GREENHOUSE GROWTH OF AMARANTH (*Amaranthus tricolor* L.) IN SOILS POLLUTED WITH HEAVY METALS

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ABSTRACT

GREENHOUSE GROWTH OF AMARANTH (Amaranthus tricolor L.) IN SOILS POLLUTED WITH HEAVY METALS. Growth of crop plants is suggested to be inhibited by elevated concentrations of heavy metals in soils. This research was to evaluate the effects of heavy-metal-containing industrial waste on growth of amaranth in two tropical soils treated with lime and/or cassava-leaf compost. Soils with low and high adsorption capacities to heavy metals were used. Soil samples were factorially treated with wastes (Control, Model Waste 1 i.e. a mixture of standard solution to increase concentrations of Cu, Zn, and Pb 10 mg.kg^{-1}, respectively, and Cd 5 mg.kg^{-1} and MW 2, i.e. 4 times MW 1, and industrial waste of metal-spoon industry at 20 and 80 ton.ha^{-1}), lime (at 0, 2.5 and 5 ton.ha^{-1}), and cassava-leaf compost (at 0, 5, and 10 ton.ha^{-1}). Soil mixtures were then cultured to amaranth for four weeks in a greenhouse experiment. The growth of amaranth in both soils was inhibited by model waste. Unlike in Gedongmeneng soil, the negative effect of model waste in Banjaragung (high adsorption capacity) was alleviated by lime and/or cassava-leaf compost additions. Conversely, industrial waste addition tended to increase the growth of amaranth in Banjaragung soil even though this effect tended to decrease with lime addition. This effect was not observed in Gedongmeneng soil.

Keywords: amaranth, cassava-leaf compost, heavy metals, industrial waste, lime

INTRODUCTION

Proper management of heavy-metal-containing industrial wastes is of great necessary in soils contaminated with heavy metals or in agricultural lands treated with industrial wastes as soil amendments. Proper management of heavy metals in soils is beneficial not only to minimize heavy metal absorption by plant roots but also to avail some heavy-metal micronutrients such as Cu and Zn at concentrations favorable to plant growth. By this way, the detrimental effects of heavy metals of industrial wastes on the living organisms can be minimized.

Metal management in contaminated soil systems is mainly related to lowering heavy metal availabilities to plants, so that only small parts of input heavy-metals are available to plant root absorption. This effort is mainly conducted by using some soil chemical principles, particularly the changes in soil adsorption capacities to heavy metals as related to changes in soil pH and organic matter contents. The increase in soil pH, usually driven by addition of lime materials, may increase the dehydrogenation of soil functional groups and, thence, enhance soil adsorption capacities to heavy metals cations (Salam and Helmke, 1998; Salam *et al.*, 1997a; Alloway, 1990). The precipitation of heavy metals at high pH due to liming is also possible in particular soils (Brummer *et al.*, 1983; Singh and Sekhon, 1977). Several authors indicated previously that organic matters contain several functional groups such as carboxylics and phenols important to form insoluble metal complexes (Parfitt *et al.*, 1995; Rodella *et al.*, 1995; Alloway, 1990; Helling *et al.*, 1964), so that their additions into soil systems may lower heavy metal solubilities.

Several studies showed the important role of these soil amendments in lowering heavy metal availabilities in soils (Salam *et al.*, 1997b; Parfitt *et al.*, 1995; Rodella *et al.*, 1995). Parfitt *et al.* (1995) and Rodella *et al.* (1995) showed that addition of organic matter increased soil adsorption capacity to heavy metals and decreased their labile fractions. Previously, McGrath *et al.* (1988) showed that soil heavy-metal labile fractions were negatively correlated with organic matter contents. Our studies also showed that addition of lime and/or cassava-leaf compost significantly decreased available Cd, Cu, Pb, and Zn in some tropical soils (Salam *et al.*, 1997b).

