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Impact of conservation agriculture production system on soil physical properties

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Abstract
The research entitled “Effect of conservation production system on soil properties and carbon dynamics in rainfed condition” was conducted at AICRP for dryland agriculture, UAS, GKVK, and Bangalore during *Kharif* 2020. With three main plot treatments “Tillage practices” (M_1-Conventional tillage, M_2-Reduced tillage, M_3-Zero tillage) and three sub plot treatments ‘Cover crops’ (C_1-Control, C_2-Field bean, C_3-Horse gram) replicated thrice and laid out in split plot design. Among different tillage practices zero tillage (M_3) with field bean (C_2) as surface mulch improved field capacity (15.39%) and MWHC (33.75%) while horse gram (C_3) as surface mulch improved aggregate stability (85.80%) compared to conventional tillage practices without surface mulch. Overall, adoption of conservation agriculture crop mulching and reduced tillage operations promotes the soil physical properties under rainfed condition.

Keywords: Conventional tillage, reduced tillage, mulching

Introduction
Conservation agriculture (CA) system consists of no or minimal tillage and permanent soil cover, either with a live crop or with crop stubbles and diversified crop rotation that include legumes (FAO, 2019) [4]. An overall CA farming system is meant to ensure the sustainability of agriculture through conserving and protecting soil, water, and biological resources as much as possible with minimal external inputs, and it is associated with many benefits such as greater soil aggregation and water storage, improved soil quality, decreased erosion and in some instances higher yield and net farm income. This has led to the identification of conservation agriculture as a valuable tool to ensure future food production and to buffer agricultural productivity (FAO, 2019) [4].
Applying conservation agriculture essentially means altering literally generations of traditional farming practices and implement use. As such, the movement towards conservation agriculture-based technologies normally is comprised of a sequence of step-wise changes in cropping system management to improve productivity and sustainability. Reduced tillage systems in the United States have been shown to reduce soil erosion, reduce nutrient losses from the field, sequester carbon as a result of increasing organic matter, and increase crop yields. The widespread adoption of CA resulted in significant development of farmer profitability which is achieved through increased agricultural productivity and reduced input costs.
Soil tillage (soil surface management to alleviate soil related constraints to crop production) is a basic and an important input with short and long term effects on sustainability. It influences agriculture sustainability through its effects on soil properties, soil processes and crop growth. Appropriate tillage systems are soil and crop specific, and their adoption is governed by both bio-physical and socio-economic factors. In addition to increasing crop yields, tillage method facilitate soil and water conservation, improve root system development, maintain a favorable level of soil organic matter content and reduce soil degradation (Lal, 1991) [11].
Crop residue and tillage affects the soil environment directly or indirectly, incorporation of crop residue into soil or retention on the surface through the adaptation of conservation agriculture practice has positive influence on physical, chemical and biological properties of soil.

Hence, the present study was undertaken to assess the effect of different management practices on soil physical properties, the present investigation entitled "Effect of conservation production system on soil physical properties in Rainfed condition" at AICRP on Dry Land Agriculture, UAS, GKVK.

Material and Methods

Experimental site and treatment details

The field experiment was carried out during *Kharif*-2020 at AICRP for Dry Land Agriculture, UAS, GKVK, and Bengaluru-65. It is located in the Eastern Dry zone of Karnataka at 13º 05' N latitude and 77^0 34' E longitude with an altitude of 924 meters above Mean Sea Level (MSL). The total rainfall during 2020 at AICRP for Dryland Agriculture, GKVK, and Bengaluru was 1,182.2 mm with maximum rainfall during July (242.8 mm) and minimum during January and February (0.0 mm). The maximum and minimum temperature of 29.1 ºC and 18.2 ºC was observed during the cropping year. Relative humidity of 89.6 per cent was recorded during the cropping period.

