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CHEMICAL AVAILABILITIES OF PHOSPHORUS, MANGANESE AND IRON IN *Limin LC* TREATED TROPICAL SOILS

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ABSTRACT

Chemical Availabilities of Phosphorus, Manganese and Iron in *Limin LC* Treated Tropical Soils (A.K. Salam, Suyatno, Handoko, D. Wiharso, and J.T. Harahap): Several industrial wastes show appreciable amounts of essential elements but their uses in agriculture are sometimes restricted by their heavy metal contents. This research was to evaluate the availabilities of P, Mn, and Fe in four tropical soils (two of them showed higher CEC values than the others) treated with a thoroughly mixed calcite, cassava-leaf compost, and industrial waste high in Cu and Zn called *Limin LC* as a fertilizer formulated to lower heavy metal availabilities but increase macronutrient availabilities in soils. After a four week incubation at 40% moisture content and room temperature, available P (Bray 1 extractable) consistently decreased with increasing levels of *Limin LC* formulations containing no cassava-leaf compost. The presence of increasing amount of cassava-leaf compost in *Limin LC* formulations enhanced the available P, particularly in low CEC soils, higher than those in control units. The related decreases in available Mn and Fe (DTPA extractable) suggest that the decrease in available P was partly due to the formation of Fe-P and Mn-P precipitates, that probably occurred at elevated pH caused by lime and/or waste components of *Limin LC*.

Keywords: Indusrial Wastes, Iron, *Limin LC*, Manganese, Phosphorus, Tropical Soils

INTRODUCTION

A great deal of research reports show that some industrial wastes contain high concentrations of essential elements, suggesting their potential for agricultural uses as plant nutrient sources (McCalla et al., 1986; Pratt et al., 1986). However, their application in agriculture is restricted, partly due to the potential negative effects of heavy metals contained in several industrial wastes (Kabata-Pendias and Pendias, 1992; Alloway, 1990a; Kardos et al., 1986). Some researchers suggest that excessive heavy metal intakes by growing plants may jeopardize animal and human health through food chains (Alloway, 1990a; Baker, 1990; Steinnes, 1990; Lagerwerff, 1982).

On the other hand, soil colloids (clays and organic matter) show chemical ability to immobilize heavy metals, reported to be manageable by lime and/or external organic matter additions into soil systems. Lime may adjust soil pH to a higher value while organic matter may increase concentrations of functional groups (Salam et al., 1997; Parfitt et al., 1995; Rodella et al., 1995; Alloway, 1990b; McGrath et al., 1988; Helling et al., 1964). Elevated dehydrogenation of soil clay and organic functional groups by liming may increase soil capacity to adsorb heavy metal cations (Salam and Helmke, 1998; Kabata-Pendias and Pendias, 1992; Keeney and Wildung, 1986; Lindsay, 1979). Increased soil pH may also, particularly at high pH, precipitate heavy metal cations due to elevated solubility products of heavy metal and OH^- ions in soil water (Udo et al., 1970). Thus, their combined effects may lower heavy metal chemical availabilities in soils (Salam et al., 1998) and, in turn, may lower their intakes by growing plants (Salam et al., 1999a).

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Thus, the positive roles of lime and/or organic matter in lowering heavy metal chemical availabilities in soils open an opportunity to formulate fertilizers composed of industrial waste, lime and/or organic matter with reduced heavy metal effects on animal and human health. This research was to evaluate chemical availabilities of P, Fe, and Mn in tropical soils amended with *Limin LC*, a fertilizer composed of various formulations of metal-spoon industrial waste, calcite, and/or cassava-leaf compost.

MATERIALS AND METHODS

Four tropical soils were used as model systems. Two of the soils, i.e. Sri Bawono soil (Alfisols) and Kalianda soil (Inceptisols), showed higher cation exchange capacity (CEC)) values than the other two, i.e. Kertosari soil (Ultisols) and Sungkai soil (Ultisols). Soil samples were all collected in 1999 from A_p horizon in Sri Bawono (East Lampung), Kalianda and Kertosari, Tanjung Bintang, (South Lampung), and North Sungkai (North Lampung). Soil samples were previously air-dried, ground, screened to 2 mm, and thoroughly mixed. Selected chemical and physical properties of the soil samples are listed in Table 1.

