MICRONUTRIENT PROBLEMS IN UPLAND SOILS IN INDONESIA

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Abstract

Information on micronutrient problems in upland soils in Indonesia is presented, including Mo, Cu and Zn deficiencies as well as Mn toxicity in a variety of soils. Lime-induced chlorosis is also discussed. It is suggested that Al toxicity in acid soils disguises the importance of micronutrient problems.

Introduction

The study of micronutrients in increasing crop production is becoming more important in Indonesia, with the role of zinc in rice production having the greatest attention. However, there is some evidence that the role of micronutrients in upland crops should not be overlooked. It seems that micronutrients are important in increasing upland crop yields because of the following factors:

(1) Expansion of agricultural land on marginal, poor or problem soils, since the more fertile soils are already under cultivation.
(2) Increasing nutrient (including micronutrient) removal, as a result of greater crop needs and better technology.
(3) Application of phosphate fertilizers, inducing zinc deficiency.
(4) Application of lime on acid soils, increasing the availability of molybdenum, but inducing other micronutrient problems.
(5) High inputs of chemical fertilizers and less use of organic manures.
(6) The introduction of new high yielding varieties, more susceptible to micronutrient deficiencies than traditional varieties.
(7) Cultivation of low and high pH soils with micronutrient deficiency or toxicity problems.

Molybdenum deficiency in acid soils

Millions of hectares of upland with acid podzolic soils form one of the largest areas for agricultural expansion in Indonesia. This soil is usually acidic in reaction and critical in phosphate, and often has aluminum toxicity.

Since molybdenum is essential for symbiotic nitrogen fixation, molybdenum deficiency is most often observed in legumes. A recent experiment indicated that molybdenum application to a podzolic soil at Bandarjaya, Lampung, could increase soybean yield (CRIA-IRRI, 1978). The effect of molybdenum application was more striking when the soybean was not inoculated with *Rhizobium* (Table 1). The yields were much higher when lime was applied. It seems that liming increases the soil pH, making it better for soybean growth. It could also increase the availability of nutrients, including molybdenum, and reduce the harmful effect of aluminum toxicity.

Soepardi and Hanafiah (1981) studied the important role of molybdenum in root nodule development of soybean grown on an acid podzolic soil at Jasinga, West Java. The number of root nodules increased with molybdenum application and decreased with increasing aluminum saturation (Fig. 1). Molybdenum application also increased the dry matter weight and pod yield

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Table 1 Soybean (Orba variety) grain yield as affected by liming, phosphorus, molybdenum and ***Rhizobium*** inoculation in Bandarjaya, Lampung, 1976 – 1977 wet season (CRIA – IRRI, 1978)

Rhizobium treatment	Yield (kg/ha)			
	Control	Mo only	P only	P + Mo
		Without lime		
Not inoculated	350	400	390	1,010
Inoculated	540	700	860	950
		With lime		
Not inoculated	680	820	850	1,640
Inoculated	560	680	1,280	1,780

Table 2 The effect of molybdenum on the dry matter weight and yield of soybean at ripening stage (Soepardi and Hanafiah, 1981)

Al saturation (%)	Pod yield (g/pot)		Total D.M. weight (g/pot)*	
	Without Mo	With Mo	Without Mo	With Mo
7	33.3	44.1	55.6	71.4
20	18.5	25.5	34.5	47.4
35	16.9	21.6	27.9	41.0
51	11.5	18.3	18.4	30.2
72	0.0	0.0	1.6	1.9

* Pod, leaf, stem and root.

(Table 2). The dry matter weight and pod yield decreased with increasing aluminum saturation. High aluminum inhibits root development: the roots become short, thick and their number is very much reduced. Consequently absorption of nutrients (including micronutrients) is much lower.

Marzuki, 1981 (personal communication) reported that molybdenum application increased mungbean yield on a Latosol at Cikeumeuh, Bogor (West Java). If lime was applied, however, molybdenum had no effect on yields (Table 3). It is known that higher pH here achieved by liming, increases molybdenum availability.

Newton (1962) reported that molybdenum application increased soybean and peanut yields on a Latosol at Muara, Bogor. He also found that when lime was added, molybdenum further increased the peanut yield.