The above results show that lime and/or organic compost may be used to alleviate the negative effects of detrimental levels of soil heavy metals on plant growth. However, such studies are limited, particularly in tropical soils. This research was to evaluate the effects of lime and/or cassava-leaf compost addition on the growth of glasshouse-grown amaranth in two tropical soils contaminated with heavy metals of standard solution or industrial waste.

MATERIALS AND METHODS

Soil samples were collected from A_p horizon (0~20 cm) of Gedongmeneng, Bandar Lampung, (Oxisol), and Banjaragung, Central Lampung, (Alfisols) Lampung. After collection, soil samples were air-dried, ground and screened to 2 mm, and mixed thoroughly. Some physical and chemical properties of the soils were reported previously (Salam *et al*., 1997a). Cassava-leaf compost was also air-dried and ground before application into soil samples.

Greenhouse experiment was conducted in The University of Lampung Gedongmeneng greenhouses. Treatments were arranged factorially in a completely randomized design with 3 replications. The treatment factors were lime, cassava-leaf compost, and wastes. Lime ($CaCO_3$) was given at: 0, 2.5, and 5 $ton.ha^{-1}$ and cassava-leaf compost was given at: 0,5, and 10 $ton.ha^{-1}$. Wastes were: No Waste, Model Waste 1, Model Waste 2, Industrial Waste 1, and Industrial Waste 2. Model Waste 1 was a mixture of standard solution with concentrations enough to increase soil Cu, Zn, and Pb as high as 10 $mg.kg^{-1}$ and Cd 5 $mg.kg^{-1}$. Model Waste 2 was Model Waste 1 with heavy metal concentrations 4 times higher. Industrial Waste 1 was a metal-spoon industrial waste (collected from the waste treatment unit of PT Star Metal Ware Industry Jakarta) given at 20 $ton.ha^{-1}$, while Industrial Waste 2 was the industrial waste given at a level 4 times greater than that of the Industrial Waste 1. The metal-spoon industrial waste showed pH 7.30, DTPA Cu 754 $mg.kg^{-1}$, DTPA Zn 44.5 $mg.kg^{-1}$, and a clay textural class. The experiment was conducted in two different soils. The soils were topsoil samples (0~20 cm) collected from Gedongmeneng (Ultisols) and Banjaragung (Alfisols) Lampung.

A 400 g soil sample (105°C oven-dry equivalent) was used as an experimental unit. Soil sample was thoroughly mixed with lime and/or cassava-leaf compost and Model Waste or Industrial Waste. Model Waste was given in a solution form and Industrial Waste was in a powder form. All materials were thoroughly mixed with soil samples and were then put in plastic pots. The soil mixtures were incubated at 40% (w/w) moisture content and at room temperature. After 1 week, two amaranth seedlings were transplanted into each of the soil mixtures. The amaranth seedlings were prepared previously in a medium consisting of 1:1:1 soil:sand:rice husk. Basal fertilizers of 100 kg Urea + 100 kg SP-36 + 100 kg $KCl.ha^{-1}$ were given before planting. During the experiment, soil water content was maintained at the field moisture capacity by adding water on a daily basis. The amaranth roots and shoots were harvested after a four week growing period. Plant responses were measured as shoot and root fresh and dry weights, plant height, and total leaf-area (measured by a leaf-area meter Li-Cor/LI-3100).

RESULTS AND DISCUSSION

Changes in the plant height of amaranth for four weeks in soils treated with heavy-metal-containing wastes, lime and cassava-leaf compost are depicted in Figs. 1 and 2, for Banjaragung and Gedongmeneng soils, respectively. Changes in total leaf-area and shoot dry-weight as affected by the treatments are depicted in Figs. 3 and 4, respectively. Comparison of amaranth root and shoot growth as affected by lime, cassava-leaf compost, and/or waste additions at the highest levels is given in Table 1. Compost of 5 $ton.ha^{-1}$ (C-2) is omitted from Figs. 1 and 2 for a practical reason in data presentation due to no difference in its effect from C-1 (Compost of 0 $ton.ha^{-1}$).

