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Long-term effect of conservation agriculture on soil properties, yield and nutrient uptakein maize crop under maize based cropping systems

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Abstract
A field study was conducted on the ongoing research project "Resource conservation technologies for stabilizing yield under different cropping system" of Bihar Agricultural University, Sabour, Bhagalpur (Bihar) initiated in the year 2011, to study the effect of conservation agriculture (CA)on soil properties, yield and nutrient uptake in maize crop under maize based cropping systems. To fulfill this study, the soil and plant samples were collected from these permanent CA plots which contains three main plots of various tillage practices *viz.* Zero tillage (ZT), Permanent raised bed (PB) and Conventional tillage (CT) and in sub-plot with three different cropping sequences *viz.* maize-maize (M-M), maize-wheat (M-W) and maize-chickpea (M-C) in a split plot design. Results showed that there was no significant effect of tillage practices and cropping system on soil pH and electrical conductivity (EC) but the management performed in the CA plots improved soil organic carbon (SOC) content, cation exchange capacity (CEC) and nutrient availability in ZT and M-C over other tillage practices and cropping systems. The highest yield gain for tillage practices was in ZT (297 Kg ha^{-1}) over PB (173 Kg ha^{-1}) as compared with CT and for cropping systems M-C (197 Kg ha^{-1}) over M-M (123 Kg ha^{-1}) as compared with M-C. Uptake of the nutrients was more in ZT and M-C over other tillage practices and cropping systems. Overall, it can be concluded that ZT and M-C was best tillage practice and cropping system, respectively as compared with other tillage practices and cropping systems.

Keywords: Soil organic carbon, conservation agriculture, maize crop, yield

1. Introduction
The soil as a natural resource forms the basis for sustainable system of productive agriculture. This resource is deteriorating at a faster rate this leads to alarm that creates a large discussion of feeding the people of the country. The population was about 370 million in 1947-48 and now it has been reached to 1 billion and still on rising continuously. It is a not an easy task on Indian farming community and the researcher world to feeding such a large growing population with a limited resources.

Extensive use of conventional tillage practice and in-situ burning of crop residues has resulted into loss of the soil fertility and degradation of resources rapidly. Therefore, in spite of the high yielding variety, the yield is either declining or remaining constant (Reynolds and Tuberosa, 2008). Conservation agriculture (CA) is nothing but a concept that thrives on resource management as well as sustainable crop production. It conserves the environment by utilizing scientific knowledge and improves the production and productivity of the soil as well as crop. Introduction of all modern technologies through CA system enhance soil quality and ecological integrity of soil (Friedrich *et al*., 2012) [4].

The CA worked works under the three key principles of namely, crop residue management, minimum tillage practices and crop rotation. The principle fallow leads to intense impact on the SOC content in soil that is essential for microorganism as well as for nutrient availability for plant system as well as transformation and distribution of nutrient in soil. It was studied that ZT that a one methods of CA causes enrichment of soil with continuous pores volume between the subsurface and the surface which leads to create a rapid passage for movement of soluble nutrients in to deeper under the soil profile comparison to soil which is continuously till (Franzluebbers and Hons, 1996) [3]. Distribution of nutrients in a soil under zero tillage is found to be different from tilled soil. In the India, the CA technologies will bring a "Revolution in tillage techniques".

Maize (*Zea mays* L.) is one of the most important cereals crops after the wheat and rice crops. Among cereals, maize in India is one that grows in diverse agro climatic conditions having wider adaptability in soil and under different cropping sequences.

It is one of the most dependable crop, which bring independence, and self-reliance, that serves as a staple food of 900 million, people in the developing countries (Zerihun *et al.*, 2013) [15]. In India maize crop emerged as an essential crop for nutritional security point of view as well as farm and food economy which cover approximately 8.17 million hectares area with 2.4t ha^{-1} of an average productivity and contribution of 8.5% to the national food basket.

Keeping in view, there is an urgent need to understand the long-term effect of CA on soil and crop system. Therefore, this present study has been designed to assess the soil properties, yield and nutrient uptake in maize crop under various tillage practices and cropping systems.

