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Effect of Establishment Techniques and Cropping Systems on Transformation of Zinc in Alluvial Soil under Conservation Agriculture

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ABSTRACT

The experiment was conducted at Bihar Agricultural University, Sabour. This experiment consisting of nine treatments under rice establishment techniques *viz*., - Zero tillage (T_1), Permanent bed (T_2)and Conventional Tillage (T_3) and Sub-plot Rice based systems rice-wheat (S_1) rice- maize (S_2) and rice- lentil (S_3).The paper focuses on conservation agriculture (CA), defined as minimum soil disturbance (NT) and permanent soil cover combined with rotations, as a more sustainable cultivation system for the future. The paper then describes the benefits of CA, a suggested improvement on CT, where NT, mulch and rotations significantly improve soil micronutrient properties. All these fractions was recorded the highest in T_1S_3 and marginal recorded in other treatment like T_2S_3, T_3S_3 and lowest recorded in $T_3S_2$and T_3S_2. Zinc fraction tend to be present in higher levels under zero tillage with residue retentions compared to conventional tillage. The distribution of total Zn into residual fraction was also reported to be more than 90 per cent. It was also recorded the highest zinc fraction in zero tillage (T_1) compared the permanent bed and lowest zinc fraction observed in conventional tillage in postharvest soil. Effect of different cropping system rice-wheat, rice-maize and rice- lentil on zinc fraction was recorded highest value in rice lentil cropping system and lowest recorded in rice-maize cropping system. The data on correlation coefficient values among different zinc fractions of soil revealed that dynamic equilibrium of zinc existed as positive and highly significant correlation co-efficient values were noted among these fractions.

Keywords

Zinc fractions, Zero tillage, Permanent bed, Conventional Tillage cropping systems

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Introduction

Conservation agriculture defined (FAO, 2017) as minimum soil disturbance (NT) and permanent bed (PB) combined, is a recent agricultural management. Intensive and conventional tillage led to a loss of soil fertility and reduction of soil water holding capacity and soil structural stability, by facilitating erosion by water and wind, and is reflected in a constant increase in the rates of fertilizers used by farmers to maintain crop productivity (Du Preez *et al*., 2001; Roldán *et al*., 2003; D´Haene *et al*., 2008). CA as a modern agricultural practice that can enable farmers in many parts of the world to achieve the goal of sustainable agricultural production and enhanced the nutrient of soil. These practices are needed to be adopted by integrating into a set of appropriate management condition for enhanced availability of extractable Zn near the soil surface where crop roots proliferate due to surface placement of crop residues (Findlater ,2013) and high concentration of extractable Zn was observed in ZT (LavadoU *et al*., 2001). Continuous long term (11 years) no tillage and residue cover practice in semiarid area to significant positive effects on soil properties (He *et al*., 2011), to conserve soil moisture (Holland, 2014), protects the soil against degradation (Balota *et al*., 2004), ZT is generally associated with greater immobilization by the residues left on the soil surface (Bradford and Peterson 2000). The major CA based technologies being adopted is zero-till (ZT) wheat in the rice-wheat (RW), rice-maize (RM) and rice –lentil (RL) system of the Indo-Gangetic plains (IGP), Cropping sequence and rotations involving legumes helps in minimal rates of build-up of population of pest species, through life cycle disruption, biological nitrogen fixation, control of off-site pollution and enhancing biodiversity (Kassam and Friedrich, 2009; Dumanski *et al*., 2006).