Limin LC was a fertilizer made up by thoroughly mixing a metal-spoon industrial waste (collected from waste treatment unit of PT Star Metal Ware Industry, Jakarta), which was known to have relatively high pH and contents of Cu and Zn (754 mg Cu kg^{-1} and 44.5 mg Zn kg^{-1}), calcite ($CaCO_3$), and cassava-leaf compost according to a pre-determined composition shown in Table 2. Calcite and cassava-leaf compost had been shown to be able to lower industrial-waste-origin heavy metal solubilities in soils (Salam et al., 1999b). The highest composition of lime (25%) and cassava-leaf compost (50%) in *Limin LC* formulations were designed to give lime and compost in soils at 5 and 10 ton ha^{-1} levels, respectively.

A 200-g soil sample (105°C oven-dry equivalent) was used as an experimental unit. All soil samples were treated with 3 levels (0, 10, and 20 ton ha^{-1}) of each formulation of *Limin LC* and incubated for 4 weeks at room temperature. Moisture content was maintained at 40% (w/w) by putting the treated soil sample in a polyethylene plastic bag after adding distilled water to 40%, taking into account the initial soil sample moisture content after air-drying.

Table 1. Selected chemical and physical properties of soil samples.

	Soil Sample Origin			
Soil Property	Sri Bawono	Kalianda	Kertosari	Sungkai
pH H_2O (1:2)	4.43	5.42	5.17	4.07
CEC ($cmol_c kg^{-1}$)	16.3	15.9	2.90	2.10
Organic C (g kg^{-1})	9.00	22.1	6.50	14.6
Total N (g kg^{-1})	1.60	2.60	1.20	1.30
C/N Ratio	5.63	8.50	5.42	11.2
Avail. P (mg kg^{-1})	85.9	16.3	26.2	50.3
Exch. Ca (mg kg^{-1})	545	648	615	73.1
Exch. K (mg kg^{-1})	167	228	41.5	21.0
Avail. Fe (mg kg^{-1})	31.2	86.6	33.2	50.8
Avail. Mn (mg kg^{-1})	169	65.7	98.2	23.0
Avail. Cu (mg kg^{-1})	2.41	0.85	0.60	0.74
Avail. Zn (mg kg^{-1})	5.49	5.66	2.24	0.80
Texture:				
- Sand (%)	20.2	40.3	73.2	59.6
- Silt (%)	21.2	38.4	10.4	12.8
- Clay (%)	58.6	21.3	16.4	27.6

Table 2. Composition of *Limin LC*.

Formulation	Lime $CaCO_3$ (%)*	Compost (%)*
F1	0	0
F2	0	25
F3	0	50
F4	12.5	0
F5	12.5	25
F6	12.5	50
F7	25	0
F8	25	25
F9	25	50

*from the dry-weight of industrial waste

Soil analyses were conducted at the end of the incubation time. Analyses included soil pH (soil:water 1:2) with a pH electrode, available P (Bray 1 extractable) using a spectrophotometer, and available Fe and Mn (DTPA method, Baker and Amacher, 1982) using a flame atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

In the absence of organic matter component, *Limin LC* significantly decreased the available P in all soil samples (Fig. 1). However, the presence of increasing levels of organic matter component in *Limin LC* (F1 to F3 or F4 to F6 or F7 to F9) increased the available P, particularly in lower CEC soils (Kertosari and Sungkai), to the levels higher than those in the control units. For example, an addition of 20 ton ha^{-1} *Limin LC* F1 (without organic matter component) decreased the available P about 18.0 mg kg^{-1} in Sungkai soil (Table 3). In contrast, the presence of 50% of organic component in *Limin LC* F3 increased the available P about 5.4 mg kg^{-1} at treatment level of 20 ton ha^{-1}.

Table 3. Changes in soil available P as affected by the levels of *Limin LC* treatments.

