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Effects of Application of Different Sources of Zn and Composts on Zn Concentration and Uptake by Upland Rice

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ABSTRACT
Global efforts are under way to improve the Zn concentrations in rice to increase Zn in human diets. Therefore, this pot experiment was conducted to examine the effects of Zn sources and different composts on two upland rice varieties. This study was a 3 factors experiment with 3 replications arrange in RCBD. Experimental units include: 2 selected upland rice varieties with highest and lowest Zn uptake, 12 treatments, including 3 types of composts (oil palm compost, vermicompost and poultry compost) and 2 different sources of Zn ($ZnSO_4$ and Zn-EDTA). Soil samples were analyzed before and after harvest. The plants were harvested 16-20 weeks after planting and analysed. All types of composts showed positive effects on Zn concentration and uptake in all parts of rice. Vermicompost is the most effective compost among these three composts. Both inorganic Zn sources used showed almost the same Zn concentration and uptake by rice in this experiment. The magnitude of Zn uptake response was magnified when zinc sulphate was applied along with organic compost. Application of Zn-amended organic composts increased the percentage distribution of Zn in grain more than the application of $ZnSO_4$ or Zn-EDTA alone.

Key words: Zinc, rice, compost, Zn source, Zn concentration, Zn uptake

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the major staples, feeding more than half of the world's population. It is grown in more than 100 countries, predominantly in Asia (Depar *et al*., 2011; Maclean *et al*., 2002). After nitrogen (N), phosphorus (P) and potassium (K), widespread zinc (Zn) deficiency has been found responsible for yield reduction in rice (Fageria *et al*., 2002). Globally, more than 30% of soils are low in plant-available Zn (Alloway, 2009). Compared with legumes, cereals are generally more prone to Zn deficiency leading to a substantial reduction in grain yield and nutritional quality (Cakmak *et al*., 1999). Nonetheless, frequency of Zn deficiency is greater in rice than other crops, with more than 50% of the crop worldwide prone to this nutritional disorder (Rehman *et al*., 2012). Hence, Zn deficiency is considered one of the most important nutritional stresses limiting rice production in Asia (Rehman *et al*., 2012).

Indeed, there is a need to improve the Zn status of staple cereal grains for human health reasons (Hotz and Brown, 2004; Kutman *et al*., 2011). Zinc application methods and sources are aimed at improving Zn availability for plant uptake. Most common method of Zn fertilization is through soil application.

Selection of appropriate Zn sources for soil application can also be an alternative strategy to improve plant availability of Zn. Zn fertilizers with good solubility (such as Zn-EDTA and $ZnSO_4$) generally results in greater Zn transport to the roots compared with insoluble ZnO or fritted Zn (Rehman *et al*., 2012).

The greater soil transport of Zn increased the possibility of Zn being intercepted by the fast-growing roots which might have been associated with a greater effect of banding Zn-EDTA than fritted Zn. However, results may vary according to the soil and application methods (Kang and Okoro, 1976). Composts are also useful sources of nutrients including N and P and their application improves micronutrient availability by changing soil chemical, physical and biological properties (Eghball *et al.*, 2004). In agriculture, compost application is the most common input of OM to soil. Composts also contain a number of metals at varying concentrations, including Zn.

The oil palm industry is one of the best sources of agricultural wastes that can be used as organic fertilizers. Oil palm composts were reported to have many characteristics that are equal or superior to peat in growing media (Kala *et al.*, 2009; Lim and Ratnalingam, 1980).

Vermicompost, whether used as soil additives or as components of greenhouse bedding plant-container media, have improved seed germination, enhanced seedling growth and development and increased overall plant productivity (Atiyeh *et al.*, 2001; Lakhdar *et al.*, 2009) and poultry manures provide a positive in uence on crop production and they also improved soil physical properties (Chen *et al.*, 1996). More and more people are now placing importance of the roles of manures in agriculture.

It was, therefore, considered worthwhile to study the relative effectiveness of Zn-EDTA and $ZnSO_4$ in maintaining Zn in available form in soil both in presence or absence of added different kinds of compost and tested using two upland rice variety. Their role in influencing the growth of upland rice and Zn concentration by all parts of rice was also included in the study and to increase Zn content in rice to supply adequate Zn in human diet.

