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Vertical distribution of chemical qualities of an alfisol under rain fed conservational and conventional agriculture systems

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Abstract
Among the soil chemical quality indicators, the values of both soil organic carbon and cation exchange capacity were significantly more in conservational agriculture systems than in conventional agriculture system. However the differences in the remaining chemical quality indicators such as soil reaction, lime potential and buffering capacity between conventional and conservational agricultural systems were non significant as indicated by the statistical tool tukey test. Another statistical tool Pearson correlation indicated that soil reaction and lime potential were strongly correlated with organic matter (-0.764** and -0542**, respectively) while both cation exchange capacity and buffering capacity were strongly correlated with clay (0.791** and 0.743**, respectively). The study indicated that any improvement in chemical quality indicators of conservational agriculture systems was not solely due to management factors but due to the combined effect of both genetic factor clay and management factors such as zero tillage and crop residue retention.

Keywords: Tillage, crop residue, soil reaction, lime potential, buffering capacity

1. Introduction
Soil quality speaks about its capacity in nourishing and providing proper anchorage to crops besides keeping the health of land, air, water and animals including man. Reduced tillage with retention of crop residues at soil surface reduces rate of decomposition of organic matter and in other words enhances build up of organic matter. Organic matter is an indispensable factor of soil productivity and is an important chemical quality indicator as it is a panacea for most of the constraints of soil and it improves total soil quality. Organic matter is intimately linked with physical, chemical and biological environment of the soil and is regarded as a primary indicator of soil quality (Conteh *et al.,* 1997) [3]. Other chemical quality indicators which are influenced by organic matter are soil reaction, lime potential, buffering capacity and cation exchange capacity which in turn determines nutrients availability to crops.

2. Material and Methods
The experimental site is situated at agricultural college farm, Bheemarayangudi in Yadgir district of Karnataka and geographically situated between 16º 72' N latitude and 76º 79' E longitude and it enjoys semi-arid climate. Five years old five 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 (ZTRB +M), T_3: Zero tillage and raised bed without retention of crop residue (ZTRB -M), T_4: Zero tillage and flat bed with retention of crop residue (ZTFB +M) and T_5: Zero tillage and flat bed without retention of crop residue (ZTFB -M), established on slightly gravelly sandy loam shallow alfisol with red gram as a test crop were selected to study vertical distribution of chemical parameters in alfisol under these systems. Each system was quadruplicated and six composite fifth year post harvest 25 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, processed and analyzed for particle size classes *viz.,* sand silt and clay by international pipette method using sodium hexametaphosphate as a dispersing agent. Soil samples were also analysed for chemical quality indicators (soil reaction, soil organic carbon, cation exchange capacity, lime potential and buffering capacity) following standard procedures.

Soil reaction in distilled water (pH) and 0.01*M* $CaCl_2$ ($pHCaCl_2$) was determined in soil: electrolyte ratio of 1:2.5 using digital pH meter (Jackson, 1973) [6]. Lime potential (LP) values of soil were obtained by introducing $pHCaCl_2$ values in the formula LP= pH_{CaCl2}-1.14 (Hesse, 1971) [5] and organic carbon was estimated by Walkley and Black's (1934) [10] wet oxidation method. Cation exchange capacity of soil was determined by neutral normal ammonium acetate saturation method (Black, 1965) [10]. Buffering capacity of soil was determined by potentiometric titration method (Baruah and Barthakur, 1998) [1].

Data pertaining to chemical quality indicators was subjected to the statistical analysis using the statistical tool SPSS 16.00 windows and the significant differences in chemical quality indicators among the different tillage and raised or flat beds with or without crop residue management systems were determined by Tukey test at $P<0.05$. These chemical quality indicators were also subjected to another statistical tool Pearson correlation with particle size classes and organic carbon of soil for better interpretation of data (Table 1 and 3).