Zinc is an essential element for crops and Zn deficiency is an ubiquitous problem (Hotz and Brown 2004; Welch and Graham 2004). Low availability of Zn in soils is one of the most widely distributed in world agriculture, particularly in Turkey, Australia, China and India (Brennan and Bolland, 2006). India alone more than 50% of the agricultural lands are deficient of Zn (Singh *et al.,* 2005), out of which ~85% of cereal growing area is frequently affected by low Zn (Regmi *et al.*, 2010) status. High-yielding cereals can remove 25 g/ha/yr of Zn in grains (Bell *et al.*, 2004). It is a wide gap between Zn availability and Zn removal which result in various Zn deficiency symptoms along with poor yield (Meena *et al.*, 2016; Parewa *et al.*, 2014). Intensive cropping of high yielding varieties of rice and wheat, Zn deficiency in rice emerged as major threats to sustaining high levels of food production (Singh *et al.*, 1999). The amount and rate of transformation of these forms of zinc solution determine the size of the labile Zn pool. There are many reports on study of different micronutrient fractions of soils (Viets, 1962; Smith and Shoukry, 1968; Iyengar and Deb, 1977; Raja and Iyenger, 1986; Meki and Olusegun, 2012), SOM exhibit a complex role in Zn partitioning in soils (Chami *et al.,* 2013). Whereas solid form of organic matter decreases Zn solubility by sorbing Zn on to surface functional groups (Boguta and Sokolowska, 2016), the complexation ofZn with dissolved organic compounds increases Zn solubility and mobility (Weng *et al.*, 2002; Houben and Sonnet, 2012). Cover crops contribute to the accumulation of organic matter in the surface soil horizon (Roldan *et al.*, 2003; Alvear *et al.*, 2005), and this effect is increased when combined with NT. Mulch also helps with recycling of nutrients, especially when legume cover crops are used, through the association with below-ground biological agents and by providing food for microbial populations. Greater carbon and nitrogen were reported under no-tillage and CT compared with ploughing (Campbell *et al.*, 1995, 1996).

Materials and Methods

Study area

This experiment was carried out in 2016 and is a part of the ongoing Conservation Agriculture which was initiated in *Kharif*-2011 at experimental Farm ($25^0$14' 03.9"N 87^0 02' 42.2"E and Elevation 24m), Bihar Agricultural Sabour, Bhagalpur (Bihar), India. The climate is semi-arid and the aridity of the atmosphere, scarcity of water, with extreme temperatures ranges between 28 to 44^{0}C and an annual average rainfall of 400 to 500 mm. Wells are the only source of irrigation and water table is quite deep (about 55-60 metres). The soil is neutral to slightly alkaline condition and soil texture sandy loam. The soil of the experimental field was loam in texture, low in organic carbon with slightly alkaline pH. Zinc fractions is influenced by soil properties such as pH, cation exchange capacity, texture and soil organic matter (Ramzan *et al*., 2014).

Technical programme

The treatments consists of three tillage practices T_1 Zero tillage (ZT), T_2 Permanent bed (PB), T_3Conventional Tillage (CT)) and threecropping systems S_1Rice-Wheat, S_2 Rice-Maize and S_3Rice-Lentil.

The study was made in split plot design with three replications. Full dose of P and K were applied as basal 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 samples

Surface and depth wise (00-15cm) Soil samples from each of the 29 plots after the harvest of 10th crops (completion of five years of the experiment, 2016) were collected. These samples were air dried and processed to pass through 2 mm sieve as usual and stored in polyethylene bags for analysis.

Fractionation of soil Zinc

Fractionation of Zn in the soil was performed according to techniques proposed by different authors (Chao (1972), Shuman (1985) Mandal *et al*., (1992) with slight modifications. To study the distribution of Zn between the various binding forms, the sequential fraction procedure outlined by Iwasaki and Yoshikawa (1993) was used, which is the modified form of the fractionation scheme of Miller, Martens, and Zeolazincy (1986). For the respective element species, the following extractants and procedures were used. Sample mass is 1.5 g in each step. Water soluble Zinc: 25 mL H_2O were shaken for 16 h. Exchangeable Zinc: 25 mL 0.5 M calcium nitrate [Ca(NO)3)2]-solution was shaken for 16h.Specifically absorbed [lead (Pb)-displaceable fraction] Zinc: 25 mLof a solution of 0.05 M lead nitrate [Pb $(NO_3)_2$] and 0.5 M ammonium acetate at pH 6.0 were shaken for 2 h. Acid-soluble fraction Zinc: 25 mL of 2.5% acetic acid were shaken for 2h.Manganese-oxide-bound fraction: 50 mL of 0.1 M hydroxylamine hydrochloride solution at pH 2.0 were shaken for 30 min.-Organic matter-bound fraction: 50 mL of 0.1 M potassium pyrophosphate solution at pH 10.0 were shaken for 2 h. Different zinc fractions in soil Analysis of standard procedures followed were briefly presented. All extract were analysed for zinc by atomic absorption spectrophotometer (AAS) instrument. Different fractions of soil Zn vary considerably in their chemical reactivity and bioavailability (Viets *et al.*, 1962; Krishnamurti *et al., (*2002).