		Soil			
Formulation	Level	Sri Bawono	Kalianda	Kertosari	Sungkai
	.. ton ha^{-1}..	.... mg kg^{-1}			
F1	10	- 23.2	- 8.0	- 3.0	- 6.0
	20	- 21.1	- 6.3	- 6.5	- 18.0
F2	10	- 4.5	- 4.0	1.8	6.1
	20	- 4.7	- 3.5	4.2	- 2.1
F3	10	2.4	- 5.1	4.2	1.3
	20	23.1	- 1.8	11.7	5.4
F4	10	- 18.3	- 6.8	- 6.5	- 18.0
	20	- 20.9	- 10.7	- 9.4	- 21.1
F5	10	- 11.5	- 6.3	- 3.0	- 6.0
	20	- 9.3	- 5.7	3.0	- 7.3
F6	10	- 13.7	- 5.7	- 0.6	0.6
	20	- 3.0	- 2.9	18.1	- 5.3
F7	10	- 6.3	- 6.8	- 8.8	- 16.1
	20	- 18.2	- 5.7	- 10.0	- 22.9
F8	10	- 18.2	- 4.6	- 1.8	- 9.9
	20	- 7.8	- 6.3	1.2	- 7.9
F9	10	- 12.1	- 4.6	3.0	- 2.7
	20	- 14.6	- 3.5	7.9	8.9