The soils of Gandhi Krishi Vignana Kendra (GKVK) belongs to Vijayapura series which is a dominant soil series of Bengaluru plateau. The soils of experimental site at AICRP on Dry Land Agriculture Project represents the typical lateritic area of Bengaluru plateau. These soils are classified as fine, kaolinitic, isohyperthermic, Typic Kandiustalf as per USDA classification. These soils are deep, yellowish red, lateritic, red sandy clay loam with good drainage and are derived from granite-gneiss under subtropical semi-arid climate.

Cropping history of the experimental plot

In the experimental plot Inter cropping of finger millet (*Eleusine coracana* (L.) Gaertn) + Pigeon pea (*Cajanus cajan*) was grown during *Kharif* 2019 and left fallow during Rabi and summer. The physico-chemical properties of initial soil sample (1986) of the experiment site were given in Table 1 and experimental details in Table 2.

Soil sampling, processing and analysis

Soil samples from experimental area were collected from 0-15 cm, after the harvest of the crop. The collected soil samples were air dried, powdered with a wooden mallet, passed through 2 mm sieve, stored in polythene bags and analysed for various physical properties adopting standard procedure. The physical variables included the aggregate size distribution which was determined by wet sieving (Yoder apparatus) and the values were expressed as mean weight diameter (MWD) after oven drying (Van Bevel, 1949) [19], water holding capacity, porosity particle density and bulk density by Keen Raczkowsks cup method given by Piper, 1966 [14] field capacity and permanent wilting point by pressure plate apparatus (Richards, 1954) [15] and soil texture by International pipete method (Piper, 1966) [14].

Statistical analysis

The observations recorded in these studies were analyzed statistically for test of significance following the Fisher's method of analysis of variance (ANOVA) as outlined by Gomez and Gomez (1984) [5]. Whenever F-test was significant for comparison amongst the treatments means an appropriate value of critical differences (CD) was worked out. Otherwise against CD values, abbreviation NS (Non-Significant) was indicated. All the data were analyzed and the results are presented and discussed at a probability level of 0.05 per cent and correlation and regression study was done as given by Gomez and Gomez (1984) [5].

Table 1: Initial soil physical properties of experimental site as influenced by conservation production system

Treatments	Bulk Density (g cc^{-1})	Particle Density (g cc^{-1})	MWHC (%)	Porosity (%)
Tillage practice				
M_1: Conventional tillage	1.40	2.81	31.67	39.74
M_2: Reduced tillage	1.45	2.84	32.09	41.21
M_3:Zero tillage	1.55	2.93	32.84	41.11
S.E.M. ±	0.02	0.03	0.88	1.01
CD (P=0.05)	0.07	NS	NS	NS
Cover crops				
C_1: Control	1.47	2.90	32.24	38.31
C_2: Field bean	1.46	2.82	32.87	42.94
C_3: Horsegram	1.45	2.82	33.53	41.31
S.E.M. ±	0.02	0.03	0.88	1.01
CD (P=0.05)	NS	NS	NS	NS
Interaction				
M_1C_1	1.40	2.84	32.57	38.86
M_1C_2	1.41	2.88	33.69	39.87
M_1C_3	1.38	2.72	34.75	40.49
M_2C_1	1.44	2.84	32.17	39.73
M_2C_2	1.45	2.81	31.97	42.87
M_2C_3	1.44	2.85	32.17	41.62
M_3C_1	1.58	2.99	31.96	40.33
M_3C_2	1.52	2.87	33.00	43.08
M_3C_3	1.54	2.93	33.69	42.84
S.E.M. ±	0.04	0.05	1.2	0.81
CD (P=0.05)	NS	NS	NS	NS

Table 2: Experimental details

Location	AICRP for Dryland agriculture.
Crop	Finger millet (*Eleusine coracana*), Pigeon pea (*Cajanus cajan*)
Cropping system	Inter cropping (8:2) Finger millet + Pigeonpea with conservation furrow
Variety	Finger millet – MR-1, Pigeon pea - BRG-5
Spacing	Finger millet (30cm × 10cm), Pigeon pea (60cm × 30cm)
Seed rate	Finger millet 12.5kg/ha, Pigeon pea 12-15kg/ha
No of treatments	9
No of replication	3
Number of plots	27
Design	Split plot design
Plot size	9.0 x 9.9 m
NPK	Finger millet (50:40:37.5 kg/ha), Pigeonpea (25:50:25 kg/ha)
FYM	Finger millet, Pigeon pea (15 t/ha)

