

Original Research Article

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Long-Term Impact of Conservation Agriculture on Chemical Properties of Soil

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ABSTRACT

A long-term field experiment was carried out in alluvial soil with conservation agriculture practices like Zero tillage (ZT), Permanent bed (PB) and Conventional tillage (CT) to see the impact on Physico-chemical Properties of soil under rice based cropping systems. After completion of 7th cycle of experiment (2018), soil samples were collected from each plot and analysis processes were executed. The results obtained from the study show that the conservation agricultural practices increased the organic carbon 0.47 to 0.71%, cation exchange capacity 9.76 to 13.04 [cmol (p⁺) kg⁻¹], available-N 150.52 to 175.67 kg/ha available P₂O₅ 150.52 to 175.67 kg/ha, available K₂O 202.40 to 245.63 kg/ha and available S 14.66 to 22.84 mg/kg of soil. It was further observed that after 7 years of experimentation, a build-up of organic carbon upto 30% (0.69%) and 26% (0.67%) from the initial value (0.53%) due to zero tillage and permanent bed respectively were observed. Among the cropping systems, Rice-Lentil system sustained the soil physico-chemical properties to a greater extent compared to Rice-Wheat and Rice-Maize systems. Retention of crop residue and minimum disturbance of surface soil under conservation agriculture increases the organic matter content leading to enhanced crop nutrition and sustain the soil health.

Keywords

Zero tillage,
Conventional
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Introduction

Conservation Agriculture (CA) originally developed in the United States of America (Thierfelder *et al.*, 2013; Thierfelder and Wall, 2009; Lahmar, 2008) and reducing land degradation and production costs was later

introduced to Europe and Africa (Lahmar, 2008; FAO, 2008; Van Wie *et al.*, 2013) Globally, CA is being practiced on about 125 M ha The major countries are USA(26.5 M ha), Brazil (25.5 M ha), Argentina (25.5 M ha), Canada (13.5 M ha) and Australia (17.0 M ha). In India adoption is still in the initial

phases. Over the past few years, adoption of zero tillage and CA has expanded to cover about 1.5 million hectares (Jat *et al.*, 2012). CA is more sustainable agriculture production practice (Wall, 2007). conservation tillage to give the maximum benefits (Hobbs *et al.*, 2008) and it combine the following basic principles (Verhulst *et al.*, 2010 and Jat *et al.*, 2012):. to bring positive changes in the physical, chemical and biological properties of a soil (Bescansa *et al.*, 2006), Improved soil fertility and structure (Choudhary *et al.*, 2018 ,Obour *et al.*, 2017 and Yadav *et al.*, 2017), providing a suitable growing environment to support high yields (Wang and Li, 2014; Cai *et al.*, 2014). Frequency and intensity of tillage had significant influence on disintegration and decomposition of organic matter including residues (Singh and Ladha, 2004). Under no till and permanent raised beds, higher total nitrogen was recorded (Govaerts *et al.*, 2007 Thomas *et al.*, 2007 and Graham *et al.*, 2002) and nitrogen mineralization (Kristensen *et al.*, 2000).

The available P under no till with straw retention (NTSC) was 97.5% higher in the 0-5 cm layer (Wang, 2008). Various studied, higher extractable P levels in no tillage than in tilled soil (Duiker and Beegle 2006, Franzluebbers and Hons, 1996; Edwards *et al.*, 1992; and Follett and Peterson, 1988) and this is due to reduced mixing of the fertilizer P with the soil, leading to lower P-fixation. Reduces loss of nutrients, environmental pollution and which reduces a serious health hazard (Sidhu *et al.*, 2007). Permanent raised beds with residue retention had higher K concentration in surface layer, Govaerts *et al.*, (2007). In no till or minimum till system, the relatively immobile nutrients P and K remains concentrated in the upper soil layer of minimum tilled plots (Shear and Moschler, 1969; Triplett and Van Doren, 1969; Fink and Wesley, 1974; and Ismail *et al.*, 1994).