All growth parameters showed that amaranth grew better in Banjaragung than in Gedongmeneng soil. For example, the plant heights were all higher in Banjaragung for all treatments than those in Gedongmeneng soil (Figs. 1 and 2). This is because of the better soil fertility status of Banjaragung compared to that of Gedongmeneng soil as reported by Salam *et al.* (1998a). In addition, due to its higher adsorption capacity to heavy metals as reported by Salam *et al.* (1998a), soil of Banjaragung was able to neutralize heavy metals better than was soil of Gedongmeneng and, hence, amaranth grew better in Banjaragung soil.

The addition of Model Waste in the absence of lime and/or compost tended to inhibit plant growth (Figs. 1 and 2). Analysis of variance showed that Model Waste 2 (W-3) significantly inhibited the growth of amaranth. The negative effect of W-3 was also shown by leaf-area and shoot dry-weight data (Figs. 3 and 4, Table 1). However, addition of lime and/or cassava-leaf compost lowered the negative effects, thereby, the growth of amaranth in Banjaragung soil treated with lime and cassava-leaf compost at the highest levels was significantly better than that in the control (without lime and/or cassava-leaf compost treatments). It is also obvious that the Model Waste 2, that contained heavy metals at concentrations four times greater than the Model Waste 1, decreased the growth of amaranth more drastically (Figs. 1 and 2).