Treatment details

A. Main Plot Treatments

M_1	Conventional tillage (1 tractor drawn ploughing + 2 harrowing + 1 intercultural operations).
M_2	Reduced tillage (1 harrowing + 1 intercultural operation + pre emergence herbicide).
M_3	Zero tillage (1 intercultural operation + pre emergence herbicide).

B. Sub Plot Treatments

C1	Control (no cover crops)
C2	Field bean (HA-4) leaving the residue after harvesting the green pods for vegetable
C3	Horse gram in-situ and mulching

Results and Discussion

Impact of conservation agriculture production system on soil physical properties

The effect of conservation agriculture on per cent water stable aggregates and mean weight diameter

The effect of conservation agriculture production system in Finger millet + Pigeonpea intercropping system on per cent water stable aggregates and mean weight diameter is presented in Table 3.

Different tillage practice *viz.*, conventional, reduced and zero tillage showed significant difference with respect to per cent water stable aggregates and mean weight diameter. Among different tillage practices zero tillage (M_3) recorded significantly higher per cent water stable aggregates (81.52%) and mean weight diameter of aggregates (1.86 mm) than conventional tillage (M_1). There was no significant difference with per cent water stable aggregates among different cover crops but was significant with mean weight diameter of aggregates. Growing of horse gram as cover crop recorded higher aggregate mean weight diameter (1.75 mm) than others. The Interaction effect between different tillage practices and cover crop were found non-significant with numerically higher values for per cent water stable aggregates (85.27%) and mean weight diameter of aggregates (1.94 mm) in M_3C_3 (Zero tillage + Horsegram).

Organic matter which is a key factor for soil aggregation, the management of crop mulches which is a key to soil structural development and stability, showed that the addition of organic substrates to soil improves its structure (Ladd *et al*., 1977) [10]. Fresh residue forms the nucleation centre for the formation of new aggregates by creating hot spots for microbial activity where new soil aggregates are developed (De-Gryze *et al.*, 2005) [3].

Earlier studies indicated that zero tillage with cover crops improved dry aggregate size distribution compared to conventional tillage (Govaerts *et al*., 2007) [6]. Li *et al*., (2007) [12] reported that, the effect on water stability of aggregates was more pronounced, with the increase in MWD of wet sieving of aggregates. Similarly, In a study on tillage effects on silty loam soil for five years under rice wheat system, Kumari *et al*. (2011) [8] reported that ZT system resulted in 2 to 4 times higher macro aggregates (> 0.25 mm) than micro aggregates (0.053-0.25 mm). Results were in line with, Somasundaram *et al*. (2018) [18] who studied the effect of tillage and cropping systems on soil aggregation in Vertisols of Central India and reported that after four years of study, water stable aggregates (WSA) were significantly affected by tillage and soil depth and their interactions.

Bulk density and Particle density

The effect of conservation agriculture production system in Finger millet + Pigeonpea intercropping system on bulk density and particle density of soil is presented in Table 4.

Bulk density which is one of the important indicator of soil health and its compactness influences various soil functions such as infiltration, plant root development, soil aeration, nutrient availability. There was no significant difference observed in bulk density and particle density among different tillage practices and it ranged from 1.32 to 1.43 g cm^{-3} and 2.32 to 2.65 g cm^{-3}. Among different cover crops, significant difference was noticed with lower bulk density (1.42 g cm^{-3}) and particle density (2.63 g cm^{-3}) in C_3 (Field bean as cover crop). However, Interaction effect between different tillage practice and cover crops was found non- significant.