MATERIALS AND METHODS

The experiment was carried out based on selecting two Malaysian upland rice varieties. It's a 3 factors pot experiment with 3 replications arrange in a Randomized Complete Block Design (RCBD), with the pot size of 20 kg in 3 replications for all treatments and controls, at University Putra Malaysia glasshouse. Experimental units include: 2 selected upland rice varieties (high-V1 and low-V2 Zn uptake), 12 treatments, including 3 types of composts and 2 different sources of Zn ($ZnSO_4$ and Zn-EDTA) at concentration of 1 mg L^{-1}. Soils were obtained from the top layer (25 cm) of Serdang serie (Typic Kandiudult). The description of the soil used in this study is given in Table 1.

Compost used for this study, consisted of poultry compost, oil palm compost and vermicompost (Table 2). Sieved compost was thoroughly mixed with soils to yield a 1% proportion of compost. Zinc sources were applied before planting (1 mg L^{-1}) solution to the pots. Germinated rice seeds were planted on November 2012 and subsequently fertilizers (NPK) were applied four times. Eventually on March 2013, all the rice plants in each pot were harvested at physiological maturity age. The Zn concentrations of rice grain, culm and leaf was determined by ICP spectrometers.

The data obtained was subjected to ANOVA using the SAS 9.2 version. Pairs of treatment means were compared (or declared significantly or not significantly different at 5% level) by applying Duncan's new multiple range test.

Table 1: Chemical characteristic of Serdang serie soil

Chemical characteristic	Values
Serdang serie	
pH	4.30
Ca (mg kg^{-1})	867.60
Mg (mg kg^{-1})	352.20
Na (mg kg^{-1})	400.00
K (mg kg^{-1})	464.00
CEC (cmol+kg^{-1})	6.50
N (mg kg^{-1})	1056.00
P (mg kg^{-1})	23.60
Total carbon (%)	0.40
Cu (mg kg^{-1})	0.15
Mn (mg kg^{-1})	1.09
Zn (mg kg^{-1})	0.71
Fe (mg kg^{-1})	22.70

Table 2: Chemical characteristic of compost used

Chemical characteristic	Chicken	Oil palm	Vermicompost
Zn (mg kg^{-1})	1.157	0.237	0.621
Fe (mg kg^{-1})	12.420	20.040	7.520
Mn (mg kg^{-1})	1.396	0.465	1.144
Cu (mg kg^{-1})	0.221	0.103	0.082
Ca (mg kg^{-1})	702.000	42.000	52.000
Mg (mg kg^{-1})	183.000	103.000	106.000
Na (mg kg^{-1})	175.000	70.000	86.000
N (mg kg^{-1})	2240.000	500.000	1060.000
K (mg kg^{-1})	198.000	360.000	400.000
P (mg kg^{-1})	1406.000	202.000	326.000
C/N (%)	25.000	7.000	12.000

RESULTS

Zn concentration: The results obtained from the ANOVA analysis of soil, culm, leaf and grains are presented in Table 3. There is significant interaction between Zn sources, composts and varieties on the concentration of Zn in soil, culm and leaf. In grain, interaction between varieties, compost and Zn sources were found not significant but compost×Zn source were significantly different at $p \leq 0.05$ (Table 3). In addition, based on Table 3, Zn sources did not show significant difference for variety V1.

Effects of application of different sources of Zn on Zn concentration in different compost treatment in the soil: The data indicated that the zinc concentrations significantly increased for Zn-EDTA and $ZnSO_4$ compared with the control (Table 4) in variety V1. The Zn concentration significantly increased for all compost treatments compared to the control (Table 4). The highest Zn concentration was with vermicompost+$ZnSO_4$ treatment (4.82 mg kg^{-1}) and the lowest was with the control (1.17 mg kg^{-1}).

Soil treated with Vermicompost+$ZnSO_4$ has Zn concentration about 4 times more than Control planted with variety V1. In addition, Zn concentration is (4.19 mg kg^{-1}) with ZnEDTA+Vermicompost treatment and (3.54 mg kg^{-1}) for Control+Vermicompost treatment. Application of all 3

Table 3: Analysis of variance for Zn sources and compost effects on soil, culm, leaf and grain Zn cocentration of upland rice

