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IMPACT OF LONG TERM TILLAGE AND RESIDUE APPLICATION ON ORGANIC CARBON POOLS AND CARBON STOCK IN SEMI ARID TROPICAL ALFISOL OF HYDERABAD

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ABSTRACT

A long term experiment was conducted in rainfed semi-arid tropical Alfisol at Hayathnagar Research Farm of Central Research Institute for Dryland Agriculture, Hyderabad, India, during the period 1995 to 2013 to study the long-term impacts of tillage and residue application on carbon sequestration, C pools and C Management Indices and their relationship with crop yield. The experiment was conducted in a split-split plot design with conventional tillage (CT) and minimum tillage (MT) as main factors, surface application of sorghum stover @ 2t ha^{-1} (SS), fresh gliricidia loppings @ 2t ha^{-1} (GL) and 'no' residue (NR) as sub factors and levels of N viz., 0 (N_0), 30 (N_{30}), 60 (N_{60}) and 90 (N_{90}) kg N ha^{-1} as sub-sub factors in a castor-sorghum yearly rotation. The results of the study clearly indicated that minimum tillage significantly increased the contents of soil C pools viz., microbial biomass carbon, labile carbon and its fractions and particulate organic carbon compared to conventional tillage. It was also observed that significant inter-correlations existed among the carbon pools studied which indicated a dynamic equilibrium with each other. Of all the treatment combinations studied, the practice of minimum tillage coupled with application of Gliricidia loppings @ 2t ha^{-1} and nitrogen applied @ 90 kg ha^{-1} (MTGLN90) was found to be the most promising in terms of maintaining significantly higher carbon stock in semi arid tropical Alfisols.

Key words: Conservation tillage, organic carbon pools, carbon stock, intercorrelations, relative yield

INTRODUCTION

Soil organic matter (SOM) is an important determinant of soil fertility, productivity and sustainability, and is a useful indicator of soil quality in tropical agricultural systems where the soils are highly weathered and poor in nutrients are managed with little external inputs (Feller and Beare, 1997; Lal, 1997). The size of soil organic matter pools in natural ecosystems decreases exponentially with temperature (Lal, 2002a) and consequently most dryland soils contain less than 1%, and frequently less than 0.5%, carbon (Lal, 2002b). Low soil organic matter particularly under semi-arid regions is a major factor contributing to their poor productivity. Conventional tillage practices play an important role in the manipulation of nutrient storage and release from SOM, with conventional tillage (CT) inducing rapid mineralization of SOM and potential loss of C from the soil. Further, the removal of crop residues from the fields is also known to hasten soil organic carbon (SOC) decline especially when coupled with conventional tillage (Yang and Wander, 1999; Mann *et al*., 2002). Optimum levels of SOC can be managed through the adoption of appropriate crop rotations (Wright and Hons, 2005), fertility management, using inorganic fertilizers and organic amendments (Schuman *et al*., 2002; Mandal *et al*., 2007; Majumder *et al*., 2008). Considering the above, the present study was undertaken with the specific objectives i) to investigate the long term effect of conservation tillage, residue application on carbon pools and carbon stocks and ii) to establish the quantitative relationship of various carbon pools with crop yields and carbon stock under sorghum-castor yearly rotation in rainfed semi arid tropical Alfisol soils.

MATERIALS AND METHODS

The present study was conducted at Hayathnagar Research Farm of Central Research Institute for Dryland Agriculture, Hyderabad, India. The experiment was started in the year 1995 in a strip split-split plot design with two tillage practices as the main treatments, three residue levels as sub plot treatments and four nitrogen levels as the sub-sub plot treatments with three replications with a sub-sub plot size of 4.5 m x 6.0 m. Sorghum (*Sorghum vulgare* (L)) variety SPV- 462 and castor (*Ricinus communis* (L)) variety DCS-9 were used as test crops in a yearly rotation. The main strip