Manganese toxicity in Brown Tropical soil

The transmigration area of Situng, West Sumatra has a Brown Tropical or Brown Forest soil (Soil Research Institute, 1977). This is a heavy acidic clay soil extremely poor in phosphate and also poor in potassium, magnesium and calcium, and high in manganese (Hidayat, Sudarman and Ismunadji, 1981).

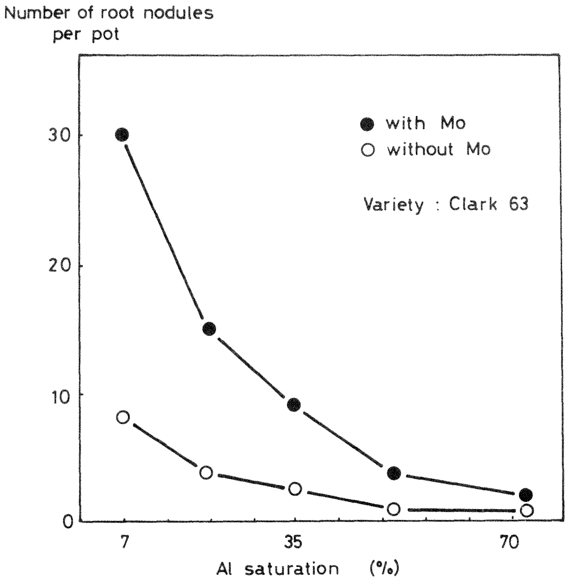

Fig. 1 **Effect of Mo application and Al saturation on the number of soybean root nodules per pot at 30 days after seeding.**

Source: Soepardi and Hanafiah (1981).

Table 3 **The effect of fertilization on mungbean yield, Latosol, Muara, Bogor (Marzuki, 1981)**

Treatment			Grain yield (kg/ha)			
			No lime		Plus lime	
NPK	S	Mg	No Mo	Plus Mo	No Mo	Plus Mo
0	0	0	471		1,017	
+	0	0	753	1,257	1,279	1,358
+	+	0	934	1,119	1,260	1,299
+	0	+	957	1,438	1,159	1,158
+	+	+	918	1,323	1,279	1,220

Minus-one element tests (macro-as well as micronutrients) in the glasshouse, using corn as the indicator plant, showed that the 30-day-old corn plants of all treatments had a high manganese content ranging from 800 to 2200 ppm. In general, plants containing more than 400 to 500 ppm of manganese showed manganese toxicity symptoms (Labanauskas, 1975). The complete treatment with lime added to reach pH 6.2 significantly increased the corn dry matter weight and the absorption of all nutrients except manganese and zinc. Addition of lime reduced the Mn content by 47% of that of the complete treatment. Zn and Mn contents and the dry matter weight of the corn plant as affected by the treatments are presented in Table 4 (Hidayat, Sudarman and Ismunadji, 1981).

Table 4 Manganese and zinc content and dry matter weight of corn plants as affected by minus-one-element treatments (Hidayat, Sudarman and Ismunadji, 1981)

Treatment	Dry matter weight (g/plot)	Mn (ppm)	Zn (ppm)
Complete	2.55	1,500	101
Complete + lime	3.12	800	67
– N	2.42	2,200	96
– P	0.72	1,400	66
– K	2.05	1,400	81
– Ca	1.96	1,400	74
– Mg	1.84	1,160	83
– S	2.51	1,600	61
– Mn	2.25	1,400	71
– Zn	2.48	1,400	39

This experiment indicates that altough liming is beneficial, its depressing effect on the availability of zinc needs special attention. We recommend application of zinc with lime, especially if the zinc content of the soil is marginal.

Lime-induced chlorosis

Upland crops with top chlorosis are often observed in the field, for instance peanut, soybean, stringbean and cassava, on Grumusols and calcareous soils with high pH. This is known as lime-induced chlorosis.