Materials and Methods

Site and soil characteristics

A long-term experimental field was initiated in *kharif* 2011 on fine sandy loam soil at Bihar Agricultural University Research Farm, Sabour (Latitude 25°23'N, longitude 87°07'E and altitude 37.19 m M.S.L.). It was carried out in 2018 and is a part of the ongoing Conservation Agriculture experiment on “Effect of rice establishment techniques on crop yield of different rice based cropping systems. The site is characterized by the aridity, semi-arid monsoon climate, with extreme temperatures ranges between 28 to 44⁰C, whereas, in winter temperature falls down to as low as 3⁰C. The average rainfall varies between 400 to 500 mm, Wells are the only source of irrigation and water table is quite deep (about 55-60metres). The experimental soil had pH 7.36, EC 0.30 dSm⁻¹, organic carbon 0.53 %, available N 160.16, P₂O₅ 26.68 and K₂O 221.60 kg/ha, respectively.

Experimental details

The treatments consists of three tillage practices Zero tillage (ZT), Permanent bed (PB), Conventional Tillage (CT) and three rice based cropping systems: Rice-Wheat (RW), Rice-Maize (RM) and Rice-Lentil (RL). The study was made in split plot design with three replications.

Full dose of P and K were applied as basal dose and N in three split doses through single super phosphate, muriate of potash and urea, respectively. Since the initiation of the experiment, Rice is being grown continuously during *Kharif* through direct seeding in Zero Tillage (ZT) and Permanent Bed (PB) plots, and on the same date rice seeds are sown in the nursery bed for conventional/puddled method of establishment. Wheat and Lentil

are grown during *Rabi* in rows, while Maize was sown through dibbler.

Soil sampling and processing

Soil samples from the surface (0-15cm) were collected from all the 27 plots after completion of seven years of the experiment in 2018. These samples were air dried and processed to pass through 2 mm sieve as usual and stored in polyethylene bags for analysis. The soil water suspension (EC) and Soil pH were measured with a electrical conductivity meter and pH meter, soil to water ratio of 1:2.5 by Jackson (1973). Easily oxidizable organic carbon of soil was estimated by Walkley and Black, 1934 method. Available N was estimated by alkaline potassium permanganate solution and determining the ammonia liberated (Subbiah and Asija, 1956). Available Phosphorus was extracted with 0.5 M Sodium bi-carbonate at pH 8.5 (Olsen *et al.*, 1965). Available K was extracted with 1 N ammonium acetate and measured with a flame photometer (Hanway and Heidel, 1952). Available sulphur content was determined Turbidimetrically (Tandon, 1991). CEC was determined by NH_4OAC method (Jackson, 1973).

Results and Discussion

Soil Reaction (pH)

Soil pH varied from 7.19 to 7.37 in establishment methods (Table 1). In Zero tillage (7.19) method was found to have slightly lower pH compared to conventional tillage (7.37). Different cropping system, soil pH varied from 7.24 to 7.28 (Table 2). Rice – Lentil (7.24) cropping system was found to have slightly lower pH than rice- wheat (7.28). The effect of crop establishment methods and rice based cropping systems were found to be statistically non-significant which varied from 7.14 to 7.38 (Table 3). Soil

pH was observed to be lower under conservation agriculture as compared to conventional method which might be due to direct incorporation of crop residues in the soil under conservation agriculture and the subsequent decomposition of these crop residues might have released various organic acids which would have resulted in decrement of soil pH under conservation agriculture. Similar result was observed by Yadav *et al.*, (2017) who stated in their work that conservation agriculture has got the potential to improve physical, chemical and biological characteristics of the soil and Govaerts *et al.*, (2006) stated that non-significant effect was found for soil pH under conservation agriculture.

Electrical Conductivity (EC)

The EC ranged between 0.26 to 0.31 dSm^{-1} (Table 3) due to interaction effect of establishment methods (T) and cropping systems (S) and was found statistically non-significant. Among the three crop establishment methods, lowest value was found to be 0.28 under ZT as compared to PB and CT which are statistically at par with each other (Table 1). EC value also declined from 0.29 to 0.28 (Table 2) due to Rice-Lentil (RL) cropping system as compared to Rice-Wheat (RW) and Rice-Maize (RM). The EC of conventional method was found to have higher value than Zero Tillage which might be due to higher pore size and porosity of the soil under Zero Tillage which would have led to leaching down of the basic cations.

Soil organic carbon

Organic Carbon (OC) content of the soil under conservation agriculture ranged from 0.47 to 0.71 % (Table 3) due to interaction effect of crop establishment methods (T) and rice based cropping systems (S) and was found to be statistically non-significant.

