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Distribution of Zinc fractions in surface Alfisol after five years of Conservation agriculture practices in Rainfed Pigeonpea

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Abstract
The experiment was conducted at Agricultural Research Station, Bheemarayanagudi. This experiment consisting of five treatments viz., conventional tillage (T_1), zero tillage raised bed with mulch (T_2), zero tillage raised bed without mulch (T_3), zero tillage with mulch (T_4) and zero tillage without mulch (T_5). Sequential extraction was employed to estimate various chemical pool of zinc viz. water soluble plus exchangeable zinc, organically bound zinc, amorphous bound zinc, crystalline bound zinc, manganese oxide bound zinc and residual zinc. Among these fractions water soluble plus exchangeable zinc was recorded the highest in T_2 (1.04%) and marginally recorded in other treatments like T_4 (0.67%), T_4 (0.67%), T_3 (0.65%), T_5 (2.02%) and the lowest recorded in T_1 (0.49%) and the highest organically bound zinc was recorded in T_4 (3.34%), marginally recorded in treatments like T_2 (2.45%), T_3 (2.23%), T_5 (2.02%) and the lowest recorded in T_1 (0.80%). Amorphous bound zinc was the highest in T_2 (2.73%), marginally it was in T_4 (2.35%), T_3 (2.25%), T_5 (2.40%) and lowest recorded in T_1 (1.54%). Crystalline bound zinc was in highest recorded in T_2 (1.58%) and other treatments like T_4 (1.44%), T_3 (1.10%), T_5 (1.52%) and the lowest recorded in T_1 (1.065%). The highest manganese oxide bound zinc value found in T_2 (1.48%) and other treatments like T_3 (1.26%), T_4 (1.12%), T_5 (1.29%) and the lowest recorded in T_1 (1.02%) and also residual zinc was dominant fraction among the zinc fraction, it was 95.44% in T_1 and it was recorded the highest among treatments and other treatments like T_3 (93.18%), T_4 (91.16%), T_5 (92.88%) and T_2 (90.86%) respectively.

Keywords: chemical pools of zinc, conservation agriculture, zinc fractions

1. Introduction

Zinc is one of the essential micronutrient element and is required by the crop plants in very small amounts. Nevertheless, from nutrition point of view, they are indispensable like any other essential element. It plays a fundamental role in various metabolic processes in plants. It is a component of a series of enzymes such as dehydrogenases, proteinases, peptiodases, phospohydrolases, carbonic anhydrase and superoxide dismutaseand it plays an important role in auxinmetabolism, preferential accumulation of chlorophyll, protein synthesis and starch metabolism. Therefore, deficiency of zinc in soil adversely affects the growth and development of crop plants. It was estimated that about 30 per cent of the agricultural soils of the world may be zinc deficient to the extent that normal growth and development of wide range of agriculturally important crops are affected (Sillanappa, 1982) [19]. Work done on All India Co-ordinated Research Scheme on micronutrients in soils and plants have shown that 47 per cent of Indian soils are deficient in zinc (Katyal, 1985) [13] whereas, among all the micronutrients. Takkar (1996) [20] indicated that zinc deficiency is wide spread in Indian soils i.e. nearly 50 per cent of the Indian soils and 78 per cent of Karnataka soils were found to be deficient. Katyal (1985) [13] reported that the deficiency of zinc in South Indian soils most commonly seen in Vertisols and Alfisols. Shivaprasad *et al*. (1996) [18] indicated that zinc is the most limiting nutrient to crop growth throughout the Karnataka state.

