ACCUMULATION OF LEAD AND COPPER AND GROWTH OF SEVERAL TROPICAL WEEDS IN A LEAD CONTAMINATED SOIL TREATED WITH LIME

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ABSTRACT

ACCUMULATION OF LEAD AND COPPER AND GROWTH OF SEVERAL TROPICAL WEEDS IN A LEAD CONTAMINATED SOIL TREATED WITH LIME. *Being detrimental to living things, lead (Pb) and copper (Cu) availabilities in soils must be controlled. One of the important techniques for controlling heavy metal availabilities in soils is liming. Lead and copper availabilities and accumulations and their possible effects on growth of several tropical weeds were evaluated in a glasshouse experiment using a lead contaminated soil. Soil medium was spiked with Pb at 20 mg kg^{-1} and treated thoroughly with $CaCO_3$ at 4 ton ha^{-1}. After incubation at the soil's field capacity at room temperature for 1 week, soil medium was planted with amaranth (Amaranthus tricolor) and three tropical weeds, i.e. pigweed (Amaranthus spinosus), green kyllinga (Cyperus kyllingia), and alang-alang (Imperata cylindrica) for 4 weeks. Except in the root-zone of alang-alang, the available Pb in soils was significantly increased by Pb addition and decreased by lime addition, in a negative correlation with pH changes. Except in alang-alang, Pb and lime additions showed no effect on Pb accumulation in plant shoots and plant growth even though the growth of all plants generally tended to decrease by lime addition and be stimulated by Pb addition. Changes in soil available Pb were in good correlations with Pb accumulation and growth of alang-alang. The soil available Cu and its accumulation in plant shoots were not affected by lime and Pb additions, except for alang-alang, in which lime addition decreased the weed Cu accumulation in soil not treated with Pb.*

Keywords: copper, lead, lime, metal accumulation, tropical soils, tropical weeds.

INTRODUCTION

Contamination of the environment by lead (Pb) occurs in areas along major roads heavy with traffics due to the use of leaded gasoline (Markus and McBratney, 1996; Akhter and Madany, 1992; Minami and Araki, 1975). Some reports indicate that contamination of soils by Pb from vehicle exhaust is usually correlated with contamination by copper (Cu) (Baker, 1990). Because these elements are detrimental to the living things (Djuangsih, 1992; Alloway, 1990b; Baker, 1990; Steinnes, 1990), particularly to humans and animals, their concentrations in the environment must be managed at levels not detrimental to living things. Management of Pb and Cu is even more important if contaminated soils are planted with heavy-metal bioaccumulators such as spinach and weeds.

An important technique possible to employ in reducing Pb and Cu availabilities in soils is liming (Salam et al., 1997a; Rodella et al., 1995; Salam, 1995a; 1995b; Sumner et al., 1991; Alloway, 1990a; Bohn et al., 1985; Helling et al., 1964). The enhancement of soil pH by lime treatment may induce ionization of hidrogen from various organic and inorganic functional groups in soils (Salam and Helmke, 1998). This process may in turn increase the number of the negative charges on the surfaces of soil particles important to build electrostatic bondings with Pb and Cu cations. Thus, lime addition may eventually reduce the soil available Pb and Cu and their absorptions by plant roots.

This research evaluated the changes in soil available Pb and Cu and their accumulations in shoots of amaranth and some tropical weeds in a lead contaminated soil treated with lime.

MATERIALS AND METHODS

The experiment was conducted in the University of Lampung green houses from October to December 1996. Soil sample was collected from the Ap horizon (0~20 cm) of University of Lampung Gedongmeneng campus in Bandar Lampung. After collection, soil sample was air-dried, thoroughly mixed, and sieved to 2 mm.

A 300 g of soil sample (105 °C oven-dry weight equivalent) was used as the experimental unit. Treatments (lime and Pb standard) were arranged factorially in a completely randomized design with four replications. Lime was given at 0 and 4 ton $CaCO_3$ ha^{-1}; and Pb standard at 0 and 20 mg kg^{-1}, given as a Pb solution with concentration of 100 mg L^{-1}. Into the experimental units not treated with Pb standard solution, a dilute HNO_3 solution was also added in the amount enough to eliminate differences in HNO_3 contents from the experimental units treated with Pb standard (Pb standard solution was diluted in a dilute HNO_3 during manufacturing). After a thorough mixing, soil mixture medium was then incubated at the soil's field capacity and room temperature. Soil medium was covered with plastic sheets during soil incubation to minimize water loss due to evaporation.

