ORGANIC MATTER ADDITION AND ZINC STATUS IN CALCAROUS SOIL OF IRAQ

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ABSTRACT

The current investigation was conducted at 2014-2015 to determine the influence of levels and periods of addition of organic matter on Zinc availability in Iraqi calcareous soil. Experiments were conducted as a field experiment in a randomized complete block design (RCBD) using four replicates. Wheat, Al-Rasheed variety was used as a test crop. The entire field was equally dived in two divisions. One of the two divisions was cultivated to wheat and the second was left uncropped. Effect of five levels of organic matter as a peat namely 0, 25, 50, 75, 100 ton ha^{-1} were determined. Soils were analyzed to determine its physical and chemical characteristics. Soil samples were collected after 3, 30, 60, 90, 120, and 180 days for determining essential parameters and indicators that reflect the effect of the level of compost addition on Zinc availability. DTPA- Zn after 3, 30, 90, 120, 150 and 180 days are the least at 20-30 cm depth and the greatest at 0-10 cm depth. DTPA-Zn increased with increase of the level of OM addition. DTPA-Zn 90 days after addition in uncropped soil at 25 ton OM ha^{-1} addition was 1.55, 1.02 and 0.36 mg kg^{-1} Zn at 0-10, 10-20, 20-30 cm depths and it was 1.40, 1.05 and 0.78 mg kg^{-1} Zn at the same soil depths, for cropped soil, respectively. DTPA extractable Zn as affected by time of addition, over the entire period of addition, was higher in cropped soil than that in uncropped soil at 50 ton OM ha^{-1} addition level. DTPA- Zn in both cropped and uncropped soil was found to increase linearly with the time after addition.

Keywords: Compost, Addition levels, Time of addition, (DTPA) extractable Zinc, Soil depth, Cropped soil, Uncropped soil.

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اضافة المادة العضوية وحالة الزنك في تربة العراق الكلسية

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المستخلص

اجريت الدراسة الحالية في عام 2014-2015 لتقدير تأثير مستويات ومدد الاضافة للمادة العضوية في جاهزية الزنك في تربة العراق الكلسية. اجريت التجارب في الحقل وفقا لتصميم القطاعات تامة التعشية (RCBD) بأربعة مكررات. واستعملت بذور الحنطة صنف الرشيد كمحصول اختبار. قسم الحقل بالكامل الى قسمين متساويين. زرع احد الاقسام بالحنطة والقسم الثاني ترك بدون زراعة. قدر تأثير خمسة مستويات من المادة العضوية (الكومبوست) وهي 0 و25 و50 و75 و100 طن هـ$^{-1}$. وقدرت خصائص التربة الفيزيائية والكيميائية. وجمعت نماذج التربة بعد 3 و30 و60 و90 و120 و180 يوم لأجل تقدير المعايير الاساسية والمؤشرات التي تعكس تأثير مستويات المادة العضوية المضافة في جاهزية الزنك. كان الزنك المستخلص بالـ DTPA الاقل عند عمق 20-30 سم وذلك بعد 3 و30 و90 و120 و150 و180 يوم في حين كان الاعلى عند عمق 0-10 سم. ازداد الزنك المستخلص بالـ DTPA بزيادة مستويات المادة العضوية المضافة. كانت تراكيز الزنك المستخلص بـ DTPA هي 1.55 و1.02 و0.36 مليغرام كغم$^{-1}$ للأعماق 0-10 و10-20 و20-30 سم في التربة غير المزروعة بعد 90 يوم من اضافة 25 طن هـ$^{-1}$ من الكومبوست، اما للتربة المزروعة بالحنطة فقد كانت 1.40 و1.05 و0.78 مليغرام كغم$^{-1}$ لنفس أعماق التربة وعلى التوالي. كان الزنك المستخلص بـ DTPA، بتأثره بالزمن طيلة مدة الاضافة، الاعلى في التربة المزروعة مقارنة بالتربة غير المزروعة وذلك عند مستوى 50 طن هـ$^{-1}$. كما ازداد الزنك المستخلص بمحلول DTPA زيادة خطية مع زمن الاضافة في كلتا الترب المزروعة وغير المزروعة.