Zinc deficiency is frequently occurring in arid and semiarid regions of the world including India and Karnataka. Soils characterized by having high pH, low organic matter content, excess soluble salts and more sodium adsorption on cation exchange sites. Hence, Zn deficiency has become a major micronutrient constraint after N and P deficiency. Total Zn content in soil is not a good indicator of its bioavailability to the growing plants. Zinc may bind with various organic and inorganic soil components ($CaCO_3$, Fe, Mn and Al oxides, organic matter etc.). In alkaline calcareous soils of arid and semiarid regions, Zn solubility may be controlled by $CaCO_3$. Plant roots directly absorb nutrients which are present in soil solution. Due to uptake of Zn^{+2} by plant roots, natural equilibrium among these different pools is disturbed. In order to attain the equilibrium, Zn bound to different soil solid phases releases to replenish the soil solution Zn. Hence, these different chemical pools of Zn control its bioavailability and transport to plant roots. Therefore, in order to assess soil Zn status and crop requirement.

Material and Methods

This experiment was conducted in Agricultural Research Station, Bheemarayanagudi and collected the soil samples from surface layer (0-15 cm) at different tillage practices, the collected soil samples were air dried, ground, passed through a 2mm sieve and analyzed for different soil chemical properties along with different zinc fractions in soil. Analysis of different chemical properties of soil and standard procedures followed were briefly presented. All extract were analysed for zinc by atomic absorption spectrophotometer (AAS) instrument.

Sl No	Zinc fractions	Solution	Soil(g) : Solution(ml)	Conditions	Reference
1	Water soluble + Exchangeable (WSEX)	1M(NH_4)OAc (pH 7.0)	5 : 20	Shake for 60 mins	Murthy(1982) modified by Mandal and Mandal (1986)
2	Organically complexed (OC)	0.05M $Cu(OAc)_2$	5 : 20	Shake for 60 mins	Murthy(1982) modified by Mandal and Mandal (1986)
3	Amorphous sesqueoxide bound form (AMOX)	0.2M$(NH_4)_2C_2O_4H_2O$ + 0.2M$H_2C_2O_4$ (pH 3.0)	5 : 20	Shake for 60 mins	Murthy(1982) modified by Mandal and Mandal (1986)
4	Crystalline sesqueoxide bound form (CRYOX)	0.3 M sodium citrate + 1.0 M $NaHCO_3$ + 1g NaS_2O_4 (Citrate-Bicarbonate and Dithionite (CBD)	5 : 20	Boiling water bath -10min, stir occasionally, keep on water bath (70-80ºC), Stir occasionally	Murthy(1982) modified by Mandal and Mandal (1986)
5	Manganese oxide bound (MnOX)		5 : 20	Shake for 30 mins	Chao(1972)
6	Residual Zinc	Total zinc – sum of all fractions of zinc			

Results and Discussion

Physico-chemical properties of soil under different tillage practices

The result showed that, there was no significant effect of either tillage or crop residues on particle size analysis like sand, silt, clay, tillage practices and these soil comes under loamy sand texture and proportion of these particles ranged from 73.50 to 75.00% sand, 14.00 to 16.00% silt and 10.00 to 12.00% clay. This might be due to the soil texture is a permanent property which is the origin of parent material where it does not change with the tillage practices. The pH of soils ranged from 6.42 to 6.76, where the highest pH 6.64 to 6.76 in both layers respectively, were noticed in the treatment offered with raised bed with mulch and remaining treatments had marginal value. Similar non-significant effect of tillage and residue management have been reported by Govaerts *et al*. (2006) [7] even after 26 successive years raising of either maize or wheat crops with different rates (0, 150 and 300 kg ha^{-1}) of N fertilization and residue management practice.

There was no significant effect of tillage practice on soil EC and was ranged from 0.25 to 0.28 dSm^{-1}. The higher conductivity was due to tillage break down of macro aggregates and increasing surface area thus releasing nutrients and contributing to the elevated levels of salts in solution. Application of residues helped to retain more moisture and accelerated dissolution of salts apart from enhanced decomposition and thus releasing of nutrients to soil solution contributed to increased solution conductivity which are comparable with the results reported by Govaerts *et al*., 2006 [7].

