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Tarun Kumar Kevat
Indira Gandhi Krishi Vishwavidyalaya, Krishak Nagar, Raipur, Chhattisgarh, India

Tapas Chowdhury
Indira Gandhi Krishi Vishwavidyalaya, Krishak Nagar, Raipur, Chhattisgarh, India

MC Bhambri
Indira Gandhi Krishi Vishwavidyalaya, Krishak Nagar, Raipur, Chhattisgarh, India

SB Gupta
Indira Gandhi Krishi Vishwavidyalaya, Krishak Nagar, Raipur, Chhattisgarh, India

Ravindra Soni
Indira Gandhi Krishi Vishwavidyalaya, Krishak Nagar, Raipur, Chhattisgarh, India

Dipika
Indira Gandhi Krishi Vishwavidyalaya, Krishak Nagar, Raipur, Chhattisgarh, India

Correspondence
Tarun Kumar Kevat
Indira Gandhi Krishi Vishwavidyalaya, Krishak Nagar, Raipur, Chhattisgarh, India

Changes in physico-chemical properties of soil as influenced by conservation agriculture in rice based cropping system of Chhattisgarh

Tarun Kumar Kevat, Tapas Chowdhury, MC Bhambri, SB Gupta, Ravindra Soni and Dipika

Abstract
An investigation was carried out at Department of Agricultural Microbiology, College of Agriculture, IGKV, Raipur, Chhattisgarh during the year 2015-16 in an Inceptisol field for two consequtive years with three crops *viz*. rice wheat and cow pea in kharif, rabi and summer season, respectively to evaluate the effect of adoption of conservation agriculture practice on soil phyico-chemical properties and organic matter content. The experiment consisted of five tillage practices which were applied in main plot with and without residue under two different crop establishment methods i.e. transplanting and direct seeding. Two different weed management methods were also tested in combination with tillage treatments compared with weedy check. Results indicated that tillage systems namely conventional tillage and zero tillage had no significant effect on soil pH and EC at end of the two-year experiment. Similarly, interaction effects of tillage management x weed management did not have significant effect on soil pH and EC value. Soil organic carbon (SOC) was recorded higher at surface layer (0-5 cm) at end of two-year experiment and its concentration decreased with increasing depth. Among different tillage management systems evaluated, zero tillage (ZT) found significantly higher SOC compared to conventional tillage (CT) at surface layer (0-5 cm) and 10-15 cm soil depth. Overall, tillage systems had significant effect on SOC at end of two-year experiment regardless of soil depths. However, tillage management x weed management did not have significant effect on SOC. At the completion of experiment, ZT with and without residue had higher organic carbon (SOC) than CT.

Keywords: Zero tillage, weed management, conservation agriculture, organic carbon

Introduction
Chhattisgarh state is known as “Rice bowl of India”. The state is mono cropped mainly with rice but this cropping system is threatening the sustainability of the system. Low levels of soil organic matter, appearance of multiple nutrient deficiencies due to their over mining by continuous cropping from soils and poor management of crop residues (CRs) are some of the major reasons for declining productivity in the region. Leaching causes nutrient stresses in soil specially with more agricultural practices (Havlin *et al.*, 1999) [13]. Agricultural production might not be sustainable unless major steps are taken to improve management of crop residue by adopting conservation agriculture (CA) (Pretty *et al.*, 2011) [18].

Conservation Agriculture is a concept for resource saving agricultural crop production to accomplish continuous production and conserving the environment. Function of conservation agriculture is based on following key principles, *viz*. effective resource conservation, input optimization and optimum productivity of the farming system. In the case of rice, resource conservation is possible with proper technological Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way that does not interfere with, or disrupt, the biological processes. To manage the preceding residues in a productive and profitable manner, conservation agriculture (CA) offers a good promise. With the adoption of conservation agriculture-based technologies these residues can be used for improving soil health, increasing crop productivity, reducing pollution and enhancing sustainability and resilience of agriculture. The resource conserving technologies (RCTs) involving no or minimum tillage, direct seeding, bed planting and crop diversification with innovations in residues management are the possible alternatives to the conventional energy and input-intensive agriculture.