كلمات مفتاحية: كومبوست، مستويات الاضافة، المدة الزمن للإضافة، الزنك المستخلص بـ DTPA، اعماق التربة، تربة مزروعة وغير مزروعة.

*** البحث مستل من اطروحة دكتوراه للباحث الاول.**

INTRODUCTION

Organic matter reacts with micronutrient elements, thus adapting their availability. It plays important role in Zn bioavailability to crops, where dissolved organic matter can form complexes with Zn that improve Zn solubility and Zn transport towards the plant roots, nevertheless this DOM creates from SOM or from root exudation. Zinc uptake from soil solution is present in divalent cations form Zn^{2+} (1, 2, 3). Zinc forms which are being available to plants uptake are the free ions (Zn^{2+} and $ZnOH^{+}$) (4) and soluble organic complexes in the soil (5). Soil Zinc content is not in straight association with the amount of Zn available to plants. The major fraction of total Zn is adsorbed to the solid phase in most soils. Consequently, the addition of organic matter might adapt the relative abundance of zinc fractions and their contribution to available pool in soils (6). Main soil factors governing plant-available Zn are the composition of parent material, total Zn content, adsorption sites, microbial activity, pH, soil organic matter content, soil moisture, redox situation, $CaCO_3$ content, and concentrations of other trace elements for instance, Fe, Cu and Ni (7, 8). (Karaca 9) found that the effect of organic wastes addition on zinc extractability in clay soil was depending on its organic matter content, soil pH, and the time after its addition. (Mandal 10) found that organic matter addition and low pH tend to decrease Zn adsorption status, thus increase zinc extractability. The quantity of metals complexed depends on the number of hydroxyl, phenoxyl, and carboxyl functional groups existing within the organic matter (7). SOM has a tendency of transition metal cations to form stable complexes with organic ligands (11). SOM-Zn complex, in soil solution, contributes in transporting Zn to plant roots, therefore, improving its availability to plant (12). Since, trace metals bind to organic functional groups, such as carboxyls, phenols, alcohols, carbonyls, and methoxyls, of organic compounds can influence mobility of several metals within soils (13). Plant roots are capable to exude low molecular weight organic anions (citrate, malate), which can increase the availability and mobility of Zn (14, 15). However, ligands, for instance, phytosiderophores, citrate and other low molecular weight organic acids and amino acids, can form Zinc complexes which increase the availability and mobility in the soil solution to plants (15, 16, 17, 18). DOM can increase Zinc mobility (19, 20), so trace metals can complexed with fulvic acid. (Shuman 21) stated that the soil pH is the greatest significant factor governing Zinc availability, which decreases with the increase of the pH. However, with the pH increases, sorption of trace metals to stable organic matter will be increases because of the ionization of organic functional groups (22), consequently, the precipitation of trace metals will increases which reduces metal concentrations existing in soil solution (23). While, organic acids production (i. e. amino acid, glycine, cystein and humic acid) during mineralization of organic materials, would lead to decrease in soil pH (24). In a study conducted to investigate the effect of levels of organic matter and their contribution towards the available pool in soil, (Chakraborty 6) found that available zinc in soil increased with the increase of FYM addition levels, without or with fertilizer compared to that of control treatment. This may be attributed to the addition of zinc to the soil through FYM and by chelating action of organic compounds (organic ligands like acetate, citrate etc.) that released during organic matter decomposition which might have prevented the zinc from precipitation and fixation in soil by forming soluble metal organic complexes (6). However, the increase in the level of FYM was found to progressively decrease the soil pH and increase soil organic carbon content. Similar findings were documented by (Karaca 9) who found that DTPA extractable Zinc in soil increased with increasing levels of diverse organic wastes amendments. Results of the study conducted by (Dhaliwal 25) stated that incorporation of FYM, Poultry manure and biogas slurry in soil before rice transplantation caused in considerably higher content of DTPA extractable Zinc. (Santos 26) indicated that the Long term addition of compost, farmyard manure and sewage sludge increased the total Zinc content of a soil, furthermore, it increased the percentage of labile-Zinc, which is available form for plant uptake, while, contrasting effects have been attained on the short term (27). The mechanisms which are responsible for this effect are possibly a dropping in pH caused by decomposition of organic matter and Zn-complexating ligands produced by decomposing microorganisms could play a role (28). (Lasley 22) stated that clay edges and Fe and/or Mn oxides are common sites for metals to be adsorbed. In calcareous soils solubility of micronutrients is extreme less due to high pH, and this decreases the capability of nutrient uptake by plants and certainly plants requirement increases to these elements (2, 29, 30, 1). Zinc deficiency in calcareous soils is connected to adsorption of solution zinc in the soil by clay and limestone particles, however, Zinc in calcareous soils can form insoluble compounds in the feature of Zinc carbonate ($ZnCO_3$) (31). Under the arid and semiarid conditions soil organic matter content is usually less than 1.0%. Consequently, evaluating the impact of different levels of organic matter added to Iraqi soil, as part of arid region, is of considerable importance. Therefore, the current study was conducted to determine the effect of various levels of well decomposed organic matter on Zinc availability in Iraqi calcareous soil.

