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ZINC STATUS OF PADDY SOILS OF MALAYSIA IN RELATION TO SOME PHYSICO-CHEMCAL PROPERTIES

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ABSTRACT

The micronutrient zinc is required by rice in a small quantity, but its deficiency has an adverse effect on healthy crop growth and the yield may decrease up to 30%. The states of Kedah and Kelantan of Malaysia are the main paddy growing areas of the country. Fifteen soil series from these states were selected for the determination of Zn^{2+}, Cu^{2+}, Mn^{2+} and Fe^{2+} status and some other physico-chemical properties. Soil samples were collected from three different locations of same soil series at the depths of 0-15, 15-30 and 30-45 cm. All the soils were acidic and low in organic carbon and P, while their texture varied from clay loam to silty clay. Copper (Cu^{2+}) and manganese (Mn^{2+}) were moderate in status, and iron was high. Available soil Zn^{2+} varied at different depths and locations for all the soil series ($P<0.05$); the top soils contained as high as 2.03 mg kg^{-1} and the subsoils as low as 0.22 mg kg^{-1}. Zinc concentration had negative correlation with Cu^{2+} (r= -0.77*), P (r= -0.65*), Fe^{2+} (r= -0.54*), Mn^{2+} (r= -0.23*) and pH (r= -0.21*) and positive correlation with organic carbon (r = 0.41). This study shows that Zn^{2+}, Cu^{2+}, Mn^{2+} and P status of paddy growing soils of Malaysia is low, and this could possibly be one of the main reasons of low rice yield.

Keywords: Malaysia, micronutrients, paddy soils, zinc status.

INTRODUCTION

Zinc (Zn) is required for the metabolic activity of about 300 enzymes, and is considered essential for cell division, and synthesis of DNA and protein in the plant. Therefore, an adequate Zn^{2+} nutrition is necessary for healthy plant growth and yield. Zinc deficiency was initially diagnosed in rice (*Oryza sativa*) on calcareous soils of northern India (Nene, 1966; Yoshida and Tanaka, 1969). According to some researchers (e.g. Neue and Lantin, 1994; Quijano-Guerta *et*

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al., 2002), Zn^{2+} deficiency is one of the most widespread nutrient disorders in lowland rice after nitrogen and phosphorus. Ahmed *et al.* (2012) reported in a review paper that world soils are deficient in plant available Zn^{2+} and correction of its deficiency has significant effect on the productivity of crops. Lindsay (1972) reported nine major factors affecting Zn^{2+} availability which include low soil Zn^{2+} content, restricted root zones, calcareous soils, low organic matter content, microbial inactivated Zn^{2+}, cool soil temperature, plant species, high level of available phosphorus and effect of nitrogen. Alloway (2004) reported that soils would have less available Zn^{2+} when they are high in pH, high in phosphorus, sandy texture, low organic matter content, acidic soils, removal of upper surface (sub soil exposed), peat soils, high carbonate and magnesium in soil or irrigation water and permanently wet soils under paddy cultivation. The deficiency of Zn^{2+} can have an adverse effect on crop yield. The application of fertilizer Zn^{2+} is an effective remedial measure to manage Zn^{2+} availability and plant health (Alloway, 2004). The Zn^{2+} deficiency can appear in rice seedlings after two to three weeks of transplanting. Singh *et al.* (2012) reported on the basis of their three years of experiments, that rice plant growth is affected by availability of sulphur and zinc in soil. The plant leaves start to develop brown blotches and streaks that may fuse to cover older leaves, growth remain stunted and in severe cases plant may die, while those that recover will show substantial delay in maturity and reduction in yield (Yoshida and Tanka, 1969; Van Breemen and Castro, 1980; Neue and Lantin, 1994). Therefore, soil sampling before sowing is always beneficial to see the status of nutrients. The states of Kedah and Kelantan are the main paddy growing areas of Malaysia. The soils in these areas are continuously under submerged condition which enables rice plants to absorb Zn^{2+} mostly from solubilization in the rhizosphere because the Zn^{2+} availability in the soil is very limited due to flooded condition (Achim and Thomas, 2000). It is important to note that rice is highly susceptible to Zn^{2+} deficiency and also cultivated under submerged condition which is favorable to Zn^{2+} deficiency. The review of literature has shown that there is no any comprehensive study to show the Zn^{2+} status in paddy growing areas of Malaysia. Keeping in view the importance of Zn^{2+} in rice cultivation, this study was conducted.