2. Materials and Methods

The present field study was conducted at permanent CA research plot, Bihar Agricultural University, Sabour, Bhagalpur (Bihar). The soil was sandy loam in texture, with initial pH 7.5 (alkaline), medium in available SOC (5.3g kg^{-1}), electrical conductivity-0.15 dSm^{-1}at 25^0C, available nitrogen-147.84kg $ha^{-1}$and available phosphorous-27.19 kg ha^{-1} and available potassium-213.06 kg ha^{-1}.

The study was laid out in nine (9) treatments combinations which were replicated thrice arranged in a split plot design (SPD). In main plots three establishment methods viz. zero tillage (ZT), permanent raised bed (PB) and conventional tillage (CT) and in sub-plots different maize based cropping systems viz. maize-maize (M-M), maize-wheat (M-W) and maize-chickpea (M-C). The maize variety 'DHM117' was sown by *khurpi* during the second week of July *i.e.*10 July 2018 using the seed rate of 20 kg ha^{-1} and two type of spacing firstly in zero tillage (ZT), and conventional tillage (CT) spacing were 60 cm x 25cm and in permanent raised bed (PB) spacing was 67.5 cm x 25 cm. A recommended dose of fertilizer (100 kg N, 60 kg P_2O_5 and 40 kg K_2O) was applied through urea, DAP and muriate of potash (MOP). Full dose of phosphorus and potassium were applied as basal application while nitrogen was applied half as basal and remaining half in two equal splits at knee high stage and tasseling stages of maize. The gross and net plot sizes were 6.0 x 3.0 m^2 and 5.60 x 2.60 m^2, respectively. The crop was raised under rainfed condition recommended package of practices.

The maize crop was harvested from different plots at maturity. The soil and plant samples were collected and processed further to analyse soil properties and nutrient content of the crop. The chemical properties were analysed viz. pH meter by (Jackson, 1973) [7], EC (dSm^{-1}at 25 ^{0}C) (by electrical conductivity bridge (1:2.5) soil water suspension (Jackson, 1973) [7], SOC (g kg^{-1})by rapid titration method (Walkley and Black, 1934) [13], Available N (kg ha^{-1}) by alkaline permanganate method (Subbiah and Asija, 1956) [12], available P_2O_5 (kg ha^{-1}) by Olsen's method (Olsen *et a1.*, 1954) [9], available K (kg ha^{-1}) by flame photometer method (Jackson, 1973) [7]. Plant samples were analysed viz. total nitrogen by Kjeldahal methods (Chapman and Pratt, 1961), total phosphorus by vanado-molybdate method (Jackson, 1973) [7] and total potassium by wet digestion method (Jackson, 1967). Nutrient uptake was calculated by multiplying nutrient content and dry matter.

The collected data for all the parameters was statistically analyzed and interpreted. Least Significant difference (LSD) was computed at the 5% probability level (Steel and Torrie, 1980) [11]. Correlation was developed between different parameters.

3. Results and discussion

3.1 Effect of tillage practices and cropping system on soil properties

There was no any impact of tillage practices and cropping systems on soil pH and EC (Table 1). Numerically, lower pH in ZT was observed than the CT; this might be attributed due to accumulation of organic matter in the soil which release organic acids on decomposition that ultimately lower the pH of the ZT plot. The cropping system M-Cwas found lower pH than M-M and M-W due to lower C:N ratio of chickpea that decomposes easily and quickly and releases more organic acidin the soilthan maize and wheat crop. The Rhoton (2000) [10] findings were in congruence with the obtained result.

The EC values were comparatively lower in ZT than CT and in cropping system it was observed to be higher in M-C as compared to M-M and M-W (Table 1). Higher SOC was found in the ZT than PB and CT. Annual residue retention in ZT enhanced the SOC content in the soil. Similar result was reported by Ismail *et al.* (1994) [6] and Kalyani (2012) [8]. Similar trend was recorded in CEC and soil nutrient status (Table 1).