CA-based crop management technologies, such as no-till with residue retention and judicious crop rotation, are gaining more attention in recent years. Furthermore, intensive tillage systems results to a decrease in soil organic matter due to acceleration of the oxidation and breakdown of organic matter and ultimately degradation of soil properties (Biamah *et al.*, 2000, Gathala *et al.*, 2011) [4, 11, 12]. Conservation agriculture's primary feature, is the maintenance of a permanent or semi-permanent soil cover, be it alive crop or dead mulch, which serves to protect the soil from sun, rain and wind, and also feed soil biota. This biotic community is essential as it provides a 'biological tillage' that serves to replace the functions of conventional tillage (FAO, 2001).

Conventional tillage is the most commonly used method for land preparation in rice production (Huang *et al*., 2011) [15, 16]. However, this practice not only requires a huge amount of energy and labour (Bhushan *et al*., 2007) [3] but also accelerates mineralization of organic matter, reduces soil fertility, increases water consumption, and damages the chemical and physical properties of the soil (Chen *et al*., 2007) [7]. In recent years, zero-tillage has been become increasingly attractive in rice production (Huang *et al*., 2011) [15, 16], owing to its benefits including saving fuel, equipment, and labour as well as conserving soil (Triplett Jr *et al*., 2007) [19]. Looking to the above facts an experiment was conducted to find out the influence of conservation agriculture practice on soil physico-chemical properties and organic carbon content which was undertaken for two consecutive years.

Materials and Methods

The investigation was carried out at Department of Agricultural Microbiology, College of Agriculture, IGKV, Raipur, Chhattisgarh during the year 2015-16 in an Inceptisol to find out the effect of adoption of conservation agriculture practices on soil physico-chemical properties comparing with conventional practices in a Rice-Wheat cropping system. The experiment was conducted in an Inceptisol field for two consequtive years with three crops *viz*. rice wheat and cow pea in kharif, rabi and summer season respectively The experiment was laid out in a split-plot design with five tillage practice were applied in main plot with and without residue under two different crop establishment methods i.e. transplanting and direct seeding. In this experiment two different weed management methods were also tested in combination with five tillage treatments. The weed management practice comprises (i) chemical weed management (ii) integrated weed management (iii) weedy check. Each treatment was replicated thrice. Zero tillage consisted of direct sowing of crops in undisturbed soil by opening a narrow slit of sufficient width and depth to place the seed. The residue retention under tillage treatment was >30% on soil surface. In this experiment we followed the recommended agronomic practices with prescribed dose of fertilizers and intercultural operations. Surface soil samples (0-10 and10-15 cm) were collected randomly from 2-3 locations from the plots. These samples were composited, processed, sieved through a 2- mm sieve after removing large plant material and analyzed for physico-chemical properties. The indicators of soil quality were selected based on the performance of considered soil functions. The selected soil properties were Bulk density: BD; physical indicators and pH, Electrical conductivity: EC; Available N, P and K: Av-N, Av-P and Av-K and Soil Organic Carbon: SOC as chemical indicators. Soil samples were analysed for their bulk density as described by Black (1965) [20]. The soil pH and Ec were measured in 1:2.5 soil-water suspensions at room temperature. Soil organic carbon was determined by wet digestion method (Walkley and Black, 1934) [21], Av.-N by using alkaline permanganate method (Subbiah and Asija, 1956) [22], Av.-P by Olsen"s extraction method (Olsen *et al*., 1954) and Av.-K by neutral normal ammonium acetate extract, using flame photometric method (Jackson, 1967). Soil of the experimental site was characterized as sandy loam in texture, neutral in reaction (pH: 6.8), Medium in organic carbon (0.46 %), medium in available N and P (220 kg/ha and 18 kg/ha, respectively), and high in available K (320 kg/ha).

Results and Discussion

Soil pH

Maximum pH was recorded in conventional tillage practice under transplanted condition and minimum in conventional tillage practice under direct seeded condition. Soil pH under conventional tillage with transplanted condition found significantly higher over conventional tillage with direct seeded condition. This may be due to enhancement of soil pH under transplanted condition as a result of continuous submergence which favoured the increase in soil pH towards neutrality.

Zero tillage without residue application also found superior to increase soil pH significantly this might be due to compaction of soil resulting less percolation of water and submergence of soil which ultimately increasing the soil pH (Table 1). These findings are in close conformity with the results of cebel *et al.* (1998) [6] who found higher soil pH in conventional tillage than minimum tillage system. In weed control practices Different weed management methods significantly affected the soil pH. Maximum soil pH was recorded in weedy check which found significantly higher over other methods of weed control. Minimum soil pH was found due to application of integrated mode of weed management. These findings are in close conformity with the results of Mishra (2010) [17] and Borthakur (2011) [15] who found pH of the hand weeded, herbicide applied and weedy check plots did not vary significantly from each other at different stages of crop growth.