MATERIALS AND METHODS

Soil samples were collected after harvesting rice from the paddy growing area in the state of Kedah and Kelantan which are located in Peninsular, Malaysia. The growers of the area informed that they have not used Zn^{2+} fertilizers at least in previous last five years. Fifteen soil series were selected for this study. The soil series sampled from Kedah and Kelantan states are listed in Table 1. The sampling site maps of Kedah and Kelantan are given in Figure 1. The soil samples were taken using a stainless steel auger from three different locations of each soil series at the depths of 0 to 15, 15 to 30 and 30 to 45 cm. Each sample was chemically analysed thrice. Soil Zn^{2+}, Cu^{2+}, Mn^{2+} and Fe^{2+} were extracted using the double acid method (0.05 N HCl + 0.025 N H_2SO_4) and analysed by atomic absorption spectrophotometer (Lindsay and Cox, 1985). Soil texture was determined by the pipette method (Gee and Bauder, 1986), soil pH in 1:2.5 soil to distilled water suspension (Jackson, 1962) and soil electrical conductivity by EC radiometer instrument at the temperature of 24 ^{0}C (Jackson, 1962). Phosphorus was extracted by Bray and Kurtz # 2 extractants (Bray and Kurtz, 1945) and soil organic carbon was determined by a carbon analyzer using non-dispersive, infrared digital-controlled instrument CR-412. The correlation of Zn^{2+} with other nutrients was carried out using SAS, statistical software, at a confidence level of 95%.

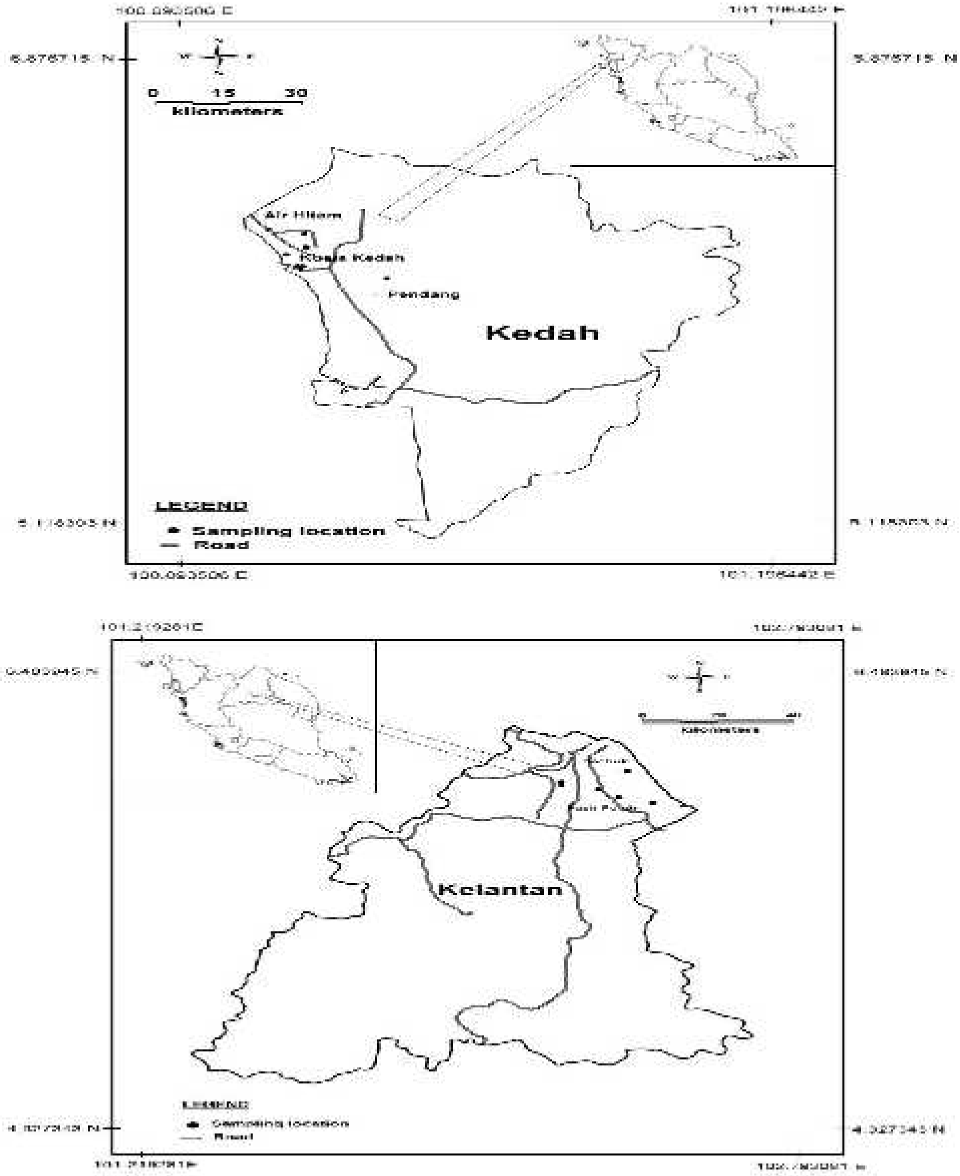

Figure 1. Maps showing soil sampling sites in Kedah and Kelantan states of Malaysia

