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# Fractionation and distribution of zinc under integrated nutrient management system on maize-wheat cropping system in Typic Haplustepts

**Priyanka, SK Sharma and RH Meena**

## Abstract
A field study entitled "Fractionation and distribution of zinc under integrated nutrient management system on LTFE's maize-wheat cropping system in Typic *Haplustept* soils of Udaipur" was conducted during *Kharif* 2014-15 and 2015-16 in the Long Term Fertilizer Experiments initiated in *Kharif*, 1997 at the Instructional Farm of the Rajasthan College of Agriculture, Udaipur. The soil of the experimental site was sandy clay loam in texture, slightly alkaline in reaction, medium in available nitrogen and phosphorus, while high in potassium and zinc. The objectives were to assess effect of INM on cationic Zinc fractions and to establish relationship among Zn fractions themselves and with yield, nutrient uptake by maize and wheat and soil properties. The soil of the experimental field was sandy clay loam in texture, non-saline and slightly alkaline in reaction. The experiment consisted of 12 treatment combinations with four replications in a randomized block design. After harvest of Wheat crop under maize-wheat rotation of both years (2014-15 & 2015-16), the pooled analysis reveals that integrated nutrient management practice (100% NPK+ FYM 10 t $ha^{-1}$) increased zinc fractions except DTPA soluble. However, DTPA–Zn was significantly high with 100% NPK +Zn application followed by 100% NPK +Zn +S. These zinc fractions deceased with depth in all INM treatments. Water soluble zinc fraction highly correlated with reducible (0.926**) and DTPA (0.914**) fractions. DTPA –Zn and reducible Zn also correlated (r = 0.920**) significantly. Positive correlation between Zn fractions and OC and negatively with pH was observed under this study. Exchangeable-Zn was highly correlated with yield and DTPA-Zn with grain yield and Zn uptake by grain. The values of different Zn fractions were correlated and found that total Zn had positive and significant correlation with other fractions, suggesting the existence of dynamic equilibrium among the different forms. It is quite evident from the values of coefficients of correlation that almost all fractions are dependent upon each other.

**Keywords:** Fraction, water soluble, exchangeable, residual, reducible, DTPA soluble

## Introduction
Micronutrient cations are usually held very strongly by the organic legends and exist in the soils in different pools. Viet (1962) [14] postulated existence of five distinct pools of micronutrient cations in soil viz., (i) soil solution or water soluble, (ii) exchangeable, (iii) adsorbed, complexed and chelated, (iv) associated with secondary minerals and as insoluble metal oxides and hydroxides, and (v) associated with primary minerals. First three pools exist in a state of dynamic equilibrium and constitute the labile pool from which the plants draw micronutrients. Consequently, a number of sequential fraction procedures have been developed for studying the relative abundance of different fractions in the soils and their relative importance in supplying micronutrients to the growing crops. Long-term experiments (LTE) offer a better platform to visualize the status of micronutrients in soil under intensive cropping and their contribution to sustained production. Organic matter redistribution the forms of applied Zn into the exchangeable and organic matter fractions. Micronutrients are important for maintaining soil health and also increasing productivity (Rattan *et al.,* 2009). They are being made available to plant through their various fractions like water soluble, exchangeable, available, reducible, soluble and residual. The availability of the micronutrients in soil is also influenced by the soil properties like soil pH, soil EC, content of organic matter, free lime, soil, moisture, proportion of clay and silt fractions, type of clay, concentrations of interacting ions, *etc.* (Atheefa *et al*., 2011).

## Material and methods
The experiment was conducted at the Instructional Farm, Rajasthan College of Agriculture, Udaipur. The site is situated in south-eastern part of Rajasthan at an altitude of 579.5 m above mean sea level, at 24º35' N latitude and 74º42' E longitude.