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consisted of two tillage treatments viz., i) conventional tillage (CT) and ii) minimum tillage .The three residues treatments included i) dry sorghum stover (SS) ii) fresh gliricidia loppings (*Gliricidia maculata*) (GL) @ 2 t ha^{-1} (fresh weight) and iii) no residue (NR). The four nitrogen levels were: i) 0 kg N ha^{-1} (N_0), ii) 30 kg N ha^{-1} (N_{30}), iii) 60 kg N ha^{-1} (N_{60}) and iv) 90 kg N ha^{-1} (N_{90}). Crops were sown in the 2nd or 3rd week of June each year. After the 18th year of experimentation, soil samples were collected from 0-20 cm depth. The samples were air dried and passed through 2 mm sieve. The different C fractions were estimated through a modified Walkley and Black method as described by Chan *et al.* (2001) using 5, 10 and 20 ml of concentrated H_2SO_4 resulting three acid–aqueous solution ratios of 0.5:1, 1:1 and 2:1 (which corresponded respectively to 12.0 N, 18.0 N and 24.0 N of H_2SO_4). Microbial biomass carbon (Jenkinson and Powlson), labile carbon (Weil *et al.,* 2003) were also estimated. Particulate organic matter was separated from 2-mm soil following the method described by Camberdella and Elliott (1992).

Statistical Analysis: The data on crop yield, carbon pools, and carbon stock was evaluated by analysis of variance (ANOVA). Simple correlation coefficients and regression equations were also developed to evaluate relationships between the response variables. The data was tested at the level of significance of 95% (p= 0.05). Statistics calculations were performed by IBM SPSS Statistics 19.

RESULTS AND DISCUSSIONS

Carbon pools

Microbial Biomass Carbon

Tillage, residues and N levels showed significant influence on microbial biomass carbon. Minimum tillage recorded 13.25% higher MBC contents compared to conventional tillage. Several studies reported that no tillage management increased MBC contents in surface soils (Doran, 1987; Dou et al 2008 and Balota *et al.,* 2003). Lack of soil disturbance under minimum tillage provides steady source of organic C substrates for soil micro organisms which enhances the activity and contribute to higher MBC as compared to CT (Balota *et al.,* 2003). In contrast, Carpenter-Boggs *et al.,* (2003) did not find any difference in MBC contents under no tillage when compared with conventional tillage. In this study, surface application of Gliricidia and sorghum stover for 18 years significantly improved MBC contents to the extent of 86 and 50% respectively compared to no residue application. On the other hand, application of N at 30, 60 and 90 kg ha^{-1} recorded higher soil MBC i.e to the extent of 28, 43 and 46% respectively compared to conventional tillage. It was also observed that the interaction effects of nitrogen levels with tillage and residue treatments were found to be significant.

Labile Carbon

Minimum tillage resulted in significantly higher labile carbon contents by 4.7% compared to conventional tillage. The results obtained in this study are in agreement with those reported by Lewis et al (2011), who reported higher levels of labile carbon under conservation tillage practices. Application of SS and GL on long term basis significantly increased labile carbon contents to the extent of 7% and 10.3%, respectively over control. The N application at 30, 60 and 90 kg ha^{-1} significantly increased labile carbon content over control. The interaction effect between tillage and residues was found to be significant. Lower amount of labile carbon under CT is likely due to increased soil disturbances resulting in rapid decomposition of aggregate protected SOC fraction (Awale *et al,* 2013).

Particulate Organic Carbon

Long term effect of tillage, residues and N levels significantly influenced particulate organic carbon. Minimum tillage practices recorded 20% higher POC contents compared to conventional tillage. These results are in agreement with the studies conducted by Dou *et al,* (2008) and Chatterjee and Lal (2009). The reason for higher POC under conservation or minimum tillage is attributed to minimal disturbance under MT compared to CT. Low levels of POC under CT is attributed to collapse of soil aggregates due to increased tillage intensity. Among the residues, application of sorghum stover and Gliricidia significantly increased particulate organic carbon content to the extent of 25 and 32%, respectively over control. The interaction effect between residues with tillage and N levels was found to be significant. The different levels of N applied also showed significant effect on POC.