***Symbols for *Limin LC* formulations, see text**

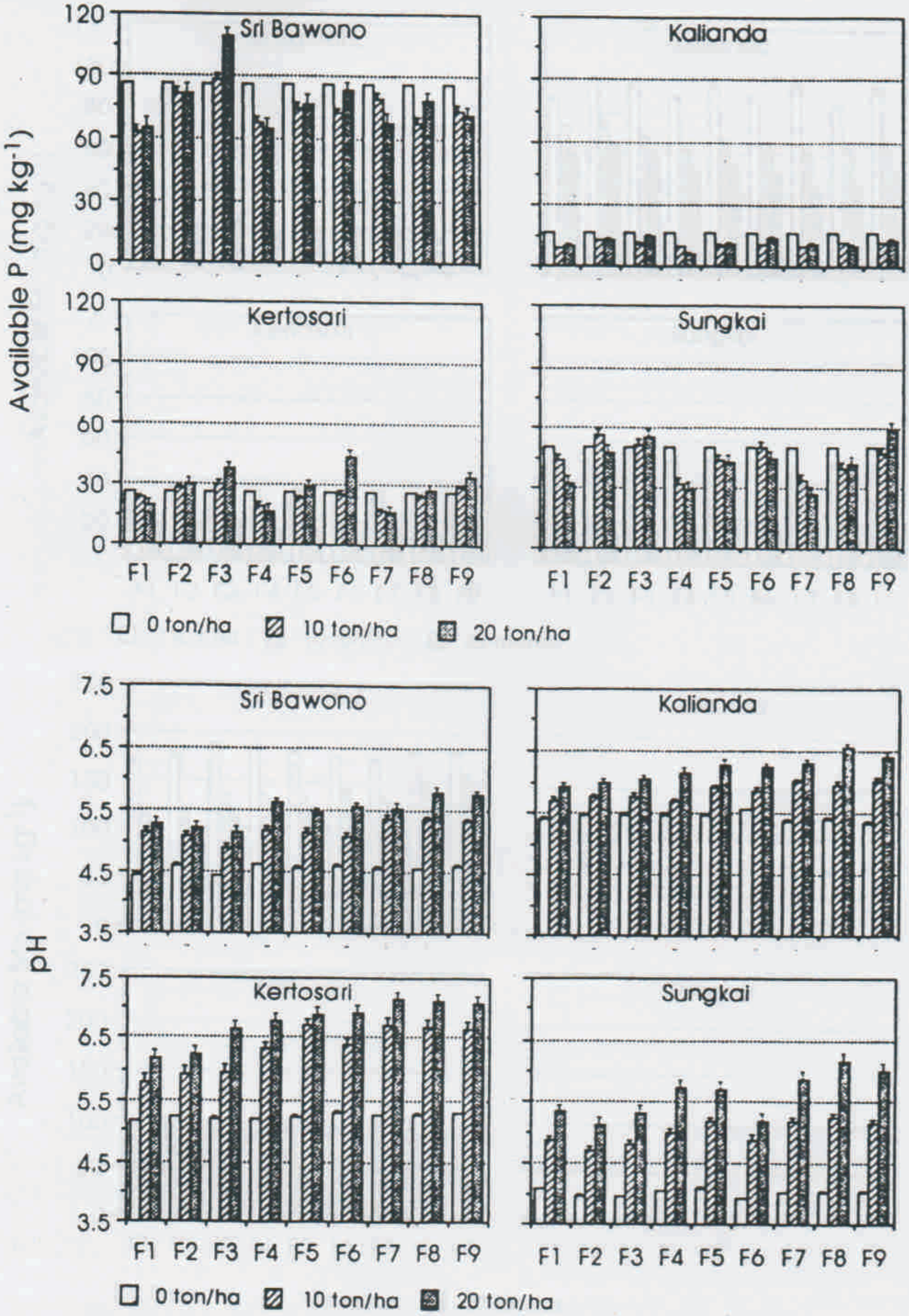

Fig. 1. Effects of *Limin LC* on pH and available P in four tropical soils (F1-F9, see text).