Grain	Leaf	Culm	Soil	df	SOV
Zn sources and compost effects on soil					
39.757ns	727.47ns	118.250ns	0.1480ns	2	Block
75.235ns	16251.04*	243904.56*	2.4930*	1	Variety
779.852*	17244.93*	124508.35*	20.444*	3	Compost
338.960*	8357.46*	21323.02*	3.6420*	2	Zn source
100.380*	1511.45*	8852.95*	0.7550*	3	Varietyt×compost
19.527ns	3553.14*	45196.76*	0.1150ns	2	Varietyt×Zn source
83.653*	1025.91*	33162.77*	0.2600ns	6	Compost×Zn source
56.072ns	2680.16*	56522.71*	0.5960*	6	Variety×compost×Zn source
27.676	395.90	1815.37	0.1330	46	Error

Grain (V2)	Grain (V1)	df	SOV
Zn concentration of upland rice			
40.203ns	8.074ns	2	Block
447.947*	432.285*	3	Compost
253.373*	105.114ns	2	Zn source
65.524*	74.203ns	6	Compost×Zn source
24.063	33.030	22	Error

ns: Not significant, *Significant at $p<0.05$

Table 4: Effects of application of different sources of Zn and composts on Zn concentration in different treatments in soil, culm and leaf of upland rice varieties used

	Zn concentration ($mg\ kg^{-1}$)					
	Soil		Culm		Leaf	
	V1	V2	V1	V2	V1	V2
Zn source						
Control						
Control	1.173^{c}	1.19^{b}	271.40^{b}	167.40^{a}	104.13^{b}	72.93^{b}
Chicken	2.44^{b}	1.33^{b}	409.13^{a}	178.93^{c}	127.00^{ab}	93.20^{b}
Oil palm	1.90^{b}	1.78^{b}	393.33^{a}	302.60^{b}	115.60^{b}	77.66^{b}
Vermi	3.54^{a}	3.77^{a}	464.00^{a}	428.86^{a}	159.53^{a}	144.73^{a}
Zn-EDTA						
Control	2.16^{c}	1.44^{b}	312.53^{a}	229.20^{a}	129.20^{b}	83.06^{b}
Chicken	2.54^{bc}	1.90^{b}	328.33^{c}	309.40^{a}	157.60^{b}	116.40^{ab}
Oil palm	3.12^{b}	2.49^{b}	560.93^{b}	305.60^{a}	151.60^{b}	162.93^{a}
Vermi	4.19^{a}	4.09^{a}	736.93^{a}	279.00^{a}	267.46^{a}	124.60^{ab}
$ZnSO_4$						
Control	1.80^{c}	1.41^{b}	223.80^{c}	210.73^{c}	93.20^{b}	86.66^{b}
Chicken	2.92^{b}	1.92^{b}	594.60^{a}	344.33^{b}	117.40^{ab}	137.00^{a}
Oil palm	2.62^{bc}	3.60^{a}	338.73^{b}	271.40^{bc}	162.13^{a}	137.06^{a}
Vermi	4.82^{a}	3.84^{a}	250.06^{c}	459.46^{a}	167.73^{a}	155.60^{a}
Zn composts						
Control						
Control	1.17^{b}	1.19^{a}	271.40^{ab}	167.4^{a}	104.13^{a}	72.93^{a}
Zn-EDTA	2.16^{a}	1.44^{a}	312.53^{a}	229.2^{a}	129.20^{a}	83.06^{a}
$ZnSO_4$	1.80^{ab}	1.41^{a}	223.80^{b}	210.7^{ab}	93.20^{a}	86.66^{a}
Chicken						
Control	2.44^{b}	1.33^{a}	409.13^{b}	178.93^{b}	127.0^{a}	93.20^{b}
Zn-EDTA	2.56^{b}	1.90^{a}	328.33^{b}	309.40^{a}	157.6^{a}	116.46^{ab}
$ZnSO_4$	2.92^{a}	1.92^{a}	594.60^{a}	344.33^{a}	117.4^{a}	137.00^{a}
Oil palm						
Control	1.90^{a}	1.78^{b}	393.33^{b}	302.6^{a}	115.60^{a}	77.66^{b}
Zn-EDTA	3.12^{a}	2.49^{b}	560.93^{a}	305.6^{a}	151.60^{a}	162.93^{a}
$ZnSO_4$	2.62^{a}	3.60^{a}	338.73^{b}	271.4^{a}	162.13^{a}	137.06^{a}
Vermi						
Control	3.54^{c}	3.77^{a}	464.00^{b}	428.8^{a}	159.53^{a}	144.73^{a}
Zn-EDTA	4.19^{b}	4.09^{a}	736.93^{a}	279.0^{b}	267.46^{a}	124.66^{a}
$ZnSO_4$	4.82^{a}	3.84^{a}	250.06^{c}	459.4^{a}	167.73^{a}	155.60^{a}

Means in the same coloumn followed by the same letters are not significantly different at $p\leq 0.05$

different compost treatments and 2 Zn source treatments caused an increase in the extractable Zn in the soil during the growth period of variety V2 which is similar to variety V1 (Table 4).

