

**Retention, Release and Plant Availability of  
Copper and Zinc in Three Tropical Peat Soils  
of Sarawak, Malaysia**

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Margaret Abat  
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Faculty of Sciences, Waite Research Institute  
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Loagan Bunut Lake, Miri, Sarawak

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Don't cry because it's over,  
smile because it happened (Dr Suess)

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## Abstract

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Natural tropical peat soils are unsuitable for cultivation of commercial crops because of their innate high acidity, high organic matter contents and low concentrations of essential nutrients. Lime is commonly applied to increase the soil pH prior to planting but this practice may affect the availability of nutrients. Deficiency of micronutrients, in particular copper (Cu) and zinc (Zn), has been reported, but there is still a lack of information on the behaviour and bioavailability of these micronutrients in tropical peat soils. The aims of this thesis were therefore to study the adsorption and desorption reactions of Cu and Zn in tropical peat soils of Sarawak, Malaysia and evaluate the effects of added Cu and Zn to correct the micronutrient deficiency problems in the soils.

The adsorption and desorption of Cu and Zn in three untreated (control) and limed soils were studied. The soils were sampled from three locations in Sarawak and were all characterised by low pH, low bulk density, high organic matter content and low concentrations of available macro- and micronutrients. For the limed soils, calcium carbonate ( $\text{CaCO}_3$ ) was used to increase the soil pH to 5.5. Both Cu and Zn adsorption followed a curvilinear (Freundlich) trend with binding affinity decreasing with concentrations of added Cu and Zn in all soils. At the same initial spiked concentrations, the adsorption of Cu and Zn were 50 and 67 times higher, respectively, in limed soils compared to that of controls.

The three soils behaved similarly in relation to sorption of both Cu and Zn. The Freundlich coefficients ( $K_F$  values) for Cu in control and limed soils were higher than those of Zn, indicating stronger solid phase sorption of Cu than Zn. The  $K_F$  values for Cu and Zn were higher than those reported for mineral soils, but were similar to those reported for other tropical peat soils, suggesting that the efficiency of micronutrient Cu and Zn fertilisers

would be low, and therefore fertiliser requirements for optimal crop production would be high.

Desorption of adsorbed Cu and Zn was assessed using 10 mM calcium nitrate ( $\text{Ca}(\text{NO}_3)_2$ ) and 5 mM diethylene triamine pentaacetic acid (DTPA). DTPA solution desorbed about 60% more Cu and Zn than  $\text{Ca}(\text{NO}_3)_2$  solution. Copper was more effectively desorbed by DTPA than Zn, as Cu has a higher critical stability constant with DTPA. The percentage of adsorbed Cu desorbed by DTPA was lower in limed soils than in control soils, indicating that added Cu in limed soils will be less labile and bioavailable. By contrast, the percentage of adsorbed Zn desorbed by DTPA was higher in limed soils than in control soils. This is likely due to the possible changes in Zn speciation with increasing soil pH.

The response of a tomato (*Solanum lycopersicum* L.) var. Tiny Tom to application of Cu and Zn as basal fertilisers was also assessed. Using the Mitscherlich model, yield responses were found to correlate well with the rates of added Cu and Zn. The shoot growth of tomato plants in fertilised soils was significantly ( $P \leq 0.05$ ) enhanced by the application of Cu and Zn fertilisers in all three soils. Leaf Cu and Zn concentrations were also significantly ( $P \leq 0.05$ ) increased. Responses to applied Zn were greater than those to applied Cu, and addition of Cu also increased Zn concentrations in tomato leaves and *vice versa*. This suggests a Zn ‘hidden’ response may exist when Cu fertiliser is added to these soils, since the addition of Cu probably displaces native Zn adsorbed to soil surfaces in these peat soils.

As the rate of added micronutrients increased, concentrations of Cu in plant shoot material were much more regulated than those of Zn. Critical Cu and Zn concentrations in plant shoot to achieve 90% maximum yield were 16-21 mg/kg and 90-96 mg/kg, respectively, greater than those reported for tomato grown in other soil types. Critical concentrations for



DTPA-extractable Cu and Zn in soil to achieve 90% maximum yield in the three soils were 1.6-2.9 and 3.5-3.6 mg/kg, respectively. The values for DTPA extractable Cu were within the range of the published critical values in other soil types. However, the critical concentrations of DTPA-extractable Zn were higher than the published critical values. These values can be used as a guide for fertiliser Cu and Zn recommendations on tropical peat soils in Sarawak.

## **Declaration**

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This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution to Margaret Abat and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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**(Margaret Abat)**

**Date:** .....

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## List of Abbreviations

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AF	Alan forest
ANOVA	Analysis of variance
AR	Analytical reagent
B	Boron
°C	Degree Celsius
Ca	Calcium
CaCl <sub>2</sub>	Calcium chloride
CaCO <sub>3</sub>	Calcium carbonate
Ca(NO <sub>3</sub> ) <sub>2</sub>	Calcium nitrate
CEC	Cation exchange capacity
Cu	Copper
CuSO <sub>4</sub>	Copper sulphate
DA	Director of Agriculture
DI	Deionised water
DTPA	Diethylene triamine pentaacetic acid
DOA	Department of Agriculture Sarawak
EDTA	Ethylene diamine tetraacetic acid
Fe	Iron
HA	Humic acid
HCl	Hydrochloric acid
HNO <sub>3</sub>	Nitric acid
ICP-MS	Inductively couple plasma – mass spectroscopy
ICP-OES	Inductively couple plasma – optical emission spectroscopy
K	Potassium
K <sub>F</sub>	Freundlich constant
K <sub>2</sub> HPO <sub>4</sub>	Potassium phosphate
LOI	Loss of ignition
M	Molarity
Mg	Magnesium
MgCO <sub>3</sub>	Magnesium carbonate
Mha	Million hectares
Mn	Manganese
Mo	Molybdenum

MSF	Mixed swamp forest
MWHC	Maximum water holding capacity
N	Nitrogen
Na	Sodium/Natrium
NaDC	Sodium dithionite citrate
NaOCl	Sodium hypochlorite
Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub>	Sodium thiosulphate
(NH <sub>4</sub> ) <sub>2</sub> HPO <sub>4</sub>	Ammonium phosphate
NH <sub>4</sub> Ox	Ammonium oxalate
(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	Ammonium sulphate
OC	Organic carbon
OM	Organic matter
P	Phosphorus
<i>P</i>	Probability
PF	Padang Alan forest
RCBD	Randomized complete block design
S	Sulphur
SD	Standard deviation
S <sub>max</sub>	Maximum adsorption
SOM	Soil organic matter
[x]	x concentration, eg. [Cu]
Zn	Zinc
ZnSO <sub>4</sub>	Zinc sulphate

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