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Research Article

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Impact of conservational agriculture on hydrological properties of rainfed alfisol

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Summary

Retention and movement of water was better in conservational agricultural systems as compared to conventional agricultural system. Statistical tool Tukey test suggested that conservational agricultural systems that too raised bed with retention of crop residue at soil surface recorded statistically significant available water, water held at field capacity and permanent wilting point over that of conventional agricultural system and however, another statistical tool Pearson correlation indicated that neither tillage, crop residue retention at surface nor raised bed influenced water retention characteristics of soil such as MWHC, AW, water at FC and PWP which were significantly correlated with particle size class rather than organic carbon the resultant product of management factors. Other hydrological properties of soil such as infiltration rate, water storage capacity as well as hydraulic conductivity were better in conservational agricultural systems than in conventional agricultural system and however, infiltration rate and hydraulic conductivity were significantly superior in no tilled soil with raised bed and crop residue retained at soil surface.

Key words : Available water, Infiltration rate, Hydraulic conductivity, Reduced tillage, Crop residue retention

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Introduction

Hydrological properties are not inherent properties of soil but emerged out due to the interaction of climate and soil. Water is the most essential input for the survival of soil flora and fauna as well as for hydration of plants, transportation of nutrients from soil to plant root and further movement of nutrients in plant system. Hydrological properties of soil are referred to the retention and movement of water in soil such as field capacity, wilting point, available water, infiltration rate and hydraulic conductivity affect the physical fertility of soil through the movement of water and air in soil. Field capacity is referred to the condition of soil at which soil retains the maximum water after the sufficient drainage while wilting point is the soil condition at which the water retained by soil is not enough to sustain the plant growth and thus plant wilts and eventually ends up the life. These hydrological properties pertaining to retention and movement of water in soil speak about water storage capacity of soil and thus help to predict time and amount of irrigation to crops. Hydraulic conductivity is expected to be higher in no tilled soil with crop residue at surface as compared to conventional tillage practices, due to large proportion of macro pores/micro pores complemented by faunal activity (Eynard *et al.*, 2004 and McGarry *et al.*, 2000) and thus, soil water content (Norwood, 1994).Conventional tillage practices rupture the soil pores and cause the discontinuity of soil pores and it leads to reduced infiltration and hydraulic conductivity (Ehlers and Van der Ploeg, 1976 and Godwin, 1990) and thus, soil water balance. Hydrological properties of soil are very much influenced by particle size class, tillage, surface retention of crop residue, raised beds and organic matter content. Thus, present investigation was taken upto know the impact of conservational agriculture on hydrological properties of an alfisol.

Resource and Research Methods

The experimental site is situated at Agricultural College Farm, Bheemarayanagudi in Yadgir district of Karnataka and geographically situated between 16^o 72' N latitude and 76^o 79' E longitude. Climatologically and geologically study site enjoys semi-arid climate and granite-gneiss lithology, respectively. Five years old five agriculture systems namely, T_1 : Conventional tillage and no retention of crop residue (CT), T_2 : Zero tillage and raised bed with retention of crop residue at soil surface (ZTRB +M), T_3 : Zero tillage and raised bed without retention of crop residue at soil surface (ZTRB -M), T_4 : Zero tillage and flat bed with retention of crop residue at soil surface (ZTFB +M) and T_5 : Zero tillage and flat bed without retention of crop residue at soil surface (ZTFB -M), established on slightly gravelly sandy loam shallow alfisol with red gram as a test crop were selected to study vertical distribution of soil quality. Each system was quadruplicated and six composite fifth year post harvest 24 soil samples from each replication at an interval of 0-5, 5-10, 10-15, 15-20, 20-25 and 25-30 cm soil depths were collected during *Kharif* 2013, processed and analyzed for physico-chemical properties (pH and particle size class). Field capacity (FC) and permanent wilting point (PWP) was determined using pressure membrane plate (Richards, 1954) and available water was computed by taking difference between PWP and FC. Soil pH was measured in 1:2.5 soil: water suspension and organic carbon was estimated by Walkley and Black (1934) wet oxidation method while particle size class was determined by international pipette method using sodium hexametaphosphate as a dispersing agent. Maximum water holding capacity of the soil was determined by keens cup method (Bernard and Henry, 1921). Available water storage capacity (AWSC) of soil solum was obtained with help of following formula (Hong *et al.*, 2013).

$$\text{AWSC (cm)} = \frac{(\text{FC} - \text{WP}) \times \text{ASG} \times \text{D}}{100}$$

(Note: AWSC= Available water storage capacity, ASG= Apparent specific gravity of soil, D= Solum depth, FC = Field capacity and WP= Wilting point).

