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STUDIES ON SOIL PHYSICAL PROPERTIES AS AFFECTED BY CONSERVATION TILLAGE AND LAND MANAGEMENT PRACTICES IN DIFFERENT SEQUENCE CROPPING SYSTEMS UNDER RAINFED CONDITIONS

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Abstract– A field experiment on conservation agriculture was conducted on a fixed plot at main agricultural research station, Dharwad, Karnataka to evaluate the effect of conservation agriculture practices on soil physical properties. After four years of experimentation, soil analyses results revealed that all conservation tillage with broad bed and furrow and flat bed, crop residues retained on the surface and partial incorporation in to the soil showed significantly improved soil physical properties *viz*. percent aggregate stability, bulk density, total porosity, maximum water holding capacity and penetration resistance at plough depth. Conventional tillage with incorporation of crop residues performed significantly superior as compared to conventional tillage with no crop residues where all crop residues were removed and land was ploughed.

INTRODUCTION

Widespread degradation of natural resources in rainfed areas and climate change are threatening the national food security. This has brought about focus on rainfed ecology now affected has very low level of sustainability. In rainfed areas conservation of natural resources is essential for increasing the crop productivity and sustainable natural resource base. Conservation agriculture has been proposed as a widely adapted set of management principles that can assure more sustainable agricultural production under such situations. It involves three basic principles mainly minimum soil disturbance, crop residue cover and crop diversification, wherein it conserves, improves and makes more efficient use of natural resources through integrated management of soil, water, crops and other biological resources in combination with selected external inputs.

Agro-ecology specific conservation agriculture strategies are needed in rainfed production systems that have the scope in saving time, reduce cost of production and increase soil carbon sequestration and nutrient stratification. Conservation tillage is a widely-used terminology in conservation agriculture to denote soil management systems that result in at least 30 per cent of the soil surface being covered with crop residues after seeding of the subsequent crop. This helps to improve the soil organic carbon, physical, chemical and biological properties. Tillage, residue management and crop rotation have a significant impact on soil physico-chemical properties, microbial activity, nutrient distribution and transformation in soil (Sharma *et al*., 2021). With this importance and usefulness of conservation agriculture on soil properties, a field experiment was carried out to study effect of conservation tillage and land management practices on soil physical properties under rainfed conditions.

METHODOLOGY

A fixed plot field experiment was initiated during 2013-14 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka, during *kharif* and *rabi* seasons and after four years of experimentation the results were discussed in this article. The soil textural class of the experimental site was *Typic Haplusters*, having medium organic carbon content (5.2 g kg^{-1}), low in available nitrogen (240.8 kg ha^{-1}), high in available phosphorus (26 kg ha^{-1}) and potassium (335 kg ha^{-1}).

The experiment was laid out in strip-split block design with three replications. Main plots consisted of six vertical blocks mainly, CT_1: No tillage with broad bed and furrow (BBF) and crop residues retained on the surface, CT_2: Reduced tillage with BBF and partially incorporation of crop residues, CT_3: Notillage with flatbed (FB) with crop residues retained on the surface, CT_4: Reduced tillage with FB with partially incorporation of crop residues, CT_5: Conventional tillage with crop residues incorporation and CT_6: Conventional tillage with no crop residues as control. Sub plots in horizontal blocks having three cropping systems in sequence *viz*. CS_1: Groundnut - sorghum, CS_2: Soybean - wheat and CS_3: Maize - chickpea, and two subsubplots, NM_1: Recommended dose of fertilizer (RDF) and NM_2: RDF + Farm Yard Manure (FYM). In CT_1 and CT_3 treatments for surface crop residues retention rotaslasher was passed in the standing crop stalk. In CT_2 and CT_4 for partial incorporation of crop residues rotavator was passed to shredthe residues and incorporation. In CT_5 plot, residues were incorporated at the time of ploughing and in control plot (CT_6) all the crop residues were removed after harvesting of both *kharif* and *rabi* crops and land was ploughed. After the harvest of *rabi* crops a composite soil samples were drawn to a depth of 15 cm from all treatments and analysed for various physical properties. Methodologies used to analyse the different properties is as follows. Soil aggregated stability by wet sieving method as outlined by Yoder (1936), bulk density by clod method (Black, 1965) maximum water holding capacity by Keen-Raczkowaski brasscup method as described by Piper (1966) and penetration resistance by soil penetrometer. The data collected from the experimental field and laboratory analysis were subjected to standard statistical analysis (Gomez and Gomez, 1984). The treatments were compared by using Duncan's multiple range test (DMRT).