Among the three crop establishment methods, minimum OC content was found to be 0.49% in CT which increased significantly to 0.67 % in PB and 0.69 % in ZT (Table 1). Zero tillage had significant effect on soil organic carbon content as compared to conventional tillage and which was found statistically at par with permanent bed. It is apparently visualized from the Figure 1 that there was an increase of 30.19% and 26.42% under ZT (Zero Tillage) and PB (Permanent Bed) respectively from initial OC values i.e. 0.53% due to different treatment combinations. Among the three different cropping systems, it was observed that OC content increased up to (Table 2) 0.63 % under Rice-Maize which was superior to 0.62 % in Rice-Wheat and 0.61 % in Rice-Lentil cropping system but was statistically non-significant. These results are in accordance with Paustian *et al.*, (1997) who reported that tillage affects the equilibrium of soil carbon balance through incorporation of crop residues and through physical disturbance and mixing of soil and the exposed aggregates. Lower amount of organic carbon was found under conventional method which was similar to the result found by Freibauer *et al.*, (2004) and Matos *et al.*, (2011).

Available nitrogen

The data ranged from 150.52 to 175.67 kg ha⁻¹ due to different treatment combinations (Table 3) and the interaction effect of establishment methods and cropping system were found statistically non-significant. Among the three different crop establishment methods, highest was recorded to be 171.43 kg ha⁻¹ under Zero Tillage and lowest value was recorded as 156.10 kg ha⁻¹ under Conventional Tillage. Maximum Available N content was found to be 170.04 kg ha⁻¹ under Rice-Lentil cropping system and lowest to be 160.28 kg ha⁻¹ under Rice- Maize cropping System (Table 2) Rice-Wheat (R-W) and

Rice-Maize (R-M) cropping system were statistically similar with respect to available Nitrogen content of soil. It might be due to larger addition of crop residues and less soil disturbances. Increased tillage practices under conventional method make the soil susceptible to erosion of nitrogen and hence conventional tillage has lowest available N. These results are in agreement with Carter *et al.*, (1998). Similar observations on the effect of tillage and residue management have been made by several workers (Dupreez *et al.*, 2001, Govaerts *et al.*, 2007 and Peng *et al.*, 2008).

Available Phosphorus

Different treatment combinations and the interaction effect of establishment methods and cropping system were found statistically non-significant, the data ranged from 24.01 to 34.85 kg ha⁻¹ (Table 3). The maximum available P₂O₅ content (34.85 kg/ha) was noted with treatment ZT-RL combination while minimum (24.01 kg/ha) available P₂O₅ was noted in CT-RM treatment combination. Among the cropping systems, maximum available P₂O₅ content was recorded to be 32.81 kg/ha under Rice-Lentil cropping system followed by 29.86 and 28.41 kg/ha soil due to Rice-Wheat and Rice-Maize cropping system, respectively (Table 2). Rice-Lentil cropping system was significantly superior over Rice-Wheat and Rice-Maize cropping system and Rice-Wheat and Rice-Maize cropping system was statistically at par with each other. Among the three different crop establishment methods, highest was recorded to be 32.64 kg ha⁻¹ under Zero Tillage and lowest value was recorded as 26.42 kg ha⁻¹ under Conventional Tillage (Table 1). The amount of available P₂O₅ was found higher under conservation agriculture as compared to conventional tillage which might be due to larger addition of crop residues in conservation agriculture which

increases P solubilisation and reduce P fixation. These results are in agreement with Kumar *et al.*, (2008) who reported increment in available P_2O_5 in the soil with incorporation of crop residues. On the other hand, Roldan *et al.*, (2007) reported that available P was not affected by different tillage systems and crop rotations.

Available potassium

The data ranged from 202.40 to 245.63 kg/ha due to different treatment combinations (Table 3) and the interaction effect of establishment methods and cropping systems were found to be statistically non-significant. Among the three establishments methods, maximum content of available K_2O (236.03 kg/ha) was noted under Zero Tillage treatment and minimum content of available K_2O (213.59 kg/ha) was found under Conventional Tillage (Table 1). The effects of different establishment methods on available K_2O content of soil were statistically non-significant. The results further indicated that cropping systems have statistically significant effect on available K_2O . Highest available K_2O content was recorded to be 239.01 kg/ha under Rice-Lentil cropping system which was significantly superior over Rice-Maize cropping system (Table 2). Rice-Wheat cropping system was statistically at par with Rice-Maize cropping system. This result was in agreement with the findings of Martin-Rueda *et al.*, (2007) who reported that extractable K was higher for no tillage in the surface layer (0-15 cm) as compared to conventional tillage. Similar result was in accordance with the findings of Carter *et al.*, (2002) who noted non-significant differences among treatments and Yadav *et al.*, (2016) reported that highest amount of K (203.1 kg ha⁻¹) in 0-15 cm soil surface was recorded under PB planting while minimum amount of available K were observed under CT after seven years of CA. Rice-Lentil cropping system was found to be significantly superior

over both Rice-Wheat and Rice-Maize cropping system having maximum content under Rice-Lentil cropping system.