MATERIAL AND METHODS

This experiment was established in December, 04, 2014, in Al-Tuwaitha farms of agricultural experimental station of Ministry of Science and Technology, which is 18 km South East of Baghdad, Iraq. The experimental lay out was randomized complete block design (RCBD) with four replicates. Al-Rasheed wheat crop variety was used, as a test crop, and it was sown manually to the field at 100 kg ha^{-1} wheat seeds in December, 04, 2014 and it was harvested at June 2015. Five levels of compost (0, 25, 50, 75, 100 ton ha^{-1}) are applied to five randomly assigned replicate plots. The experiment is, therefore, consisted of 40 plots, 20 of which (5 treatment levels × 4 replicates) were uncropped and 20 plots were cropped to Al-Rasheed wheat. Each plot is 4 m^2 in dimension. The mineral fertilizers (N, P) were added to the soil according to the recommendations of the nitrogen fertilizer 92 kg N ha^{-1} (200 Kg urea ha^{-1}), and 100 kg ha^{-1} TSP for phosphorus, usually assigned for wheat in Iraqi calcareous soil. Before planting of wheat crop, soil sampling were carried out on December 2014, and the next soil sampling were done after 3, 30, 60, 90, 120, 150, 180 days after planting of wheat crop using Lord sampler tool, three soil depths 0-10, 10-20, 20-30 cm were taken. All soil samples for each experimental plot for each particular depth were thoroughly mixed, air dried, and grinded to pass through a 2 mm opining sieve. Soil particle size analysis was carried out via the hydrometer method utilizing sodium hexametaphosphate, then soil texture was assign based on the ratio of soil particles (clay, silt, sand) (32).

Table 1. Chemical and physical characterization of soil, compost and irrigation water

Chemical characterization of soil (water soluble at ratio 1:1)							
EC (dS m^{-1})	**pH**	**Na^{1+}**	**K^{1+}**	**Ca^{2+}**	**Mg^{2+}**	**Cl^{1-}**	**SO_4^{2-}**
				meq L^{-1}			
1.63	7.41	3.20	0.39	6.84	1.95	6.12	10.45
CEC (Cmol$_c$ kg^{-1})		**Ammonium Acetate Extractable Cations (mg kg^{-1})**					
		Na^{1+}	**K^{1+}**	**Ca^{2+}**			**Mg^{2+}**
17.53		174	222	5755			524
Total Elemental analysis (%)				**DTPA extractable Zinc**			**(mg kg^{-1})**
N		**O.M**					
0.414		0.895			0.66		
Physical characterization of soil							
Soil Texture				**Particles Soil Analysis**			
Silty Clay Loam		**Clay %**		**Silt %**		**Sand %**	
		39.20		44.16		16.64	
characterization of compost, water soluble at ratio 1:5							
EC (dS m^{-1})	**pH**	**Na^{1+}**	**K^{1+}**	**Ca^{2+}**			**Mg^{2+}**
				mg kg^{-1}			
1.75	7.16	1123	3387	1297			491
characterization of irrigation water							
EC (dS m^{-1})	**pH**	**Na^{1+}**	**K^{1+}**	**Ca^{2+}**			**Mg^{2+}**
				meq L^{-1}			
0.75	7.92	2.113	0.088	2.113			1.132