The region falls under agro-climatic zone IV a (Sub- Humid Southern Plain and Arawali Hills) of Rajasthan. Initial status of LTFE field in 1997 was N, P and K 360 22.4, 671 kg $ha^{-1}$ and Zn, Fe, Cu and Mn was 3.76, 2.52, 3.12, and 17.4 ppm. The experiment consisted of 12 treatment combinations *viz.*, $T_1$-Control, $T_2$-100%N, $T_3$-100%NP, $T_4$-100%NPK, $T_5$-100%NPK+Zn, $T_6$-100%NPK+S, $T_7$-100%NPK+Zn+S, $T_8$-100% NPK+ *Azotobacter*, $T_9$-100% NPK+FYM 10 t $ha^{-1}$, $T_{10}$-FYM 10 t $ha^{-1}$ +100%NPK (-NPK of FYM), $T_{11}$-150%NPK and $T_{12}$-FYM @ 20 t $ha^{-1}$ with four replications in a randomized block design. The sources used for applying N, P and K were urea, DAP (adjusted for its N content) and muriate of potash, respectively. Gypsum and zinc sulphate ($ZnSO_4$. $7H_2O$) were used to supply S and Zn respectively. The other sources of nutrients were FYM (farm yard manure) and bio fertilizer (*Azotobacter* sp.). Soil samples from two different depths (0-15 and 15-30 cm) from each plot were drawn before sowing and after harvest of crop and analysed by standard procedure to assess the zinc fractions by Jackson (1979) [4], Viet (1962) [14] sequential fraction analysis method.

**Result and discussion**

Data pertaining to the effect of INM treatments on different fractions of zinc were presented in Table 1 to 6. Application of fertilizers alone or in combination with FYM treatment resulted in a significant build up of all forms of Zn over control.

**Water Soluble Zn:** Data presented in Table 1 shows that water soluble zinc (WSZn) content of the soil after harvest of maize- wheat crop varied from 0.160 to 0.460 ppm and 0.160 to 0.420 ppm at 0-15 cm and 0.150 to 0.420 and 0.140 to 0.400 ppm at15-30 cm depth during 2014-15 and 2015-16, respectively. Application of 100% NPK + FYM 10 t $ha^{-1}$ resulted higher content of WSZn at both depth, during 2014-15 and 2015-16. Pooled data also reveals that the highest 0.440 and 0.420 ppm WSZn with 100% NPK + FYM 10 t $ha^{-1}$ application at 0-15 cm and 15-30 cm as compared to 0.160 and 0.145 ppm under control was obtained. Water soluble zinc content reduces with depth irrespective of INM treatment applied.

**Exchangeable Zn:** Examination of data in Table 2 indicates that Exchangeable Zinc (ExZn) significantly increases as compared to control in all INM treatments at both depths during experimentation. The highest ExZn 0.670 and 0.690 ppm during 2014-15 at 0-15 cm depth was observed with 100% NPK + FYM 10 t $ha^{-1}$. Pooled data also indicates highest ExZn under this treatment i.e. 0.680. This treatment was statistically significant than all other treatment combinations. Similar trend was observed at 15-30 cm depth as 0.620 ppm ExZn was obtained under 100% NPK + FYM 10 t $ha^{-1}$ treatments under pooled analysis and this treatment was significantly superior than other treatments.

**DTPA Soluble Zn:** DTPA soluble Zn differed significantly during both of years (Table 3). Application of zinc fertilizer had direct relation with exchangeable zinc in soil. DTPA soluble Zn content of the soil at 0-15 cm and 15-30 cm depth after harvest of wheat crop varied from 2.02 to 3.71 ppm and 1.95 to 3.64 ppm in $T_1$ to $T_5$ (100% NPK + Zn) treatments, respectively during 2014-15 and 2015-16. The higher value was recorded in $T_5$-100% NPK + Zn at 0-15 cm (3.71 and 3.67 ppm) and at 15-30 cm (3.59 and 3.64 ppm) during 2014-15 and 2015-16, respectively, followed by $T_7$ (100% NPK+ Zn + S) with 3.66 and 3.68 ppm exchangeable Zn at 0-15 cm depth which was at par with $T_5$. Thus, the complete recommended doses of fertilizer with $ZnSO_4$ recorded the highest value compare to other treatment. The decreasing trend of this fraction with depth was observed. Pooled analysis also reveals the same pattern of the exchangeable Zinc.

**Reducible Zn:** The pooled analysis of both year results reveals that the highest reducible form of zinc was found in integrated nutrient management treatment i.e. $T_9$-100% NPK + FYM 10 t $ha^{-1}$. The highest values of reducible form of zinc 6.83 and 6.74 ppm and 6.59 and 6.53 ppm at 0-15 cm and 15-30 cm depth was recorded during 2014-15 and 2015-16 followed by FYM 10 t $ha^{-1}$+100% NPK (-NPK of FYM) ($T_{10}$) with pooled values 6.63 and 6.40 ppm at 0-15 cm and 15-30 cm depth. This form of zinc also decreases with depth irrespective of different INM treatments applied (Table 4.34).