Organic carbon was significantly influenced by different tillage practices and the highest organic carbon at 0-15cm depth was recorded in zero tilled plot with mulch (0.64%) and it was *on par* with raised bed with mulch (0.55%) and zero tillage without mulch (0.54%) which signified the importance of retention of residues on organic carbon build up. The organic carbon in conventional tillage consistently remained as the lowest (0.21%), but marginal value (0.42%) was noticed in raised bed without mulch. Organic carbon build up is intimately linked to all other properties discussed so far which increased due to both tillage and residue management (Karlen *et al*., 1992) [12].

The available soil phosphorus (kg ha^{-1}) was also greatly influenced by the previous crop residues. Therefore at surface layer of soil the highest soil available phosphorus was noticed in zero tillage with mulch (25.75 kg ha^{-1}) and it was *on par* with other treatments like raised bed with mulch (23.64 kg ha^{-1}) and raised bed without mulch (21.25 kg ha^{-1}). These treatments were significantly superior over rest of the treatments i.e. 19.38 kg ha^{-1}. More available phosphorus was noticed in zero tillage than conventional tillage without mulch(17.71 kg ha^{-1}) might be due to soil P mineralization accelerated under zero till than conventional till system (DuPreez *et al.* 2001 and Duiker and Beegle, 2006) [5, 4].

The soil CEC was recorded the lowest in conventional tillage (6.5 cmol (P^+) kg^{-1}) followed by zero tillage without mulch (6.60 cmol (P^+) kg^{-1}). The highest value was observed in zero tillage with mulch (8.02 cmol (P^+) kg^{-1}) followed by raised bed with mulch(7.54 cmol (P^+) kg^{-1}) and raised bed without mulch(6.80 cmol (P^+) kg^{-1}) and these treatments were *on par* with each other and were significantly superior over flat bed without mulch and conventional tillage practices. It might be due to clay and organic matter contents of the soil.

Amorphous form of iron oxide was recorded significantly higher in flat bed with mulch (0.35%) and raised bed with mulch (0.33%) and also it was *on par* with raised bed without mulch (0.31%) and flat bed without mulch (0.31%) treatment. But significantly the lowest iron oxide was recorded in conventional tillage (0.27%) and it was due to crop residues as well as completely weathered soil. Enrichment of iron due to intense weathering and subsequent loss of basis due to their position at higher topography, with the age of soil and also different tillage practices. Similar results were reported by Arduino P., 1986. [1]

Available zinc was significantly recorded the highest in zero tillage with mulch 0.58 ppm and also marginally recorded in raised bed with mulch 0.55 ppm and rest of the other treatments like raised bed without mulch (0.50 ppm), zero tillage without mulch (0.47 ppm) but significantly the lowest value recorded in conventional tillage(0.42 ppm). It might be due to complementary of crop residues to the nutrient pool. Providing mulch reduced losses of micronutrients and leaching through the temporary immobilization. Similar opinions 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) [5, 6, 17] and residue retention significantly affected organic carbon, available macro and micro nutrients and physical properties etc.

Distribution of different forms of zinc in different conservation agriculture practices

The results of the different chemical pools of zinc under different tillage practices are presented and their relative percentage are depicted in the figure 1.

Water-soluble + exchangeable zinc (WSEX-Zn): In conventional tillage, out of that total zinc per cent contribution of water-soluble + exchangeable zinc was the lowest (0.49%). This might be due to high zinc buffering capacity of soils which results in low amount of water soluble + exchangeable zinc. Similar findings were reported by Iyengar and Deb, 1977 [9] and the highest water soluble plus exchangeable zinc in raised bed with mulch(1.04%) but marginal values were recorded in raised in raised bed without mulch 0.65%, zero tillage with mulch 0.67% and zero tillage without mulch 0.57%. Among all the treatments, raised bed with mulch and zero tillage with mulch recorded higher amount of WS+EX-Zn it might be due to more crop residues helps to increase organic matter content in soil. The variation in the content of WS+EX-Zn fraction among the different treatments might be due to the soil reaction which determines solubility of zinc.