Results and Discussion

A strong integrated effect of conservation agriculture such as Zero tillage (ZT), Permanent bed (PB) and Conventional Tillage (CT) with different cropping systemS_1, $S_2$and $S_3$was observed on transformation of zinc.

The variation among different fractions of zinc like Water soluble (WS-Zn), Exchangeable zinc (EX-Zn), Organic bound zinc (ORG-Zn) Amorphous zinc (AMO-Zn) Acid soluble zinc (Acid S.-Zn), Manganese bound zinc (MnO-Zn) Crystalline bound zinc (CRY-Zn), Specifically bound zinc (Sp.B.-Zn),) Residual zinc (RES-Zn) and Total zinc.

Distribution of different forms of zinc in different conservation agriculture practices

Result of different fraction of Zn are shows in table-1, rice establishment technique like zero tillage (T_1) significantly increased the WS-Zn, from 1.10 to 1.35 mg/kg, EX-Zn 0.76 to 0.89 mg/kg, ORG-Zn 5.67 to 7.30 mg/kg, AMO-Zn 4.95 to 5.92 mg/kg, CRY-Zn 6.01 to 7.30 mg/kg, MnO-Zn 3.75 to 5.29 mg/kg, Acid sol. Zn 2.99 to 3.57 mg/kg and Specifically bound 2.93 to 3.43 mg/kg post harvest soil. These results were statistically at par with permanent bed (T_2) and significantly over conventional tillage (T_3) treatment.

The effect of zero tillage, permanent bed and conventional tillage on RES-Zn and total-Zn were found statistically non significant. While, a perusal of data in table 2 indicated that rice-lentil (S_3) cropping system significantly augments WS-Zn from 1.11 to 1.30 mg/kg, Ex-Zn 0.78 to 0.88 mg/kg, ORG-Zn 6.13 to 6.72 mg/kg, AMO-Zn 5.37 to 5.86 mg/kg, MnO-Zn 3.82 to 5.57 mg/kg and Acid sol.-Zn 3.08 to 3.68 mg/kg soil as compare to rice-maize (S_2) cropping system. These results were also revealed that rice-maize (S_2) and rice-wheat (S_1) system statistically at par with each other.

The effects of different cropping systems were found non significant with CRY-Zn, Sp.B.-Zn, RES-Zn and Total-Zn of post harvest soil under conservation agriculture. The results clearly indicated that in soils under different conservation agriculture practices the water soluble zinc has showed significantly higher as compare to other zinc fractions, with bio-available nutrients in zero tillage with mulch. It might be due to different establishment technique. In case of Zero tillage and Permanent bed less disturb the layer of soil surface as compare to conventional tillage then the more retention of crop residue in soil.

Tilling allows the incorporation of the residues, which speeds up the decomposition process, which allows the nutrients to be available to plants for the next cropping season. minimum tillage may lead to nutrient immobility causing farmers to experience reduced yields (Giller *et al*., 2009). The decomposition of maximum crop residues, which have high nitrogen immobilization because of increased biological activity by organisms (Verhulst*et al*., 2010). Legume in cereal–cereal rotation enhances soil quality and raises organic matter level in soil (Ghosh et al., 2012). It greatly enhances SOC status of soil when adopted along with CA practice (Lal, 2004).residue decomposition, soil structural improvement, increased recycling and availability of plant nutrients (Jat *et al*., 2009).

The shows in table 3 of soil zinc fractions. The evaluations of the Zn fractions in these soils revealed that the Zn were present in the different treatments. It was varied from water soluble zinc 1.06 to 1.52 mg/kg.