RESULTS AND DISCUSSION

After four years of conservation agriculture experimentation on a fixed sight the fourth year data revealed that conservation tillage practices had significantly positive impact on soil physical properties. All conservation tillage systems with cop residues retained on the surface and partial incorporation recorded significantly higher aggregate stability, total porosity, maximum water holding capacity, and lesser bulk density and lower penetration resistance. However conventional tillage with incorporation of total crop residues performed significantly better as compared to conventional tillage with no crop residues treatment. Cropping systems did not showed any significant influence on soil aggregate stability and maximum water holding capacity. However maize-chickpea system recorded significantly lower bulk density and penetration resistance and increased porosity as compared to groundnut-sorghum and soybean-wheat systems. Nutrient management practices had significant influence on aggregated stability and on rest of the physical properties showed no significant effect.

Aggregate stability

Soil physical properties mainly content of macro aggregates, water stable aggregates, water holding capacity, bulk density and total porosity of the soil, directly influence the crop growth by influencing on diffusion and exchange of gases especially oxygen and carbon dioxide, and water availability. Continuity of pores and voids to retain and transmit fluids, organic and inorganic substances will determine the vigorous root growth and development. After four years of conservation agriculture experimentation on a fixed sight the fourth year data revealed that all conservation tillage practices had significantly increased 3-4 % soil water stable aggregates of size more than 0.25 mm over conventional tillage with no crop residues (Table 1). Whereas conventional tillage with crop residues incorporation improved 1% of water stable aggregates over control.

The reduced aggregation in conventional tillage was mainly due to tillage disturbance effect on macro aggregate and also disturbance for soil aggregate formation. The aggregate formation process in conventional tillage was interrupted each time the soil was tilled with the corresponding destruction of aggregates, and fragments of roots and mycorrhizal hyphae which are major binding agents for macro aggregates (Bronick and Lal, 2005). The residues retained on the surface in no tillage plots (CT_1 and CT_3) may protect the soil from rain drop impact and improves soil organic carbon content by continuous addition of previous crop residues. Organic carbon content is key component for microbial diversity and their activity. Some of polysaccharides and proteins like glomaline produced by microbe's act as a binding agents for

Table 1. Effect of different tillage and land management practices on soil physical properties

Treatment		Aggregate stability (%)			Bulk density (g cc^{-1})			Porosity (%)		
Tillage practices (CT)		Nutrient management (NM)			Nutrient management (NM)			Nutrient management (NM)		
Cropping systems (CS)		NM_1	NM_2	Mean	NM_1	NM_2	Mean	NM_1	NM_2	Mean
CT_1	CS_1	63.1 c-g	63.3 b-f	63.1a	1.21de	1.21de	**1.21b**	54.5a-d	54.5a-d	**54.4a**
	CS_2	62.4 ij	62.5 h-j		1.21de	1.22cd		54.2c-f	53.9e-g	
	CS_3	63.4 a-d	63.9 a		1.21de	1.20e		54.3b-e	54.7ab	
CT_2	CS_1	62.6 h-j	62.8 e-i	62.6a	1.21de	1.21de	1.21b	54.2c-f	54.5a-d	54.5a
	CS_2	62.2 jk	62.5 hj		1.21de	1.21de		54.5a-d	54.3b-e	
	CS_3	62.8 f-i	62.6 g-j		1.20e	1.20e		54.8a	54.7ab	
CT_3	CS_1	62.9 e-i	63.2 c-f	63.2a	1.22cd	1.21de	1.21b	54.1d-g	54.3b-e	54.2a
	CS_2	62.5 h-j	63.0 d-h		1.22cd	1.23dc		54.0e-g	53.7gh	
	CS_3	63.8 ab	63.6 a-c		1.20e	1.21de		54.6a-c	54.5a-d	
CT_4	CS_1	62.9 e-i	63.3 b-e	63.0a	1.21de	1.20e	1.21b	54.5a-d	54.6a-c	54.5a
	CS_2	62.6 g-j	62.6 g-j		1.21de	1.22cd		54.2c-f	54.1d-g	
	CS_3	63.3 b-f	63.1 c-g		1.20e	1.20e		54.8a	54.7ab	
CT_5	CS_1	61.1 n-p	61.4 l-n	61.4b	1.22cd	1.23bc	1.21b	53.8fg	53.7gh	53.6a
	CS_2	61.0 n-q	61.3 m-o		1.24ab	1.24ab		53.3hi	53.2i	
	CS_3	61.7 lm	61.8 kl		1.22cd	1.22cd		53.8fg	53.8fg	
CT_6	CS_1	60.4 r	60.8 o-r	60.8c	1.24ab	1.24ab	1.24a	53.2i	53.3hi	53.3b
	CS_2	60.5 qr	61.0 n-q		1.25a	1.24ab		53.0i	53.1i	
	CS_3	60.8 p-r	61.3 l-n		1.24ab	1.23bc		53.3hi	53.7gh	
NM Mean			62.2b	62.5a		1.22a	1.22a		54.1a	54.1a
CS Mean										
CS_1			62.3a			1.22a			54.1b	
CS_2			62.0a			1.22a			53.8c	
CS_3			62.7a			1.21b			54.3a	
Sources			S.Em. ±			S.Em. ±			S.Em. ±	
CT			0.3			0.006			0.22	
CS			0.2			0.001			0.04	
NM			0.02			0.001			0.03	
CT × CS × NM			0.1			0.004			0.14	