Soil Electrical conductivity

Maximum EC was recorded in zero tillage practice under direct seeded rice with residue application and minimum in conventional tillage practice under transplanted condition. Soil EC under zero tillage practice under direct seeded rice with residue application found significantly higher over conventional tillage practice under transplanted condition. This finding are close confirmly with the result of Urkurkar *et al.* (2010) who mentions that EC is increased in soil after two continuous crop growing seasons due to application of inorganic fertilizer only. Higher water soluble salt content under zero tillage practice under direct seeded rice with residue application may be due to lower permeability of soil under this system which facilitates the accumulation of salt in different soil profile put under long run. In weed control practices it is apparent from the data that EC of the hand weeded, herbicide applied and weedy check plots did not vary significantly from each other at initial to harvest stage. Where comparatively higher EC in soil was observed in weedy check plots than hand weeded and herbicide treated plots. Urkurkar *et al.* (2010) also found increase in electrical conductivity in inorganic fertilizer treated plots at the end of the rice- wheat cropping season. Borthakur (2011) [15] also found in his research work that there was a minute increase in water soluble salt content in soil within the crop growth period, but the increment was non consistent and non significant over control in herbicides treated and non treated plots.

Table 1: pH and Ec (dsm^{-1}) of soil as influenced by adoption of conservation agriculture practice.

Treatments		
Tillage management	**pH**	**Ec (dsm^{-1})**
T1- CT (TR) – CT-CT Tillage	6.80	0.187
T2- CT (TR) – CT-ZT Tillage	6.79	0.185
T3- CT (DSR) – CT-ZT Tillage	6.76	0.186
T4- ZT (DSR) – ZT+R-ZT Tillage	6.78	0.188
T5- ZT (DSR) +R-ZT+R-ZT Tillage	6.77	0.189
SEm±	0.004	0.001
CD (P=0.05)	0.01	0.004
Weed management		
W1- Rec. Herbicide	6.76	0.188
W2- Integrated Weed Management	6.76	0.187
W3- Unweeded	6.81	0.187
SEm±	0.003	0.002
CD (P=0.05)	0.009	0.005
T×W	NS	NS

Table 2: Organic carbon (%) of soil as influenced by adoption of conservation agriculture practice.

Treatments	**ORGANIC CARBON (%)**			
Tillage management	**0 DAS**	**30 DAS**	**60 DAS**	**At harvest**
T1- CT (TR) – CT-CT Tillage	0.48	0.49	0.52	0.53
T2- CT (TR) – CT-ZT Tillage	0.49	0.51	0.53	0.54
T3- CT (DSR) – CT-ZT Tillage	0.50	0.52	0.54	0.56
T4- ZT (DSR) – ZT+R-ZT Tillage	0.50	0.51	0.54	0.56
T5- ZT (DSR) +R-ZT+R-ZT Tillage	0.52	0.53	0.55	0.57
SEm±	0.003	0.003	0.003	0.003
CD (P=0.05)	0.01	0.01	0.01	0.02
Weed management				
W1- Rec. Herbicide	0.51	0.51	0.53	0.53
W2- Integrated Weed Management	0.48	0.50	0.52	0.55
W3- Unweeded	0.51	0.53	0.56	0.57
SEm±	0.003	0.004	0.003	0.002
CD (P=0.05)	0.01	0.01	0.01	0.01
T×W	NS	NS	NS	NS

Table 3: Organic carbon (%) of soil as influenced by adoption of conservation agriculture practice.