Table 1: Long term effect of tillage, residues and N levels on carbon pools after the harvest of Sorghum crop (2013)

Treatments	Microbial biomass carbon (mg kg^{-1})	Labile carbon (mg kg^{-1})	Particulate organic carbon (%)	Organic carbon (g kg^{-1})	Labile Carbon fractions (g kg^{-1})			Carbon stock (Mg ha^{-1})
					Very labile	Labile	Less labile	
CT	295.28	271.88	0.43	5.70	1.30	0.78	0.78	12.35
MT	334.41	284.73	0.52	6.47	1.37	0.89	0.89	13.63
GL	402.75	290.44	0.53	6.73	1.47	0.97	0.97	13.76
SS	325.81	281.31	0.50	6.57	1.39	0.81	0.81	14.06
NR	215.99	263.16	0.40	4.96	1.14	0.71	0.71	11.15
N0	243.98	272.78	0.42	5.68	1.14	0.69	0.69	12.28
N30	311.38	275.98	0.46	5.83	1.27	0.76	0.76	12.40
N60	348.07	281.60	0.49	6.22	1.35	0.88	0.88	13.26
N90	355.95	282.85	0.52	6.61	1.58	1.01	1.01	14.02
CD (P = 0.05)								
Tillage	6.95	0.93	0.011	0.04	0.014	0.012	NS	0.135
Residues	1.26	0.43	0.066	0.03	0.009	0.005	0.007	0.06
N levels	4.85	1.32	0.012	0.08	0.044	0.028	0.021	0.202
TxR	1.14	0.61	0.008	0.04	0.013	NS	0.01	0.085
TxN	6.86	NS	NS	NS	NS	0.040	0.029	NS
RxN	8.40	NS	0.021	NS	0.076	0.049	0.036	0.350
TxRxN	11.88	NS	0.03	NS	NS	0.069	0.051	NS

Organic carbon, carbon stock, carbon fractions:

Soil organic carbon content was found to be significantly influenced by tillage, residues and N levels. Minimum tillage recorded significantly higher organic carbon contents (6.47 g kg^{-1}) compared to conventional tillage (5.7 g kg^{-1}) and registered an increase of 13.5 %. Six et al (2001) also reported the stabilization of soil organic carbon with reduced or no tillage practice. Application of Gliricidia and sorghum stover increased the soil organic carbon contents to the extent of 36 and 32% respectively over no residue application. Application of N @30, 60 and 90 kg ha^{-1} significantly influenced the organic carbon contents by 3, 9 and 16% respectively. Srinivasarao etal (2012) also observed on increase in SOC concentrations to the extent of 52% with application of various organic amendments. The soil organic C stock in minimum tillage (13.63 Mg ha^{-1}) increased considerably over conventional tillage (12.35 Mg ha^{-1}) and reported an increase of 10 per cent. On an average, SS and GL treatments also maintained 26% and 23% higher carbon stocks over no residue application. Significant effect on carbon stock was also found with increase in the N levels. The contents of carbon fractions viz., very labile, labile and less labile were also significantly influenced by soil management treatments. In case of very labile carbon, the interactions between tillage and residues (TxN) as well as residues and N levels (RxN) were found to be significant. These results are in corroboration with the findings of Bona *et al.* (2008).

Table 2: Correlation coefficients (r) among different soil organic C pools and with, castor bean, sorghum grain yield and carbon stock

	Castor Yield	Sorghum Yield	Carbon stock
MBC	0.831**	0.831**	0.786**
LC	0.664**	0.664**	0.880**
POC	0.748**	0.748**	0.918**
OC	0.714**	0.714**	0.982**
Very labile C	0.810**	0.810**	0.821**
Labile C	0.777**	0.777**	0.763**
Less Labile C	0.777**	0.777**	0.763**

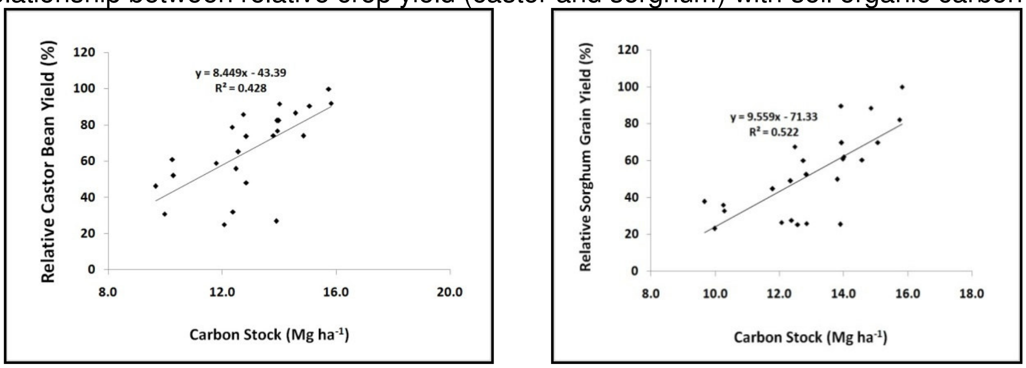
Relationship between crop yield and carbon stock