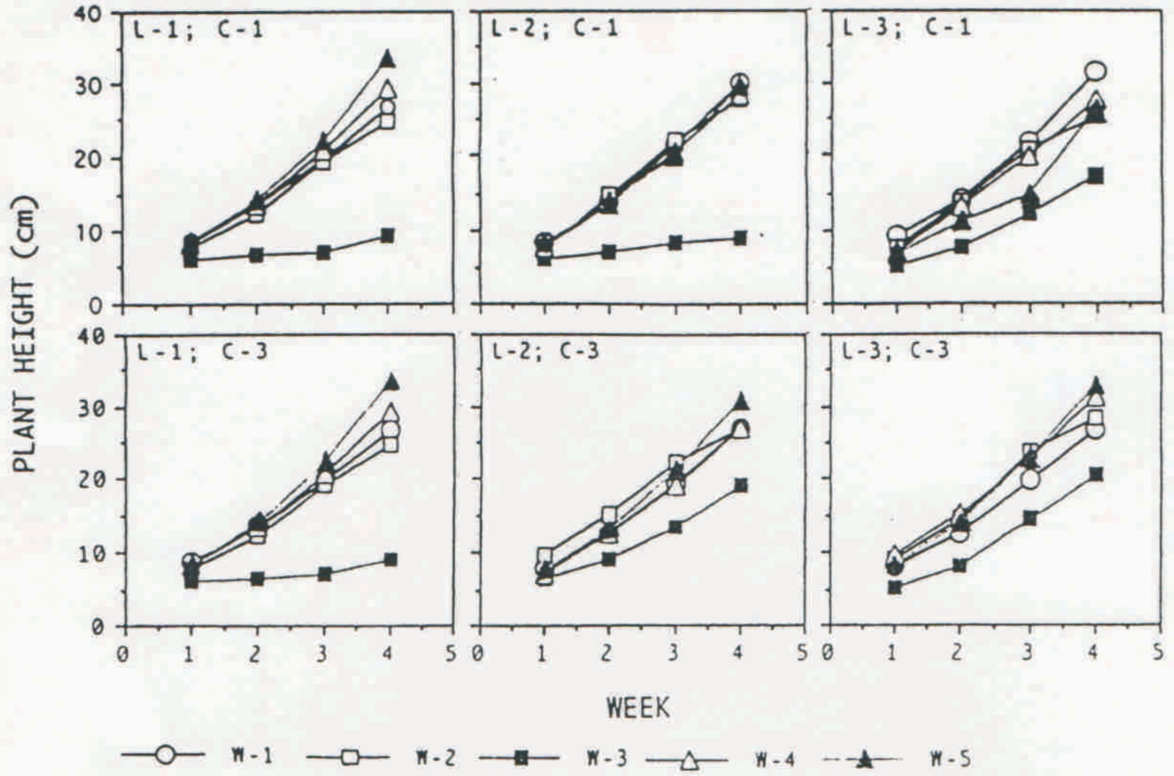

Fig. 1. Growth of amaranth in Banjaragung soil treated with wastes, lime, and cassava-leaf compost (Lime L-1 = 0, L-2 = 2.5, and L-3 = 5 ton $CaCO_3$ ha^{-1}; Compost C-1 = 0 and C-3 = 10 ton ha^{-1}; Waste W-1 = Control, W-2 = Model Waste 1, W-3 = Model Waste 2, W-4 = Industrial Waste 1, and W-5 = Industrial Waste 2).

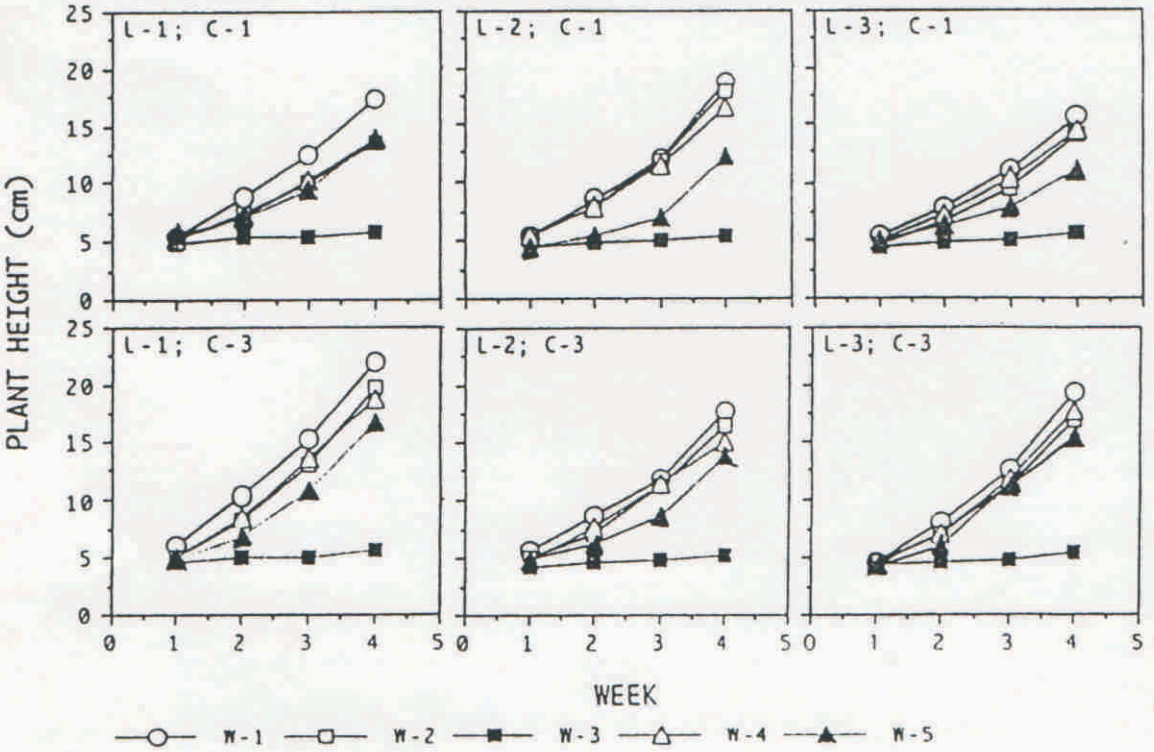

Fig. 2. Growth of amaranth in Gedongmeneng soil treated with wastes, lime and cassava-leaf compost (Lime L-1 = 0, L-2 = 2.5, and L-3 = 5 ton $CaCO_3$ ha^{-1}; Compost C-1 = 0 and C-3 = 10 ton ha^{-1}; Waste W-1 = Control, W-2 = Model Waste 1, W-3 = Model Waste 2, W-4 = Industrial Waste 1, and W-5 = Industrial Waste 2).