Available sulphur

The data ranged from 14.75 to 18.25 mg/kg (Table 3) due to different treatment combinations and the interaction effect of establishment methods and cropping systems were found to be statistically non-significant. Among different crop establishment methods, highest content of available S 19.76 mg/kg was recorded under Zero Tillage which was followed by 18.07 mg/kg under Permanent Bed and lowest value was 15.25 mg/kg recorded under Conventional Tillage (Table 1). The effect of different establishment methods on available S content of the soil was found to be statistically significant. Rice based cropping systems was found to be statistically significant with highest value of 19.74 mg/kg recorded under Rice-Lentil cropping system which was significantly superior over Rice-Maize cropping system which was noted to be 16.59 mg/kg followed by Rice-Wheat cropping system with a value of 16.59 mg/kg (Table 2). These results are in agreement with the findings of Sarkar *et al.*, (1998) who reported that incorporation of various organic residues like compost, FYM and crop residues can enhance the supply of adequate quantity of sulphur to crops. Rice – Lentil cropping system was found to be statistically superior over both Rice-Wheat and Rice-maize cropping systems.

Cation Exchange Capacity (CEC)

It ranged from 9.76 to 13.04 cmol(p⁺)kg⁻¹ (Table 3) due to interaction effect of different establishment methods (T) and cropping systems (S) but results were observed to be non-significant. Crop establishment methods (Table 1) increased CEC significantly from 10.33 to 11.92 cmol(p⁺) kg⁻¹ (Table 1).

Table.1 Effect of establishment method on nutrient of soil under conservation agriculture

	pH	EC (dSm ⁻¹)	O.C. (%)	CEC [cmol (p ⁺) kg ⁻¹]	Avail.N (kg/ha)	Avail. P ₂ O ₅ (kg/ha)	Avail. K ₂ O (kg/ha)	Avail. S (mg/kg)
ZT	7.19	0.28	0.69	11.92	171.43	32.54	236.03	19.76
PB	7.27	0.29	0.67	11.41	167.25	32.12	231.90	18.07
CT	7.37	0.29	0.49	10.33	156.10	26.42	213.59	15.71
SEm(±)	0.07	0.01	0.02	0.27	4.37	0.78	9.16	0.36
LSD (P=0.05)	NS	NS	0.08	1.04	NS	3.06	NS	1.43

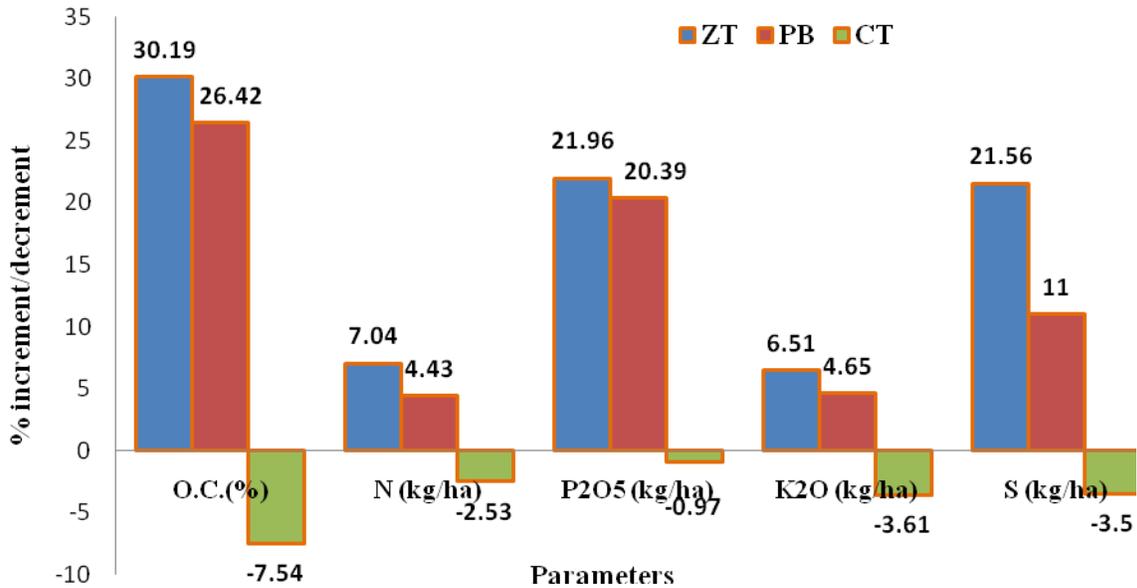
Table.2 Effect of cropping system on nutrient of soil under conservation agriculture