Thereafter, no such effect was observed. Zn concentration was the highest with vermicompost+Zn-EDTA treatment (4.09 $mg\ kg^{-1}$) and the lowest was with the control (1.19 $mg\ kg^{-1}$). Vermicompost+ZnEDTA affected Zn concentration about 5 times more than control in variety V2. In addition, Zn concentration is (3.84 $mg\ kg^{-1}$) in $ZnSO_4$+Vermicompost treatment and (3.77 $mg\ kg^{-1}$) in Control+Vermicompost treatment as illustrated in Table 4. It indicated that Vermicompost treatments are the most effective treatment among all composts and Zn source treatments. The results (Table 4) showed that application of both the sources of Zn always caused an increase in extractable Zn in the soil, but the magnitude of increase varied with the sources, the same being more with $ZnSO_4$ than with Zn-EDTA. Table 4 showed, $ZnSO_4$ treatment affected Zn concentration (1.8 $mg\ kg^{-1}$) about 0.15 times more than control (1.17 $mg\ kg^{-1}$) and vermicompost treatment affected Zn concentration (3.54 $mg\ kg^{-1}$) about 3 times more than control (1.17 $mg\ kg^{-1}$).

In addition, as illustrated in Table 4, vermicompost+$ZnSO_4$ (4.82 $mg\ kg^{-1}$) affect Zn concentrations about 4 times more than control (1.17 $mg\ kg^{-1}$). It shows that Vermicompost alone is 2 times more effective than $ZnSO_4$ and the effect of these 2 treatments together (Vermicompost+$ZnSO_4$) is about 4 times more effective than control in increasing the Zn level in soil.

Effect of application of different sources of Zn on Zn concentrations in different compost treatments in culm of upland rice varieties used: The highest Zn concentration in culm was observed in Vermicompost+Zn-EDTA treatment (736.93 $mg\ kg^{-1}$). Rice culm in this treatment has Zn concentration (736.93 $mg\ kg^{-1}$) about 2.7 times more than control (271.4 $mg\ kg^{-1}$) in variety V1. In addition, Zn concentration is significantly very high for Zn-EDTA+Oil palm compost treatment (560.933 mg kg^{-1}) and at $ZnSO_4$+Chicken compost treatment (594.6 mg kg^{-1}). Application of all different compost and Zn source treatments caused increase in Zn concentration in culms of both varieties, but the effects observed were different (Table 4).

Based on data collected, Vermicompost+$ZnSO_4$treatment had the highest (459.47 mg kg^{-1}) and the lowest was recorded with the control (167.4 mg kg^{-1}). Vermicompost+$ZnSO_4$ affected Zn concentration about 2.7 times more than control in variety V2. Zinc concentration in Control+Vermicompost treatment was 428.867 and 344.33 mg kg^{-1} for $ZnSO_4$+Chicken compost treatment as illustrated in Table 4.

The results (Table 4) showed that application of both the sources of Zn always caused an increase in the level of Zn in the culm but the magnitude of increase varied with the sources. The same being more with Zn-EDTA than with $ZnSO_4$ in V1 variety but in contrast, $ZnSO_4$ than with ZnEDTA in V2 variety. Table 4 shows, in V1 variety Zn-EDTA+Vermicompost (736.93 mg kg^{-1}) and in V2 $ZnSO_4$+Vermicompost (459.46 mg kg^{-1}) are the most effective treatments on culm Zn concentration. Furthermore, $ZnSO_4$+Chicken compost in both varieties affected culm Zn level very much (about 1.5 times more than control (1.17 mg kg^{-1}).

Effects of application of different sources of Zn on Zn concentrations in different compost treatments in leaf of upland rice varieties: Data indicated that the Zn concentration significantly increased for Zn-EDTA and $ZnSO_4$ compared to the control in leaf of V1 variety (Table 4). Referring to the data, the Zn concentration significantly increased at all compost treatments compared to the control (Table 4). Zinc concentration was the highest for Vermicompost+Zn-EDTA treatment (267.47 mg kg^{-1}) and the lowest was at Control+$ZnSO_4$ (93.2 mg kg^{-1}). Leaf affected by Vermicompost+Zn-EDTA has Zn concentration about 2.5 times more than control in V1 variety.