**Residual Zn:** The residual Zn (Table 5) which contributed the major fraction in soil and apparently associated with soil minerals, showed a higher pooled value of 263.60 ppm in 0-15 cm and 261.93 ppm in 15-30 cm. The residual form of Zn differed significantly when pooled over years. The highest value was recorded under application of 100% NPK + FYM 10 t $ha^{-1}$ ($T_9$) followed by $T_{10}$. The residual zinc fraction constituted higher percentage of total zinc fraction.

**Total Zn:** The higher pooled value was recorded under application of 100% NPK + FYM 10 t $ha^{-1}$ ($T_9$) followed by $T_{10}$ - FYM 10 t $ha^{-1}$ + 100% NPK (-NPK of FYM). In two years run only slightly decline was observed in the mean value of total zinc. In general, total Zn converted into available Zn under its depletion status of soil, which might utilize by crop. The total soil zinc concentration ranged from 255 to 280 ppm in 0-15 cm and 254 to 276 ppm at 15-30 cm depth during research years (Table 6).

**Correlation:** Water soluble zinc fraction highly correlated with reducible (r = 0.926**) and DTPA (0.914**) fractions (Table 7). DTPA –Zn and reducible Zn also correlated (r = 0.920**) significantly. Zn fractions positively correlated with OC and negatively with pH. Exchangeable-Zn was highly correlated with yield and reducible Zn also significantly correlated with grain yield and Zn uptake by grain. The values of different Zn fractions were correlated and found that total Zn had positive and significant correlation with other fractions, suggesting the existence of dynamic equilibrium among the different forms. It is quite evident from the values of coefficients of correlation that almost all fractions are dependent upon each other. Similar results were previously reported by Chahal *et al.* (2005) [2] and Yadav and Meena (2009) [16]

The fractions of Zn showed slight decrease in their contents in the control and N alone treated plots probably due to removal of Zn from these fractions by the crops as these fractions are highly correlated with available Zn. Since no external Zn was applied in these treatments, hence, whatever Zn was mobilized from other Zn fractions to these pools might be the major source of Zn nutrition to the crops. These findings are in agreement with Meena *et al.* (2013) [5] and Nadaf and Chidanandappa (2015) [6].

As regards to the integrated fertilizer and FYM application plots, different fractions were found to increase significantly in comparison to the control. Such an increase in content in the treatments receiving fertilizers may be due to higher organic carbon content in these treatments. Zinc is known to form strong complexes with organic matter in the soil (Sharad and Verma, 2001 and Sharma *et al.* 2014) [10]. Zinc fractions were low in control as some of the Zn might have converted and moved to specifically adsorbed, exchangeable and Al and Fe-oxide bound forms. Sharma (2004) [12]; Dhiman (2007) [3]; Naria *et al.* (2008a) [7] also observed an increase in Zn fractions with the application of fertilizers.

The conjoint use of organics and chemical fertilizers increased the fractions significantly in comparison to the control and 100 per cent NPK. This may be due to the conversion of added Zn through inorganics into these pools and transformation of native zinc to these fractions. Application of chemical fertilizers decreased zinc which might be due to the reason that application of fertilizers increased the crop yield significantly which might have left higher amount of crop residues and root mass in the soil ultimately increasing the organic matter content in soil. Since the addition of fertilizers increased the organic matter content, most of the Fe and Al might have formed strong complexes with the increased amount of organic matter and thus render little amount of oxides for adsorption of zinc. The results are in conformity to the findings of Sharma (2004) [12]; Dhiman (2007) [3]; Regmi *et al.* (2010) [9].

Residual Zn associated with the mineral fraction constituted the major amount of native soil Zn and was the most dominant portion of total Zn. Higher Res-Zn could be due to reduction in yields that resulted in less removal of Zn. The formation of metallo-organic complexes with ligands, mineralization and solubilization from organic sources might be the reason for increased concentration of zinc fractions in plots receiving FYM. These results corroborate with findings of Sharma and Kanwar, (1999) [11]; Verma and Subehia, (2005) [13]; Obrador *et al*., (2007) [8]; Behera *et al.*, (2008) [1] and Wijebandara *et al.* (2011) [15].