RESULTS

Zinc concentrations at three soil depths and within locations of the ten soil series of Kedah and five of Kelantan state were different from each other (Table 2). Soil samples taken from the surface layer (0-15 cm) possessed significantly higher Zn^{2+} concentration as compared to the lower depths in most soil series of both states. The study revealed that Zn^{2+} concentrations varied at different locations ($P<0.05$). However, most of the soils contained less than 1.0 mg Zn^{2+} kg^{-1} and only few soils had more than 1.5 mg Zn^{2+} kg^{-1}. The data presented in Table 3 of Kedah soils revealed that Zn^{2+} was negatively correlated with Cu^{2+} (r= -0.775*), P (r= -0.311*), Fe^{2+} (r= -0.546*), Mn^{2+} (r= -0.233*) and pH (r= -0.213*) and positively correlated with organic carbon (r= 0.412). This same trend of correlation was observed in Kelantan soils (Table 4).

The data for various physical and chemical properties of soils of Kedah and Kekantan soils is given in Table 5. The pH of all soil series was acidic in nature. The highest soil pH (6.20) was noted in Kuala Kedah soil series. The lowest soil pH (3.7) was observed in Guar soil series. Phosphorus was low (< 20 mg kg^{-1}) in the Sedeka, Guar and Kundur soil series and high (>40 mg kg^{-1}) in Rotan and Batu Hitam. All the remaining soil series were medium (20 to 40 mg kg^{-1}) in phosphorus content. Organic carbon percentage in the majority of soil series was in medium range (1.5 to 3%) but in some soil series namely Kangkong, Sedu, Guar and Tepus it was high (> 3%). The lowest organic carbon was found in soil series Kranji (1.5%). The significantly higher organic carbon was in the upper layer (0-15 cm) probably due to the presence of higher amount of plant straw from previous crops and in lower depths it was comparatively lower. Almost all soil series had silty clay and loam textural class.

Table 1. Taxonomical classification of the soils collected from rice growing areas of Kedah and Kelantan states of Malaysia (first ten soil series belong to Kedah and last five soil series belong to Kelantan state).

Soil Series	Great Group	Parent Material
Kranji	Sulfaquents	Marine, estuarine deposits
Sedaka	Paleudults	Marine, estuarine deposits
Guar	Hydraquents	Brackish water deposits
Kundur	Fluvaquents	Marine, estuarine deposits
Tualang	Fluvaquents	Riverine deposits
Teluk Changai	Paleudults	Marine, estuarine deposits
Kuala Kedah	Fluvaquents	Marine, estuarine deposits
Rotan	Fluvaquents	Marine, estuarine deposits
Sedu	Sulfaquepts	Marine, estuarine deposits
Kangkong	Tropaquepts	Marine, estuarine deposits
Batu Hitam	Endoaqualfs	Recent alluvium
Lubok Itek	Fluvaquents	Recent alluvium
Tepus	Kandiaquults	Recent alluvium
Telemong	Udorthents	Recent alluvium

(Source: Paramananthan, 1987, 2000)

Table 2. Zinc status (mg kg^{-1}) of 15 soil series at different depths.

Soil Series	Depth (cm)		
	0-15	15-30	30-45
Kranji	0.81a	0.62b	0.46c
Sedaka	1.34a	0.68b	0.53b
Guar	0.98a	0.79b	0.61c
Kundur	0.69a	0.60ab	0.48b
Tualang	0.52a	0.33b	0.26b
Teluk Chengai	0.63a	0.48b	0.35c
Kuala Kedah	0.87a	0.68b	0.42c
Rotan	2.02a	1.68ab	0.86b
Sedu	2.03a	1.33b	0.81c
Kangkong	0.42a	0.32b	0.22c
Batu Hitam	0.55a	0.51a	0.55a
Lubok Itek	0.36b	0.40ab	0.48a
Tepus	0.42a	0.35a	0.50a
Telemong	0.48a	0.51a	0.54a
Tok Yong	0.54a	0.58a	0.64a

Within rows, means followed by same letters are not different from each other at $P \geq 0.05$

Table 3. Correlation coefficients of zinc in Kedah soils with soil properties (*n*=270).

