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Carbon sequestration potential under soybean-chickpea cropping system as influenced by conservation practices in swell shrink soils of central India

Chetna S Kumbhar, VK Kharche, SD Jadhao and NM Konde

Abstract
A field experiment was conducted during *kharif* and *rabi* seasons of 2018-19 to evaluate the impact of conservation agricultural management practices on carbon sequestration potential through soybean-chickpea cropping system in different villages of Barshi Takali tahsil, Akola District in Maharashtra. The results of study showed that carbon input in *kharif* through leaf litter biomass and stubble biomass was noted significantly higher (2.27 Mg ha^{-1}) under conservation tillage for 15 years which is followed by treatment T5 (2.22 Mg ha^{-1}) and T6 (2.16 Mg ha^{-1}) under conservation tillage done for 12 and 10 years respectively. The highest (3.23 Mg ha-1) total carbon input through leaf litter biomass and stubble biomass of Soybean-Chickpea cropping system was recorded under conservation tillage for 15 years and the lowest (2.36 Mg ha-1) was observed under conventional tillage during 2018-19. By adoption of conservation tillage practices along with residue retention of leaf litter biomass and stubble biomass total carbon input addition was increased by 36.86 per cent over conventional tillage. Hence, the consistent adoption of conservation agricultural management practices along with residue management improves the total carbon input and carbon sequestration potential under conservation agricultural system.

Keywords: Conservation tillage, biomass, carbon input, residue management

Introduction
Maintenance of soil organic carbon is essential for long-term sustainable agriculture, since declining levels generally lead to decreased crop productivity. As SOC changes are generally directly related to the quantity of crop residues returned to the land, agronomic practices that influence yield and affect the residues returned to soil are likely to influence SOC (Campbell *et al*. 1997, 2000) [2, 3]. Corsi *et al*. (2012) [4] define conservation agriculture (CA) as a method of managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. They added that minimum mechanical soil disturbance, permanent organic soil cover and crop diversification are the three basic principles of CA. Retention of crop residue protects the soil from direct impact of raindrops and sunlight while the minimal soil disturbance enhances soil biological activities as well as soil air and water movement. Conservation agriculture helps in sequestering atmospheric carbon in soil plant system through change in agricultural operations and management practices. Addition of gross C input to the soil linearly related to changes in soil organic carbon levels. Conservation agriculture plays a vital role in sequestering carbon in soil-plant system through change in management practices, use of improved cropping systems, less disturbance of soil and hence less disruption of carbon rich soil aggregates and retention of crop residues in soil (Lal and Stewart 2010, Wang *et al*. 2010) [12, 22]. Annual C input was 22% of the harvestable above-ground biomass of soybean in a Vertisol in Central India (Kundu *et al*. 2001) [9]. Shamoot *et al*., 1968 [20] reported that rhizode positon of C from root turnover and exudates represented 5-20% of the above-ground biomass.

Materials and Methods
The experiment was conducted on ten farmer's fields identified from three villages namely Sukali, Alanda and Nimbhara of Barshi Takali tahsil, Akola District, Maharashtra during 2018-19 under Soybean-Chickpea cropping system. The fertility status of the soils indicates that the soils were, low in available nitrogen, medium in available phosphorus and very high in

available potassium. All the selected farmers have been following same cropping pattern for last ten years. Soybean was grown in *kharif* season and chickpea was grown in *rabi* season. Each farmer treated as one treatment. Each sample has been treated as one replication and three samples have been taken from each site. Thus 10 treatments with 3 replications have been studied in RBD design. Leaf litter of soybean plant was collected in *Kharif* season and leaf litter of chickpea plant in *Rabi* season from 1 m^2 area between the two rows. The samples were collected by hand on a nylon net and the weight of leaf litter biomass was recorded. Stubble left after the harvest of crop was collected, washed and weighed. The amount of stubble was estimated as the fraction of total aboveground biomass. Rhizodeposition of C from root turnover and exudates was assumed to be 10 percent of the harvestable above-ground biomass of crop. Carbon sequestration potential was calculated by considering soil organic carbon stock and total carbon input through cropping sequence.