**Table 1:** Effect of INM on Water soluble Zinc (ppm) under Maize –Wheat cropping system at different depths

| Treatments | Water soluble Zn (ppm) | | | | | |
|---|---|---|---|---|---|---|
| | 0-15 cm | | | 15-30 cm | | |
| | 2014-15 | 2015-16 | Pooled | 2014-15 | 2015-16 | Pooled |
| $T_1$ = Control | 0.160 | 0.160 | 0.160 | 0.150 | 0.140 | 0.145 |
| $T_2$ = 100% N | 0.190 | 0.170 | 0.180 | 0.160 | 0.150 | 0.155 |
| $T_3$ = 100% NP | 0.220 | 0.240 | 0.230 | 0.200 | 0.220 | 0.210 |
| $T_4$ = 100% NPK | 0.270 | 0.250 | 0.260 | 0.240 | 0.230 | 0.235 |
| $T_5$ = 100% NPK + Zn | 0.320 | 0.300 | 0.310 | 0.290 | 0.270 | 0.280 |
| $T_6$ = 100%NPK + S | 0.280 | 0.290 | 0.285 | 0.320 | 0.280 | 0.300 |
| $T_7$ = 100% NPK+ Zn + S | 0.350 | 0.330 | 0.340 | 0.320 | 0.300 | 0.310 |
| $T_8$ = 100% NPK + *Azotobacter* | 0.390 | 0.370 | 0.380 | 0.330 | 0.310 | 0.320 |
| $T_9$ = 100%NPK + FYM 10 t $ha^{-1}$ | 0.460 | 0.420 | 0.440 | 0.400 | 0.440 | 0.420 |
| $T_{10}$ = FYM 10 t $ha^{-1}$ + 100% NPK (-NPK of FYM) | 0.380 | 0.420 | 0.400 | 0.420 | 0.400 | 0.410 |
| $T_{11}$ = 150% NPK | 0.390 | 0.390 | 0.390 | 0.390 | 0.400 | 0.395 |
| $T_{12}$ = FYM 20 t $ha^{-1}$ | 0.300 | 0.340 | 0.320 | 0.350 | 0.370 | 0.360 |
| SEm± | 0.005 | 0.005 | 0.004 | 0.005 | 0.005 | 0.003 |
| CD at 5% | 0.014 | 0.015 | 0.010 | 0.013 | 0.014 | 0.009 |

**Table 2:** Effect of INM on Exchangeable Zinc (ppm) under Maize –Wheat cropping system at different depths

| Treatments | Exchangeable Zinc (ppm) | | | | | |
|---|---|---|---|---|---|---|
| | 0-15 cm | | | 15-30 cm | | |
| | 2014-15 | 2015-16 | Pooled | 2014-15 | 2015-16 | Pooled |
| T1 | 0.380 | 0.360 | 0.370 | 0.360 | 0.340 | 0.350 |
| T2 | 0.470 | 0.430 | 0.450 | 0.420 | 0.400 | 0.410 |
| T3 | 0.490 | 0.470 | 0.480 | 0.450 | 0.390 | 0.420 |
| T4 | 0.540 | 0.500 | 0.520 | 0.460 | 0.520 | 0.490 |
| T5 | 0.620 | 0.620 | 0.620 | 0.520 | 0.630 | 0.575 |
| T6 | 0.550 | 0.570 | 0.560 | 0.560 | 0.480 | 0.520 |
| T7 | 0.660 | 0.630 | 0.645 | 0.590 | 0.570 | 0.580 |
| T8 | 0.490 | 0.460 | 0.475 | 0.500 | 0.420 | 0.460 |
| T9 | 0.670 | 0.690 | 0.680 | 0.650 | 0.590 | 0.620 |
| T10 | 0.600 | 0.580 | 0.590 | 0.580 | 0.520 | 0.550 |
| T11 | 0.500 | 0.540 | 0.520 | 0.520 | 0.450 | 0.485 |
| T12 | 0.470 | 0.460 | 0.465 | 0.480 | 0.400 | 0.440 |
| SEm± | 0.005 | 0.006 | 0.004 | 0.010 | 0.006 | 0.006 |
| CD at 5% | 0.014 | 0.017 | 0.011 | 0.028 | 0.016 | 0.016 |

**Table 3:** Effect of INM on DTPA soluble Zinc (ppm) under Maize –Wheat cropping system at different depths

| Treatments | DTPA soluble Zinc (ppm) | | | | | |
|---|---|---|---|---|---|---|
| | 0-15 cm | | | 15-30 cm | | |
| | 2014-15 | 2015-16 | Pooled | 2014-15 | 2015-16 | Pooled |
| T1 | 2.06 | 2.02 | 2.04 | 2.05 | 1.95 | 2.00 |
| T2 | 2.29 | 2.15 | 2.22 | 2.16 | 2.05 | 2.11 |
| T3 | 2.71 | 2.32 | 2.52 | 2.55 | 2.35 | 2.45 |
| T4 | 2.47 | 2.41 | 2.44 | 2.32 | 2.43 | 2.38 |
| T5 | 3.71 | 3.67 | 3.69 | 3.59 | 3.64 | 3.61 |