Singh *et al.* (2016) [17] studied the long term (15 years) effect of tillage (CT and ZT) in three different soil types under rice-wheat cropping system and reported that reducing tillage intensity from the CT to ZT resulted in an increase in bulk density of the surface soil. Similarly, Chikkaramappa *et al.* (2014) [2] cited that addition of organic manures results in the decrease in bulk density and increase in porosity of soil.

Table 3: Per cent water stable aggregates and mean weight diameter as influenced by conservation agriculture practice in finger millet + pigeon pea intercropping (8:2)

Treatments	% Water stable aggregates	Mean weight Diameter (mm)
Tillage practice		
M_1: Conventional tillage	67.22	1.43
M_2: Reduced tillage	78.00	1.78
M_3:Zero tillage	81.52	1.86
S.E.M. ±	2.53	0.05
CD (P=0.05)	9.92	0.19
Cover crops		
C_1: Control	72.43	1.57
C_2: Field bean	75.38	1.74
C_3: Horsegram	78.92	1.75
S.E.M. ±	2.64	0.04
CD (P=0.05)	NS	0.12
Interaction		
M_1C_1	65.92	1.38
M_1C_2	66.04	1.48
M_1C_3	69.69	1.42
M_2C_1	74.88	1.63
M_2C_2	77.30	1.82
M_2C_3	81.81	1.89
M_3C_1	76.49	1.72
M_3C_2	82.80	1.93
M_3C_3	85.27	1.94
S.E.M. ±	4.58	0.07
CD (P=0.05)	NS	NS

Porosity and maximum water holding capacity

The effect of conservation agriculture production system in Finger millet + Pigeonpea intercropping system on porosity and maximum water holding capacity of soil is presented in Table 3.

The increased organic matter status, aggregation and pore size distribution influences porosity of soil while the water holding capacity (WHC) of soil depends on organic matter, number of pores, size of pores and specific area of soil. Significant difference was recorded among different tillage practices with higher values of porosity (42.32%) and water holding capacity (36.46%) in zero tillage (M_3). Among cover crops significant effect was noticed only with respect to porosity (43.53%) and numerically higher maximum water holding capacity (35.00%) was with field bean as cover crop (C_2). Interaction between different tillage practices and cover crops showed significant variation with respect to water holding capacity with higher value in M_3C_2 (36.93%).

Table 4: Bulk density, particle density, maximum water holding capacity and porosity of soil as influenced by tillage practice and cover crops in finger millet + pigeon pea intercropping (8:2)

Treatments	Bulk Density (g/cc)	Particle Density (g/cc)	MWHC (%)	Porosity (%)
Tillage practice				
M_1: Conventional tillage	1.43	2.65	33.12	39.47
M_2: Reduced tillage	1.46	2.71	33.41	41.04
M_3:Zero tillage	1.52	2.82	36.46	42.32
S.E.M. ±	0.02	0.03	0.87	0.79
CD (P=0.05)	NS	NS	NS	3.08
Cover crops				
C_1: Control	1.53	2.84	33.49	39.34
C_2: Field bean	1.42	2.63	35.00	43.53
C_3: Horsegram	1.46	2.71	34.50	42.95
S.E.M. ±	0.01	0.02	0.51	0.48
CD (P=0.05)	0.04	0.07	NS	1.47
Interaction				
M_1C_1	1.49	2.76	32.01	38.03
M_1C_2	1.42	2.63	32.44	39.85
M_1C_3	1.39	2.56	34.91	40.52
M_2C_1	1.53	2.84	32.90	40.71
M_2C_2	1.46	2.70	35.67	43.16
M_2C_3	1.40	2.59	31.66	42.24
M_3C_1	1.58	2.91	35.56	40.29
M_3C_2	1.51	2.80	36.93	43.59
M_3C_3	1.49	2.75	36.88	42.08
S.E.M. ±	0.02	0.04	0.88	0.83
CD (P=0.05)	NS	NS	2.72	NS