Soil properties	Zn^{2+}	P	pH	Mn^{2+}	Fe^{2+}	Cu^{2+}	Organic Carbon
P	-0.311*						
pH	-0.213*	0.371*					
Mn	-0.233*	0.296*	0.084				
Fe	-0.546*	0.605*	0.319*	0.231*			
Cu	-0.775*	0.790*	0.351*	0.350*	0.656*		
Organic carbon	0.412*	-0.344*	-0.563*	-0.132*	-0.303*	-0.411*	
EC	0.003	0.017	-0.111	0.011	0.048	0.004	0.151*

*significant at $P < 0.05$

Table 4. Correlation coefficients of zinc in Kelantan soils with soil properties (*n*=135).

Soil properties	Zn^{2+}	Cu^{2+}	Mn^{2+}	Fe^{2+}	pH	Organic Carbon
Cu	-0.640*					
Mn	-0.498*	0.626*				
Fe	-0.459*	0.558*	0.603*			
pH	-0.965*	0.108	0.051	0.337*		
Organic Carbon	0.278*	-.368*	-0.438*	-0.427*	-0.270*	
P	-0.212*	0.290*	0.249*	0.188*	-0.079	-0.106

*significant at $P < 0.05$

Table 5. Physico-chemical properties and micronutrient status of Kedah and Kelantan soils.

Soil Series	Depth (cm)	pH	Organic Carbon %	P (mg kg^{-1})	Cu^{2+} (kg ha^{-1})	Mn^{2+} (kg ha^{-1})	Fe^{2+} (kg ha^{-1})	Textural Class
Karanji	0-15	5.40	1.88	19.29	2.86	8.40	99.8	Silty clay
	15-30	5.70	1.35	23.80	2.72	6.82	69.6	Silty clay
	30-45	6.10	0.88	26.03	2.69	7.42	42.8	Silty clay
Sedeka	0-15	4.30	3.00	21.34	3.10	5.58	67.4	Silty clay
	15-30	4.20	1.60	17.68	2.90	6.33	38.0	Silty clay
	30-45	4.00	1.60	16.78	2.90	5.09	28.6	Silty clay
Guar	0-15	3.74	4.10	8.58	2.80	1.28	102.8	Silty clay
	15-30	3.70	3.90	10.70	2.70	1.19	69.5	Silty clay
	30-45	3.60	4.60	25.01	1.10	0.85	36.5	Silty clay
Kundar	0-15	4.80	2.80	19.39	0.80	5.88	117.6	Silty clay
	15-30	4.80	2.60	20.21	0.70	5.76	58.9	Silty clay
	30-45	4.70	2.20	18.88	0.60	3.82	24.9	Silty clay
Tualang	0-15	5.10	2.80	24.71	0.90	3.01	42.8	Silty loam
	15-30	5.20	2.30	25.12	0.70	1.79	41.9	Silty clay
	30-45	5.20	1.80	21.37	0.50	1.01	20.0	Silty clay
Teluk Chengai	0-15	4.60	2.20	19.50	0.70	1.86	90.2	Silty clay
	15-30	4.70	1.80	22.10	0.50	1.21	49.7	Silty clay
	30-45	4.70	1.50	23.68	0.40	0.80	51.3	Silty clay
Kuala Kadah	0-15	5.50	2.30	27.14	2.90	1.19	136.1	Silty clay
	15-30	5.70	1.80	25.93	0.30	0.66	92.0	Silty clay
	30-45	6.20	1.10	24.24	0.50	0.08	70.3	Silty clay
Rotan	0-15	4.80	3.70	35.67	0.60	8.64	187.2	Silty clay
	15-30	4.80	3.30	38.30	0.40	7.54	152.2	Silty clay
	30-45	4.80	2.40	45.52	0.30	8.99	48.7	Silty clay
Sedu	0-15	4.70	3.40	32.22	0.70	8.46	92.0	Clay
	15-30	4.60	2.90	34.08	1.50	7.74	98.5	Silty clay
	30-45	4.50	2.30	35.14	0.20	5.92	85.5	silty clay
Kangkong	0-15	5.00	3.40	22.43	0.90	0.22	91.6	Silty
	15-30	5.10	2.90	19.63	0.70	0.51	92.5	Loam
	30-45	5.30	2.40	19.93	0.50	0.27	95.9	Loam
Batu Hitam	0-15	5.58	1.59	50.69	0.70	8.64	51.8	Loam
	15-30	5.45	1.65	46.45	0.50	7.54	41.9	Silty clay
	30-45	5.22	1.28	40.07	0.40	8.99	21.0	Silty clay
Lubok Itek	0-15	4.65	1.25	35.63	2.90	7.46	90.2	Clay
	15-30	4.69	1.96	33.20	0.30	7.74	49.7	Silty clay
	30-45	4.72	1.35	30.53	0.50	5.92	51.3	Silty clay
Tepus	0-15	4.03	3.64	22.43	2.86	0.22	85.1	Loam
	15-30	4.29	3.25	19.63	2.72	0.51	92.0	Loam
	30-45	5.46	1.46	30.45	2.69	0.27	70.3	Loam
Telemong	0-15	5.36	0.56	26.36	3.10	8.40	87.2	Silty clay
	15-30	4.46	0.63	30.65	2.90	6.82	82.2	Silty clay
	30-45	4.56	1.85	40.41	2.90	7.42	88.7	Clay
Tok Yong	0-15	5.36	1.56	36.23	2.80	5.58	51.3	Silty clay
	15-30	5.94	1.23	30.22	2.70	6.33	65.1	Silty clay
	30-45	5.50	1.50	28.40	2.80	5.09	62.0	Clay