Organically complexed Zinc: The per cent contribution of organically bound zinc from the total zinc was recorded the highest in zero tillage with mulch (3.34%) and marginally values were recorded in raised bed with mulch (2.45%), raised bed without mulch (2.23%) and zero tillage without mulch (2.02%). It might be due to crop residue mulch helps to build up organically complexed zinc. Similar results were reported by Iwasaki and Yoshikawa, 1993 but the lowest values were recorded in conventional tillage which was 0.80% and might be due to less addition of crop residues and FYM, where organically complexed zinc play a important role in plant nutrition point.

Manganese sesquioxide bound zinc: The per cent contribution of manganese sesquioxide bound zinc from the total zinc was the highest that means next only to amorphous sesquioxide bound zinc and residual zinc. The Mnox-Zn was recorded the lowest contribution in conventional tillage (1.02%) whereas, the highest values were recorded in raised bed with mulch (1.48%) followed by zero tillage without mulch (1.29%) and marginal values were recorded in raised bed without mulch(1.26%) and zero tillage with mulch (1.12%) respectively. This might be due to addition of crop residues and minimum tillage operation and also due to occluded or co-precipitating with hydrous oxide of manganese, iron and form a principal matrix with abundant held zinc. Similar findings were also reported by Jenne, 1968 [11].

Amorphous sesquioxide bound zinc (AMOX-Zn): The contribution of amorphous sesquioxide zinc from the total zinc was recorded the highest in raised bed with mulch (2.73%) which followed by zero tillage with mulch (2.35%) and zero tillage without mulch (2.40%) whereas, the lowest values were recorded in conventional tillage (1.54%). It might be due to higher content of amorphous sesquioxide bound zinc than crystalline sesquioxide bound zinc which attributed to greater ability of amorphous sesquioxide to adsorb zinc because of their high specific surface area. Similar results were reported by Devis and Leckie, 1978 [3].

Crystalline oxide bound zinc (CRY-Zn): The per cent contribution of CRY-Zn from the total Zn was 1.58per cent and 1.33 per cent. The highest distribution of CRY-Zn was recorded in raised bed with mulch 1.58 per cent followed by zero tillage without mulch 1.52 per cent and the lowest values were recorded in conventional tillage 0.87 per cent. The research findings resulted that the CRY-Zn was dominant when compared with the other fractions, it might be due to chemical affinity or specific adsorption and also due to predominance of crystalline iron oxide content. Similar findings were also reported by Pal *et al*., 1997 [16].

Residual Zinc: Residual zinc fraction constituted the largest proportion from the total zinc content of soil. The per cent contribution of residual zinc from total zinc was 95.39 per cent and 95.44 per cent in tillage. The highest per cent contribution was observed in conventional tillage 95.44 per cent whereas, marginal values were recorded in raised bed without mulch 93.12 per cent, zero tillage without mulch 92.88 per cent but the lowest recorded in raised bed with mulch 90.86 per cent and zero tillage with mulch 91.16 per cent. It might be due to inactive clay lattice of residual zinc which indicates the unavailable form of zinc to plant nutrition point of view. The crop residues treatments have the lowest residual zinc as compared to conventional tillage. It indicates active clay lattice of nutrients which helps in increasing availability of nutrients to plants. It is considered as the primary form of the native zinc and associated with soil mineral fractions. Type of dominant clay mineral (smithosite, franklinite, wilmite) in a soil decides the amount of residual Zn fraction (Iyengar *et al*., 1981) [10].

Total Zinc: The contribution of total zinc was recorded the lowest in conventional tillage practice (52.50 ppm) whereas, total zinc recorded marginal values in raised bed with mulch 56.72 ppm followed by raised bed without mulch 54.23 pm and zero tillage without mulch 56.53 ppm but zero tillage with mulch recorded the highest among the treatments it was 70.60 ppm it might be due to complimentary effect of organics. Although, total zinc content is considered as a poor indicator of zinc supplying capacity of soil for long term management of a cropping system.