The hydraulic conductivity was measured by the reverse head (drain outflow method) by knowing drain discharge following the standard procedures (Black, 1965). Infiltration rate of the soil under different tillage cum residue management systems was determined using double ring infiltrometer (Baruah and Barthakur, 1998).

Research Findings and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Hydrological properties of soil :

Irrespective of systems hydrological properties of soils such as MWHC, FC, WP and AW showed increasing trend and this could be attributed to genetic factor clay which increased with depth. System mean values of MWHC, FC, WP and AW recorded by the soils under conservational agricultural systems (36.83 to 38.71, 18.65 to 21.22, 7.55 to 8.93 and 11.10 to 12.43%, respectively) were more than that of conventional agriculture system (36.47, 17.79, 7.54 and 10.25%, respectively) and this could be attributed to higher organic matter content in the former systems than in later system. Soil depth mean suggested that content of these hydrological properties was comparatively more in lower solum than in upper solum and this could be attributed to higher clay content in the lower solum than in upper solum (Table 1).

Maximum water holding capacity of soil (MWHC):

However, either tillage or crop residue did not influence MWHC of soil significantly as per the statistical tool Tukey test used to analyze the data on MWHC of soil and is also evident from correlation studies where, management factors both tillage and crop residue management in terms of organic matter was non-significantly (-0.343) correlated with MWHC while genetic factor clay (0.711**) was significantly correlated with MWHC of soil (Table 3). Which suggested that genetic factor clay rather than management factors

Table 1 : Water retention characteristics of soil

Hydrological properties	Depth (cm)	Different tillage and raised or flat beds with or without crop residue management systems					SDM
		CT (T_1)	ZTRB+M (T_2)	ZTRB-M (T_3)	ZTFB+M (T_4)	ZTFB-M (T_5)	
MWHC (%)	00-05	32.52	38.25	34.30	36.50	34.56	35.23
	05-10	34.44	35.35	36.51	36.90	35.78	35.80
	10-15	36.13	38.50	36.97	37.47	35.90	36.99
	15-20	36.80	39.28	39.70	38.50	36.10	38.08
	20-25	39.40	39.70	41.10	39.68	38.76	39.73
	25-30	39.50	41.20	41.68	40.25	39.85	40.50
	SM	36.47	38.71	38.38	38.22	36.83	
		System		Depth		System × Depth	
S.E. ±		1.91		2.09		4.69	
C.D.(P=0.05)		NS		NS		NS	
FC	00-05	16.70	21.50	18.75	19.25	17.45	18.73
	05-10	16.90	20.05	19.56	18.65	17.96	18.62
	10-15	17.25	20.42	20.32	18.70	18.50	19.04
	15-20	17.90	21.65	21.65	20.15	19.45	20.16
	20-25	18.65	21.82	21.87	21.25	19.21	20.56
	25-30	19.32	21.85	21.90	22.65	19.30	21.00
	SM	17.79	21.22	20.68	20.11	18.65	
		System		Depth		System × Depth	
S.E.±		0.396		0.434		0.971	
C.D.(P=0.05)		1.10		1.21		2.71	
AW (%)	00-05	10.35	13.34	11.70	11.45	10.65	11.50
	05-10	10.08	12.05	12.01	10.73	10.91	11.16
	10-15	10.10	11.67	12.57	10.60	10.60	11.11
	15-20	10.70	12.45	13.55	11.90	11.25	11.97
	20-25	10.00	12.17	12.62	12.71	11.56	11.81
	25-30	10.25	12.05	12.10	12.85	11.60	11.77
	SM	10.25	12.29	12.43	11.71	11.10	
		System		Depth		System × Depth	
S.E.±		0.23		0.25		0.57	
C.D.(P=0.05)		0.65		0.72		1.61	
PWP	00-05	6.35	8.16	7.05	7.80	6.80	7.23
	05-10	6.82	8.00	7.55	7.92	7.05	7.47
	10-15	7.15	8.75	7.75	8.10	7.90	7.93
	15-20	7.20	9.20	8.10	8.25	8.20	8.19
	20-25	8.65	9.65	9.25	8.54	7.65	8.75
	25-30	9.07	9.80	9.80	9.80	7.70	9.23
	SM	7.54	8.93	8.25	8.40	7.55	
		System		Depth		System × Depth	
S.E.±		0.107		0.117		0.262	
C.D.(P=0.05)		0.29		0.32		0.73	