Maximum water soluble was found zero-tillage in rice-lentil cropping system (T_1S_3),which was significantly superior but not a statistically at par with other treatment, lowest value was recorded in conventional tillage in rice-wheat system (T_3S_1) and conventional tillage in rice- maize system (T_3S_2).

Table.1 Effect of establishment techniques (T) and cropping systems (S) on zinc (mg kg^{-1}) fractions of soil under conservation agriculture

	WS-Zn	EX-Zn	ORG-Zn	AMO-Zn	Acid Sol.-Zn	MnO-Zn	CRY-Zn	Sp. B.-Zn	Residual–Zn	Total-Zn
T_1S_1	1.37	0.89	7.00	5.81	3.35	5.54	7.01	3.45	93.67	128.07
T_1S_2	1.16	0.83	6.71	5.78	3.20	3.99	6.85	3.22	88.13	120.42
T_1S_3	**1.52**	**0.95**	**7.30**	**6.18**	**4.16**	**6.34**	**7.05**	**3.64**	**93.70**	**130.16**
T_2S_1	1.36	0.85	6.46	5.67	3.36	4.37	6.88	3.54	90.46	123.29
T_2S_2	1.15	0.76	6.46	5.51	3.20	4.21	6.33	3.07	86.45	117.76
T_2S_3	**1.38**	**0.90**	**7.20**	**6.15**	**3.79**	**6.15**	**6.91**	**3.17**	**92.59**	**126.89**
T_3S_1	1.06	0.74	5.60	4.78	3.05	3.76	5.96	3.00	84.35	112.63
T_3S_2	1.06	0.74	5.22	4.82	2.85	3.26	5.97	2.57	83.01	109.84
T_3S_3	**1.18**	**0.80**	**5.67**	**5.26**	**3.08**	**4.22**	**6.11**	**3.22**	**87.63**	**117.19**
SEm(±)	0.06	0.06	0.36	0.31	0.28	0.47	0.36	0.29	4.15	4.00
C.D (P=0.05)	0.12	NS	NS	NS	NS	NS	NS	NS	NS	NS

WS: Water soluble EX-exchangeable, OC: organically complexed, AMOX: Amorphous sesqueoxide bound form, CRYOX: Crystalline sespueoxide bound form, MnOX: Manganese oxide bound

Table.2 Effect of establishment techniques (T) on zinc fractions (mg kg^{-1}) of soil under conservation agriculture

	WS-Zn	EX-Zn	ORG-Zn	AMO-Zn	Acid Sol.-Zn	MnO-Zn	CRY-Zn	Sp. B.-Zn	Residual–Zn	Total-Zn
ZT (T_1)	**1.35**	**0.89**	**7.30**	**5.92**	**6.97**	**5.29**	**3.57**	**3.43**	**91.83**	**126.26**
PB (T_2)	1.29	0.84	7.20	5.77	6.71	4.91	3.45	3.26	89.83	122.77
CT (T_3)	1.10	0.76	5.67	4.95	6.01	3.75	2.99	2.93	85.00	113.00
SEm(±)	0.04	0.03	0.32	0.22	0.19	0.27	0.16	0.13	2.45	2.18
C.D (P=0.05)	0.11	0.08	0.88	0.63	0.55	0.73	0.43	0.36	NS	NS

Table.3 Effect of cropping systems (S) on zinc fractions (mg kg^{-1}) of soil under conservation agriculture

	WS-Zn	EX-Zn	ORG-Zn	AMO-Zn	Acid Sol.-Zn	MnO-Zn	CRY-Zn	Sp. B.-Zn	Residual–Zn	Total-Zn
R-W (S1)	1.26	0.82	6.35	5.42	6.62	4.56	3.25	3.33	89.49	121.11
R-M (S2)	1.11	0.78	6.13	5.37	6.39	3.82	3.08	2.95	85.87	115.51
R-L (S3)	**1.30**	**0.88**	**6.72**	**5.86**	**6.69**	**5.57**	**3.68**	**3.34**	**91.20**	**125.41**
SEm(±)	0.03	0.03	0.21	0.17	0.20	0.27	0.16	0.16	2.39	2.31
C.D (P=0.05)	0.07	0.07	0.46	0.39	NS	0.60	0.35	NS	NS	NS