Table 1: Treatment details

T_1: Conventional tillage
T_2: Zero tillage with raised bed with mulch
T_3: Zero tillage raised bed without mulch
T_4: Zero tillage flat bed with mulch
T_5: Zero tillage flatbed without mulch

Table 2: Effect of tillage and crop residues on different Zinc fractions in soil at 0-15cm depth

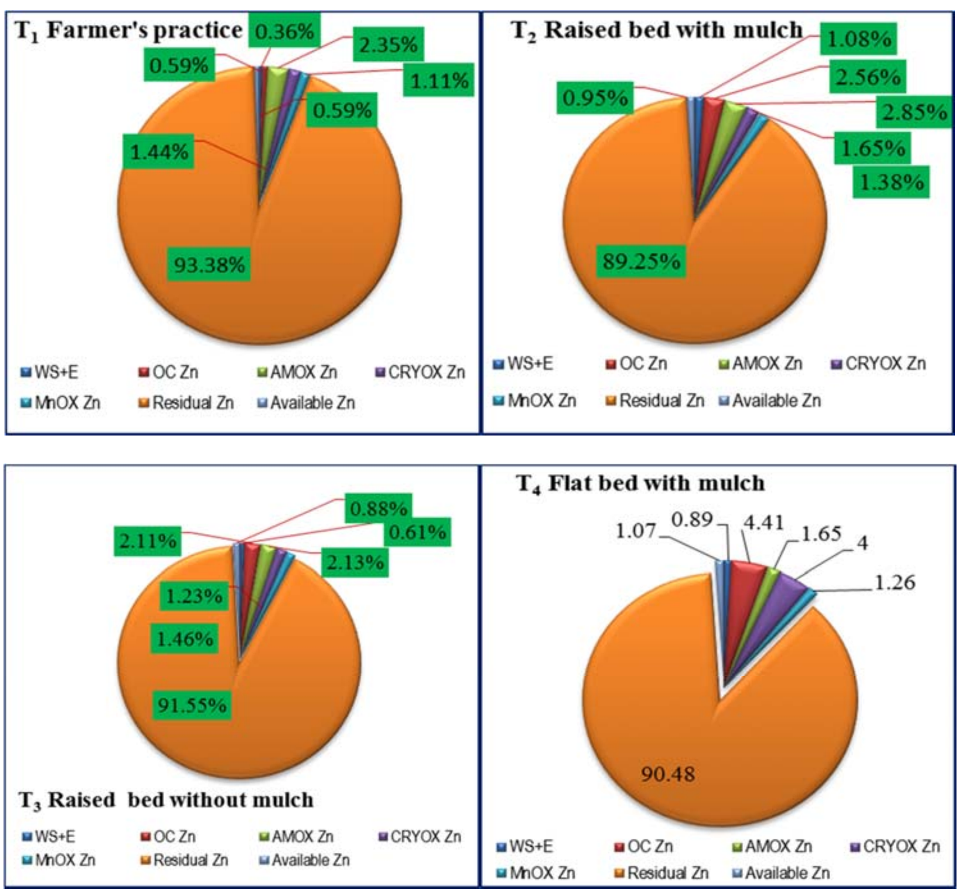
Treatments	WS+E	(OC) Zn	(AMOX) Zn	(CRYOX)Zn	(MnOX) Zn	Residual Zn	Total Zinc	Available Zn
	ppm							
T1 - Farmer's practice	0.26 (0.36)	0.42 (0.59)	1.66 (2.35)	1.02 (1.44)	0.79 (1.11)	66.03 (93.38)	70.60	0.42 (0.59)
T2 - Raised bed with mulch	0.59 (1.08)	1.39 (2.56)	1.55 (2.85)	0.90 (1.65)	0.75 (1.38)	48.43 (89.25)	54.26	0.52 (0.95)
T3 - Raised bed without mulch	0.35 (0.61)	1.20 (2.11)	1.21 (2.13)	0.83 (1.46)	0.70 (1.23)	51.93 (91.55)	56.72	0.50 (0.88)
T4 - Zero tillage with mulch	0.48 (0.89)	2.37 (4.41)	0.89 (1.65)	0.54 (1.0)	0.68 (1.26)	48.59 (90.48)	53.70	0.58 (1.07)
T5 - Zero tillage without mulch	0.31 (0.59)	1.10 (2.09)	0.75 (1.42)	0.46 (0.87)	0.53 (1.0)	48.88 (93.10)	52.50	0.47 (0.89)
S. Em±	0.030	0.175	0.071	0.132	0.172		10.979	0.143
C.D. at 5%	0.093	0.541	0.219	NS	NS	NS	NS	NS