Leaf samples of soybean plants with top chlorosis were collected recently from a Grumusol area in Ngale, East Java. The samples were dried in an oven, ground, and analysed for macro-and micronutrients (Table 5). The plants were found to be low in zinc, copper and potassium. Yoshida and Chaudry (1972) also reported the presence of zinc deficiency in lowland rice in pot experiments using Ngale soil. There were distinct differences in performance between the improved Orba and local variety. When grown side by side, the local variety remained green, while the Orba variety showed strong chlorosis. It seems that the Orba is more susceptible to the problem soil than the local variety.

This indicates that plant genotypes differ in their response to soil problems, and therefore breeding crop varieties for problem soils is very important. We should not underestimate the importance of genetic variability in the plant kingdom in seeking plants adaptable to specific environments. Fitting the soils to plants has been emphasized for more than 50 years, but tailoring the plant to fit the soil appears to be more practical.

Copper and zinc status in Central Java

Twenty-one soil samples were collected from Central Java in the 1979 dry season to evaluate the copper and zinc status of the region. The samples were taken from plots where corn is usually grown. The sites, soil types, pH and the 0.1 N extractable Cu and Zn are shown in Table 6. There were 7 locations low in Cu ($<$ 0.10 mg Cu), 10 locations moderate in Cu (0.10 – 0.20 mg Cu) and 4 locations high in Cu ($<$ 0.20 mg Cu). Those with low copper included alluvial soils, Regosols, Complex Regosol and Lithosols, and Complex Mediterranean and Latosols.

Six out of the 21 locations were low in Zn ($<$ 0.15 mg Zn), 6 locations moderate in Zn (0.15 – 0.20 mg Zn) and 9 locations high in Zn ($<$ 0.20 mg Zn). Soils low in zinc included Regosols, alluvial soils, Complex Regosol and Lithosols, and Complex Mediterranean and Latosols.

Further investigations using plants as indicators are needed to determine the capabilities of these soils.

Table 5 Chemical analysis of soybean leaves with top chlorosis at pod-filling stage, Ngale, East Java

Element	Content (%)	Element	Content (ppm)
N	1.94	Mn	76
P	0.14	Fe	188
K	0.50	Cu	0.17
Ca	1.71	Zn	18
Mg	0.48		
S	0.17		

Table 6 Sites, soil type, and Cu and Zn status of Central Java upland soils

No.	Site	Soil type	pH	Cu-0.1N HCl (mg/100g)	Zn-0.1N HCl (mg/100g)
1.	Sukorejo, Nganjuk	Alluvial	6.85	0.09	0.17
2.	Mbodo, Malang	Alluvial	6.81	0.23	0.32
3.	Jetis, Jember	Alluvial	6.31	0.13	0.29
4.	Curah galak, Situbondo	Alluvial	4.40	0.09	0.22
5.	Sumberejo, Probolinggo	Alluvial	6.01	0.22	0.29
6.	Tanjung, Probolinggo	Alluvial	7.80	0.20	0.30
7.	Wedusan, Probolinggo	Alluvial	7.65	0.21	0.22
8.	Sumberagung, Pasuruhan	Alluvial	6.15	0.13	0.17
9.	Tambakrejo, Pasuruhan	Alluvial	7.28	0.08	0.12
10.	Pucah Ngawon, Kediri	Regosol	6.81	0.20	0.09
11.	Sidomulyo, Kediri	Regosol	6.99	0.19	0.21
12.	Kedok, Malang	Regosol	6.71	0.20	0.21
13.	Kutorenon, Lumajang	Regosol	6.50	0.21	0.31
14.	Besur, Bondowoso	Regosol	6.42	0.09	0.18
15.	Bendo, Blitar	Compl. Regosol and Latosol	6.85	0.05	0.03
16.	Karanggagam, Mojokerto	Compl. Regosol and Lithosol	6.89	0.08	0.14
17.	Tejo, Jombang	Compl. Regosol and Lithosol	7.05	0.14	0.12
18.	Subah, Situbondo	Compl. Mediterranean and Latosol	7.15	0.11	0.14
19.	Kalibogor, Situbondo	Compl. Mediterranean and Latosol	6.88	0.08	0.17
20.	Lerejo, Lumajang	Ass. Latosol and Regosol	6.81	0.13	0.20
21.	Sidodadi, Banyuwangi	Ass. Latosol and Regosol	6.90	0.14	0.20

Copper deficiency in peat soils

The wide coastal plains of eastern Sumatra, Western and southern Kalimantan, and the southern coast of West Irian are covered with swamp forests with thick peat layers. These layers vary from 0.5 to more than 16 m in thickness. The pH of the peat is 3.5–4.5. Owing to their low mineral matter contents, these peat soils are infertile. If they are drained well, however, the structure of the soils is favorable for crop growth (Polak, 1950).