3. Results and Discussion

3.1 Soil reaction (pHw): Soil reaction showed increasing trend with depth in all the systems and it could be attributed to coarser soil texture which facilitated leaching of basic cations to the lower soil layers. System mean Soil reaction (pHw) was comparatively low in conservational agriculture systems (6.43-6.89) than in conventional agriculture system (6.93) and this could be attributed to more of leaching environment in the former systems than in the later system as the soil in the former systems was tilled minimum and or covered with crop residue which favoured leaching of the basic cations to lower depths as well as acidification at soil surface due to the decomposition of crop residue (Table 2). Difference in soil reaction between the conventional and conservational agriculture systems at soil surface was due to greater accumulation of soil organic matter in the later than in former system. Similar kind of observation was reported by Duiker and Beegle (2006) [4]. Statistically there was no difference in soil reaction either due to difference in tillage or due to difference in crop residue management as per the statistical tool tukey test and however strong significant negative correlation between organic matter and pH (-0.764**) confirmed the significant influence of both reduced tillage and crop residue retention on pH as soil under conservational agriculture systems registered lower pH as compared to conventional agriculture system (Table 3).

3.2 Lime potential: Lime potential is a more reliable tool to measure the soil reaction rather than conventional method of estimation of soil pH in water as the former is not influenced by either dilution or salt concentration unlike the later. Increasing trend of lime potential down the solum in all the agriculture systems, as well as the highest system mean lime potential value of soil under conventional agriculture system (5.55) as compared to that of conservational agriculture systems (5.13-5.42) could be attributed to more organic matter at soil surface and decreasing trend of the same down the solum as well as higher organic matter content of soil under conservational agriculture systems than in conventional agriculture system (Table 2). The management factors tillage and crop residue retention at soil surface influenced lime potential either by increasing or decreasing both soil reaction and organic matter. More of lime potential of soil under conventional agriculture system than in the soil under conservational agricultural systems could be attributed to more pH and less organic matter in the former system and reverse was true in the later systems. This was further supported by significant correlation of lime potential with both pH and organic matter (-0.542**). However statistical tool, tukey test employed to analyze the data on lime potential suggested no significant difference in lime potential of soil among the systems studied (Table 3).

3.3 Buffering Capacity: Slightly lower buffering capacity of soil in conventional agriculture system (0.71 meq 100 gm^{-1}) as compared to the soil in conservational agriculture systems (0.71-0.75 meq 100 gm^{-1}) as indicated by system mean and this average could be attributed to lower organic matter in the former system than in the later systems and it was supported by positive but no significant correlation between buffering capacity and organic matter. Increasing trend of buffering capacity down the solum in all the agriculture systems could be attributed to clay which increased with depth (Table 2). This suggested that genetic factor influenced the buffering capacity of soil much more than the management factors either tillage or crop residue retention at soil surface through conserving organic matter as the correlation coefficient value between buffering capacity and clay was significantly positive (0.743**). However statistical tool tukey test employed to analyze the data suggested that no significant difference in buffering capacity of soil among the systems studied (Table 3). This is in agreement with Narayanaswamy (2002) [8].

3.4 Soil Organic Carbon: organic matter, the primary soil quality indicator was comparatively more in conservational agriculture systems (3.20 g kg^{-1}) as compared to conventional agriculture system. Soil organic matter decreased with depth in all the systems studied but the content of organic matter at different soil depth in conventional agriculture system was comparatively lower than that of corresponding soil depths of conservational agriculture systems (Table 2). This suggested that as the soil was tilled less in conservational agriculture systems than in conventional agriculture system the rate of oxidation of organic matter was less in former than in the later system. In addition to this there was a continuous accumulation of below ground portion of crop year after year in the soil under conservational agriculture systems and thus conservational agriculture system registered more organic matter content and reverse was true in the conventional agriculture system. Among the conservational agriculture systems T_2 and T_4 recorded higher organic matter content as these systems retained crop residue at soil surface in addition to less soil disturbance retarded rate of oxidation of organic matter and conserved the same in larger quantity as compared to the conventional agriculture system. Impact of tillage and crop residue management on soil organic matter content was further confirmed by the statistical analysis. Soil organic matter content in T_2 and T_4, in 0-5 cm soil depth and due to the interaction of both T_2 and T_4 with both 0-5 and 5-10 cm soil depths was significantly superior over that of the rest of the systems, soil depths and interactions, respectively. This is in agreement with Lopez and Pardo (2009) [7] and Singh and Kaur (2012) [9].