Soil pH was evaluated in 1:1 (Weight : Volume) soil water suspension utilizing a pH meter (33). The measurement of soil organic matter was established by multi EA 2000 analyzer which equipped with software (multiwin) version 3.06 (34), while soil soluble salts extraction and determination were carried out according to (Rhoades 35). The measuring of the carbonate content in the soil was evaluated according to (Horvath 36). DTPA extraction was carried out according to the procedure of (Leggett 37), the Zn concentration in the filtrate was determined by atomic absorption spectrophotometry using standards made up in the DTPA solution (Dale 38). The soil cation exchange capacity (CEC) was determined using the procedure in (Sumner 39). The soil exchangeable cations was determined using the procedure in (Thomas 40). The table 1 indicates that the soil of the field is of silt clay loam textured class which is considered as heavy textured soils. Calcium carbonate content is 250 g kg^{-1} and the pH of soil is 7.41. Consequently, field used in this study is of a typical calcareous soil of the arid region

Organic Matter Characterization

Total elemental analysis of compost added was given in table 2 indicated that the compost used in this study is of high cations and trace elements content. That may explain the tremendous increase in soil cations and trace elements with the increase of level of compost added to soil.

Table 2. Total elemental analysis of organic matter (OM) used in this experiment

Total elemental analysis					
Ca	Mg	Na	K	Zn	P
(mg kg^{-1})					%
63350	13138	2259	8072	196	0.48

RESULTS AND DISCUSSION

Soil Characterization

Results in table 3 showed that the EC of soil is increase with the increase of OM addition being the least 1.63 dS m^{-1} at 0 ton OM ha^{-1} and being the highest 2.05 dS m^{-1} at 100 ton OM ha^{-1} addition. Furthermore, Electrical conductivity of 1:1 soil water extract, K^{1+} content, Mg^{2+} and Cl^{1-} were found to increase linearly with the increase of OM addition. Substantial increase in EC and cations with the increase of levels of OM addition may be attributed to natural content of OM of salts and various cations. The rapid liberation of cations and anions from the well decomposed OM added to soils may indicate that this OM materials are easily decomposed organic matter, while, the soil was of 0.89% organic matter content. DTPA extractable Zn (Table 3) was also increased with the increase of level of OM addition being the least at the 0 OM ton ha^{-1} additions and the greatest at the 100 ton OM ha^{-1} additions, which is agree with (9, 6). DTPA extracted Zn for example was 0.66 mg kg^{-1} at 0 ton OM ha^{-1} increased to 1.78 mg kg^{-1} at 100 tons OM ha^{-1}. Soil was not cropped for the past 3 years, which might cause the soil to be above critical levels in term of trace element Zn content (Table 3).

Table 3. Influence of OM addition at different levels on some soil characterizations

	Compost addition levels (tons ha^{-1})			
	25	50	75	100
	Water soluble at ratio 1 : 1 (soil : water) meq L^{-1}			
K^{1+}	0.50	0.61	0.77	0.92
Mg^{2+}	2.02	2.02	2.23	2.40
Cl^{1-}	7.12	7.89	8.49	9.40
	Electrical Conductivity (dS m^{-1})			
EC	1.71	1.8	1.94	2.05
	(DTPA) Extractable Zn (mg kg^{-1})			
Zn	0.86	1.11	1.28	1.78
	Total Elemental analysis (%)			
N	0.426	0.4659	0.493	0.577
O.M	1.158	1.551	1.769	1.917