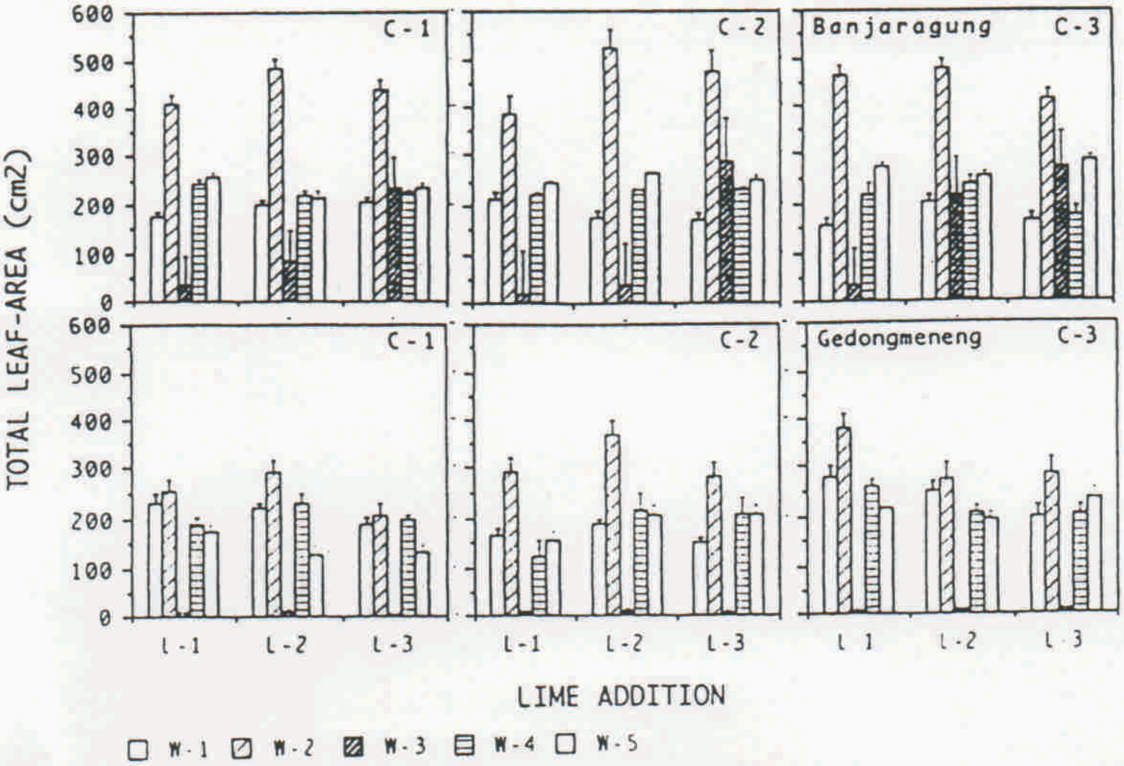

Fig 3 Changes in leaf areas of amaranth in Banjaragung and Gedongmeneng soils treated with wastes, lime, and cassava-leaf compost (Lime L-1 = 0, L-2 = 2.5, and L-3 = 5 ton $CaCO_3$ ha^{-1}. Compost C-1 = 0, C-2 = 5 and C-3 = 10 ton ha^{-1}; Waste W-1 = Control, W-2 = Model Waste 1, W-3 = Model Waste 2, W-4 = Industrial Waste 1, and W-5 = Industrial Waste 2)

