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Aggregate associated phosphorus and zinc affected by long term crop residue incorporation and initial zinc application in calcareous soil

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Abstract
Calcareous soil usually suffer from lack of nutrient especially zinc and phosphorus. We studied the influence of different levels crop residues incorporation on aggregate associated phosphorus and zinc in soil aggregates after 23 years of continuous rice- wheat cropping system on sandy loam calcareous soil. The result shows that concentration of available phosphorus and zinc within water-stable aggregate showed an inverse relationship with aggregate size. It might be due to increase in surface area with decrease in particle size.

Keywords: Aggregate associated zinc, aggregate associated phosphorus, calcareous soil

Introduction
Zinc (Zn) is an essential element for crop production, and Zn deficiency problems around the world are associated with sandy soils, highly weathered soils of the tropical regions and calcium-carbonate-rich soils (Mousavi *et al*., 2013) [15]. Zinc deficiency is a serious micronutrient problem affecting agricultural productivity in India. Mobility, bioavailability and phytotoxicity of Zn depend not only on their total concentrations but also on their speciation, which in turn depends on basic soil properties such as pH, redox potential, cation-exchange capacity (CEC), texture and soil organic matter (Strawn *et al*., 2012) [17]. Zn bound into different size aggregates are believed to have different impacts on soil fertility because of their different ability to release and transport in soil. Hence, understanding the distribution of zinc in soil aggregate fractions is important.

The effect of fertilization and cultivation on the availability of micronutrients in soil was linked with the concentration of micronutrients in bulk soils and with their spatial location in soil micro-sites, namely, their distribution in aggregates (Acosta *et al*., 2011) [1]. According to Eary *et al.* (1990) [7] microelements are attached to the smaller particle sizes and exist mainly on soil particle surfaces. Macroaggregates (>250 µm) contain 30% to 45% of the Cu and Zn in soil, whereas the corresponding value for the silt + clay fraction is 13% to 19% (Zhang *et al*. 2003) [20]. Fan *et al*. (2012) [9] showed that after Thirty-year amendment of horse manure and chemical fertilizer, DTPA-extractable Zn was greater in microaggregates. Ding *et al*. (2010) [6] showed that the highest metals extracted by DTPA in different aggregates was Zn in <0.002 mm fraction.

Phosphorus (P) lost from agricultural soils is generally considered to be a major source of P to surface water where it contributes to eutrophication, because P often limits the primary production in freshwater ecosystems (Correll, 1998) [5]. In agricultural systems, P is generally added in the form of mineral or organic fertilizers in order to ensure adequate P availability to crops. P may be initially adsorbed to only a thin surface layer of the aggregates and therefore, smaller aggregates with a larger outer surface area might have higher P sorption, and hence less availability of applied P. The larger soil aggregates with the relatively less surface area than smaller aggregates may reduce P fixation, resulting in increased availability of recently applied P. However, excessive P fertilization can result in increased P losses by erosion, surface runoff, and subsurface leaching. Soil aggregate formation has an impact on P-sorption, as well as on bio-availability of P. Understanding the distribution of P in soil-aggregate fractions as a result of long-term crop residue incorporation in soil is important in evaluating the risk of P run-off and leaching in agricultural soils.

Distribution of P-forms among aggregate fractions may depend on the type of manures or fertilizers applied, as well as on management practices (Green *et al*., 2005) [10].

In addition, P attachment to soil aggregates depends on soil particle size (Whalen and Chang, 2002) [18]. Manures may also affect the distribution of P-fractions among aggregate-size classes. In a loamy soil, Bhatnagar and Miller (1985) [3, 4] found that the application of liquid poultry manure increased P concentration in large aggregates (> 2mm) much more than that in small aggregates (< 1 mm), while the addition of mineral-P solution slightly increased the P concentration of the large aggregates only. Xiying *et al*. (2004) [19] observed that long-term application of cattle manure significantly increased the total phosphorus content in the water stable aggregates. They also reported that the increase in total phosphorus was greater in larger than in smaller (<0.17 mm) aggregates. Bhatnagar *et al*. (1985) [3, 4] reported that the non-uniform distribution of available P among aggregates could be a random process of preferential sorption of P by specific aggregate fractions on specific surface areas. Fertilization markedly increased the available P in the < 0.1 mm fraction (He *et al.,* 2004; Emadi *et al*., 2008) [11, 8].

Material and Methods

Experimental details

A long-term field experiment with a rice–wheat cropping system on an Entisol located in the hot, humid subtropics was established at the University Research Farm, Rajendra Prasad Central Agricultural University, Pusa, Bihar, India (25^0 98'N, 85^0 66' E, 52.00 above sea level), in *kharif*, 1994. The experimental design was split-plot with four crop-residue (0, 25, 50 & 100%) levels in main plots and four levels of Zn application (0, 2.5, 5.0 & 10 kg ha^{-1}) in sub-plots. subplot treatments were applied only once in the year 1994. Each treatment was replicated three times. Rice and wheat crops are being grown continuously with necessary tillage under rice-wheat system during *kharif* and *rabi* seasons. The chopped straw of the previous crops treated as crop residues, was incorporated as per treatment. The source of N, P and K was urea, di-ammonium phosphate (DAP), muriate of potash (MOP), respectively. Dose of fertilizer was 120, 60, 40 (N, P_2O_5, K_2O).