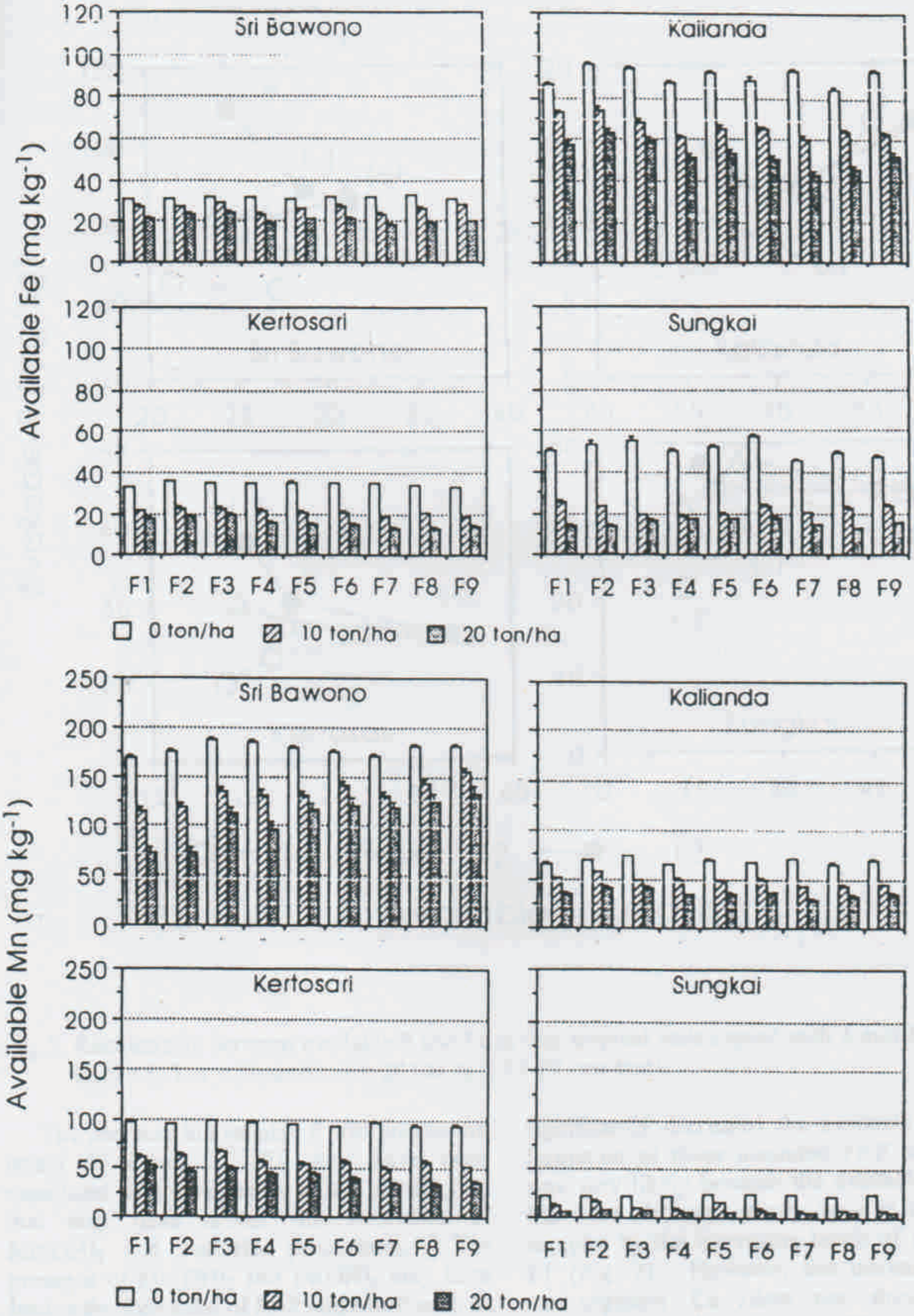

Fig. 2. Effect of *Limin LC* on available Fe and Mn in four tropical soils (F1-F9, see text).

