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SOME HIGHLIGHTS OF TROPSOILS STUDIES ON SOIL MANAGEMENTS OF ACID UPLAND SOILS AT SITIUNG, WEST SUMATRA

I P.G. Widjaja-Adhi,[1] M.K. Wade,[2] and M. Sudjadi[1]

[1] Center for Soil Research
[2] North Carolina State University

INTRODUCTION

The TROPSOILS project functions in Indonesia as a collaborative soils research program among three institutions: the Centre for Soil Research (CSR)/AARD, the University of Hawaii (lead US institution), and North Carolina State University (support US institution), and funded jointly by GOI and USAID/Washington. The program has field operation in Sitiung, West Sumatra. The site was selected by CSR as a transmigration area with many soil problems, but representative of the upland, acid soil conditions of many of the outer islands where transmigration and other regional development are taking place.

The TROPSOILS program has been carried out in a farming system research (FSR) approach, which means that the opportunity to learn from farmers, a better understanding of the farmers' world and constraints, the value of seeing and working with farmers in their fields, all contribute to the development of appropriate technology. Any components of the research should be studied with due consideration of its role in the overall farming operation.

In this paper results of the TROPSOILS' researchs on soil managements are highlighted. To be relevant with the theme of IFDC workshop it only deals with soil fertility aspects of the soil managements.

SOIL ACIDITY MANAGEMENT

The objectives of a study on the amelioration of soil acidity were: (1) to find a soil acidity parameter that correlates well with crop yield, (2) to determine the critical level of the parameter for several important crops and varieties, (3) to estimate the lime requirement in ameliorating detrimental soil acidity, and (4) to maintain established soil acidity levels by annual reapplications, based on the indicator parameter (Wade et al, 1985).

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Rice and particularly soybean have shown strong responses to lime on a Typic Haplorthox in Sitiung (Figure 1). Both Al saturation and exchangeable (Ca-Mg) show good correlation with yield of both crops. Al saturation of 40% and 0% appear as critical values for rice (variety CIAT 7) and soybean (variety Orba), respectively (Wade et al, 1985).

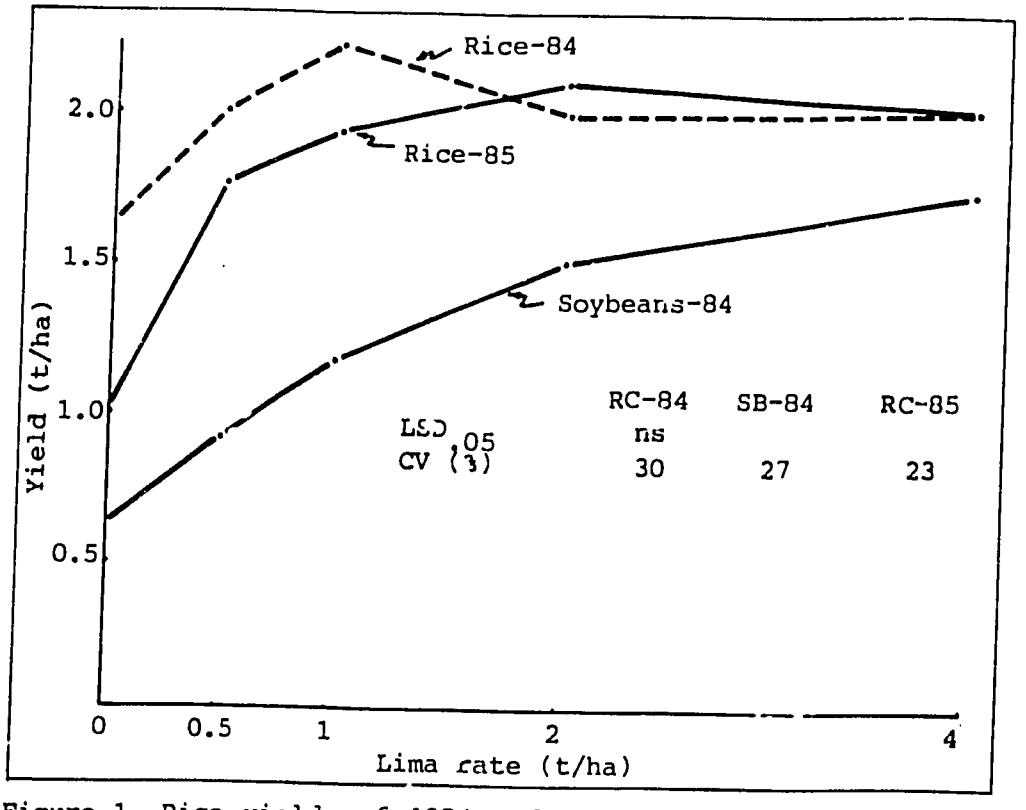

Figure 1. Rice yields of 1984 and 1985 and soybean yields of 1984 as affected by initial lime rates (Wade et al, 1985

Residual evaluation of the lime indicated only moderate increase in Al and decrease in Ca over 16 months (Table 1). There was evidence of considerable leaching of Ca and/or Mg into the subsoil as the 15-30 cm and 30-50 cm layers showed increases in (Ca+Mg) only 1[illegible] months after lime ($Ca(OH)_2$) application (Table 2).