Kursheed *et al*. (2019) [9] reported the conservation tillage improves soil aggregate stability that enhances nutrient retention and reduces soil erosion thereby contributing to soil fertility and mediates air permeability, water infiltration, and nutrient cycling. CT is particularly important in arid and semi-arid zones, where water is the limiting factor for crop development and thus crop mulching is essential to achieve sustainable yields. CT with mulch/ cover crop improved the soil porosity, soil structure, and water transmission in Alfisols.
The results are in agreement with findings of Saha *et al.* (2010) [16] who reported increase in porosity due to better aggregation and changing pore size distribution of soil and WHC is governed by porosity of soil. Hatfield *et al*. (2001) [7] Showed that conservation agriculture has the potential to increase water holding capacity over a wide range of soils. Soil management practices that increase the organic matter content of the soil could have a positive impact on the soil water holding capacity consequently, there was an increase in water availability with increases in soil organic matter.

Field capacity and permanent wilting point

Effect of conservation agriculture practice in finger millet + pigeon pea intercropping system on field capacity and permanent wilting point are presented in Table 5.

Table 5: Field capacity and permanent wilting point as influenced by conservation agriculture practice in finger millet + pigeon pea intercropping (8:2)

Treatments	Field capacity (Moisture content at 0.3 bar), (%)	PWP (Moisture content at 15 bar), (%)
Tillage practice		
M_1: Conventional tillage	11.21	14.60
M_2: Reduced tillage	13.07	10.84
M_3:Zero tillage	14.08	10.14
S.E.M. ±	0.96	1.13
CD (P=0.05)	NS	NS
Cover crops		
C_1: Control	12.01	13.92
C_2: Field bean	13.48	10.18
C_3: Horsegram	12.87	11.37
S.E.M. ±	0.45	0.74
CD (P=0.05)	NS	2.29
Interaction		
M_1C_1	10.68	16.90
M_1C_2	11.74	14.28
M_1C_3	11.20	12.63
M_2C_1	13.07	12.00
M_2C_2	13.79	9.20
M_2C_3	13.84	9.20
M_3C_1	12.27	12.87
M_3C_2	15.39	8.69
M_3C_3	13.09	10.89
S.E.M. ±	0.78	1.29
CD (P=0.05)	NS	NS

Different tillage practice *viz.*, conventional, reduced and zero tillage showed non-significant results with respect to field capacity (%) and permanent wilting point (%). Zero tillage recorded numerically higher field capacity (14.08%) and lower permanent wilting point (10.14%). Similarly, growing of cover crops also showed non-significant results with field capacity and permanent wilting point. But, growing of field bean as cover crop recorded numerically higher field capacity (13.48%) and lower permanent wilting point (10. 18%).
Interaction effect between different tillage and cover crop was found to be non-significant with field capacity and permanent wilting point. However combination of zero tillage with field bean as cover crop recorded numerically higher field capacity (15.39%) and lower permanent wilting point (8.69%).
Alam *et al*. (2014) [1] reported that field capacity and permanent wilting point are influenced by different tillage practices and varied considerably ($p \leq 0.05$). The field capacity increased due to different tillage practices and the field capacity was found minimum under conventional tillage. Similarly, Mloza-Banda *et al*. (2014) [13] also reported that conversion of long term ridge tillage to conservation agriculture practice did not significantly influence field capacity and permanent wilting point.

Conclusion

Among different tillage practices zero tillage (M_3) recorded significantly higher per cent water stable aggregates, mean weight diameter, porosity and water holding capacity than conventional tillage (M_1). There was no significant difference with per cent water stable aggregates among different cover crops but was significant with mean weight diameter. There was no significant difference observed in bulk density and particle density among different tillage practices. Zero tillage recorded higher field capacity (14.08%) and lower permanent wilting point (10.14%). Crop residue and tillage affects the soil environment directly or indirectly, incorporation of crop residue into soil or retention on the surface through the adaptation of conservation agriculture practice.

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