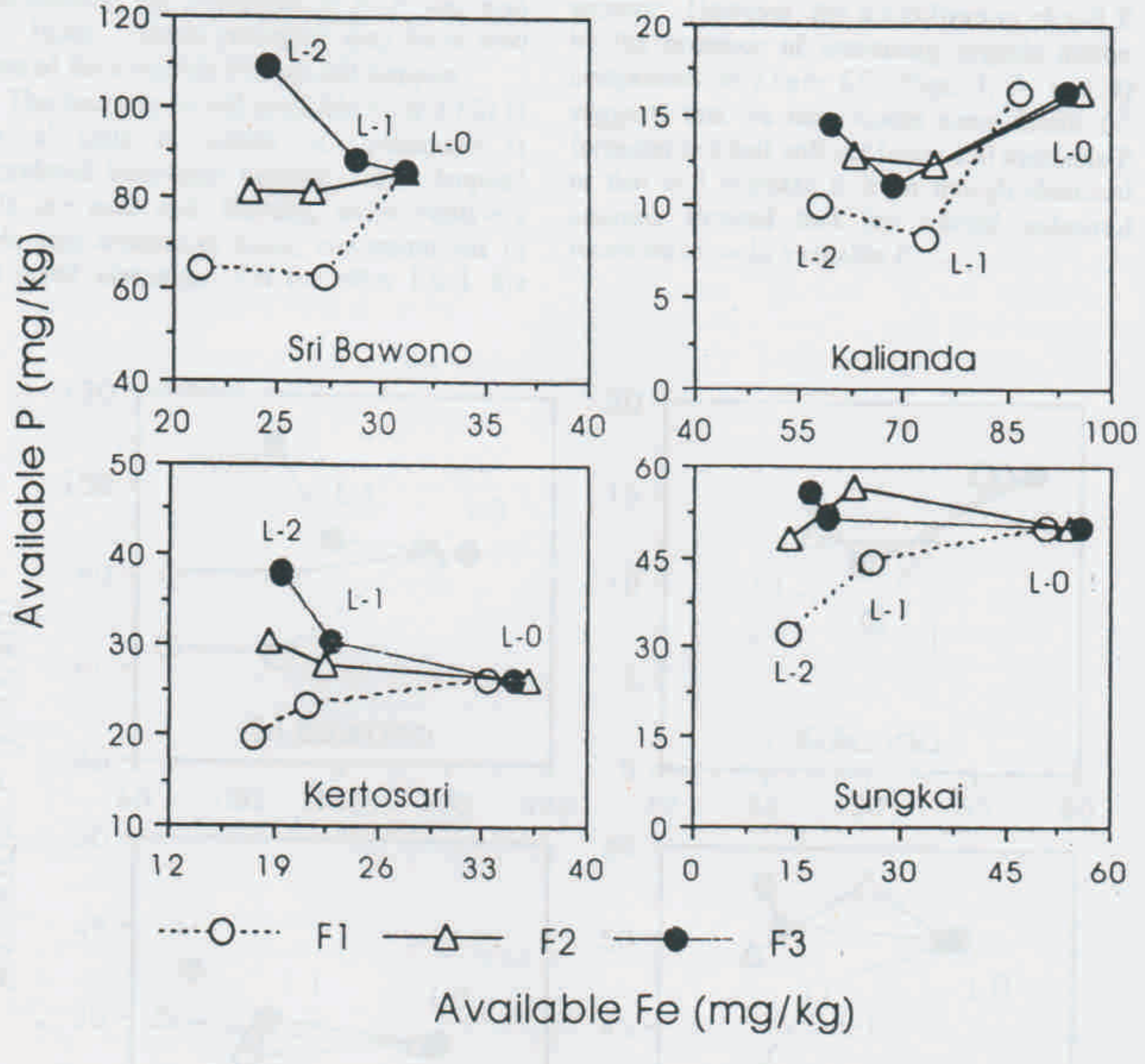

Fig. 3. Relationship between available P and Fe in four tropical soils treated with *Limin LC* F1-F3 (L-0 = 0, L-1 = 10, and L-2 = 20 ton ha^{-1}; F1-F3, see text).

The decrease in available P with increasing levels of *Limin LC* F1 may have been associated with the increase in soil pH (Fig. 1), that may have driven the formation of $Mn(OH)_2$ and $Fe(OH)_2$ precipitates. The presence of $Mn(OH)_2$ and $Fe(OH)_2$ may have lead to the formation of Fe-P and Mn-P such as $FeOHH_2PO_4$ and $MnOHH_2PO_4$, that significantly decreased the available P. The formation of these insoluble Fe-P and Mn-P was very likely because the available Fe and Mn were also consistently lowered in all soil samples by the increasing levels of *Limin LC* F1 (Fig. 2). However, the increase in the exchangeable Ca (data not shown) with increasing levels of *Limin LC* F1 suggests that formation of Ca-P in the form of $Ca(H_2PO_4)_2$ or $CaHPO_4$ was also probable (Lindsay, 1979). Additionally, the formation of Al-P was also very likely. These processes may have also lowered the available P in all soil samples.

The decrease in soil available Fe and Mn in tropical soils by *Limin LC* treatments is considered beneficial because most tropical soils are acid and, thereby, show relatively high, and sometimes toxic, concentrations of the metal elements. On the other hand, the decrease in available P is not beneficial because P is needed by plants at a great amount. However, the solubilization of soil P by the presence of increasing organic matter component in *Limin LC* (Figs. 1, 3, and 4) suggests that we can choose some *Limin LC* formulations that will not lower soil available P or that will increase it, even though chemical analysis showed that the related industrial waste was low in available P.