Aggregate-associated phosphorus

Phosphorus content in soil associated with different aggregate-size fractions was determined by the method described by Olsen *et al*. (1954). Macroaggregate-associated phosphorus was calculated by taking the average value of aggregate-associated phosphorus of sieves having diameter more than 0.25 mm (8.0-5.0 mm, 5.0-2.0 mm, 2.0-1.0 mm, 1.0-0.5 mm, 0.5-0.25 mm) and microaggregate-associated phosphorus was determined from the soil aggregates passed through 0.25 mm sieve and retained in 0.1 mm sieve.

Aggregate-associated Zinc

Zinc content in soil associated with different aggregate-size fractions was determined by the method described by Lindsay and Norvel (1978) [12]. Macroaggregate-associated zinc was calculated by taking the average value of aggregate-associated zinc content of sieves having diameter more than 0.25 mm (8.0-5.0 mm, 5.0-2.0 mm, 2.0-1.0 mm, 1.0-0.5 mm, 0.5-0.25 mm) and microaggregate-associated zinc was determined from the soil aggregates passed through 0.25 mm sieve and retained in 0.1 mm sieve.

Result and Discussion

Aggregate Associated-phosphorus

The concentration of available phosphorus (P) in macroaggregates and microaggregates varied from 8.69 to 17.13 and 12.73 to 17.39 ppm, respectively (Table 1). No significant effect of crop residue incorporation and residual zinc levels was found on aggregate-associated P. The available phosphorus content was higher in microaggregates than macroaggregates. This might be due to the large surface area of the microaggregates (<0.25 mm) than macroaggregates (>0.25 mm). Similar results also found by are Adesodun *et al*. (2007) [2]. They reported that the distribution of available P within aggregates showed preferential enrichment of phosphorus in the microaggregate fraction (<0.25 mm). Maguire *et al*. (2007) [14] and He *et al*. (2004) [11] reported that the aggregate-associated phosphorus increased with decreasing aggregate size. Linquist *et al.* (1997) [13] also reported the proportion of available P increased with decreasing aggregate fraction under all treatment because of P sorption generally increases with decreasing aggregate size due to increases in surface area and reactivity.

Aggregate-associated zinc

The concentration of DTPA extractable zinc in macroaggregates and microaggregates varied from 6.28 to 8.46 and 7.66 to 9.56 ppm respectively (Table 2). Aggregate-associated Zn was non-significantly affected by the graded levels of crop residue and different rate of starter Zn. The concentration zinc within the water-stable aggregate showed an inverse relationship with aggregate size fraction irrespective of the treatments i.e., the concentration of available zinc was higher in microaggregates than macroaggregates. It might be due to large surface area of microaggregates. Similar result was found by Zhang *et al.* (2003) [20]. They reported that the highest Zn extractability by Mehlich-3 in the sandy soils was shown in both 0.5–0.25 and 0.25–0.125mm fractions. Fan *et al*. (2012) [9] also found that after thirty-year application of horse manure and chemical fertilizer, DTPA-extractable Zn was higher in microaggregates.

Table 1: Effect of long-term crop residue incorporation and initial zinc application on aggregate associated phosphorus

Crop residue level (% of straw produced)	Macroaggregate associates phosphorus (mg kg^{-1})	Microaggregate associated phosphorus (mg kg^{-1})	Zn levels (kg ha^{-1})	Macroaggregate associates phosphorus (mg kg^{-1})	Microaggregate associated phosphorus (mg kg^{-1})
0	10.76	14.10	0	12.84	14.97
25	13.89	15.06	2.5	12.08	14.65
50	13.96	16.29	5	13.77	15.69
100	14.03	15.73	10	13.95	15.88
S.Em±	0.860	0.558	S.Em±	0.772	0.531
CD (P=0.05)	NS	NS	CD (P=0.05)	NS	NS

Table 2: Effect of long-term crop residue incorporation and initial zinc application on aggregate associated zinc

Crop residue level (% of straw produced)	Macroaggregate associates Zinc (mg kg^{-1})	Microaggregate associated Zinc (mg kg^{-1})	Zn levels (kg (ha^{-1})	Macroaggregate associates Zinc (mg kg^{-1})	Microaggregate associated Zinc (mg kg^{-1})
0	7.41	8.62	0	8.08	9.27
25	7.96	8.91	2.5	7.46	8.57
50	7.90	8.57	5	7.85	8.91
100	7.58	8.88	10	7.46	8.24
S.Em±	0.192	0.212	S.Em±	0.188	0.263
CD (P=0.05)	NS	NS	CD (P=0.05)	NS	NS

Conclusion

The effect of crop-residue incorporation and starter Zn application on aggregate-associated phosphorus and zinc was non-significant. However, the content of phosphorus and zinc were higher in microaggregate than macroaggregates and it shows inverse relation with aggregate size.

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