A quantitative relationship between relative yield of sorghum and castor with soil organic carbon stock was developed using simple linear regression equation (Fig.1). From these relationships, it was understood that there was significant association between relative yields of sorghum grain and castor bean yield (R^2= 0.522 and 0.428 respectively). Abrol *et al.* (2000) have attributed the declining trend in crop productivity of the rice-based cropping system in Indo-Gangetic plains in India to the declining C stock in soil.

$Y_{\text{Rel Sorghum Yld}} = 9.559\,x - 71.33$ (R^2 = 0.522)

$Y_{\text{Rel Castor Yld}} = 8.449x\text{-}43.39$ (R^2 = 0.522)

Fig 1: Relationship between relative crop yield (castor and sorghum) with soil organic carbon stocks.



Relationship of different soil organic C pools with crop yields

In the present study, significant inter-correlations were observed among the carbon pools studied which indicated a dynamic equilibrium with each other (Table 2). Depletion or enrichment in one would shift the equilibrium and affect the size of the others. The correlations of carbon pools with sorghum and castor yields were found to be significant. MBC showed highest correlation with sorghum and castor yield compared to other carbon pools.

The results of the present study clearly indicated that conservation agriculture practices viz, minimum tillage and application of residues significantly improved microbial biomass carbon, other carbon pools and carbon stock. Strong interrelationships between carbon pools and carbon stock observed in this study indicated their interdependence and dynamics. The relationship between relative yield of sorghum and castor with carbon stock was also found to be significant. The practice of minimum tillage coupled with application of Gliricidia loppings @ 2t ha^{-1} and nitrogen applied @ 90 kg ha^{-1} (MTGLN90) was found to be the best treatment in terms of maintaining significantly higher carbon stock in these Alfisol soils.

REFERENCES

Abrol, I.P., Bronson, K.F., Duxbury, J.M. and Gupta, R.K. (2000) Long-term soil fertility experiments in rice–wheat cropping systems. rice–wheat consortium paper series 6. New Delhi, pp. 171

Awale, R., Chatterjee, A. and Franzen, D. (2013) Tillage and N-fertilizer influences on selected organic carbon fractions in a North Dakota silty clay soil. *Soil and Tillage Research* **134**: 213–222

Balota, E.L., Colozzi-Filho, A., Andrade, D.S., Dick, R.P. (2003) Microbial biomass in soils under different tillage and crop rotation systems. *Biology and Fertility of Soils* **38:** 15–20.

Blair, G.J., Lefroy, R.D.B. and Lisle, L. (1995) Soil carbon fractions based on their degree of oxidation and the development of a carbon management index for agricultural systems. *Australian Journal of Agricultural Research* **46**: 1459 –1466

Bona, F.D. de, Bayer, C., Diekow, J., Bergamaschi, H. (2008) Soil quality assessed by carbon management index in a subtropical Acrisol subjected to tillage and irrigation. *Australian Journal of Agricultural Research* **46**: 469-475.

Camberdella, C.A. and Elliott, E.T. (1992) Particulate soil organic matter across grassland cultivation sequence. *Soil Science Society of American Journal* **56**: 777–783.

Carpenter-Boggs, L., Stahl, P.D., Lindstrom, M.J. and Schumacher, T.E. (2003) Soil microbial properties under permanent grass, conventional tillage, and no-till management in South Dakota. *Soil and Tillage Research* **71:** 15–23.

Chan, K.Y., Bowman. A., Oates. A. (2001) Oxidizable organic carbon fractions and soil quality changes in an oxic paleustaff under different pastures leys. *Soil Science* **166**:61–67

Chatterjee, A., Lal, R. (2009) On farm assessment of tillage impact on soil carbon and associated soil quality parameters. *Soil and Tillage Research* **104:** 270–277.