	pH	EC (dSm ⁻¹)	O.C. (%)	CEC [cmol (p ⁺) kg ⁻¹]	Avail. N (kg/ha)	Avail. P ₂ O ₅ (kg/ha)	Avail. K ₂ O (kg/ha)	Avail. S (mg/kg)
R-W	7.28	0.29	0.62	11.00	164.47	29.86	223.57	17.24
R-M	7.32	0.29	0.63	10.51	160.28	28.41	218.94	16.59
R-L	7.24	0.28	0.61	12.15	170.04	32.81	239.01	19.74
SEm(±)	0.04	0.01	0.02	0.24	6.36	0.78	4.34	0.41
LSD (P=0.05)	NS	NS	NS	0.74	NS	3.06	13.37	1.27

Table.3 Effect of establishment methods and cropping systems of soil under Conservation agriculture

	pH	EC (dSm ⁻¹)	O.C. (%)	CEC [cmol (p ⁺) kg ⁻¹]	Avail. N (kg/ha)	Avail.P ₂ O ₅ (kg/ha)	Avail. K ₂ O (kg/ha)	Avail. S (mg/kg)
ZT-RW	7.21	0.29	0.69	11.68	171.44	32.29	232.77	18.54
ZT-RM	7.23	0.29	0.71	11.03	167.25	30.47	229.68	17.99
ZT-RL	7.14	0.26	0.67	13.04	175.67	34.85	245.63	22.84
PB-RW	7.28	0.31	0.67	11.17	167.25	32.03	229.50	17.33
PB-RM	7.34	0.30	0.70	10.73	163.07	30.75	224.73	17.13
PB-RL	7.21	0.28	0.65	12.32	171.43	33.57	241.47	19.76
CT-RW	7.35	0.30	0.49	10.16	154.71	25.25	208.43	15.87
CT-RM	7.38	0.30	0.47	9.76	150.52	24.01	202.40	14.66
CT-RL	7.38	0.28	0.50	11.08	163.07	30.00	229.93	16.61
SEm(±)	0.13	0.01	0.03	0.42	11.02	1.87	7.51	0.72
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Fig.1 Soil physico-chemical properties as influenced by conservation agriculture after 7 years of experimentation



Zero tillage (ZT) was observed to be statistically at par with permanent bed (PB) and significantly superior over conventional tillage (CT). Rice based cropping systems increased CEC significantly from 10.51 to 12.51 cmol(p+)/kg (Table 2) and Rice-Lentil cropping system was found to be superior over Rice-Maize cropping system. Highest value was recorded under zero tillage and rice-lentil cropping systems under different crop establishment methods and rice based cropping systems, respectively. This might be due to presence of high organic matter which in turn leads to presence of phenolic and carboxylic acids and which increases negative charge due to lower dissociation of constant. Burle *et al.*, (1997) studied the effect of cropping systems on soil chemical parameters and they observed that increase in soil CEC may occur in no-till systems with legumes because of larger addition of organic residues which increases soil acidification through carbon and nitrogen cycles. These results are also in accordance with the findings of Sharma *et al.*, (1988) and Dasappagol *et al.*,

(2017).

Conclusion can be drawn from the above discussion that the organic carbon, CEC, available P₂O₅ and Sulphur content of soil were significantly build up after 7 years of experimentation due to zero tillage and permanent bed establishment methods as well as rice lentil cropping system under conservation agriculture which might be due to the accumulation of higher amount of organic carbon in surface soils that has resulted from its recycling over the years by subsequent crop residue accumulation under zero tillage and permanent bed technique. Thus, CA-based management practices are superior and sustainable for long-term crop production that maintains the soil health as compared to conventional tillage practices.

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