Table.4 Correlation coefficient among the soil zinc fractions

	WS-Zn	EX-Zn	ORG-Zn	AMO-Zn	CRY-Zn	MnO-Zn	Acid Sol-Zn	Sp. Bound-Zn	RES-Zn
EX	0.675*								
ORG	0.422	0.407							
AMO	0.611	0.641	0.476						
CRY	0.801**	0.858**	0.620	0.871**					
MnO	0.586	0.800**	0.179	0.766*	0.773*				
Acid Sol	0.602	0.619	0.225	0.827**	0.763*	0.927**			
Sp.Bd.	0.871**	0.709*	0.550	0.675*	0.793*	0.683*	0.706*		
RES	0.805**	0.931**	0.396	0.797*	0.914**	0.916**	0.822**	0.843**	
Total-Zn	0.817**	0.860**	0.393	0.839**	0.926**	0.933**	0.911**	0.839**	0.980**

***and ** denote significant at 5 and 1% level, respectively.**

The evaluations of the Zn fractions were present in the highest in T_3S_2 treatment of total zinc (130.16 mg/kg) and followed by residual zinc (93.70 mg/kg), organic bound zinc (7.30 mg/kg), crystalline bound zinc (7.05mg/kg), manganese bound zinc (6.34 mg/kg), amorphous zinc 6.18 (mg/kg), acid soluble zinc (4.16 mg/kg), specifically bond zinc (3.64 mg/kg), water soluble zinc (1.52 mg/kg), exchangeable zinc (0.95 mg/kg).It might be due to higher CEC and organic matter content under zero tillage owing to least disturbance of soil than conventional tillage. The data from this study agreed with data of Shuman (1976, 1977) and Dasappagol *et al.,* (2017). The concentration and per cent contribution of WS and EX - Zn fraction to total Zn was the lowest among all the Zn fractions and the high buffering capacity of these soils resulted in low amount of water soluble + exchangeable Zn (Deb 1997). Alloway (2008) noted that when soils are rich in rapidly decomposable organic matter, zinc may become more available due to the formation of soluble organic zinc complexes which are mobile and also probably capable of absorption into plant roots. Xu *et al.*, (2006) reported that planting rice could increase the concentration of carbonate- and Fe-Mn oxides bound Zn in soil. Thus, roots activities also influenced the availability of Zn via changing the transformation between chemical fractions of Zn in soil. Zn can increase the Zn availability by decreasing the pH and enhancing the transformation and distribution of exchangeable, loose organic- and carbonate bound Zn, thus promoting the Zn uptake in the roots of winter wheat (Liu *et al*., 2018). Residual and oxide bound Zn is known to be more stable while as exchangeable and water soluble Zn fractions are more soluble (Rahmani *et al*., 2012). Hence, there is a scope for the establishment of crop residues with mulch with different tillage practice etc. with improving the micronutrient status in soil and growth of the plants and which can be promoted for sustainable agricultural development reported by Dasappagol *et al.*, (2017).

Correlation study among the Zinc fractions

The data on correlation coefficient values among different zinc fractions of soil (Table 4) revealed that dynamic equilibrium of zinc existed between water soluble, exchangeable, organically complex, acid soluble and MnO-Zn as positive and highly significant correlation co-efficient values were noted among these fractions. Organically bounded zinc had positive correlation but failed to produce significant correlation with any fraction of zinc. Existences of dynamic equilibrium among these fractions have been reported by Sharad and Verma (2001). This suggested that mutual transformation of water soluble plus exchangeable inorganically complex, organically complex, crystalline sesquioxide bound and residual zinc seems to be dominant for maintaining zinc equilibrium in soil during absorption of zinc by crops. The mutual significant correlation among different fractions also helps in maintaining quick equilibrium and replenishing the available fractions in soil to meet the crop requirement

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