Amaranth (*A. tricolor*) and weed seedlings were planted after the soil medium was incubated for 1 week. Weeds used in this experiment were pigweed (*A. spinosus*), green kyllinga (*C. kyllingia*), and *alang-alang* (*I. cylindrica*). All these plants were employed as test plants separately in each of four similar experiments.

Amaranth and pigweed seedlings were prepared by seeding their seeds in a medium containing soil and sand (1:1). Seedlings of *alang-alang* and green kyllinga were prepared from rhizomes in a medium containing soil and sand (1:1). Seedlings were transplanted into experimental pots 2 weeks after their germinations. Each experimental unit contained 1 seedling.

Plant growth was observed for a 4 week growing period. Observation was conducted on plant height, plant dry-weights (root, shoot, and total), and accumulation of Pb and Cu in amaranth and weed shoots. Changes in soil properties including soil available Pb and Cu and soil pH were also observed; soil available Pb and Cu were determined with the DTPA method (Baker and Amacher, 1982) and soil pH with a pH electrode. Data were analyzed using Analysis of Variance (ANOVA) followed by the Least Significant Difference (LSD) test.

RESULTS AND DISCUSSION

Soil available Pb significantly increased with addition of Pb and in general decreased when lime was added to the Pb-treated soils. As suggested by several reports (Salam and Helmke, 1998; Salam et al., 1997a), lime addition may have increased the soil adsorption capacity with respect to Pb and other metals due to the increase in soil pH by lime addition. This, in turn, may have decreased the soil available Pb. Due to the high amount of Pb standard added into the soil system, precipitation of Pb was also possible to participate in lowering the soil available Pb. Both mechanisms immobilized more than 60% of the added Pb in the experimental units treated with lime and/or planted with *alang-alang*. *Alang-alang* showed a different effect on available Pb with respect to Pb addition probably because it caused a higher soil pH than the other weeds (Table 1). Salam et al. (1997b) also showed previously that *alang-alang* produced higher activities of phosphatases than did pigweed, amaranth, and green kyllinga.

Changes in soil available Pb due to Pb addition and lime showed no relation with Pb accumulation in shoots, except in soil planted with *alang-alang* (Table 3). This data indicates that Pb accumulation was not affected by the changes in Pb availabilities in soil resulted from Pb standard and/or lime additions. However, heights of pigweed, amaranth, and green kyllinga were negatively correlated with soil pH (r=-0.664, -0.245, and -0.634, respectively) and with total dry-weight (r=-0.638, -0.557, and -0.980, respectively). This data may indicate that the significant pH increases by lime addition (Table 1) may have increased the root cation exchange capacity (CEC) and caused greater nutrient retainments by weed root surfaces and, hence, decreased root ability to absorb plant nutrients. Consequently, the growth of all plants (indicated by plant heights and total dry weights) tended to be worse in limed than in unlimed soils (Table 2).

Lead addition tended to increase the total dry-weight (Table 2), particularly for amaranth and *alang-alang* that showed positive correlation with soil available

Table 1. Soil availability and accumulation of Pb and Cu in shoot of amaranth and some tropical weeds.

Treatments		Soil pH	Pb		Cu	
			Availability (mg kg-1)	Accumulation (μg-1)	Availability (mg kg-1)	Accumulation (μg-1)
Amaranth	Control	5.03 b	1.13 b	0.26 a	1.00 a	12.7 a
	+ Lime	6.34 a	0.69 b	0.26 a	0.60 a	12.9 a
	+ Pb	5.19 b	8.13 a	0.25 a	0.99 a	13.4 a
	+ Pb&Lime	6.35 a	1.24 b	0.25 a	1.00 a	13.0 a
Pigweed	Control	5.01 ab	0.74 c	0.35 a	0.69 a	13.5 a
	+ Lime	5.32 a	0.76 c	0.26 a	0.48 a	10.8 a
	+ Pb	4.65 b	7.72 a	0.25 a	0.59 a	12.3 a
	+ Pb&Lime	5.09 a	6.25 b	0.36 a	0.57 a	14.9 a
Green Kyllinga	Control	5.64 a	0.50 b	0.26 a	1.23 a	14.9 a
	+ Lime	6.37 a	1.03 b	0.26 a	1.21 a	13.5 a
	+ Pb	5.44 a	7.20 a	0.25 a	1.38 a	12.4 a
	+ Pb&Lime	6.34 a	6.76 a	0.26 a	1.30 a	15.0 a
Alang-alang	Control	0.23 a	0.19 b	0.23 a	0.44 a	10.3 a
	+ Lime	0.24 a	0.42 b	0.24 a	0.73 a	6.70 b
		0.27 a	1.27 a	0.27 a	0.68 a	6.70 b