Effect of compost addition levels on DTPA-Extractable Zinc in calcareous soil of Iraq

DTPA – Extractable Zn as affected by level of OM addition and time after addition in uncropped and cropped soil is given in figures 1 to 5 for (a) uncropped and (b) for cropped soils. Extractable Zn after 3, 30, 90, 150 and 180 days were the least at 20-30 cm depth and the greatest at 0-10 cm depth (8, 10). At all depths in uncropped and cropped soil, extractable Zn decreased with time after addition, this finding agrees with (9). As it shown by the figure 1 extractable Zn in cropped soil was less than that in uncropped soil. Extractable Zn was best fitted to cubic equation with significant regression coefficient. This shows that extractable Zn increase with increase of the level of OM addition (25). Extractable Zn at 90 days after addition in uncropped soil at 25 ton OM ha^{-1} addition was 1.55, 1.02 and 0.36 mg kg^{-1} Zn at 0-10, 10-20, 20-30 cm depths, respectively. However, for cropped soil it was 1.40, 1.05, 0.78 mg kg^{-1} Zn at 0-10, 10-20 and 20-30 cm depth, respectively. Accordingly, extractable Zn in both uncropped and cropped soil after 30 days of 25 ton compost ha^{-1} addition was relatively equal. These results prove that liberated Zn was high enough to be not affected by plant uptake (28). These results clearly indicate the importance of maintaining adequate levels of OM in soils (16).

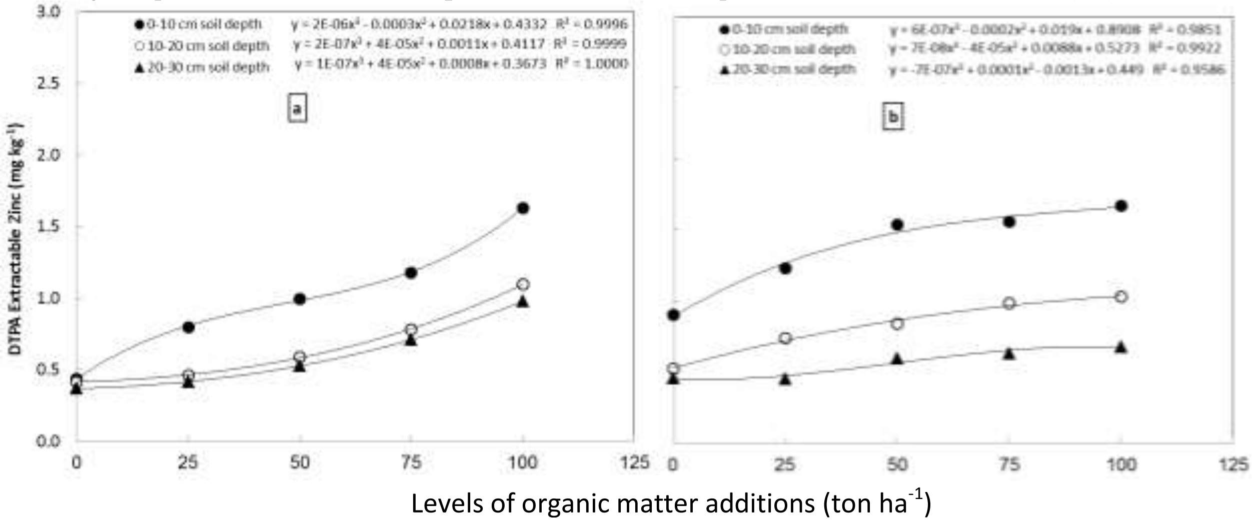

Figure 1. The effect of organic matter addition levels to soil on DTPA extractable Zinc three days after addition to (a) uncropped and (b) cropped