Although their natural fertility is low, these soils are cultivated along their edges because of the need for arable land. Large areas of peat soils are now used for agricultural production by

Table 7 Chemical composition of peat samples from West Kalimantan (Polak and Supraptohardjo, 1951)

Peat origin	% dry matter						
	Ash	N	P_2O_5	K_2O	CaO	MgO	Fe_2O_3
Sumur Bor	2.28	1.80	0.12	0.10	0.42	0.14	0.63
Sungai Kunyit	1.73	1.70	0.04	0.05	0.51	0.22	0.07

transmigrants, especially in Sumatra and Kalimantan. When a part of the forest is cleared and drained, the surface layer and the remains of trees are burned. The ash supplies plant nutrients and increases pH, so that the first yields are satisfactory. After some years, however, the soil deteriorates and becomes deficient in macro- and microelements (Polak, 1950).

Pot experiments using peat soil from West Kalimantan, namely Sumur Bor (2 – 3 m peat layer) and Sungai Kunyit (5 – 6 m peat layer) were conducted by Polak and Supraptohardjo (1951). The Sungai Kunyit is poorer than the Sumur Bor peat (Table 7). Lime in the form of $CaCO_3$ was thoroughly mixed with the soil 2 – 3 weeks before planting. This gradually increased the soil pH to above 5.2. Forty days after planting corn, the plants that had received the highest amount of nitrogen and those to which copper and magnesium had been applied, made the most progress. At maturity the heaviest ears and plants were obtained with the heaviest application of nitrogen. In both series a dressing of 0.5 g copper sulfate per pot (12.5 kg peat) yielded twice as much as when no copper was added (Table 8). In the Sungai Kunyit series iron deficiency was observed. Injection of the leaves with iron solution cured the deficiency (Polak and Supraptohardjo, 1951).

Field experiments conducted by Polak and Supraptohardjo (Table 9) reconfirmed the importance of copper in increasing corn yields.

Table 8 Corn dry weight grown on peat soils from West Kalimantan (Polak and Supraptohardjo, 1951)

Origin of peat	Treatment	pH after 11 weeks	Air-dry weight (g)	
			Plant + ear	Ear
Sumur Bor	Ca- N-P-K	5.6	42.0	7.7
	Ca- ½N-P-K	5.7	32.7	5.2
	Ca-1 ½N-P-K	5.6	45.0	18.9
	Ca- N-P-K-Cu	5.6	43.7	16.3
	Ca- N-P-K-Mn	5.6	38.4	15.1
	Ca- N-P-K-Mg	5.6	42.6	13.2
Sungai Kunyit	Ca- N-P-K	5.4	34.7	12.3
	Ca- ½ N-P-K	5.4	34.7	9.7
	Ca-1½ N-P-K	5.4	40.6	19.9
	Ca- N-P-K-Cu	5.4	46.3	22.0
	Ca- N-P-K-Mn	5.3	33.6	9.8
	Ca- N-P-K-Mg	5.3	28.8	1.4
	Ca- N-P-K-Fe	5.2	37.8	12.8

Table 9 Yields of air-dry ears of corn at Sumur Bor and Sungai Kunyit, West Kalimantan (Polak and Supraptohardjo, 1951)

Treatment *	Yield (kg/ha)	
	Sumur Bor	Sungai Kunyit
10 ton lime/ha	200	733
15 ton lime/ha	467	967
15 ton lime + 50 kg $CuSO_4$/ha	2,167	1,400
15 ton lime + 50 kg $MgSO_4$/ha	533	1,000

* All treatments received 200 kg ammonium sulfate, 250 kg double superphosphate and 200 kg potassium sulfate /ha.