Values followed by the same characters in each column for each weed were not significantly different at 5% LSD test

Pb (r=+0.924 and +0.621, respectively). Lead cations may have satisfied parts of the root CEC so that weed roots may have absorbed more nutrients needed by plants. However, as lime was added the root CEC may have increased and adsorbed more nutrients. As a result, addition of Pb in the presence of lime did not stimulate weed growth. The decrease in plant growth in the presence of Pb and lime may have been caused either by retainment of more nutrients by root CEC or by root destruction caused by adsorption of more Pb from soil solution. This suggestion, however, needs further investigation.

Alang-alang showed different behaviour with respect to Pb standard addition. Unlike in amaranth and other weeds, Pb accumulation in shoot of *alang-alang* showed a good correlation with the soil available Pb in the root-zone of *alang-alang* (Table 3). Both soil available Pb and Pb accumulation also showed good correlations with plant dry-weight, particularly root dry-weight. This indicates that the presence of high concentration of Pb in soil stimulated the growth of *alang-alang* roots and, as a result, it stimulated *alang-alang* shoot growth.

Except in soil planted with *alang-alang*, soil available Cu and its accumulation in shoots of amaranth and weeds were not significantly affected by lime and /or Pb addition, but plant species seemed to affect Cu availability; soil available Cu in the root-zone of green kyllinga was higher than those in the root zones of amaranth and other weeds. Accumulation of Cu in shoot of *alang-alang* from limed soils was lower than from the control soil.

Table 2. Growth of amaranth and some tropical weeds in soil contaminated with lead and treated with lime.

Treatment		Plant Height (cm)	Dry Weight (g)		
			Root	Shoot	Total
Amaranth	Control	23.2 ns	126 ns	740 ns	865 ns
	+ Lime	22.0	113	698	811
	+ Pb	25.5	117	858	975
	+ Pb&Lime	25.0	141	741	882
Pigweed	Control	8.22 ns	120 ns	362 ns	482 ns
	+ Lime	8.13	76.1	458	534
	+ Pb	8.60	94.4	609	703
	+ Pb&Lime	7.70	63.1	308	371
Green Kyllinga	Control	29.0 ns	149 ns	762 ns	911 ns
	+ Lime	23.3	54.6	430	484
	+ Pb	25.6	116	618	984
	+ Pb&Lime	25.2	95.5	515	611
Alang-alang	Control	66.8 ns	85.7 ns	750 ns	836 ns
	+ Lime	55.2	90.4	755	845
	+ Pb	66.4	95.8	952	1050
	+ Pb&Lime	65.1	99.4	734	833

ns : not significant at 5% LSD test.

Table 3. Correlation coefficients for the relationships between growth parameters of *alang-alang* and soil properties.

Soil Property	Pb	Pb	Plant	Dry Weight		
				Root	Shoot	Total
PH	- 0.045	+ 0.114	- 0.668	+ 0.308	- 0.693	- 0.666
Pb Availability	+ 1.00	+ 0.986	+ 0.346	+ 0.931	+ 0.579	+ 0.621
Pb Accumulation	+ 0.986	+ 1.00	+ 0.274	+ 0.979	+ 0.440	+ 0.487

CONCLUSIONS

The soil available Pb significantly increased by Pb addition but it decreased by lime addition in a negative correlation with pH changes, except in the root-zone of *alang-alang* and green kyllinga. Except in *alang-alang*, the changes in soil available Pb were not correlated with Pb accumulation in shoots and plant growth even though the growth of all plants in general tended to be stimulated by Pb addition and decreased by lime addition. Changes in soil available Pb were in good correlations with Pb accumulation and growth of *alang-*

alang. The soil available Cu and Cu accumulation in plant shoots were not affected by lime and Pb additions, except for *alang-alang*, in which Cu accumulation from the limed soil was lower than that from the control soil.

ACKNOWLEDGMENT

Thanks are due to Mutia Heradilla, a former student of The Department of Agronomy, The University of Lampung, Bandar Lampung, for conducting the greenhouse and laboratory works.

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