Note: CT: Conventional tillage and no retention of crop residue (T_1), ZTRB+M: Zero tillage and raised bed with retention of crop residue (T_2), ZTRB-M: Zero tillage and raised without retention of crop residue (T_3), ZTFB+M: Zero tillage and flat bed with retention of crop residue (T_4), ZTFB-M: Zero tillage and flat bed without retention of crop residue (T_5), SWA: Solum weighted average, NS= Non-significant tillage and crop residue contributed much more to MWHC of soil and increasing trend of MWHC same as that of clay down the solum was the evident of it and these finding are in accordance with observations of (Khurshid *et al*., 2006).

Field capacity (FC) and permanent wilting point (PWP):

Tukey test suggested that system mean per cent water content at both FC and PWP recorded by the soils under T_2, T_3 and T_4 was significantly superior (>18.89 and 7.83%) over that of T_1 which was at par with T_5. Among T_2, T_3 and T_4, T_2 was significantly superior (>21.21 and 8.54% over rest of the systems and this could be attributed to reduced tillage which retarded the oxidation of organic matter and helped to build up of the same while raised bed and surface retention of crop residue encouraged more intake of water (Table 1). Depth mean per cent water content at FC recorded by the soil depth 15-30 cm depth and PWP recorded by the soil depth 10-30 cm was significantly superior (>19.83% and 7.55%) over that of 0-15 and 0-10 cm depth, respectively and it suggested that influence of genetic factor was more than that of management factors tillage, crop residue retention and raised beds. The interaction studies suggested that per cent water content at FC recorded by both T_2 and T_3 with all the soil depths and both T_4 and T_5 with lower soil depths was significantly superior over the rest of the interactions while per cent water content at PWP due to the interactions of both T_1 and T_5 with the soil depths 0-5 and 5- 10 cm was significantly inferior (<7.08%) to the rest of the interactions which suggested that the management factors in addition to genetic factor clay influenced the water content at FC and PWP and it was evident from the Pearson correlation coefficient values of FC and PWP with clay (0.646**) and organic carbon (-0.148).

Available water (AW) :

Significantly higher (10.90%) system mean AW content recorded under conservational agriculture systems over the conventional agriculture system could be attributed to the more of organic matter content in former than in later and the same was very much prevalent at 0-5 cm soil depth. Among conservational agriculture systems T_2 and T_3 recorded significantly higher (11.75 %) AW as compared to that of rest of the systems and this could be attributed to the reduced tillage