Treatment details

T_1-Conservation tillage for 15 years, No ploughing since 15 years, Harrowing, Crop residues incorporated in soil, T_2-Conservation tillage for 8 years, No ploughing since 8 years, Harrowing, Crop residues incorporated in soil, T_3 - Conservation tillage for 4 years, No ploughing since 4 years, Harrowing, Crop residues incorporated in soil, T_4-Conventional tillage each year, Regular ploughing each year, Harrowing,T_5-Conservation tillage for 12 years, No ploughing since 12 years, Harrowing, Crop residues incorporated in soil, T_6- Conservation tillage for 10 years, No ploughing since 10years, Harrowing, Tillage preparation by five tines implements, Crop residues incorporated in soil, T_7-Conservation tillage for 6 years, No ploughing since 6 years, Harrowing, Crop residues incorporated in soil, T_8-Reduced tillage for alternate year gap, Alternate 1 year gap ploughing, Crop residues incorporated in soil, T_9- Reduced tillage once in 4 year, Alternate 4 year gap ploughing, Crop residues incorporated in soil, T_{10}- Reduced tillage once in 2 year, Alternate 2 year gap ploughing, Crop residues incorporated in soil.

Results and Discussion

Total carbon* addition *through leaf litter biomass and stubble biomass during Kharif 2018-19

It is emanated from the results that total of shaded leaf litter biomass and stubble biomass of soybean were found to range from 4.45 to 5.66 Mg ha^{-1} during 2018-19 (Table 1). The total leaf litter and stubble biomass were recorded significantly higher (5.66 Mg ha^{-1}) under conservation tillage for 15 years along with crop residue addition in soil over the rest of other treatments which was followed by treatment T_5 (5.49 Mg ha^{-1}) and T_6 (5.33 Mg ha^{-1}). Kler and Walia (2006) [8] and Kundu *et al*. (2008) [10] reported that the organic farming treatment supplemented with FYM along with crop residue incorporation recorded higher growth components viz., dry matter accumulation, leaf area index. Carbon input addition through leaf litter biomass and stubble biomass during 2018-19 ranged between 1.74 to 2.27 Mg ha^{-1}. In the present investigation results of carbon input through leaf litter biomass and stubble, biomass was recorded highest in treatment T_1 (2.27 Mg ha^{-1}) which is followed by treatment T_5 (2.22 Mg ha^{-1}) and T_6 (2.16 Mg ha^{-1}) under conservation tillage adopted for 12 and 10 years respectively (Table 1). The increase in leaf litter biomass might be due to the direct incorporation of organic matter which provides a congenial environment for better growth and more plant residues addition. C input increased by 30.45 per cent during 2018-19 as compared to conventional tillage. This might be due to the balancing of organic and inorganic sources which resulted in solubilization of nutrients in the soil and thereby increased the availability to the plants, which resulted in better crop growth into the adequate supply of macro and micronutrients. Similar results were reported by Ghosh *et al*. (2005) [7], Padmavati *et al.* (1998), Lal *et al.* (1999) [11]. Rhizodeposition of C from root turnover and exudates was assumed to be 10 percent of the harvestable above-ground biomass of crop (Shamoot *et al.*, 1968) [20]. It is evident from Table 1. that the total rhizodeposition biomass during *kharif* leaf litter and stubble biomass was observed significantly higher in the treatment where conservation tillage practices followed at 15 years (0.227 Mg ha^{-1}) over the rest of all other treatments while lower rhizodeposition biomass was recorded in treatment under the conventional tillage (0.174 Mg ha^{-1}) during 2018-19. Based on the result, it can be observed that the total carbon input through leaf litter biomass and stubble biomass of soybean was ranged between (1.912 to 2.497 Mg ha^{-1}). It is enumerated that organic carbon was maintained and slightly increased due to the huge biomass or leaf fall of soybean. The higher the biomass addition higher will be the carbon content of the soil. The higher leaf litter biomass production by soybean might be due to other benefits apart from N, P and K supply, such as secondary nutrients micronutrients, enhanced microbial activity and improved soil physical conditions by use of organic and inorganic sources Ghosh *et al.* (2001) [6]. These findings are in accordance with Sapkota *et al.*, (2017) [18] reported that over the seven years, the total carbon input from above-ground residues was 14.5 t ha^{-1} in ZTDSR-ZTW+R (Zero-tilled direct dry-seeded rice followed by zero-tilled wheat with residue retention) and PBDSR-PBW+R (Direct dry-seeded rice followed by direct drilling of wheat both on permanent beds with residue retention), almost sixfold greater than in the other systems. Ghosh *et al.* (2001) [6] enumerated that organic carbon was maintained and slightly increased due to the huge biomass or leaf fall of soybean. Similarly, Liu *et al.* (2014) [13], Maillard and Angers (2014) [14] concluded that manure application and stubble retention are among the most predominant management practices driving SOC changes because they directly add C into the soil and increase carbon input in soil. The combined use of NPK and FYM produced higher biomass and subsequently higher C input (Srinivasarao *et al*., 2014) [21].