3.5 Cation Exchange Capacity (CEC): As per solum weighted average significantly higher soil CEC under conservational agriculture systems [17.85cmol (p+) kg^{-1}] than in conventional agriculture system, and among conservational agriculture systems significantly higher value of the same in both T_2 and T_4 could be attributed to higher organic matter in soil under conservational agriculture systems than in conventional agriculture system as well as in both T_2 and T_4 as compared to the soils under rest of the conservational agriculture systems respectively. However CEC was not significantly correlated with organic matter and it was confirmed by increased values of CEC as organic matter content decreased down the solum (Table 3). Statistical analysis also suggested that CEC was significantly higher in lower solum than in upper solum and even the interaction between T_2 and 25-30 cm soil depth also registered significantly higher CEC. These findings suggested that contribution of management factors such as tillage and crop residue retention was much lesser than the genetic factor clay and the same was confirmed by significant positive correlation (0.791**) between CEC and clay. Duiker and Beegle (2006) [4] also opined the same. These findings revealed that genetic factor clay contributed much more than management factors tillage and crop residue to CEC and however the positive influence of management factors, reduced tillage and crop residue retention at soil surface in conservational agriculture systems on CEC through conserving of organic matter was mainly confined to 0-5 cm soil depth.

4. Conclusion

Among the chemical quality indicators changes in organic matter and cation exchange capacity were significantly higher in conservational agriculture systems as compared to conventional agriculture system. Other chemical quality indicators such as soil reaction and lime potential were lower while buffering capacity was higher in conservational agriculture systems as compared to conventional agriculture system. However, there was no significant difference in these qualities between conventional and conservational agriculture systems. This suggested that soil under conservational agriculture systems need much more time to register significant positive changes in the above said chemical quality indicators.

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Table 1: Vertical distribution of soil particle size classes

Soil properties	Depth (cm)	Different tillage and raised or flat beds with or without crop residue management systems					Depth Mean
		CT (T_1)	ZTRB+M (T_2)	ZTRB-M (T_3)	ZTFB+M (T_4)	ZTFB-M (T_5)	
Sand (%)	00-05	68.93	66.16	67.65	66.03	66.41	67.04
	05-10	68.19	64.92	67.46	64.60	65.96	66.23
	10-15	66.65	63.85	66.92	65.12	65.40	65.59
	15-20	64.80	63.20	66.86	65.25	65.20	65.06
	20-25	65.44	62.80	66.48	65.72	66.86	65.46
	25-30	64.20	62.72	62.62	64.88	67.00	64.28
	SWA	66.36	63.94	66.33	65.27	66.14	
Silt (%)	00-05	15.50	16.60	16.00	16.82	16.49	16.28
	05-10	16.10	15.80	16.20	17.60	16.56	16.45
	10-15	16.50	15.40	16.10	16.98	16.20	16.24
	15-20	15.90	15.30	15.58	16.55	15.90	15.85
	20-25	15.20	15.20	15.20	15.10	15.34	15.21
	25-30	15.70	15.10	14.90	15.02	15.10	15.16
	SWA	15.82	15.57	15.66	16.35	15.93	
Clay (%)	00-05	15.57	17.24	16.35	17.15	17.10	16.68
	05-10	15.71	19.28	16.34	17.80	17.48	17.32
	10-15	16.85	20.75	16.98	17.90	18.40	18.18
	15-20	19.30	21.50	17.56	18.20	18.90	19.09
	20-25	19.36	22.00	18.32	19.18	17.80	19.33
	25-30	20.10	22.18	22.48	20.10	17.90	20.55
	SWA	17.82	20.49	18.01	18.39	17.93	

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

Table 2: Vertical distribution of chemical quality indicators in soil

Quality indicators	Depth (cm)	Different tillage and raised or flat beds with or without crop residue management systems					Depth mean
		CT (T_1)	ZTRB+M (T_2)	ZTRB-M (T_3)	ZTFB+M (T_4)	ZTFB-M (T_5)	
pHw	00-05	6.71	6.22	6.33	6.43	6.48	6.43
	05-10	6.80	6.30	6.39	6.47	6.52	6.50
	10-15	6.84	6.41	6.41	6.57	6.72	6.59
	15-20	7.03	6.47	6.88	7.07	7.22	6.93
	20-25	6.97	6.56	6.98	7.24	7.06	6.96
	25-30	7.24	6.64	7.06	7.52	7.33	7.16
	SWA	6.93	6.43	6.68	6.88	6.89	
	Treatment		Depth		Treatment × Depth		

