available S (kg/ha)	4.12-14.67	10.7
SMBC (mg/kg)	158.7-227.5	193.3
DHA (µg TPF g/24 hr)	36.4-56.4	46.1

Table 2 Soil organic carbon fractions (g/kg) in shrink-swell soils of Jalgaon district

District		SOC fractions (g/kg)							
		VLC	LC	LLC	NLC	Active pool	Passive pool	OC	TOC
Jalgaon	Range	0.49-4.21	0.41-3.10	0.97-8.07	1.00-3.00	1.21-5.05	1.97-11.07	4.40-9.80	5.40-12.80
	Mean	1.36	1.03	4.63	1.92	2.38	6.55	7.01	8.93
	SD	0.89	0.62	1.40	0.45	0.99	1.62	1.11	1.42
	% of TOC	15.38	11.85	51.25	21.52	27.13	72.77	78.49	

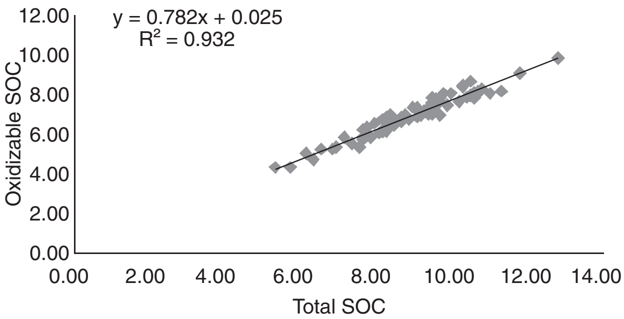

Fig 1 Relationship between total SOC and oxidizable SOC in swell-shrink soils of Jalgaon district

33.6%, 17.6%, 11.5% and 37.3% of the TOC, respectively. The data also indicated that % distribution of C in LLC fraction was markedly higher than the other fractions of TOC in Jalgaon district. The active pool (VLC + LC) and passive pools (LLC + NLC) are presented in Table 2. As LLC and NLC together contribute the passive pool, it is very important to note that the passive pool contributes 72.77% of the TOC which is in contrast with the reported value of "passive pool" (30-40%) by Parton *et al.* (1992).

The regression line relating SOC (y, in g C/kg soil) and TOC (x, in g C/kg soil) showed linear relationships as y= 0.782x + 0.025 (R^2 = 0.932) (Fig. 1), indicating that SOC comprised 78.2% of the TOC, which in-turn showed that the correction factor (inverse of the slope of linear regression line) was found to be 1.278, which is in consonant with factor of 1.32 proposed by De Vos *et al.* (2007) for converting the SOC to TOC. In-spite of more stable organic carbon in clay-humas complexes (Wattel – Kockkocke *et al.* 2001), the observed correction factor was found lower in shrink-swell soils indicating high recovery (78.2%) of SOC. Ghosh *et al.* (2001) suggested that correction factor ranging from 1.15 to 1.33 is to be multiplied to the values of oxidizable SOC to get the estimates of TOC in sandy loam Inceptisol of NW Himalayas, while Krishan *et al.* (2009) worked out correction factor 2.40 and 1.95 for Himalaya soils and Vertisols of central India, respectively.

The relationship between different fractions of TOC and the average yields of the cotton is presented in Table 3. The yield was highly correlated with VLC fraction of TOC, suggesting its greater influence on the crop production (r = 0.512**). It was observed that the coefficient of determination (R^2) (Table 4) was on higher side in the regression lines in relating the yield with SOC, TOC and very labile C, while for other fractions of C, the R^2 values were not acceptable for making any conclusion. The SOC, TOC and very labile C were related to mean relative yield in the form of y = 0.164x + 1.752 (R^2 = 0.458), y = 0.187x + 2.952 (R^2 = 0.388) and y = 0.100x - 1.853 (R^2 = 0.264), respectively.

The crop yield was collected from farmers' field indicated that the yield from high to low management ranged from 40 q/ha to 24 q/ha. Using the highest yield (40 q/ha), the value of 'x' from those equations indicated the optimum value of each of this measurement of SOC. The calculated optimum values for very labile C, SOC and TOC for the shrink-swell soils were 2.147 g C/kg soil, 8.312 g C/kg soil and 10.432 g C/kg soil, respectively. Similarly putting lowest yield (24 q/ha) the value of 'x' from those regression lines to obtain the threshold values of each of the measurements of SOC. The computed threshold values for very labile C, SOC and total SOC were 0.547 g C/kg soil, 5.688 g C/kg soil and 7.440 g C/kg (Table 4) in the shrink- swell soils of

Table 3 Correlation coefficients of various soil carbon fractions and cotton yield

	Yield	VLC	LC	LLC	NLC	Active	Passive	OC	TOC
Yield	1								
VLC	0.512**	1							
LC	-0.180	-.176	1						
LLC	0.261*	-.427**	-.380**	1					
NLC	0.343**	.132	.033	.359**	1				
Active	0.347**	.789**	.467**	-.621**	.140	1			
Passive	0.322**	-.332**	-.319**	.965**	.591**	-.498**	1		
OC	0.642**	.164	-.065	.713**	.580**	.107	.779**	1	
TOC	0.610**	.170	-.040	.670**	.773**	.128	.796**	.965**	1

Table 4 Threshold and optimum levels of different soil carbon fractions computed on the basis of regression lines relating yield and different fractions of C

Carbon pools	Regression line	R^2	Threshold value	Optimum value
Very labile C	y = 0.100x - 1.853	0.264	0.547	2.147
Labile C	y = -0.022x + 1.737	0.026	1.209	0.857
Less labile C	y = 0.086x + 1.869	0.078	3.933	5.309
Non labile C	y = 0.022x + 1.2	0.061	1.728	2.080
Oxidizable SOC	y = 0.164x + 1.752	0.458	5.688	8.312
Total SOC	y = 0.187x + 2.952	0.388	7.440	10.432

Jalgaon district.

Present study finds the carbon sequestration potential of cotton-growing shrink-swell soils of Jalgaon district. The potential was found to be the minimum threshold value of 5.68 g C/kg to and maximum value of 8.31 g C/kg. Conversion factor for SOC to TOC was found to be 1.278 among the carbon fraction of TOC. VLC shows good relation with the yield.

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