Diekow, J., Mielniczuk. J., Knicker. H., Bayer, C. and Dick, D.P. (2005) Carbon and nitrogen stocks in physical fractions of a subtropical Acrisol as influenced by long-term no-till cropping systems and N fertilization. *Plant and Soil* **268**: 319–328

Doran, J.W. (1987) Microbial biomass and mineralizable nitrogen distributions in no-tillage and plowed soils. *Biology and Fertility of Soils* **5:** 68–75

Dou, F., Wright, A.L. and Hons, F.M. (2008) Sensitivity of labile soil organic carbon to tillage in wheat-based cropping systems *Soil Science Society of American Journal* **72:** 1445–1453.

Feller, C. and Beare, M.H. (1997) Physical control of soil organic matter dynamics in the tropics. *Geoderma* **79**: 69–116

Jenkinson, D.S., and Powlson, D.S. (1976) The effects of biocidal treatments on metabolism in soil: V. A method for measuring soil biomass. *Soil Biology and Biochemistry* **8**: 209–213.

Lal, R. (2002a) Soil carbon dynamics in cropland and rangeland. *Environmental Pollution* **116**: 353-362.

Lal, R. (1997) Residue management, conservation tillage and soil restoration for mitigating greenhouse effect by CO_2 –enrichment. *Soil and Tillage Research* **43**:81–107.

Lal, R. (2002b) Carbon sequestration in dryland ecosystems of west Asia and north Africa. *Land Degradation and Development* **13**: 45-59.

Lewis, D.B., Kaye, J.P., Jabbour, R., Barbercheck, M.E. (2011) Labile carbon and other soil quality indicators in two tillage systems during transition to organic agriculture. *Renewable Agriculture and Food Systems* **26**: 342–353.

Majumder, B., Mandal, B., Bandyopadhyay, P.K., Gangopadhyay, A., Mani, P.K., Kundu,A.L., Majumder, D. (2008) Organic amendments influence soil organic carbon pools and crop productivity in a 19 years old rice-wheat agroecosystems. *Soil Science Society of American Journal* **72**: 775–785.

Mandal, B., Majumder, B., Bandyopadhyay, P.K., Hazra, G.C., Gangopadhyay, A.,Samantaray, R.N., Mishra, A.K., Chaudhury, J., Saha, M.N., Kundu, S. (2007) The potential of cropping systems and soil amendments for carbon sequestration in soils under long-term experiments in subtropical India. *Global Change Biology* **13**: 1–13.

Mann L, Tolbert V, Cushmann J. (2002) Potential environmental effects of corn (Zea mays L) stover removal with emphasis on soil organic matter and erosion. *Agricultural Ecosystems and Environment* **89**:149-166.

Schuman, G.E., Janzen, H.H., Herrick, J.E. (2002) Soil carbon dynamics and potential carbon sequestration by rangelands. *Environmental Pollution* **116**: 391–396.

Six J., G. Guggenberger, K. Paustian, L. Haumaier, E. T. Elliott and W. Zech. (2001). Sources and composition of soil organic matter fractions between and within soil aggregates. *European Journal of Soil Science* **52**(4): 607-618.

Srinivasarao, Ch., Venkateswarlu B., Lal, R., Singh, A.K., Kundu, S., K.P.R. Vittal, G. Balaguravaiah, M. Vijaya Shankar Babu, G. Ravindra Chary, M.B.B. Prasadbabu,T. Yellamanda Reddy (2012) Soil carbon sequestration and agronomic productivity of an Alfisol for a groundnut-based system in a semiarid environment in southern India. *European Journal of Agronomy* **43**: (2012) 40– 48.

Weil, R.W., Islam, K.R., Stine, M.A., Gruver, J.B., Liebig, S.E., (2003) Estimating active carbon for soil quality assessment: a simplified method for laboratory and field use. Am. *Journal of Alternate Agriculture* **18**: 3–17.

Wright, A.L., Hons, F.M., (2005) Tillage impacts on soil aggregation and carbon and nitrogen sequestration under wheat cropping sequences. *Soil and Tillage Research* **84**: 67–75.

Yang XM, Wander MM (1999) Tillage effects on soil organic carbon distribution and storage in silt loam soil in Illinois. *Soil and Tillage Research* **52**:1– 9.