S.Em±	0.28		0.31		0.69		
C.D at 0.05	NS		NS		NS		
pHCaCl$_2$	00-05	6.49	6.21	6.15	6.33	6.02	6.24
	05-10	6.52	6.23	6.21	6.41	6.05	6.28
	10-15	6.45	6.32	6.33	6.49	6.27	6.37
	15-20	6.80	6.33	6.41	6.55	6.27	6.47
	20-25	6.92	6.33	6.66	6.68	6.42	6.60
	25-30	7.01	6.41	6.79	6.91	6.58	6.74
	SWA	6.69	6.29	6.41	6.56	6.26	
	Treatment		Depth		Treatment × Depth		
S.Em±	0.26		0.29		0.65		
C.D at 0.05	NS		NS		NS		
Soil organic carbon (g kg^{-1})	00-05	4.28	5.85	4.95	5.18	4.28	4.91
	05-10	3.83	5.18	3.83	5.20	3.90	4.39
	10-15	3.45	4.80	3.68	4.28	3.30	3.90
	15-20	3.00	4.38	3.60	3.73	3.15	3.57
	20-25	2.78	4.37	3.60	3.50	2.93	3.44
	25-30	2.55	4.37	2.78	3.15	2.78	3.13
	SWA	3.32	4.83	3.83	4.17	3.39	
	Treatment		Depth		Treatment × Depth		
S.Em±	0.22		0.12		0.13		
C.D at 0.05	0.61		0.33		0.37		
Buffering capacity (meq 100gm^{-1})	00-05	0.72	0.74	0.72	0.73	0.71	0.72
	05-10	0.70	0.74	0.70	0.72	0.68	0.71
	10-15	0.70	0.75	0.69	0.74	0.68	0.71
	15-20	0.72	0.78	0.73	0.75	0.71	0.74
	20-25	0.72	0.80	0.76	0.77	0.73	0.76
	25-30	0.73	0.81	0.78	0.80	0.75	0.77
	SWA	0.71	0.77	0.73	0.75	0.71	
	Treatment		Depth		Treatment× Depths		
S.Em±	0.039		0.042		0.095		
C.D at 0.05	NS		NS		NS		

Contd...Table 2

CEC [c mol (P$^+$) kg^{-1}]	00-05	14.50	21.10	16.20	21.50	17.30	18.12
	05-10	15.10	21.20	17.10	21.80	18.90	18.82
	10-15	16.85	22.26	18.10	22.00	19.63	19.77
	15-20	19.25	23.65	20.19	22.16	22.16	21.48
	20-25	19.90	24.12	22.89	22.23	22.25	22.28
	25-30	21.50	25.31	23.90	22.46	23.12	23.26
	SWA	17.85	22.94	19.73	22.03	20.56	
	Treatment		Depth		Treatment × Depth		
S.Em±	0.59		0.63		1.46		
C.D at 0.05	1.66		1.82		4.09		
Lime potential	00-05	5.35	5.07	5.01	5.19	4.88	5.10
	05-10	5.31	5.09	5.07	5.27	4.91	5.13
	10-15	5.38	5.18	5.19	5.35	5.13	5.25
	15-20	5.66	5.19	5.27	5.41	5.13	5.33
	20-25	5.78	5.19	5.52	5.54	5.28	5.46
	25-30	5.87	5.27	5.65	5.77	5.44	5.60
	SWA	5.55	5.17	5.29	5.42	5.13	
	Treatment		Depth		Treatment × Depth		
S.Em±	0.22		0.24		0.54		
C.D at 0.05	NS		NS		NS		

Note: CT**:** Conventional tillage and no retention of crop residue (T$_1$), ZTRB+M**:** Zero tillage with raised bed and retention of crop residue (T$_2$), ZTRB-M**:** Zero tillage with raised bed and no retention of crop residue (T$_3$), ZTFB+M**:** Zero tillage with flat bed and retention of crop residue (T$_4$) ZTFB-M**:** Zero tillage with flat bed and no retention of crop residue (T$_5$), SWA: Solum weighted average.

Table 3: Correlation co-efficient values between soil chemical quality indicators and soil properties

Quality indicators \ Soil properties	Sand	Silt	Clay	SOC
Soil reaction	-0.028	-0.505**	0.207	-0.764**
Cation exchange capacity	-0.778**	-0.358	0.791**	-0.062
Lime potential	-0.166	-0.417*	0.293	-0.542**
Buffering capacity	-0.622**	-0.589**	0.743**	0.056

Note: *significant at 0.01 level; **significant at 0.05 level

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