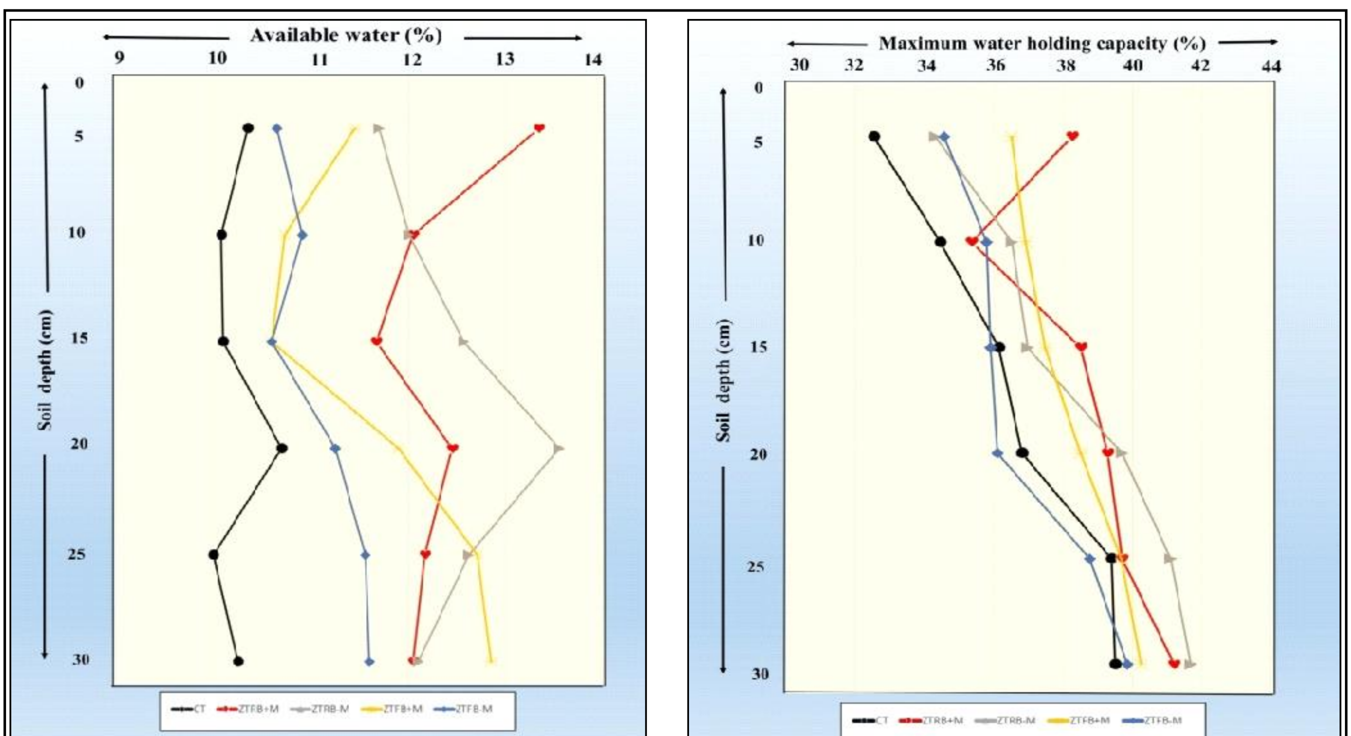

Fig. 1 : **Vertical distribution of available water and maximum water holding capacity under conventional and conservational agricultural systems**

with raised bed and crop residue retention at surface encouraged water intake by soil as compared to the soils with flat beds (T_1, T_4 and T_5) and the raised bed with crop residue (T_2) also encouraged water intake by the soil as it facilitated build up of organic matter at soil surface. Soil depth mean AW content at 15-20 cm soil depth was significantly superior (>11.83%) over rest of the soil depths and this could be attributed to the combined effect of both management factors and genetic factor clay. The interaction studies suggested that AW recorded by the conservational agricultural systems with all depths was better than the interaction of T_1 with all the soil depths and however, it was conspicuous and significantly superior (> 11.71%) in T_2 and T_3 and this could be attributed to the management factors reduced tillage, residue retention at surface and raised (Table 1 and Fig. 1). The first two management factors encouraged soil aggregation through accumulation of organic matter and while the later factor, raised bed enhanced water intake capacity of soil. However, correlation studies indicated that both clay and organic matter were positively but no significantly correlated with AW. Bescansa *et al*. (2006); Khurshid *et al*. (2006) and Mupangwa *et al*. (2007) also opined that higher AW content of soil under conservational agriculture systems was due to higher organic matter content that too in upper solum.

Available water storage capacity of soil (AWSC):

Water storage capacity of soil under conventional agriculture system was less (4.63cm) than that of conservational agriculture systems (4.76-5.25cm) and among the later systems AWSC of soil under T_3 was the highest (5.25 cm) and this could be attributed to both the management factors such as reduced tillage which disturbed the soil structure and organic matter minimum and raised bed favoured more water movement down the solum as compared to the flat beds (Table 2).

Infiltration rate and hydraulic conductivity of soil :

Soil under conservational agriculture systems with exception to T_5 witnessed higher (2.88-5.31cm hr^{-1}) infiltration rate as compared to conventional agricultural system (2.76 cm hr^{-1}). Statistical analysis suggested that Infiltration rate observed in T_2 and T_3 was significantly superior (3.47cm hr^{-1}). Hydraulic conductivity of soil was also more (15.15-23.90cm hr^{-1}) in conservational agricultural systems as compared to conventional agriculture system (14.50 cm hr^{-1}) and statistically T_2 was significantly superior (16.99cm hr^{-1}) over the rest of the systems (Table 2 and Fig. 2). Comparatively excessive tillage and no surface cover with vegetation in conventional agriculture system might have destroyed organic matter and soil aggregates which favoured the