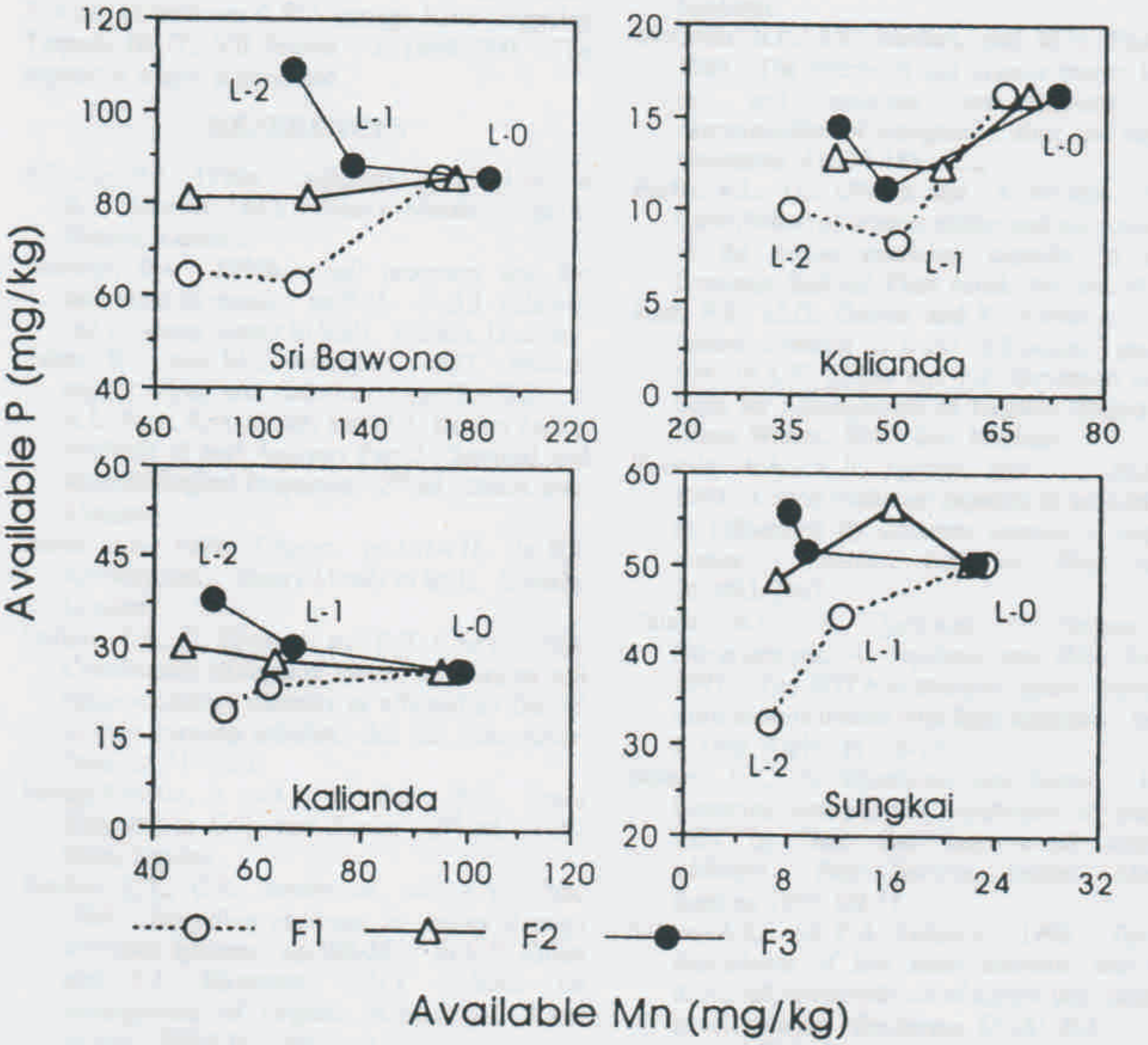

Fig. 4. Relationship between available P and Mn in four tropical soils treated with *Limin LC* F1-F3 (L-0 = 0, L-1 = 10, and L-2 = 20 ton ha^{-1}; F1-F3, see text).

The solubilization of insoluble P with increasing organic component in *Limin LC* was most probably due to the formation of soluble or insoluble organic chelates that were more easily extracted by Bray 1 than were Fe-P, Mn-P, Al-P, or Ca-P. This change did not affect the decreasing patterns of available Fe and Mn with increasing levels of *Limin LC* of any formulation (Fig. 2) because Fe and Mn ions were more strongly associated with OH ions in the forms of hydroxides.

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REFERENCES

Alloway, B.J. 1990a. Cadmium. pp.100-124. *In* B.J. Alloway (ed.). Heavy Metals in Soils. Blackie, London.

Alloway, B.J. 1990b. Soil processes and the behaviour of metals. pp.7-28. *In* B.J. Alloway (ed.). Heavy Metals in Soils. Blackie, London.

Baker, D.E. and M.C. Amacher. 1982. Nickel, copper, zinc, and cadmium. pp.323-336. *In* A.L. Page, R.H. Miller, and D.R. Keeney (eds.). Methods of Soil Analysis Part 2 Chemical and Microbiological Properties. 2nd ed. SSSA Inc., Madison.

Baker, D.E. 1990. Copper. pp.151-176. *In* B.J. Alloway (ed.). Heavy Metals in Soils. Blackie, London.

Helling, C.S., C. Chesters, and R.B. Corey. 1964. Contribution of organic matter and clay to soil cation-exchange capacity as affected by the pH of the saturating solution. Soil Sci. Soc. Amer. Proc., 28:517-520.

Kabata-Pendias, A. and H. Pendias. 1992. Trace Elements in Soils and Plants. 2nd ed. CRC Press, London.