Table 1: Effect of tillage practices and cropping systems on soil properties after harvest of 8th crop cycle of maize crop

Soil properties	pH	EC	SOC	CEC	Av. N	Av. P_2O_5	Av. K_2O
Tillage practices			(g kg^{-1})	(cmol kg^{-1})	(kg ha^{-1})	(kg ha^{-1})	(kg ha^{-1})
ZT	7.13	0.35	5.92	15.90	174.20	30.00	284.80
PB	7.23	0.35	5.56	14.70	166.90	25.50	268.50
CT	7.37	0.38	5.17	13.10	149.00	22.80	261.50
SEm(±)	0.01	0.01	0.10	0.40	2.00	0.50	3.70
LSD (p=0.05)	NS	NS	0.29	1.23	5.70	1.30	10.40
Cropping Systems							
M-M	7.36	0.35	5.70	14.20	158.10	24.90	262.70
M-W	7.17	0.36	5.23	14.20	160.70	23.50	270.20
M-C	7.19	0.37	5.71	15.30	171.30	29.90	281.90
SEm(±)	0.13	0.01	0.14	0.6	3.0	1.0	1.5
LSD (p=0.05)	NS	NS	0.32	NS	6.6	2.1	3.4
Interactions							
SEm(±)	0.29	0.02	0.25	1.03	5.3	0.2	6
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS

The highest Av. N, Av. P_2O_5 and Av. K_2O were 174.2, 30.0 and 284.8 Kg ha^{-1}, respectively was recorded in ZT. However the lowest Av. N, Av. P_2O_5 and Av. K_2O were 149.0, 22.8 and 261.5 Kg ha^{-1}, respectively was recorded in CT. Increasing trend of CEC for tillage practices was CT<PB<ZT and for cropping system was M-M=M-W<M-C (Table 1). There was no significant interaction effect of soil properties on tillage practices and cropping systems.

3.2 Effect of tillage practices and cropping system on yield

Figure 1 depicts the effect of tillage practices and cropping systems on grain yield of maize crop on 8th maize based crop cycle. There was significant effect of yield of ZT and PB over the CT and M-C and M-M over the M-W. Trend of yield for tillage practices was ZT>PB>CT and for cropping systems M-C>M-M>M-W. The increase in yield was 297 and 173 Kg ha^{-1}, respectively for ZT and PB over CT and 197 and 123 Kg ha^{-1}, respectively for M-C and M-M over M-W. The interaction effect of tillage practices and cropping systems on yield was found to be non-significant. The higher yield in ZT and M-C might be due to more compound effect of all the nutrient availability in the practice and cropping system as compared to other practices and cropping systems. The optimal nutrient concentration especially of potassium in soil causes stomata mechanism of closing and opening by which the wastage of water is prevented that helps in plant growth and finally enhance yield of the crop (Wiebold, 2006) [14].

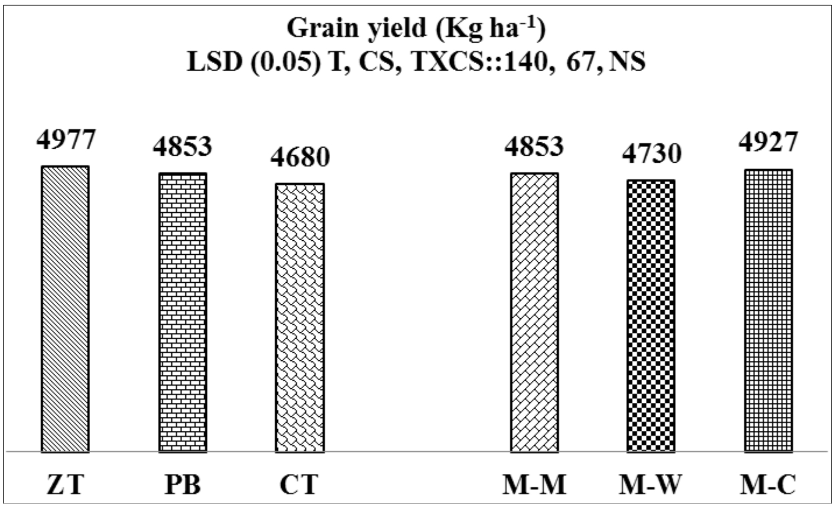

Fig 1: Effect of tillage practices and cropping system on yield (where, ZT= Zero tillage, PB = Permanent raise bed and CT=Conventional tillage, M-M = Maize-Maize, M-W=Maize-Wheat and M-C=Maize-Chickpea)