Figures with same alphabet did not differ significantly at 5 % level of probability

Main plots
CT_1: No tillage with BBF and crop residues retained on the surface
CT_2: Reduced tillage with BBF and incorporation of crop residues
CT_3: No tillage with flat bed with crop residues retained on the surface
CT_4: Reduced tillage with flat bed with incorporation of crop residues
CT_5: Conventional tillage with crop residues incorporation
CT_6: Conventional tillage (no crop residues)

Sub plots
CS_1: Groundnut – Sorghum
CS_2: Soybean - Wheat
CS_3: Maize - Chickpea

Sub-sub plots
NM_1: RDF (Recommended doses of fertilizer)
NM_2: RDF + FYM (Farm Yard Manure)

soil aggregation. Due to the presence of more organic matter and crop residues in conservation tillage plots might have increased microbial diversity bacteria, fungi, mycorrhizal population and had direct influence on soil aggregate formation (Degryze *et al*., 2005, Six *et al*., 2004).

Cropping systems had no significant influence on aggregate stability however nutrient management practices had very lesser influence on soil aggregation (0.4 %). Which means FYM application can be excluded in long term conservation tillage practices where complete crop residues were used for incorporation or for mulching.

Bulk density and porosity

The total porosity is normally calculated from bulk density and these are indirectly proportional to each other. All conservation tillage practices and conventional tillage with incorporation of crop residues noticed significantly lower bulk density (2.4 %) and higher porosity (2.25 %) as compared to conventional tillage with no crop residues (1.24 $g\ cc^{-1}$ and 53.3%) (Table 1). This might be due to the presence of higher soil organic carbon content in the top layer which influenced soil aggregate formation, which improves micro and macro porosity of the soil in turn decreased the bulk density. Whereas, in

Table 2. Effect of different tillage and land management practices on soil physical properties

Treatment Tillage practices (CT)	Cropping systems (CS)	Maximum water holding capacity (%) Nutrient management (NM)			Penetration resistance (kPa) Nutrient management (NM)		
		NM_1	NM_2	Mean	NM_1	NM_2	Mean
CT_1	CS_1	53.9a-d	53.9a-d	53.8a	409.4j-o	412.0h-o	410.5c
	CS_2	53.7c-e	53.4ef		415.0f-l	416.3f-l	
	CS_3	53.8b-e	54.2ab		404.3l-o	405.8l-o	
CT_2	CS_1	53.7c-e	53.9a-d	54.0a	404.3l-o	405.7 l-o	403.9c
	CS_2	53.9a-d	53.8b-e		404.7 l-o	410.7i-o	
	CS_3	54.3a	54.2ab		398.7o	399.3o	
CT_3	CS_1	53.5d-f	53.8b-e	53.6a	411.3h-o	413.0g-n	411.6bc
	CS_2	53.4ef	53.2f		414.7g-l	420.7e-j	
	CS_3	54.0a-c	53.9a-d		404.0l-o	406.0l-o	
CT_4	CS_1	53.9a-d	54.0a-c	53.9a	407.0l-o	408.7j-o	407.9c
	CS_2	53.7c-e	53.5d-f		414.3g-m	416.0f-l	
	CS_3	54.3a	54.2ab		400.3no	401.0m-o	
CT_5	CS_1	50.6g	50.5g	50.4a	424.3c-h	426.0c-g	425.8ab
	CS_2	50.1h	50.0h		434.0a-d	427.7c-f	
	CS_3	50.6g	50.6g		420.0e-k	422.6d-i	
CT_6	CS_1	47.9ij	48.0ij	47.9b	435.5g-i	441.2a-c	438.2a
	CS_2	47.7j	47.8j		441.7ab	444.4a	
	CS_3	48.0ij	48.3i		431.7b-e	434.8a-d	
NM Mean			52.3a	52.3a		415.3a	417.3a
CS Mean							
CS_1			52.3a			416.5a	
CS_2			52.0a			421.7a	
CS_3			52.5a			410.7b	
Sources			**S.Em. ±**			**S.Em. ±**	
CT			0.16			4.7	
CS			0.04			1.2	
NM			0.03			0.9	
CT × CS × NM			0.13			3.9	