| | | | | | | |
|---|---|---|---|---|---|---|
| T6 | 2.47 | 2.45 | 2.46 | 2.46 | 2.36 | 2.41 |
| T7 | 3.66 | 3.68 | 3.67 | 3.51 | 3.53 | 3.52 |
| T8 | 2.62 | 2.46 | 2.54 | 2.59 | 2.43 | 2.51 |
| T9 | 3.49 | 3.50 | 3.50 | 3.42 | 3.52 | 3.47 |
| T10 | 3.50 | 3.40 | 3.45 | 3.45 | 3.35 | 3.40 |
| T11 | 2.51 | 2.43 | 2.47 | 2.51 | 2.32 | 2.42 |
| T12 | 2.71 | 2.79 | 2.75 | 2.75 | 2.65 | 2.70 |
| SEm± | 0.029 | 0.034 | 0.023 | 0.047 | 0.049 | 0.034 |
| CD at 5% | 0.084 | 0.099 | 0.064 | 0.134 | 0.142 | 0.096 |

**Table 4:** Effect of INM on Reducible Zinc fraction (ppm) under Maize –Wheat cropping system at different depths

| Treatments | Reducible Zinc (ppm) | | | | | |
|---|---|---|---|---|---|---|
| | 0-15 cm | | | 15-30 cm | | |
| | 2014-15 | 2015-16 | Pooled | 2014-15 | 2015-16 | Pooled |
| $T_1$ | 3.39 | 3.43 | 3.41 | 3.33 | 3.39 | 3.33 |
| $T_2$ | 3.62 | 3.54 | 3.58 | 3.45 | 3.44 | 3.45 |
| $T_3$ | 3.65 | 3.62 | 3.64 | 3.59 | 3.53 | 3.59 |
| $T_4$ | 4.78 | 4.72 | 4.75 | 4.50 | 4.61 | 4.50 |
| $T_5$ | 4.92 | 4.86 | 4.89 | 4.74 | 4.70 | 4.74 |
| $T_6$ | 5.24 | 5.22 | 5.23 | 5.19 | 5.00 | 5.19 |
| $T_7$ | 4.97 | 4.95 | 4.96 | 4.61 | 4.50 | 4.61 |
| $T_8$ | 5.44 | 5.36 | 5.40 | 5.29 | 5.19 | 5.29 |
| $T_9$ | 6.83 | 6.74 | 6.78 | 6.59 | 6.53 | 6.59 |
| $T_{10}$ | 6.69 | 6.56 | 6.63 | 6.40 | 6.44 | 6.40 |
| $T_{11}$ | 5.62 | 5.60 | 5.61 | 5.35 | 5.36 | 5.35 |
| $T_{12}$ | 5.39 | 5.41 | 5.40 | 5.28 | 5.20 | 5.28 |
| SEm± | 0.059 | 0.052 | 0.039 | 0.103 | 0.080 | 0.077 |
| CD at 5% | 0.168 | 0.149 | 0.110 | 0.297 | 0.231 | 0.218 |

**Table 5:** Effect of INM on Residual Zinc (ppm) under Maize –Wheat cropping system at different depths

| Treatments | Residual Zinc (ppm) | | | | | |
|---|---|---|---|---|---|---|
| | 0-15 cm | | | 15-30 cm | | |
| | 2014-15 | 2015-16 | Pooled | 2014-15 | 2015-16 | Pooled |
| $T_1$ | 256.01 | 252.03 | 254.02 | 254.35 | 251.18 | 252.77 |
| $T_2$ | 248.43 | 251.71 | 250.07 | 247.81 | 253.96 | 250.89 |
| $T_3$ | 248.93 | 251.35 | 250.14 | 252.21 | 247.51 | 249.86 |
| $T_4$ | 251.94 | 256.12 | 254.03 | 250.48 | 248.21 | 249.35 |
| $T_5$ | 253.43 | 255.55 | 254.49 | 259.86 | 245.76 | 252.81 |
| $T_6$ | 260.46 | 250.47 | 255.47 | 251.47 | 255.88 | 253.68 |
| $T_7$ | 259.36 | 250.41 | 254.89 | 258.97 | 251.10 | 255.04 |
| $T_8$ | 256.06 | 249.35 | 252.71 | 257.29 | 245.65 | 251.47 |
| $T_9$ | 258.55 | 268.65 | 263.60 | 258.94 | 264.92 | 261.93 |
| $T_{10}$ | 253.83 | 267.04 | 260.44 | 265.15 | 253.29 | 259.22 |
| $T_{11}$ | 256.98 | 251.04 | 254.01 | 251.23 | 255.47 | 253.35 |
| $T_{12}$ | 260.13 | 252.00 | 256.07 | 250.14 | 258.38 | 254.26 |
| SEm± | 3.53 | 3.50 | 2.49 | 3.444 | 3.774 | 2.555 |
| CD at 5% | 10.15 | 10.08 | 7.02 | 9.910 | 10.860 | 7.214 |