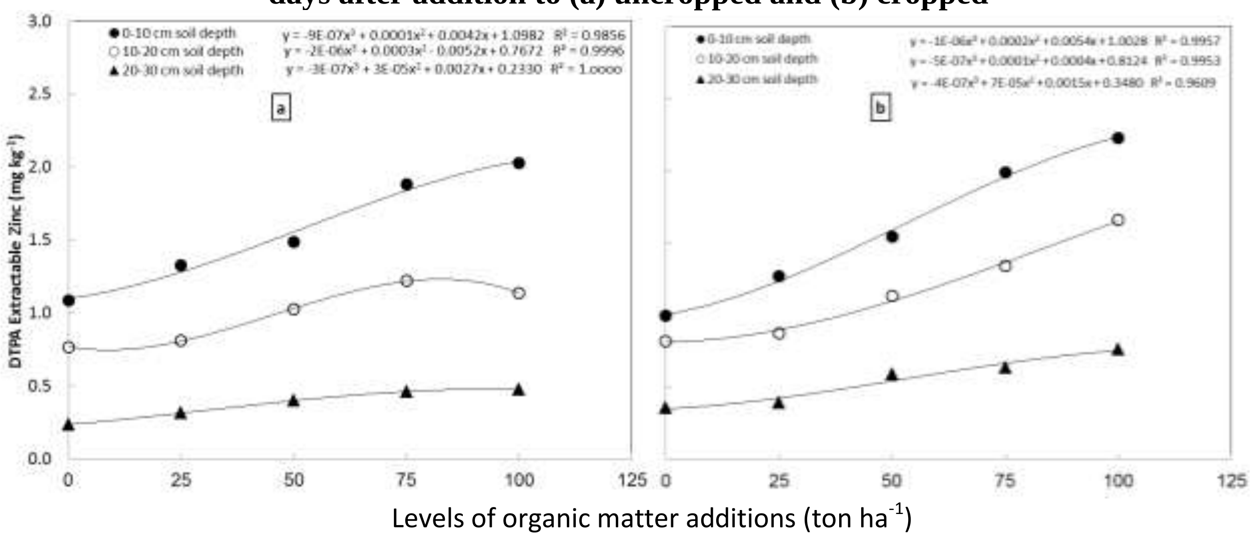

Figure 2. The effect of organic matter addition levels to soil on DTPA extractable Zinc 30 days after addition to (a) uncropped and (b) cropped soils