In addition, Zn concentration was high for Zn-EDTA+Chicken compost, $ZnSO_4$+Oil palm compost and $ZnSO_4$+Vermicompost treatments. Application of all 3 different compost treatments and 2 Zn sources enhanced the Zn in the leaf of both upland rice varieties (Table 4).

The Zn concentration was the highest for oil palm compost+Zn-EDTA treatment (162.93 mg kg^{-1}) and the lowest was for the Control (77.93 mg kg^{-1}). Oil palm compost+Zn-EDTA affected Zn concentration about 2 times more than the control in V2 variety. In addition, Zn concentration was 155.6 mg kg^{-1} for $ZnSO_4$+Vermicompost treatment, 137 mg kg^{-1} for $ZnSO_4$+Chicken compost treatment and 137.07 mg kg^{-1} for $ZnSO_4$+Oil palm compost as is illustrated in Table 4. It indicates that $ZnSO_4$ treatments are the more effective treatment than Zn-EDTA. The results (Table 4) show that application of both the sources of Zn always caused an increase in the level of Zn in leaves, but the magnitude of increase varied with the sources, with more increase with $ZnSO_4$ than with Zn-EDTA.

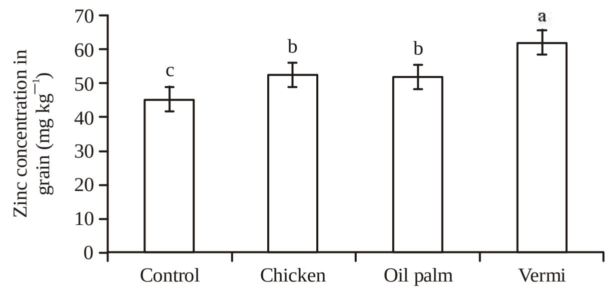

Fig. 1: Means comparison of application of different compost treatments on Zn concentration in grain of V1 variety (Means followed by the same letters are not significant at $p \leq 0.05$ by Duncan)

Table 5: Analysis of variance for Zn source and compost effect on soil, culm, leaf and grain Zn uptake of upland rice

Grain	Leaf	Culm	df	SOV
0.720ns	0.017ns	0.720ns	2	Block
193.608*	7.080*	193.608*	1	Variety
91.604*	3.534*	91.604*	3	Compost
12.994*	0.734*	12.994*	2	Zn source
17.810*	0.573*	17.810*	3	Variety×compost
30.722*	0.345*	30.722*	2	Variety×Zn source
16.598*	0.107*	16.598*	6	Compost×Zn source
7.808*	0.186*	7.808*	6	Variety×compost×Zn source
0.628	0.015	0.628*	46	Error

*Significant at $p<0.05$, ns: Not significant

Effect of application of different sources of Zn on Zn concentrations in different compost treatments in grain of upland rice varieties used: The highest Zn concentration in grain of V1 was observed for Vermicompost treatment (62.17 mg kg^{-1}). Zn concentration in rice grain which was affected by Vermicompost contain about 1.37 time more than control (45.33 mg kg^{-1}) inV1 variety (Fig. 1).

Application of all different composts and Zn source treatments increased the Zn in the grain of V2 variety too but the effects observed were different (Fig. 2a, b). Zinc concentration was the highest for oil palm compost+Zn-EDTA treatment (62.46 mg kg^{-1}) and the lowest was for the Control (31.2 mg kg^{-1}). Oil palm compost+ZnEDTA affected Zn concentration about 2 times more than the Control in V2 variety. In addition, Zn concentration is 57.46 mg kg^{-1} for $ZnSO_4$+Chicken compost treatment and 57.13 mg kg^{-1} for $ZnSO_4$+Vermicompost treatment as illustrated in Fig. 2a and 2b.

The results of evaluation of Zn concentration in V2 variety showed that both applications of the sources of Zn increased the Zn concentration in grain, but both of them did not follow the expected trend.

Zn uptake: Table 5 provides the results obtained from the analysis of variance (ANOVA) of culm, leaf and grain Zn uptake in 2 upland rice varieties. There is significant interaction between varieties, composts and Zn sources on the Zn uptake in all parts of these two varieties.