The copper and manganese contents were in moderate range and iron content was high in soil. The lowest Mn^{2+} values (0.08 kg ha^{-1}) were found in Kuala Kadah soil series at 30-45 cm and highest (8.99 kg ha^{-1}) were observed in Rotan and Batu Hitam soil series at 30-45 cm depth. The lowest Fe^{2+} concentration (20.0 kg ha^{-1}) was noted in Tualang soil series at 30-45 cm depth whereas highest (136.1 kg ha^{-1}) was in Kuala Kadah soil series at 0-15 cm depth. The lowest (0.2 kg ha^{-1}) Cu^{2+} was found in Sedu soil series at 30-45 cm depth and highest (3.1 kg ha^{-1}) was observed in Sedeka and Telemong at 0-15 cm depth.

DISCUSSION

The laboratory analysis of paddy soils showed different levels of Zn^{2+} and other soil properties. This could probably be due to the nutrient mining as rice is grown in these areas from last many years without application of any Zn fertilizer. Achim and Thomas (2000) reported that under the submerged condition, the Zn^{2+} uptake is reduced and subsequently plant growth is inhibited. The uptake of Zn^{2+} is also adversely affected under acidic rhizosphere condition possibly due to the release of H^+ ion from the roots which balance the surplus intake of cations over anions. Under acid rhizosphere conditions, Zn^{2+} is released from acid-soluble fractions (e.g. adsorbed Zn^{2+}, organic matter or Fe^{2+} (OH_3)) and becomes available to plants. The rice plants absorb Zn^{2+} mostly in the rhizosphere because the available Zn^{2+} in soil is very small under flooded conditions. This might be due to the ambiguity in leaching. Fageria and Zimmerman (1979) also indicated that Zn^{2+} deficiency can be induced with the application of lime and P. The soil Zn^{2+} deficiency probably is due to the application of P fertilizer which was applied continuously in all seasons. Zinc uptake efficiency can be increased with the higher levels of Fe^{2+}, Cu^{2+}, and Mn^{2+} in soil (Fageria *et al.,* 2002). The negative relationship between soil Zn^{2+} and soil pH has also been reported by some researchers (Agarwai and Sastry, 1995). These findings are similar with the results of Lee *et al.* (1992), Sharifuddin *et al.* (1992), and Zulkefl *et al.* (1992). According to them micronutrient concentrations in Malaysian soils were very low. The results of this study indicates that soil Zn^{2+} content generally decreased with soil depth. Yin *et al.* (2012) stated low bioavailability of Cu^{2+} and Zn^{2+} in the paddy soils of Kelantan state. They further stated that anthropogenic-based Zn^{2+} and Cu^{2+} in the paddy growing areas are probably from applications of chemical fertilizers.

CONCLUSION

The soils of rice growing areas of Malaysian states Kedah and Kelantan are generally deficient in zinc, and zinc content of these soils decreased with soil depth. The soils of Kelantan are generally considered less fertile than the soil of other rice growing areas of Malaysia. This study also proves that the soils of this region contained less Zn^{2+}, as compared to soils of Kedah state. To increase the yield potential of the paddy growing areas, farmers should use organic matter or crop residues as much as possible along with the application of chemical Zn^{2+} fertilizers. Beside this land management guidelines may be developed for the studied areas focusing on basic agro needs of the farmers.

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