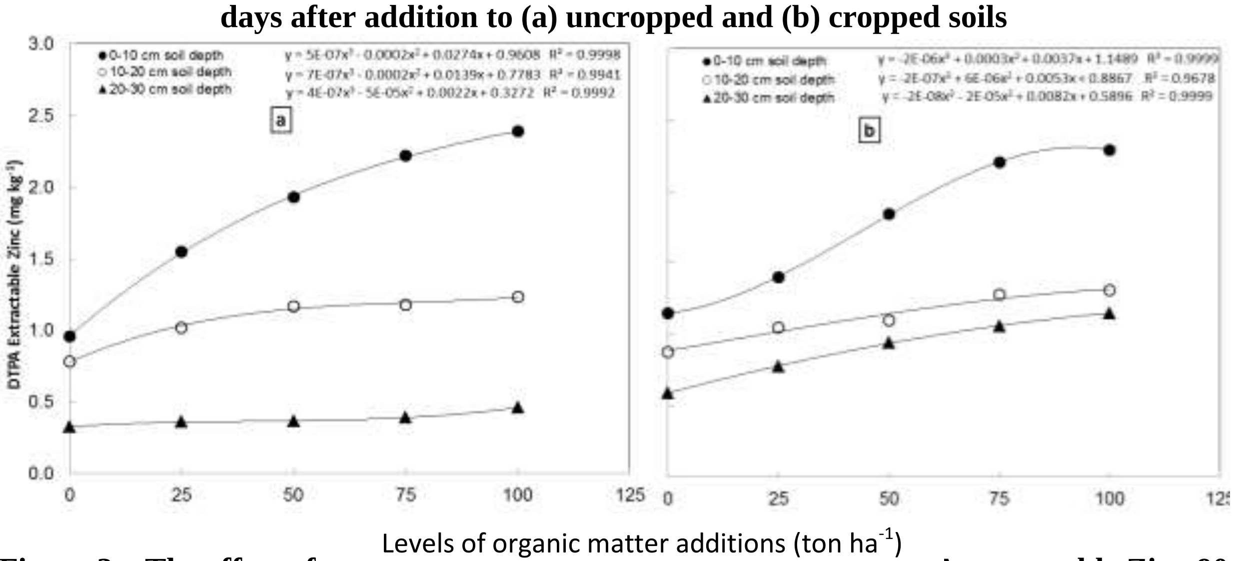

Figure 3. The effect of organic matter addition levels to soil on DTPA extractable Zinc 90 days after addition to (a) uncropped and (b) cropped soils

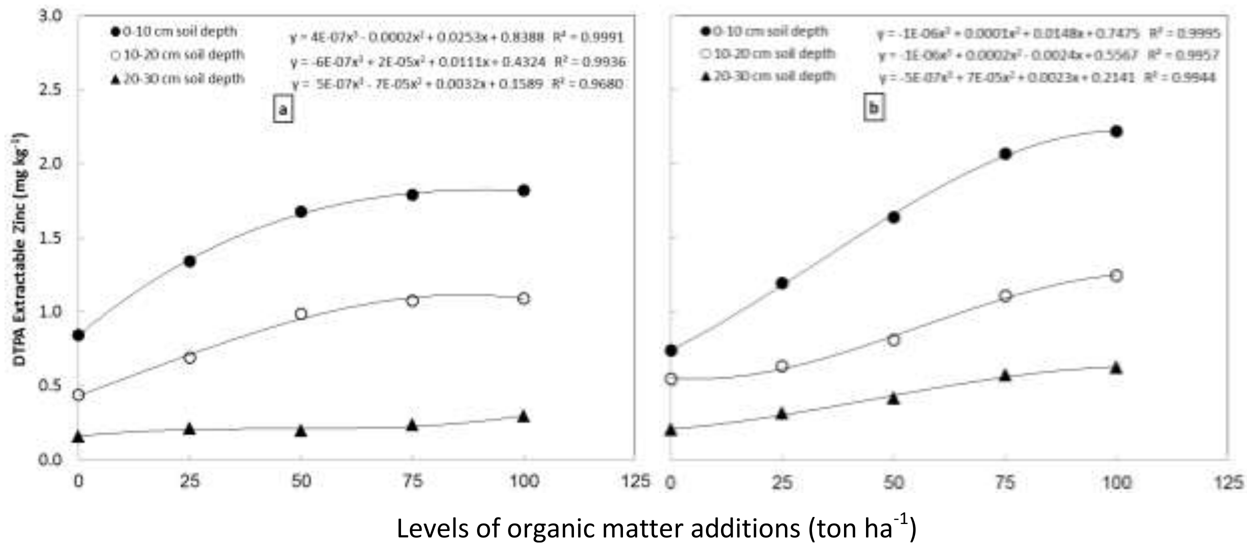

Figure 4. The effect of organic matter addition levels to soil on DTPA extractable Zinc 150 days after addition to (a) uncropped and (b) cropped soils