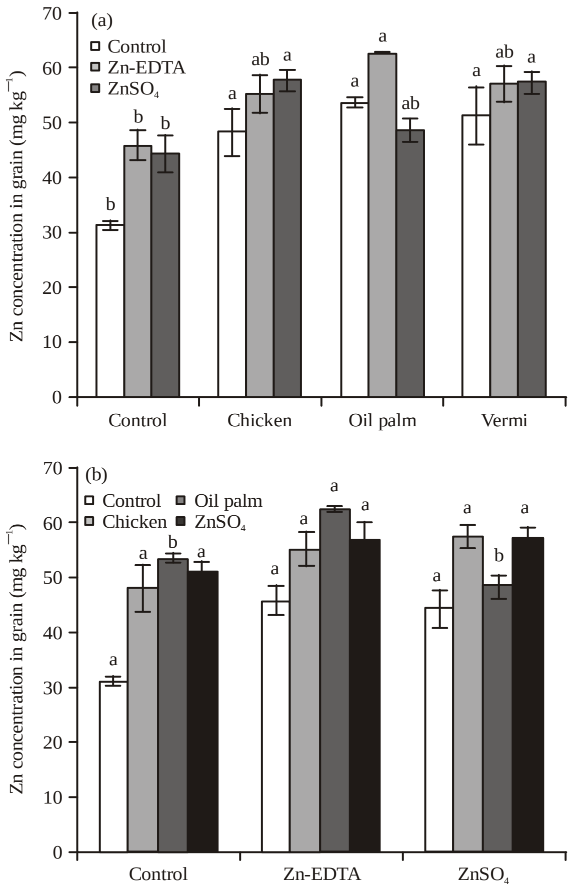

Fig. 2(a-b): Means comparison of application of different (a) Composts and (b) Zn source treatments on Zn concentration in grain of V2 variety (Means followed by the same letters are not significant at $p \leq 0.05$ by Duncan)

Effect of application of different sources of Zn on Zinc uptake in different compost treatments in culms of upland rice varieties used: The highest culm Zn uptake was detected in vermicompost+Zn-EDTA (12.93 mg kg^{-1}) followed by Chicken compost+$ZnSO_4$ treatment (12.72 mg plant^{-1}) without significant differences between these two treatments. The amount is about 5 times of Control in V1 variety (2.58 mg plant^{-1}). In addition,, Zn concentration is significantly higher in Zn-EDTA+Oil palm compost treatment (12.02 mg kg^{-1}) (Table 6, 7).

Application of different compost and Zn source treatments caused an increase in the culm Zn uptake of V2 variety too, but the amounts observed were different (Table 6, 7). Zinc uptake was the highest with Chicken compost+$ZnSO_4$ treatment (7.99 mg plant^{-1}) and the lowest was with the Control (1.18 mg plant^{-1}). This treatment, affected Zn uptake about 6.7 times more than control in V2 variety. Other treatments affected significantly compared to the control but not as much as Chicken compost+$ZnSO_4$ treatment. Culm Zn uptake was the highest with Chicken compost+$ZnSO_4$

Table 6: Effects of application of different sources of Zn on Zn concentration in different compost treatments in soil,culm and leaf of V1 and V2 upland rice varieties

	Zn uptake (mg plant^{-1})					
	Culm		Leaf		Grain	
Zn source and Compost	V1	V2	V1	V2	V1	V2
Control						
Control	2.585^{c}	1.182^{b}	0.733^{c}	0.355^{d}	0.130^{c}	0.246^{a}
Chicken	8.647^{a}	4.925^{a}	2.072^{a}	0.697^{a}	0.302^{a}	0.200^{a}
Oil palm	6.343^{b}	4.044^{a}	0.866^{c}	0.568^{c}	0.182^{b}	0.217^{a}
Vermi	8.83^{a}	4.399^{a}	1.552^{b}	0.940^{a}	0.315^{a}	0.248^{a}
Zn-EDTA						
Control	4.243^{c}	2.366^{c}	0.946^{c}	0.394^{b}	0.278^{b}	0.202^{b}
Chicken	8.949^{b}	4.304^{ab}	2.212^{a}	1.004^{a}	0.329^{b}	0.282^{a}
Oil palm	12.02^{a}	3.356^{bc}	1.585^{b}	1.091^{a}	0.267^{b}	0.211^{b}
Vermi	12.93^{a}	4.937^{a}	2.188^{a}	1.058^{a}	0.530^{a}	0.290^{a}
$ZnSO_4$						
Control	1.799^{c}	4.124^{c}	0.398^{c}	0.744^{c}	0.154^{b}	0.175^{b}
Chicken	12.72^{a}	7.99^{a}	1.974^{a}	1.565^{a}	0.377^{a}	0.269^{a}
Oil palm	6.413^{b}	3.607^{c}	1.453^{b}	0.769^{c}	0.372^{a}	0.231^{ab}
Vermi	5.386^{b}	5.841^{b}	1.808^{a}	1.074^{b}	0.386^{a}	0.287^{a}