Kardos, L.T., C.E. Scarsbrook, and V.V. Volk. 1986. Recycling elements in wastes through soil-plant systems. pp.300-324. *In* L.F. Elliott and F.J. Stevenson (eds.). Soils for Management of Organic Wastes and Waste Waters. SSSA Inc., Madison.

Keeney, D.R. and R.E. Wildung. 1986. Chemical properties of soils. pp.74-97. *In* L.F. Elliott and F.J. Stevenson (eds.). Soils for Management of Organic Wastes and Waste Waters. SSSA Inc., Madison.

Lagerwerff, J.V. 1982. Lead, mercury, and cadmium as environmental contaminant. pp.593-636. *In* J.J. Mortvedt, P.M. Giordano, and W.L. Lindsay (eds.). Micronutrients in Agriculture. SSSA Inc., Madison.

Lindsay, W.L. 1979. Chemical Equilibria in Soils. John Willey & Sons, Inc., New York.

McCalla, T.M., J.R. Peterson, and C. Lue-Hing. 1986. Properties of agricultural and municipal wastes. pp.10-43. *In* L.F. Elliott and F.J. Stevenson (eds.). Soils for Management of Organic Wastes and Waste Waters. SSSA Inc., Madison.

McGrath, S.P., J.R. Sanders, and M.H. Shalaby. 1988. The effects of soil organic matter levels on soil solution concentrations and extractabilities of manganese, zinc, and copper. Geoderma, 42:177-188.

Parfitt, R.L., D.J. Giltrap, and J.S. Whitton. 1995. Contribution of organic matter and clay minerals to the cation exchange capacity of soils. Commun. Soil Sci. Plant Alnal., 26:1343-1355.

Pratt, P.F., M.D. Thorne, and F. Wiersma. 1986. Future direction in waste utilization. pp.620-634. *In* L.F. Elliott and F.J. Stevenson (eds.). Soils for Management of Organic Wastes and Waste Waters. SSSA Inc., Madison.

Rodella, A.A., K.R. Fischer, and J.C. Alcarde. 1995. Cation exchange capacity of an acid soil as influenced by different sources of organic matter. Commun. Soil Sci. Plant Anal., 26:2961-2967.

Salam, A.K., S. Djuniwati, N. Sriyani, H. Novpriansyah, A. Septiana, and H.D. Putera. 1997. The DTPA-extractable heavy metals in tropical soils treated with lime materials. Indon. J. Trop. Agric., 8(1):6-12.

Salam, A.K., S. Djuniwati, and Sarno. 1998. Lowering heavy metal solubilities in tropical soils by lime and cassava-leaf compost additions. Proc. Environ. Technol. Manag. Seminar 1997, D2-11.

Salam, A.K. and P.A. Helmke. 1998. The pH dependence of free ionic activities and total dissolved concentrations of copper and cadmium in soil solution. Geoderma. 83:281-291.

Salam, A.K., Sarno, N. Kulsum, and E. Setyaningsih. 1999a. Studi penyerapan Cu dan Zn oleh tanaman bayam (*Amaranthus tricolor*

L.) dan jagung (*Zea mays* L.) dari tanah Alfisol Banjaragung Lampung yang diperlakukan dengan limbah industri berlogam, berat. J. Tanaman Trop., 2:41-51 (In Indonesian).

Salam, A.K., S. Djuniwati, Sarno, N. Sriyani, and H. Novpriansyah. 1999b. Manipulasi Sifat Kimia Tanah untuk Mengurangi Dampak Negatif Logam Berat Asal Limbah Industri terhadap Tanah, Air, dan Tanaman. Hibah Bersaing IV/1-4 Res. Report. Fac. Agriculture, Univ. Lampung, Bandar Lampung. (In Indonesian)

Steinnes, E. 1990. Mercury. pp.222-236. *In* B.J. Alloway (ed.). Heavy Metals in Soils. Blackie, London.

Udo, E.J., H.L. Bohn, and T.C. Tucker. 1970. Zinc adsorption by calcareous soils. Soil Sci. Soc. Amer. Proc., 34:405-407.