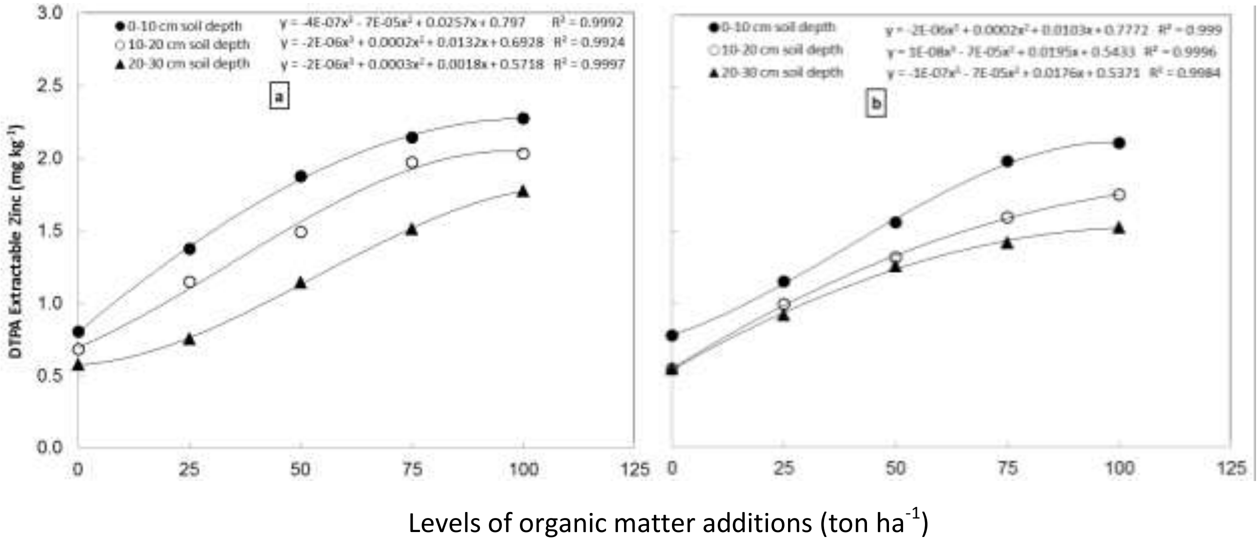

Figure 5. The effect of organic matter addition levels to soil on DTPA extractable Zinc 180 days after addition to (a) uncropped and (b) cropped soil.

Figure 6 shows DTPA extractable Zn as affected by time of addition of 50 ton ha^{-1} organic matter indicated by location of the graph. Extractable time starting from the zero till 180 days after addition was higher in copped soil than that of uncropped soil. This may be attributed to the fact that existing of plant root with expected higher microorganism mobilized Zn higher than that of uncropped soil, moreover, Plant roots are capable to exude low molecular weight organic anions (citrate, malate), which can increase the availability (15). Higher microbial content may lead to higher rate of OM decomposition which in turn liberated more Zn to soil in organo-metallic compound

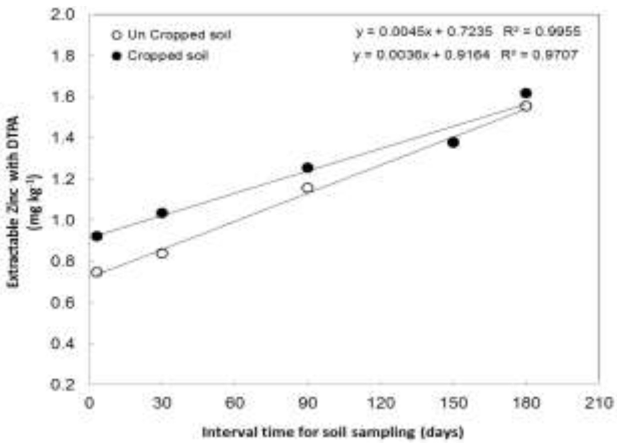

Figure 6. The effect of organic matter addition at 50 ton ha^{-1} on DTPA extractable – Zinc for soil sampling at different interval time 3, 30, 90, 150, 180 days at 0-30 cm soil depth

DTPA- Zn in both cropped and uncropped soil was found to increase linearly with the time after addition. Linear model was found the best to fit the date of uncropped soil and cropped soil. Soil is of calcareous type with pH > 7.0 in which Zn ion is rapidly convert to un extractable form (2). Accordingly, the linear increase firmly indicates that Zn liberated from decomposed organic matter was in organo-metallic form (6).

Conclusions

1- DTPA Zn in soil received various additions of OM at all-time intervals evaluated is higher than that of zero OM addition.

2- DTPA- Zn increase with the increase of the level of OM addition. DTPA-Zn, for uncropped and cropped soil of certain soil depth is relatively equal being the greatest at 0-10 cm depth and the least at 20-30 cm depth. DTPA extractable Zn as affected by time of addition, over the entire period of addition, was higher in copped soil than that of uncropped soil.

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