Conclusion

The results of these experiments indicate that micronutrient deficiencies and toxicities are important for increasing upland crop production in the tropics. More studies seem to be needed on these to clarify problems and to find proper practices in particular areas.

Soepardi and Hanafiah's (1981) experiments indicate that plant dry matter weight decreases with increasing Al saturation. This leads to reduced absorption of nutrients and presumably also of micronutrients. Al toxicity thus seems to be very important in acid upland soils. Probably it frequently masks micronutrient problems. More study in this area is necessary.

References

1) CENTRAL RESEARCH INSTITUTE FOR AGRICULTURE – INTERNATIONAL RICE RESEARCH INSTITUTE (1978): Annual Report for 1976-1977. Cropping system research (Indramayu and Lampung). Cooperative CRIA-IRRI Program, Bogor, September 1978.
2) HIDAYAT, A., SUDARMAN O., and ISMUNADJI M., (1981): Nutrient status of Sitiung transmigration area. *Penelitian Pertanian* **1(2)** (in Indonesian, in press).
3) LABANAUSKAS, L.K. (1975): Manganese. *In:* Diagnostic criteria for plants and soils. Edited by H.D. Chapman, Eurasia Publishing House (P), Ltd., Ram Nagar, New Delhi, 793p.
4) NEWTON, J.D. (1962): Soil fertility and legume inoculation investigation in Indonesia. FAO Expanded Program of Technical Assistance, No. 1541.
5) MARZUKI, R. (1981): Personal communication.
6) POLAK, B. (1950): Occurrence and fertility of tropical peat soils in Indonesia. *Contr. Gen. Agric. Res. Sta.* **104**.
7) POLAK, B. and SUPRAPTOHARDJO. (1951): Pot and field experiments with maize on acid forest peat from Borneo. *Pemberitaan Balai Besar Penyelidikan Pertanian* **125**.
8) SOEPARDI, G. and HANAFIAH A.S., (1981): The effect of different Al-saturation, with or without Mo, on the growth and N-fixation of soybean. Workshop on N-fixation, National Biological Institute/Indonesian Council of Science, April 29-30, 1981, Bogor (in Indonesian).
9) SOIL RESEARCH INSTITUTE, BOGOR. (1977): Progress report of semi-detailed soil mapping of Sungai Dareh-Kotabaru (Mimeograph, Indonesian).
10) YOSHIDA, S. and CHAUDRY M.R., (1972): Sulfur nutrition of rice. IRRI Saturday Seminar, Plant Physiology Dept., March 1, 1972.

Discussion

Benckiser, G, (IRRI): You mentioned the existence of manganese toxicity in Indonesia. According to the literature, the tolerance of plants to manganese is comparatively high, in particular in the case of rice. Do you consider that under certain soil conditions peculiar to Indonesia (very low degree of exchangeable potassium, high level of Mn_t) the threshold would be lower?

Answer: I referred to manganese toxicity in corn on the basis of leaf discoloration. In the case of rice the toxicity level of manganese is much higher, amounting to more than 2000 ppm manganese.

Zahari, A.B. (Malaysia): In one of your slides you showed the incorporation of organic materials such as weeds and straw in a rice field with acid sulfate soil. Did you record any hydrogen sulfur toxicity in this field?

Answer: The straw and weeds in the field with peat soil were obtained from weeding and shallow preparation of soil. After decomposition, this material was spread all over the fields before rice was planted. Hydrogen sulfide toxicity did not occur. Oxidation of the pyrites was low as the peat soils are always wet.

von Uexkull, H.R. (Singapore): 1) You did not discuss boron deficiency in your paper. In liming experiments carried out in Lampung (Gunungmadu), boron was the first trace element deficiency that came up in the case of sugar cane. 2) In one of the tables you showed, in Sungai peat soil, magnesium seemed to severely depress yield. Could you tell me why?

Answer: 1) and 2) I do not have enough data in this regard.

Ryu, J.C. (Korea): Which method of *Rhizobium* inoculation did you apply for soybean? Seed inoculation, soil inoculation or liquid *Rhizobium* inoculation?

Answer: The seeds were inoculated with *Rhizobium* from soils previously cropped with soybeans.