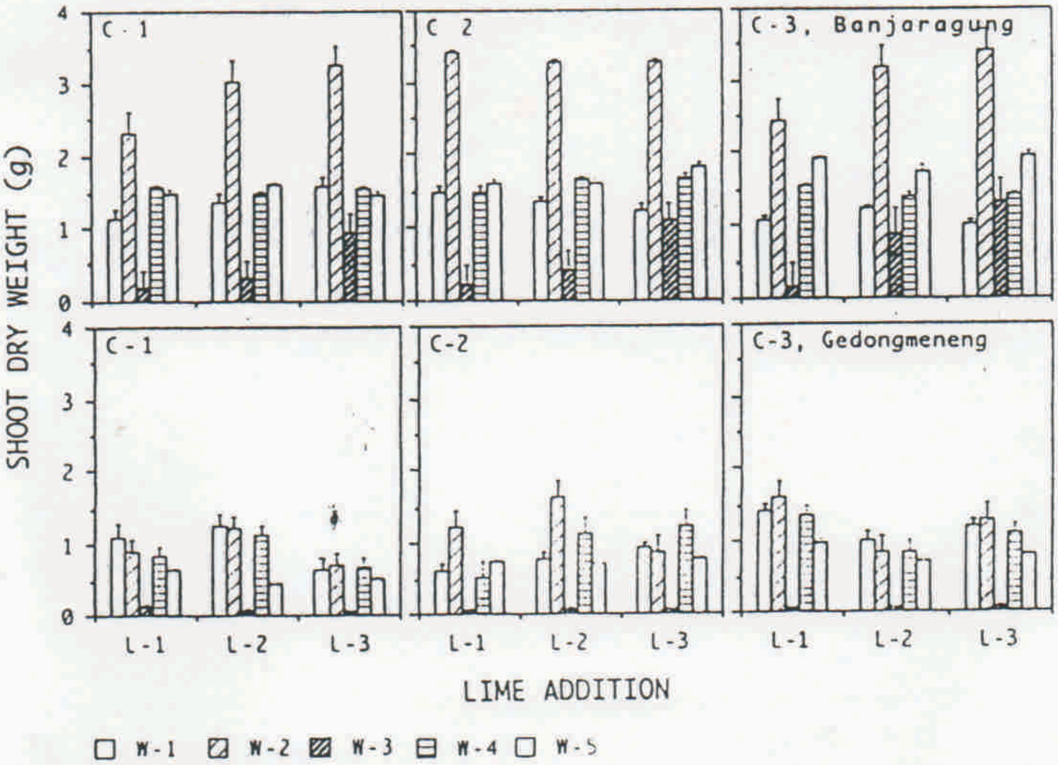

Fig. 4. Changes in dry weights of amaranth shoots in Banjaragung and Gedongmeneng soils treated with wastes, lime, and cassava-leaf compost (Lime L-1 = 0, L-2 = 2.5 and L-3 = 5 ton $CaCO_3$ ha^{-1}. Compost C-1 = 0, C-2 = 5 and C-3 = 10 ton ha^{-1}; Waste W-1 = Control, W-2 = Model Waste 1, W-3 = Model Waste 2, W-4 = Industrial Waste 1, and W-5 = Industrial Waste 2).

Table 1. Shoot and root dry-weights of amaranth affected by lime, cassava-leaf compost, and waste additions.

Lime ($CaCO_3$)	Compost	Waste	Root	Shoot
…… ton.ha^{-1} …….			…………… g . 2 plants^{-1}	……………
Banjaragung:				
0	0	Control	0.26 cd	1.07 cd
		MW	0.02 e	0.25 e
		IW	0.30 bc	1.50 ab
	10	MW	0.01 e	0.11 e
		IW	0.42 a	1.73 a
5	0	MW	0.18 d	0.92 d
		IW	0.35 ab	1.37 abc
	10	MW	0.27 bc	1.13 bcd
		IW	0.26 cd	1.76 a
Gedongmeneng:				
0	0	Control	0.14 a	0.56 ab
		MW	0.09 abc	0.16 bc
		IW	0.08 abc	0.42 abc
	10	MW	0.01 c	0.06 c
		IW	0.13 a	0.74 a
5	0	MW	0.01 c	0.07 c
		IW	0.03 bc	0.19 bc
	10	MW	0.01 c	0.06 c
		IW	0.12 ab	0.56 ab

Note: Lime: MW = Model Waste to increase soil heavy metals 40 mg kg^{-1}; IW = Industrial Waste at 80 ton ha^{-1} .Different characters in one column for each soil type indicate a significant difference by LSD Test as a 5%.