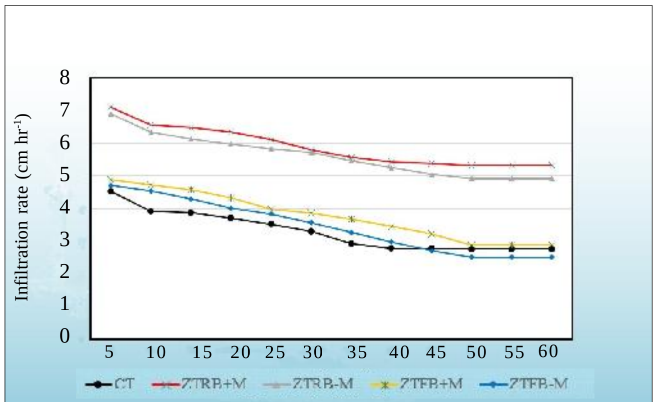

Fig. 2 : Soil infiltration under conventional and conservational agricultural systems

Table 2 : Hydrological properties of soil

Hydrological properties	Depth (cm)	Different tillage and raised or flat beds with or without crop residue management systems				
		CT (T_1)	ZTRB+M (T_2)	ZTRB-M (T_3)	ZTFB+M (T_4)	ZTFB-M (T_5)
Available water storage capacity (cm)	0-30	4.63	5.05	5.25	4.91	4.76
Soil infiltration (mm ha^{-1})	0-30	2.76	5.31	4.92	2.88	2.52
Bulk density (g cm^3)	0-30	1.51	1.37	1.41	1.40	1.43
S.E.±				0.23		
C.D. (P=0.05)				0.71		
Hydraulic conductivity	0-30	14.50	23.90	16.60	16.25	15.15
S.E.±				0.81		
C.D. (P=0.05)				2.49		

Note: CT: Conventional tillage and no retention of crop residue (T_1), ZTRB+M: Zero tillage and raised bed with retention of crop residue (T_2), ZTRB-M: Zero tillage and raised without retention of crop residue (T_3), ZTFB+M: Zero tillage and flat bed with retention of crop residue (T_4), ZTFB-M: Zero tillage and flat bed without retention of crop residue (T_5)

Table 3: Correlation co-efficients of hydrological properties with soil properties

Quality indicators \ Soil properties	SAND	SILT	CLAY	SOC
MWHC	-0.597**	-0.562**	0.711**	-0.343
FC	-0.544**	-0.507**	0.646**	0.046
AW	-0.159	-0.341	0.259	0.219
PWP	-0.789**	-0.534**	0.864**	-0.148

** indicate significance of value at P=0.01

clogging of soil pores with finer particles that lead to the reduced macro pores and lowered both infiltration rate and hydraulic conductivity. Raised bed as compared to flat bed improved both infiltration rate and hydraulic conductivity as the soil under raised bed was less compacted and had more macro pores as compared to flat bed. Systems with retention of crop residue at soil surface registered higher infiltration and hydraulic conductivity than the system with no crop residue retention at soil surface as crop residue protected the soil from destruction, kept the soil soft and delayed rate of decomposition of organic matter as it was of wider C/N ratio and thus enhanced accumulation of organic matter and improved soil aggregate stability. Lal and Sukla (2004); Liebig *et al*. (2004) and Sharratt *et al*. (2006) also opined the same. Correlation studies indicated that none of the soil properties studied was significantly correlated with both infiltration rate and hydraulic conductivity, however, more positive correlation coefficient values between infiltration rate and both organic carbon (0.711) and clay (0.677) as well as between hydraulic conductivity and both organic carbon (0.682) and clay (0.611) as compared to correlation co-efficient values between other soil properties and both infiltration rate and hydraulic conductivity suggested that both genetic factor soil texture and management factors tillage and crop residue at surface in terms of organic matter and raised bed in terms of increasing water intake improved both infiltration rate and hydraulic conductivity in conservational agriculture systems as both clay and organic matter improved the aggregate stability of the present light textured soil under study (Table 3).

Conclusion :

Water retention characteristics such as FC, PWP, AW, MWHC and WSC of soil as well as hydrological properties of soil such as IR and HC were better in conservational agricultural systems as compared to conventional agriculture system. Among conservational agricultural systems raised beds with crop residue at soil surface recorded the better hydrological properties of soil. Reduced tillage conserved the organic matter while crop residue at soil surface reduced runoff and increased down ward water movement and it also added organic matter to soil while raised beds enhanced water intake and improved WSC of soil.

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