Table 1: Effect of conservation agriculture management practices on total Carbon addition through leaf litter biomass and stubble biomass of Soybean-Chickpea during Kharif and Rabi 2018-19.

Treatment		Total Carbon Addition Through Biomass (Leaf litter+Stubble)										
		Total biomass (Mg ha^{-1})		Total C (%)		Carbon Input (Mg ha^{-1})		Rhizo-deposition carbon (Mg ha^{-1})		Total C input (Mg ha^{-1})		Total C input through Soybean + Chickpea (Mg ha^{-1})
		Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif+Rabi*
T_1	Conservation tillage for 15 years	5.66	1.37	158.05	96.84	2.27	0.66	0.227	0.066	2.497	0.730	3.23
T_2	Conservation tillage for 8 years	5.28	1.23	160.98	95.03	2.15	0.58	0.215	0.058	2.361	0.637	2.99
T_3	Conservation tillage for 4 years	5.07	1.14	159.87	93.99	2.05	0.52	0.205	0.052	2.251	0.572	2.82
T_4	Conventional tillage each year	4.45	1.02	158.37	87.84	1.74	0.41	0.174	0.041	1.912	0.452	2.36
T_5	Conservation tillage for 12 years	5.49	1.36	160.06	96.38	2.22	0.65	0.222	0.065	2.440	0.715	3.15
T_6	Conservation tillage for 10 years	5.33	1.33	160.64	93.39	2.16	0.61	0.216	0.061	2.380	0.674	3.05
T_7	Conservation tillage for 6 years	5.13	1.17	153.76	94.24	1.96	0.54	0.196	0.054	2.161	0.594	2.75
T_8	Reduced tillage for alternate year	4.65	1.04	160.61	88.89	1.86	0.43	0.186	0.043	2.044	0.477	2.52
T_9	Reduced tillage once in 4 year	5.00	1.11	158.48	92.52	1.98	0.49	0.198	0.050	2.174	0.545	2.72
T_{10}	Reduced tillage once in 2 years	4.80	1.09	159.46	90.92	1.91	0.47	0.191	0.048	2.096	0.525	2.62
SE(m)±		0.062	0.039	1.051	0.263	0.031	0.018	0.003	0.002	0.034	0.020	-
CD at 5%		0.184	0.117	3.123	0.780	0.092	0.053	0.009	0.005	0.102	0.058	-

Total Carbon addition through leaf litter biomass and stubble biomass during Rabi 2018-19