Means in the same coloumn followed by the same letters are not significantly different at $p \leq 0.05$

Table 7: Effects of application of different composts and different Zn source treatments on Zn uptake in culm,leaf and grain of upland rice varieties used

	Zn uptake (mg plant^{-1})					
	Culm		Leaf		Grain	
Compost and Zn source	V1	V2	V1	V2	V1	V2
Control						
Control	2.585^{a}	1.181^{b}	0.739^{a}	0.355^{b}	0.13^{b}	0.246^{a}
Zn-EDTA	4.243^{a}	2.366^{b}	0.945^{a}	0.394^{b}	0.278^{a}	0.202^{a}
$ZnSO_4$	1.799^{a}	4.124^{a}	0.398^{b}	0.744^{a}	0.154^{b}	0.175^{a}
Chicken						
Control	8.647^{b}	4.925^{b}	2.072^{a}	0.697^{c}	0.302^{b}	0.200^{b}
Zn-EDTA	8.495^{b}	4.304^{b}	2.212^{a}	1.004^{b}	0.329^{b}	0.282^{a}
$ZnSO_4$	12.728^{a}	7.99^{a}	1.974^{a}	1.565^{a}	0.377^{a}	0.269^{a}
Oil palm						
Control	6.343^{b}	4.044^{a}	0.86^{b}	0.568^{b}	0.182^{c}	0.217^{a}
Zn-EDTA	12.021^{a}	3.356^{a}	1.585^{a}	1.091^{a}	0.267^{b}	0.211^{a}
$ZnSO_4$	6.412^{b}	3.606^{a}	1.453^{a}	0.769^{b}	0.372^{a}	0.231^{a}
Vermicompost						
Control	8.83^{b}	4.398^{a}	1.552^{b}	0.940^{a}	0.315^{c}	0.248^{a}
Zn-EDTA	12.93^{a}	4.937^{a}	2.188^{a}	1.058^{a}	0.535^{a}	0.29^{a}
$ZnSO_4$	5.386^{c}	5.841^{a}	1.808^{ab}	1.074^{a}	0.386^{b}	0.287^{a}

Means followed by the same letters are not significantly different at $p \leq 0.05$

treatment in both varieties (12.72 mg plant^{-1}); but was not significantly higher in comparison to culm Zn concentration (Table 6 and 7).

Effects of application of different sources of Zn and compost treatments on Zinc uptake in leaf of upland rice varieties: Application of different composts and Zn sources showed similar shoot Zn uptake in both varieties (Table 6, 7). Leaf Zn uptake is the highest with Chicken compost+Zn-EDTA treatment (2.21 mg plant^{-1}) and Vermicompost+Zn-EDTA (2.18 mg plant^{-1}). These are about 3 times more than control (0.73 mg plant^{-1}) in V1 variety. In V2 variety, Chicken compost+$ZnSO_4$ treatment showed the highest leaf Zn uptake (1.56 mg $plant^{-1}$) in comparison with the control (0.35 mg $plant^{-1}$) which is about 4 times higher than the control.

Effect of application of different sources of Zn on Zinc uptake in different compost treatments in grain of upland rice varieties: Grain Zn uptake was the highest in Vermicompost+ZnEDTA treatment (0.53 mg $plant^{-1}$). In the Control treatment, Zn uptake in grain was almost one quarter (0.13 mg $plant^{-1}$) of grain which was treated with Vermicompost+ZnEDTA treatment in V1 variety. In addition,, Zn uptake is significantly higher in $ZnSO_4$+Vermicompost (0.38 mg $plant^{-1}$) and $ZnSO_4$+Chicken compost treatment (0.37 mg $plant^{-1}$) (Table 6 and 7). Application of different composts and Zn sources treatments caused increase in grain Zn uptake of V1 variety in contrast to V2 variety.