WS+E: Watersoluble +exchangeable, OC: organically complexed, AMOX: Amorphous sesqueoxide bound form, CRYOX: Crystalline sespueoxide bound form, MnOX: Manganese oxide bound

Table 3: Effect of tillage and crop residues on different Zinc fractions in soil at 15-30cm depth

Treatments	WS+E	(OC) Zn	(AMOX) Zn	(CRYOX) Zn	(MnOX) Zn	Residual Zn	Total Zinc	Available Zn
	ppm							
T1 - Farmer's practice	0.25 (0.36)	0.25 (0.36)	1.57 (2.29)	0.91 (1.31)	0.84 (1.22)	63.84 (93.38)	68.36	0.34 (0.49)
T2 - Raised bed with mulch	0.56 (0.99)	1.2 (2.15)	1.53 (2.70)	0.69 (1.22)	0.67 (1.18)	50.97 (90.16)	56.53	0.55 (0.97)
T3 - Raised bed without mulch	0.34 (0.62)	1.15 (2.12)	1.36 (2.50)	0.60 (1.10)	0.84 (1.54)	49.51 (91.29)	54.23	0.43 (0.79)
T4 - Zero tillage with mulch	0.43 (0.75)	2.29 (4.03)	0.97 (1.71)	0.57 (1.0)	0.68 (1.19)	50.80 (89.59)	56.70	0.50 (0.88)
T5 - Zero tillage without mulch	0.31 (0.57)	1.0 (1.86)	0.83 (1.54)	0.67 (1.24)	0.55 (1.02)	50.39 (93.74)	53.75	0.39 (0.72)
S. Em±	0.067	0.149	0.088	0.083	0.121		17.478	0.041
C.D. at 5%	0.206	0.458	0.271	NS	NS		NS	0.127

WS+E: Watersoluble +exchangeable, OC: organically complexed, AMOX: Amorphous sesqueoxide bound form, CRYOX: Crystalline sespueoxide bound form, MnOX: Manganese oxide bound



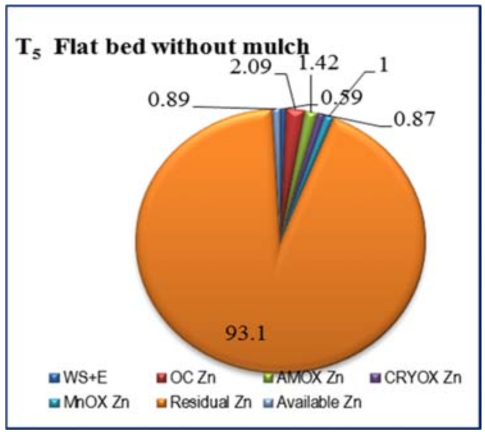


Fig 1: Effect of tillage and crop residues on different Zinc fractions in soil at 0-15cm depth