3.3 Effect of tillage practices and cropping systems on nutrient uptake

Nitrogen, phosphorus and potassium uptakeby straw and grain were significantly related to tillage practices and cropping systems as presented in Table 2. Nutrient uptake was highest in ZT followed by PB and lowest in CT. For tillage practices, nitrogen, phosphorus and potassium uptakeby straw was 36.3, 21.7 and 12.9 percent, respectively higher in ZT than CT and in cropping systems M-C was found to be 20.2,8.1 and 7.4percent, respectively higher than the M-M (Table 2). Similarly, nitrogen, phosphorus and potassium uptake by grain was found to be 15.4, 23.3 and 12.2 percent, respectively higher in ZT than CT while in cropping system M-C was found to be 15.1, 24.4 and 9.8 percent higher than M-M (Table 2).The interaction effect of tillage practices and cropping systems on nutrient uptake was found to be non-significant. Enhanced soil available nutrients increase the nutrient uptake by improving plant growth and yield. The increase in uptake of one nutrient synergistically/ antagonistically improves the uptake of the other nutrients. The present condition synergistic effect of the nutrients was observed. The long-term residue retention, clay transformation and biological nitrogen fixation improved the soil fertility that ultimately resulted into better crop yield and nutrient uptake. Nitrogen concentration obtained to be higher in dry matter it might be due to synergistic effect of potassium on nitrogen. Availability of potassium also enhances the uptake of nitrogen. This studied was also observed by Fridgen and Varca 2004 [5]. There was 18.5% higher concentration of phosphorus observed in conservation tillage than CT system (Essington and Howard. 2000) [2].

Table 2: Effect of tillage practices and cropping systems on nutrient uptake by grain and straw

	N uptake		P uptake		K uptake	
	Straw	Grain	Straw	Grain	Straw	Grain
Tillage practices	(kg ha^{-1})					
ZT	36.70	69.36	13.34	19.31	144.85	17.38
PB	33.47	68.51	12.53	16.67	135.33	16.63
CT	26.93	60.08	10.96	15.66	128.27	15.49
SEm(±)	0.68	0.57	0.45	0.30	2.94	0.32
LSD (p=0.05)	1.88	1.58	1.25	0.89	8.16	0.89
Cropping Systems						
M-M	29.44	61.24	11.70	15.44	131.81	15.71
M-W	32.27	66.19	12.44	16.98	135.03	16.54
M-C	35.39	70.52	12.70	19.21	141.61	17.25
SEm(±)	0.50	0.99	0.51	0.41	2.66	0.28
LSD (p=0.05)	1.08	2.15	NS	0.84	5.80	0.62
Interactions						
SEm(±)	0.86	1.71	0.88	0.71	4.61	0.49
LSD (p=0.05)	NS	NS	NS	NS	NS	NS

3.4 Relationship between soil properties and nutrient uptake by maize crop

Relationship between soil properties and nutrient uptake by maize crop has been presented in the Table 3. Soil pH was significantly correlated with nutrient uptake while no significant correlation was observed with EC. Nutrient uptake was significantly increased on increasing SOC content. There was positive and significant relation between soil available nutrient and nutrient uptake.

Table 3: Correlation coefficient between soil propertiesand nutrient uptake

	Nitrogen uptake	Phosphorus uptake	Potassium uptake
pH	-0.85**	-0.79*	-0.73*
EC	-0.37	-0.38	-0.39
SOC	0.75*	0.81*	0.85**
Av. N	0.98**	0.97**	0.95**
Av. P	0.87**	0.88**	0.94**
Av. K	0.81*	0.99**	0.97**

*,**Significant at 0.05 and 0.01 probability levels, respectively

4. Conclusion

ZT and M-C was found to be the better tillage practices and cropping systems as compared to other tillage practices and cropping systems. The long-term residue retention, clay transformation and biological nitrogen fixation improved the soil fertility in ZT and M-C that ultimately resulted into better crop yield and nutrient uptake.

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