Treatments	**ORGANIC CARBON (%)**			
Tillage management	**0 DAS**	**30 DAS**	**60 DAS**	**At harvest**
T1- CT (TR) – CT-CT Tillage	0.47	0.48	0.51	0.47
T2- CT (TR) – CT-ZT Tillage	0.48	0.49	0.52	0.48
T3- CT (DSR) – CT-ZT Tillage	0.48	0.49	0.51	0.48
T4- ZT (DSR) – ZT+R-ZT Tillage	0.48	0.49	0.53	0.48
T5- ZT (DSR) +R-ZT+R-ZT Tillage	0.50	0.51	0.54	0.50
SEm±	0.001	0.001	0.01	0.002
CD (P=0.05)	0.01	0.01	0.02	0.01
Weed management				
W1- Rec. Herbicide	0.48	0.49	0.51	0.52
W2- Integrated Weed Management	0.47	0.49	0.51	0.53
W3- Unweeded	0.49	0.51	0.53	0.55
SEm±	0.003	0.003	0.003	0.002
CD (P=0.05)	0.01	0.01	0.01	0.01
T×W	NS	NS	NS	NS

Organic carbon

The observations on organic carbon content as influenced by different tillage systems were recorded periodically and the data tabulated in table 2 & 3. The organic carbon content found to increase in soil with the advancement of crop and reached to highest level at harvest. Maximum organic carbon content was found under zero tillage practice in direct seeded rice with residue application and minimum was recorded in conventional tillage under transplanted condition. Direct seeding under zero tillage with and without residue application and direct seeding under conventional tillage system found significantly superior over transplanted condition with respect to organic carbon content. It is apparent from the data that zero tillage favoured the accumulation of organic carbon is soil which also found more effective when residue was retained on the soil. Hazarika *et al*. (2009) [14] reported that 14-17 per cent higher SOC in surface soil under NT and RT than CT practices. In weed management methods found significantly effective to alter the organic carbon content in soil maximum organic carbon was found under weedy check and minimum under integrated weed management method in the whole crop growth period. At harvest maximum organic carbon percentage was found in (0.57 & 0.59) weedy check and minimum (0.53 & 0.55) in integrated weed management. Minimum organic carbon is due to integrated weed management is because of proper weed management throughout the growth period of crop which ultimately reduced the biomass of weeds as they are a potential source of soil organic matter. The critical look into the data that reveals that organic carbon in integrated weed management, recommended herbicide and weedy check did not vary significantly from each other harvest stage of the crops. Higher organic carbon content was recorded in weedy check plot in comparison to herbicide treated plots. At harvest stage of the crop significant quantity of organic matter was accumulated in weedy check and hand weed condition over herbicide application. This might be due to higher crop weed density in control plots and hand weeded plots in comparison to herbicide treated plots which contributed higher organic matter in soil. The present study results were congruent with the findings of Zanatta *et al.* (2007) [26], who concluded that conservation tillage specially NT had higher SOC than CT and resulted in SOC accumulation, mainly in the 0-5 cm depth. Also, the rate of increase of SOC depends on the amount of crop residues addition and thus SOC increased during initial 5-9 years thereafter decreased exponentially over time. Similarly, Bayer *et al*., (2006) reported that the adoption of no tillage (NT) in subtropical Brazilian soil has led to accumulation of soil organic carbon in the 0-20 cm layer, indicating that NT soils can acts as an atmospheric C sink. Also, the less oxidative environment and the physical protection mechanism imparted by the stable aggregates of NT soils reduce soil organic matter mineralization rates (Six *et al*., 2002; Zanatta *et al*., 2007) [24, 26] and also favoured SOC accumulation. The differences in TOC accumulation among tillage treatment were highest in the upper most soil layer where they were ranked as follows: ZT (DSR) +R > ZT (DSR > CT (DSR)>CT (TPR) and this trend were similar to our results (Zanatta *et al*., 2007) [26]. Besides the adoption of zero tillage (ZT) practices, the cultivation of crops and cover crops (especially legumes) with high potential for C-biomass addition is another prerequisite for SOC accumulation Bayer *et al*. (2006) and Diekow *et al*. (2005) [8] observed that soils subjected to NT management for long period under low biomass addition cropping systems did not accumulate SOC, although NT under legume-based cropping systems showed SOC accumulation rates higher than RT and CT. Our results corroborated with findings of Bhattacharya *et al*. (2015), who concluded from a 6 year study under rice–wheat cropping system in the western Indo Gangetic Plains, all conservation agriculture (CA) plots had significantly higher gain (over initial value) in total SOC than that in TPR-CTW and TPR-ZTW treatments in the 0–15 cm layer and the gain in total SOC in the plots under MBR + DSR- ZTW + RR-ZTMB was significantly higher than all CA plots, despite having similar total SOC stocks. It is evident from the present study that the TOC concentration under NT and RT is significantly (P>0.05).

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