**Table 6:** Effect of INM on Total Zinc (ppm) under Maize –Wheat cropping system at different depths

| Treatments | Total Zinc (ppm) | | | | | |
|---|---|---|---|---|---|---|
| | 0-15 cm | | | 15-30 cm | | |
| | 2014-15 | 2015-16 | Pooled | 2014-15 | 2015-16 | Pooled |
| $T_1$ | 262 | 258 | 260 | 259 | 257 | 258 |
| $T_2$ | 255 | 258 | 257 | 254 | 260 | 257 |
| $T_3$ | 256 | 258 | 257 | 259 | 254 | 257 |
| $T_4$ | 260 | 264 | 262 | 258 | 256 | 257 |
| $T_5$ | 263 | 265 | 264 | 269 | 255 | 262 |
| $T_6$ | 269 | 259 | 264 | 260 | 264 | 262 |
| $T_7$ | 269 | 260 | 265 | 268 | 260 | 264 |
| $T_8$ | 265 | 258 | 261 | 266 | 254 | 260 |
| $T_9$ | 270 | 280 | 275 | 270 | 276 | 273 |
| $T_{10}$ | 265 | 278 | 272 | 276 | 264 | 270 |
| $T_{11}$ | 266 | 260 | 263 | 260 | 264 | 262 |
| $T_{12}$ | 269 | 261 | 265 | 259 | 267 | 263 |
| SEm± | 4.59 | 2.89 | 2.71 | 2.538 | 2.974 | 1.955 |
| CD at 5% | 13.22 | 8.33 | 7.66 | 7.303 | 8.558 | 5.520 |

**Table 7:** Correlation among different Zn fractions and with Yield, Contents & soil properties

| Zn Fractions | MAIZE | | | | WHEAT | | | |
|---|---|---|---|---|---|---|---|---|
| | Yield | | Zn contents | | Yield | | Zn contents | |
| | Grain | Stover | Grain | Stover | Grain | Straw | Grain | Straw |
| Water Soluble | 0.665* | 0.510 | 0.525 | 0.359 | 0.613* | 0.619* | 0.687* | 0.522 |
| Exchangeable | 0.856** | 0.794** | 0.898** | 0.852** | 0.849** | 0.828** | 0.911** | 0.898** |
| DTPA soluble | 0.620* | 0.471 | 0.547 | 0.426 | 0.577* | 0.550* | 0.670* | 0.541 |
| Reducible | 0.773** | 0.654* | 0.552* | 0.437 | 0.743* | 0.739* | 0.761** | 0.614* |
| Residual | 0.487 | 0.353 | 0.653* | 0.567* | 0.448 | 0.444 | 0.702* | 0.625* |
| Total Zn | 0.644* | 0.498 | 0.639* | 0.518 | 0.600* | 0.597* | 0.760* | 0.637* |
| | Water Soluble | Exchangeable | DTPA soluble | Reducible | Residual | Total | pH | OC |
| Water Soluble | 1 | | | | | | | |
| Exchangeable | 0.680* | 1 | | | | | | |
| DTPA soluble | 0.914** | 0.685* | 1 | | | | | |
| Reducible | 0.926** | 0.697* | 0.920** | 1 | | | | |
| Residual | 0.779** | 0.695* | 0.856** | 0.777** | 1 | | | |
| Total Zn | 0.930** | 0.743* | 0.951** | 0.926** | 0.948** | 1 | | |
| pH | -0.402 | -0.610 | -0.292 | -0.456 | -0.261 | -0.365 | 1 | |
| OC | 0.609* | 0.660* | 0.695* | 0.783** | 0.515 | 0.647* | -0.258 | 1 |

## Conclusion

The result suggested that in Zn, the predominant component was DTPA soluble followed by reducible, exchangeable and water soluble form. In a long run, application of chemical fertilizers enhanced the utilization of DTPA available form as compare to organic manure.

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