The Zn uptake was the highest in Vermicompost+ZnEDTA treatment (0.29 mg $plant^{-1}$), followed by Vermicompost+$ZnSO_4$ (0.28 mg $plant^{-1}$), Chicken compost+ZnEDTA (0.28 mg $plant^{-1}$) and Chicken compost+$ZnSO_4$ (0.26 mg $plant^{-1}$) and the lowest was control (1.182 mg kg^{-1}) treatments. This treatment affected grain Zn uptake more than others in V2 variety. Grain Zn uptake and grain Zn concentration both are the highest in Vermicompost+ZnEDTA treatment in V1 variety. In addition, in V2 the four treatments mentioned above, have the highest Zn uptake and also high Zn concentrations. Although Oil palm compost+ZnEDTA treatment showed high Zn concentration in grain, Zn uptake in this treatment was not very high (Table 4, 6 and 7).

DISCUSSION

The data revealed that Zn application from all the different Zn sources and composts caused an increase in the extractable Zn in the soil during the growth period of both upland rice varieties but Vermicompost+$ZnSO_4$ affected the soil more than other treatments. This supports the results by Imtiaz *et al.* (2010) who reported that Soil Organic Matter (SOM) like composts, significantly affect the bioavailability of micronutrients. Imtiaz *et al.* (2010) and Marschner (1998) showed that composts contribute to Zn accumulation through N supply and organic acids which decreased the soil pH and improved mobilization of soil Zn in soils.

Similar results were reported by Bruulsema *et al.* (2012) that, ZnEDTA is not the preferred source compared to $ZnSO_4$ for use in the correction of the Zn deficiency problem. Erhart and Hartl (2010) reported that soil Cation Exchange Capacity (CEC) increases with compost use, improving Zn availability. Furthermore, nitrogen mineralization from compost takes place relatively slowly and there are virtually no reports of uncontrollable N-leaching.

Results showed that all composts have a positive effect on Zn concentration in all parts of rice including shoots, leaves and grains. Vermicompost is the most efficient compost among these three composts.

Sujatha and Bhat (2013) and Khan *et al.* (2000) stated that vermicompost have less C:N ratio with higher nutrient content like Zn and Fe compared to other composts. As a confirmation Jordao *et al.* (2006) reported that the plants grown in soil amended with vermicompost enriched with Zn showed high Zn concentrations in the leaves.

Referring to the results of this study, it has been found that although chicken compost has more Zn concentration, it seems that because of high concentration of other elements (such as P which have interaction with Zn), plant could not absorb Zn properly. On the other hand, because of high N in chicken compost and increasing the dry weight of plant under this treatment, plant Zn uptake did not show a significant difference with Zn uptake under vermicompost treatment.

On opposite position of the present achievement, a study has indicated that Zn chelates are more stable in soil, particularly under upland condition than their inorganic counterparts (Marschner, 1993). In addition, Tariq *et al.* (2007) reported that artificial chelates such as (Zn-EDTA) have been shown to be more plant available than the inorganic forms.

Chatterjee and Mandal (1985) reported that an organic matter application like composts increased the translocation of Zn from native as well as applied $ZnSO_4$ source from the root to shoot, but such effect was not so marked when the chelate was the Zn source. This study also has revealed that, in the absence of added organic matter, ZnEDTA was more effective than $ZnSO_4$ in increasing the Zn concentration in shoots and its uptake by the upland rice plants.

Mandal *et al.* (1988) reported that owing to high N in chicken compost and increasing the dry weight of the plant under this treatment, the Zn concentration in the shoot and root increased because of the application of Zn but decreased due to use of organic matter. The decrease might be due to the dilution effect since there was an increase in the dry matter yield in the presence of added organic matter. In conclusion, results showed that the uptake of Zn by all parts of upland rice recorded a significant increase in the presence of Vermicompost and Zn sources ($ZnSO_4$ and Zn-EDTA) which was the most effective method for Zn fortification of upland rice plants.

Catlett *et al.* (2002) reported that the use of compost can affect soil properties which may influence Zn in soil and crop uptake. The N and organic acids of the composts and manures may decrease soil pH and mobilize Zn already present in the soil. Vermicompost has a low C:N ratio and high porosity and water-holding capacity that contains most nutrients in forms that are readily taken up by the plants.

The present results have illustrated that, both Zn sources showed almost the same efficiency on Zn concentration and Zn uptake by upland rice in this experiment. Singh *et al.* (1983) expressed that the magnitude of Zn uptake response was magnified when zinc sulphate was applied along with organic compost. Application of Zn-amended organic composts increased the percentage distribution of Zn in grain more than the application of $ZnSO_4$ alone.

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