The inhibition of amaranth growth as shown by plant height, total leaf-area and shoot dry-weight was caused by the high concentrations of heavy metals added through the model waste. There is also a possibility that the significant decrease in soil pH of up to 1.50 units by the model waste addition directly inhibited the amaranth growth. Soil without lime and compost treatment treated with W-3 showed pH values of 4.15 and 3.55 for Banjaragung and Gedongmeneng soil, respectively. However, based on the fact that the height of amaranth in Gedongmeneng soil treated with Model Waste 2 was not affected by addition of lime and/or cassava-leaf compost (Fig. 2), this possibility is rejected.

Different from that in Banjaragung soil (Figs. 1, 3, and 4), addition of lime and/or cassava-leaf compost did not improve the amaranth growth in Gedongmeneng soil (Figs. 2, 3, and 4). It was probably caused by the lower adsorption capacity of Gedongmeneng soil compared to that of Banjaragung with respect to heavy metal inputs through the model waste and, thereby, the growth of amaranth was still inhibited even though treated with lime and/or cassava-leaf compost.

Unlike the model waste, addition of the industrial waste showed no inhibition effect on plant growth. The industrial waste seemed to increase the growth of amaranth in Banjaragung soil as shown by plant height, total leaf-area, and shoot dry-weight data (Figs. 1, 3, and 4). However, addition of the industrial waste at the same levels did not show this tendency in Gedongmeneng soil. On the contrary, the addition of the industrial waste tended to decrease the height of amaranth in Gedongmeneng soil (Fig. 2). This data indicated that parts of the heavy metals of the industrial waste might be neutralized by Banjaragung soil so that parts that were in available forms sufficed the amounts needed by amaranth. Gedongmeneng soil, however, possessed lower adsorption capacity. As a result, the heavy metals available in this soil were greater than those probably needed by amaranth.

The increasing tendency of amaranth height by industrial waste addition seemed to decrease with lime addition. When soils were also limed, addition of industrial waste tended to inhibit the growth of amaranth (Figs. 1 and 2). Because the solubility of Zn of industrial waste had been reported to increase with liming (Salam *et al.*, 1998a), it is possible that the amaranth (Figs. 1 and 2). Because the solubility of Zn of industrial waste had been reported to increase with liming (Salam *et al.*, 1998a), it is possible that the presence of more Zn was the reason for this phenomenon. The negative effects of lime on the growth of amaranth in soil treated with industrial waste was more obviously observed in Gedongmeneng soil (Fig. 2). However, the negative effect was alleviated by an addition of cassava-leaf compost. This phenomenon is related to the fact that available Zn of industrial waste origin decreased with cassava-leaf compost addition reported by Salam *et al.* (1998a).

SUMMARY AND CONCLUSIONS

Heavy metals of model waste slowed the growth of amaranth but their effects were lower in soil of Banjaragung. The negative effects of heavy metals on amaranth growth in Banjaragung soil was alleviated by lime and/or cassava-leaf compost addition. This phenomenon was related to the decrease in heavy metal availabilities in the plant root-zone. Copper availability in the root-zone of amaranth significantly decreased with lime addition in Banjaragung soil (Salam *et al.*, 1998b). This negative effects were not alleviated by lime addition in Gedongmeneng soil, whose adsorption capacity with respect to heavy metals was lower than that of Banjaragung soil.

In contrast, the heavy-metal-containing industrial waste tended to increase the growth of amaranth. However, this positive effect tended to decrease with liming. Because the solubility of Zn of industrial waste increased with increasing pH, this phenomenon was probably related to the increase in Zn availability caused by lime addition. The positive effect of industrial waste on the growth of amaranth was not observed in Gedongmeneng soil. Because this soil possessed a lower adsorption capacity than the Banjaragung soil to heavy metals, heavy metal inputs still in available forms was probably relatively high and toxic to amaranth.

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