Figures with same alphabet did not differ significantly at 5 % level of probability

Main plots

CT_1: No tillage with BBF and crop residues retained on the surface

CT_2: Reduced tillage with BBF and incorporation of crop residues

CT_3: No tillage with flat bed with crop residues retained on the surface

CT_4: Reduced tillage with flat bed with incorporation of crop residues

CT_5: Conventional tillage with crop residues incorporation

CT_6: Conventional tillage (no crop residues)

Sub plots

CS_1: Groundnut – Sorghum

CS_2: Soybean - Wheat

CS_3: Maize - Chickpea

Sub-sub plots

NM_1: RDF (Recommended doses of fertilizer)

NM_2: RDF + FYM (Farm Yard Manure)

conventional tillage, ploughing which directly influenced the bulk density and pore size distribution. Continuous ploughing might destruct the macro soil aggregates and also cause the organic carbon redistribution in the top plough layer which has resulted in loss of organic carbon and destruction of soil aggregates. Hence, it recorded higher bulk density and lower porosity (Gal *et al*., 2007; Thomas *et al.,* 2007; Hernanz *et al*., 2014). Yang and Wander (1999) found lower bulk density with zero tillage than with mould board tillage in the 0-5 cm and 20-30 cm soil layer.

Crop rotation and incorporation or mulching of previous crop residues had significant influence on bulk density of soil by altering the organic carbon input and microbial activity. Maize-chickpea systems recorded lower bulk density (1.21 g cc^{-1}) and increased total porosity (54.3 %) than groundnut-sorghum and soybean-wheat systems, which might be due to more biomass production and application in these systems which influenced the soil organic carbon and aggregate formation which might have reduced bulk density and increased porosity of the soil. Whereas nutrient management practices had no significant influence on bulk density and porosity.

Maximum water holding capacity

Per cent maximum water holding capacity was higher in all conservation tillage practices and recorded 12-13% increase over conventional tillage with no crop residues (Table 2). Conventional tillage with incorporation of crop residues noticed 5% increase in maximum water holding capacity (50.4 %) of the soil over no crop residues (47.9 %). This was mainly because of higher organic matter content which is an adsorbing agent for water molecules and increased water movement in reduced tillage and no tillage practices due to the larger macropore conductivity as a result of increased bio pores that were commonly observed in conservation tillage practices (Eynard *et al*., 2004; McGarry *et al*., 2000). Hudson (1994) showed that over a wide range of soils, there was an increase in water availability with increase in soil organic matter. Cropping systems and nutrient management practices has no significant influence on soil maximum water holding capacity.

Soil penetration resistance

Significantly lower soil penetration resistance observed in reduced tillage with BBF with partial incorporation of crop residues (403.9 kPa) and reduced tillage with FB and partial incorporation of crop residues (407.9 kPa) as compared to conventional tillage with and without crop residues incorporation (425.8 and 438.2 kPa respectively). Maize-chickpea cropping system noticed significantly lower penetration resistance (410.7 kPa) as compared to groundnut-sorghum and soybean-wheat systems (416.5 and 421.7 kPa respectively). Whereas, nutrient management practices did not noticed any significant differences (Table 2). Increased penetration resistance in conventional tillage plots might be due to the continuous ploughing of soil which resulted in destruction of soil structure and particle arrangement and creation of plough pan at a plough depth. Addition of higher level of crop residues in maize-chickpea and its recycling had significantly resulted in higher organic carbon recycling which inturn improved micro and macro fauna in the soil. The increased microbial diversity and activity might have influenced on better development of soil physical properties in conservation tillage as compared to conventional tillage practices.

CONCLUSION

Combination of no tillage with BBF and FB and crop residues retained on the surface or partial incorporation in sequence cropping systems recorded significantly improved soil physical properties.

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