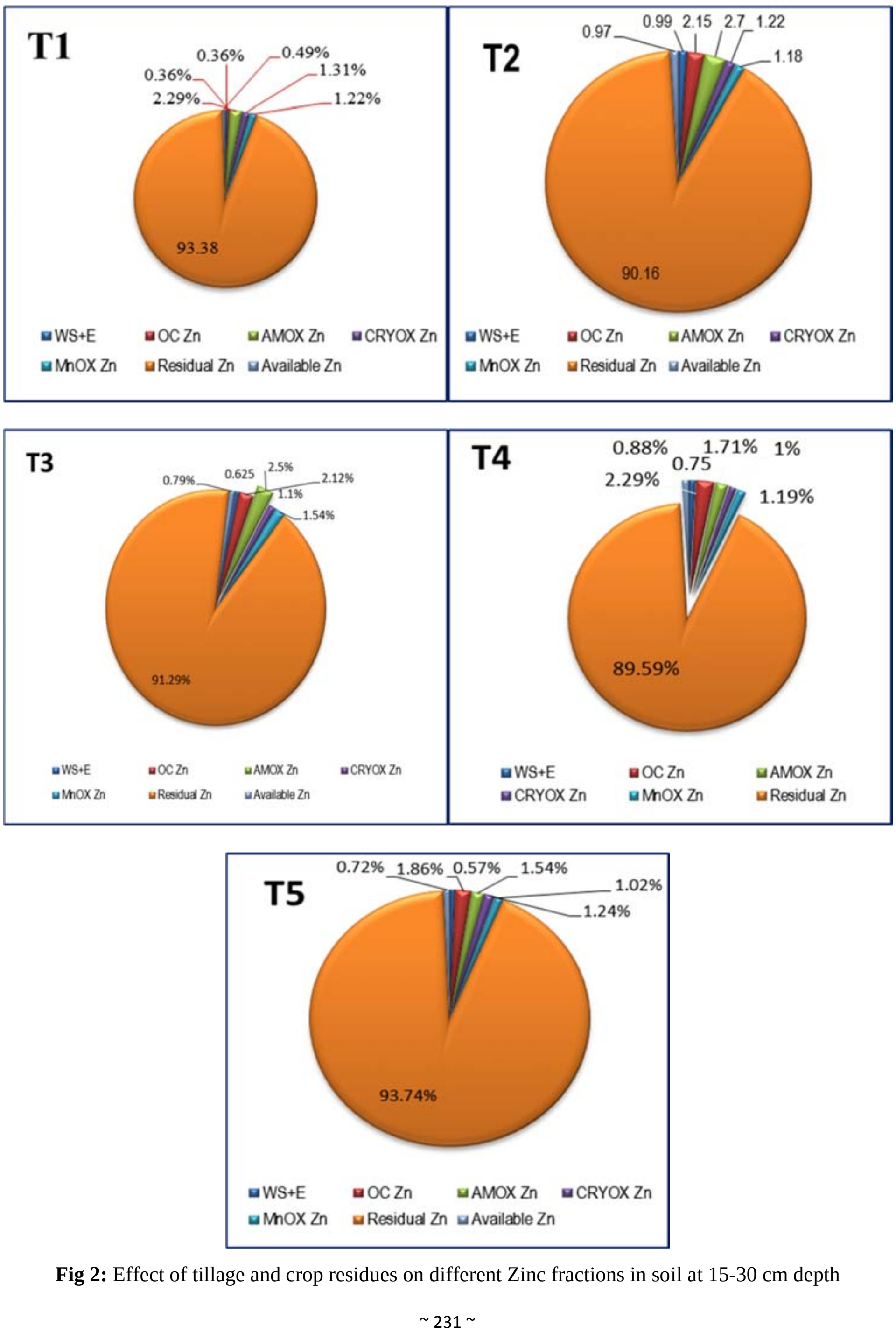


Fig 2: Effect of tillage and crop residues on different Zinc fractions in soil at 15-30 cm depth

Conclusion

The results clearly indicated that in soils under different conservation agriculture practices the available zinc has showed significantly higher as well organic bound zinc with bioavailable nutrients in zero tillage with mulch followed by zero tillage raised bed with mulch. Among the different zinc fractions water soluble plus exchangeable zinc, organically bound zinc and bioavailable nutrients were the lowest in conventional tillage but zero tillage with mulch practice recorded significantly higher water soluble + exchangeable zinc, organic bound zinc and available zinc when compared with other treatments. Hence, there is a scope for the establishment of crop residues with mulch with different tillage practice etc. with improving the better growth of the plants and which can be promoted for sustainable agricultural development.

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