Data further revealed that the total leaf litter biomass and stubble biomass of chickpea ranged from 1.02 to 1.37 Mg ha^{-1} during 2018-19 (Table 1).The results of total leaf litter and stubble biomass were recorded significantly higher in the treatment (1.37 Mg ha^{-1}) where conservation tillage practices adopted for 15 years over the rest of other treatments during both years which was followed by treatment T_5 (1.36 Mg ha^{-1}) and T_6 (1.33 Mg ha^{-1}) which found at par with each other during 2018-19. The carbon input through leaf litter biomass and stubble biomass of chickpea during 2018-19 ranged between (0.41 to 0.66 Mg ha^{-1}). On present investigation results of total carbon input in leaf litter biomass and stubble biomass during the first year was recorded highest (0.66 Mg ha^{-1}) in treatment T_1 where conservation tillage practices done for 15 years. Lower (0.41 Mg ha^{-1}) carbon input was noted in treatment T_4. The lower rhizodeposition biomass of chickpea leaf litter and stubble biomass was recorded in treatment T_4 (0.041Mg ha^{-1}) where conservation tillage practices followed at each year. Significantly higher rhizodeposition biomass of chickpea leaf litter and stubble biomass was observed in T_1 (0.066 Mg ha^{-1}) where conservation tillage practices followed for 15 years along with crop residue management over the rest of all other treatments during 2018-19 and 2019-20. The highest total carbon input recorded in treatment T_1 (0.730 mg ha^{-1}) during 2018-19 where conservation tillage practices were adopted for 15 years which is at par with treatment T_5 (0.715 Mg ha^{-1}). Due to the production of higher straw yield, the total carbon input was recorded higher where conservation tillage practices were adopted for 15 years. Furthermore, it was observed that the total carbon input through Soybean-chickpea cropping system was ranged from 2.36 to 3.23 Mg ha^{-1} during 2018-19. The highest total carbon input was recorded in treatment where conservation tillage practices followed at 15 years (3.23 Mg ha^{-1}) and the lowest was observed in treatment T_4 (2.36 Mg ha^{-1}) during both the year. By adoption of conservation tillage practices along with residue retention of leaf litter biomass and stubble biomass total carbon input addition was increased by 36.86 per cent over conventional tillage. Nutrient management influences C input to soil by stimulating crop residue production and retention in the soil after crop harvest (Schuman *et al*., 2002) [19].

Carbon sequestration potential

Carbon sequestration potential was calculated by considering soil organic carbon stock and total carbon input through cropping sequence. Carbon sequestration potential was ranged between 13.53 to 17.22 Mg ha^{-1} during 2018-19 (Table 2).The treatment T_4 having conventional tillage practice for each year showed lower carbon sequestration potential (13.53 Mg ha^{-1}) during 2018-19 while higher carbon sequestration potential was observed in treatment T_1 (17.22 Mg ha^{-1},) where conservation tillage practices followed for 15 years along with crop residue management practices. This might be one of the reasons for higher SOC sequestration as it could provide more carbon through plant biomass addition to soil (Manna *et al.*, 2005) [15]. The effectiveness of soil C sequestration potential depends on the quantity and quality of biomass returned to the soil and the principal source of biomass is the crop residues due to this carbon sequestration was higher in treatment where conservation tillage was done along with residue incorporation in soil. Large variability in SOC sequestration rate may be attributed to a high diversity of cropping systems, amount and frequency of biomass C input, and soil properties (Batlle-Bayer *et al*., 2010) [1]. Conservation agriculture with continuous input of a large amount of biomass to the soil surface creates a positive C budget, enhances the C sequestration, and restoration soil organic carbon (De Oliveira Ferreira *et al*., 2018) [5], increasing soil quality and agronomic productivity (Sa *et al.*, 2015) [17].

Table 2: Carbon sequestration potential under Soybean -Chickpea sequence in Vertisols during 2018-19

Treatments		C sequestration Potential (Mg ha^{-1})
		Soybean-Chickpea Sequence
T_1	Conservation tillage for 15 years	17.22
T_2	Conservation tillage for 8 years	17.07
T_3	Conservation tillage for 4 years	16.13
T_4	Conventional tillage each year	13.53
T_5	Conservation tillage for 12 years	17.13
T_6	Conservation tillage for 10 years	16.72
T_7	Conservation tillage for 6 years	16.40
T_8	Reduced tillage for alternate year gap	14.92
T_9	Reduced tillage once in 4 year	15.39
T_{10}	Reduced tillage once in 2 years	15.91

***Note:** C sequestration potential = (SOC Stock Mg ha^{-1}) + (Total C input through Soybean-Chickpea sequence Mg ha^{-1})

Conclusions

The consistent adoption of conservation agricultural management practices along with residue management improves the total carbon input, carbon sequestration potential and soil carbon stocks. Under conservation agricultural system with continuous addition of a large amount of biomass to the soil surface creates a positive C budget, enhances the C sequestration and restoration soil organic carbon. Therefore based on the results generated it is advocated to follow conservation agricultural practices involving reduced intensity of tillage along with residue management for long-term sustainability of soil.

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