Another study showed that lime applications had almost immediate reaction with the soil, such that no incubation period was necessary (Wade and Al-Jabri, 1986). Soil pH and KCl-extractable acidity (Al+H) were stable during the first year after application, whereas exchangeable (Ca+Mg) increase overtime. Soybean grown on an Inceptisol and an Oxisol

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Table 1. Effect of lime rate and time after application on exchangeable Ca+Mg and Al, and Al saturation (Wade et al, 1985)

Lime rate	Months after application 4	8	12	16	Total change	Percentage of first analysis
	exchangeable Ca+Mg me/100 ml					
ton/ha						%
0.0	1.1	1.1	1.2	0.8	- 0.3	27
0.5	1.8	1.9	1.3	1.2	- 0.6	33
1.0	2.7	2.8	2.3	2.4	- 0.7	26
2.0	4.1	2.8	2.3	2.4	- 1.7	41
4.0	6.3	4.5	4.0	4.0	- 2.3	36
	exchangeable Al me/100 ml					
ton/ha						%
0.0	2.3	2.4	2.3	2.9	+ 0.6	26
0.5	1.5	1.7	1.5	2.0	+ 0.5	33
1.0	0.7	1.2	1.1	1.5	+ 0.8	114
2.0	0.3	1.2	0.9	1.2	+ 0.8	300
4.0	0.0	0.3	0.2	0.3	+ 0.3	-
	Al saturation %					
ton/ha						
0.0	66	66	68	74	+ 8	12
0.5	42	46	50	57	+ 15	36
1.0	20	36	36	41	+ 21	105
2.0	6	26	28	33	+ 18	300
4.0	0	6	6	6	+ 6	-

consistently responded to lime during three consecutive crops, but did not on a recently cleared Ultisol.

Acid saturation ((Al+H)/ECEC)*100 was the most universal, across time and soil type, in correlating with soybean yield among the soil acidity parameters tested. A critical level of 10-15% acid saturation (AS) was established (Figure 2).

Figure 3 shows the relationship between pH and acid saturation for the three soils. The acid saturation (Al+H) curve reaches 10% at about pH 5 and is reaching 0 (minimum) at about pH 5.5. It clearly supports that the liming rate is more then enough when it is formulated just to attain pH 5.5 for tropical soils (Widjaja-Adhi, 1985).

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Table 2. Exchangeable Ca+Mg and Al in the subsoil as affected by lime rates (Wade et al, 1985)

Soil depth	Lime rates	Exch. Al	Exch. Ca+Mg
cm	ton/ha	me/100 ml	
15 - 30	0.0	2.2	0.7
	0.5	2.0	0.7
	1.0	2.1	0.8
	2.0	2.1	0.8
	4.0	2.0	1.1
30 - 50	0.0	1.9	0.6
	0.5	1.8	0.6
	1.0	1.9	0.6
	2.0	2.0	0.7
	4.0	2.0	0.8

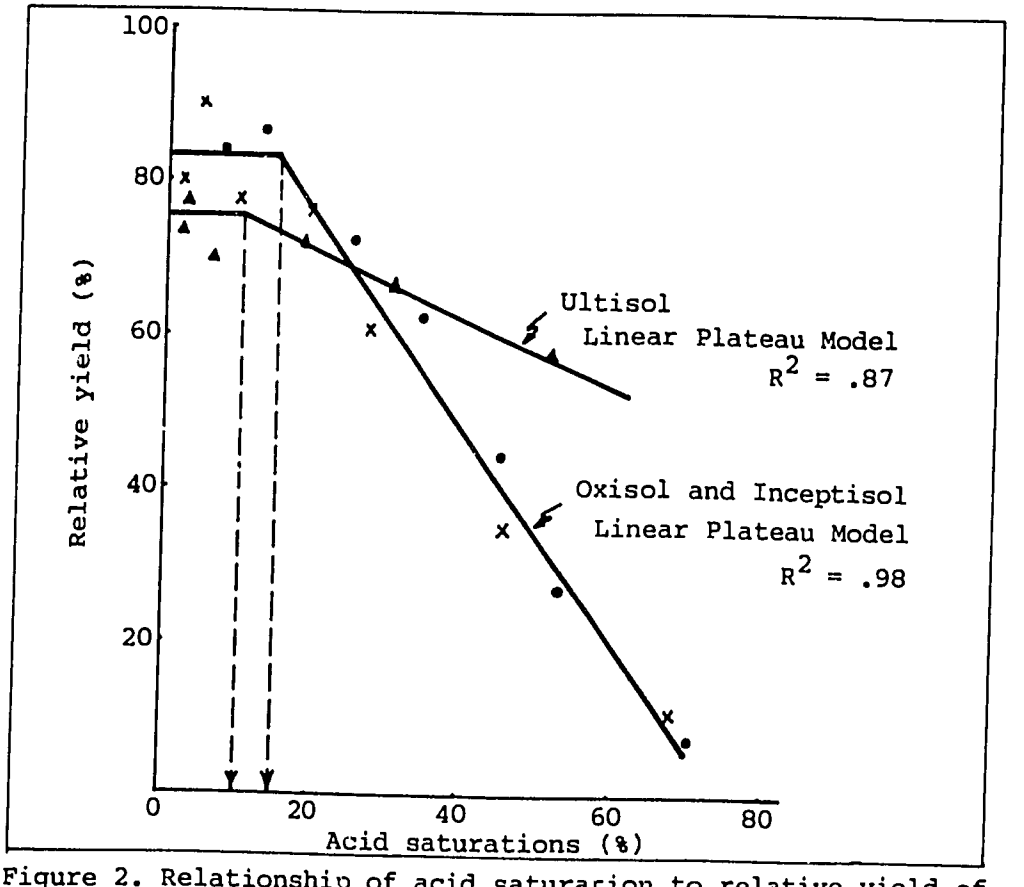

Figure 2. Relationship of acid saturation to relative yield of soybeans grown on three soils (Wade and Al-Jabri, 1986)

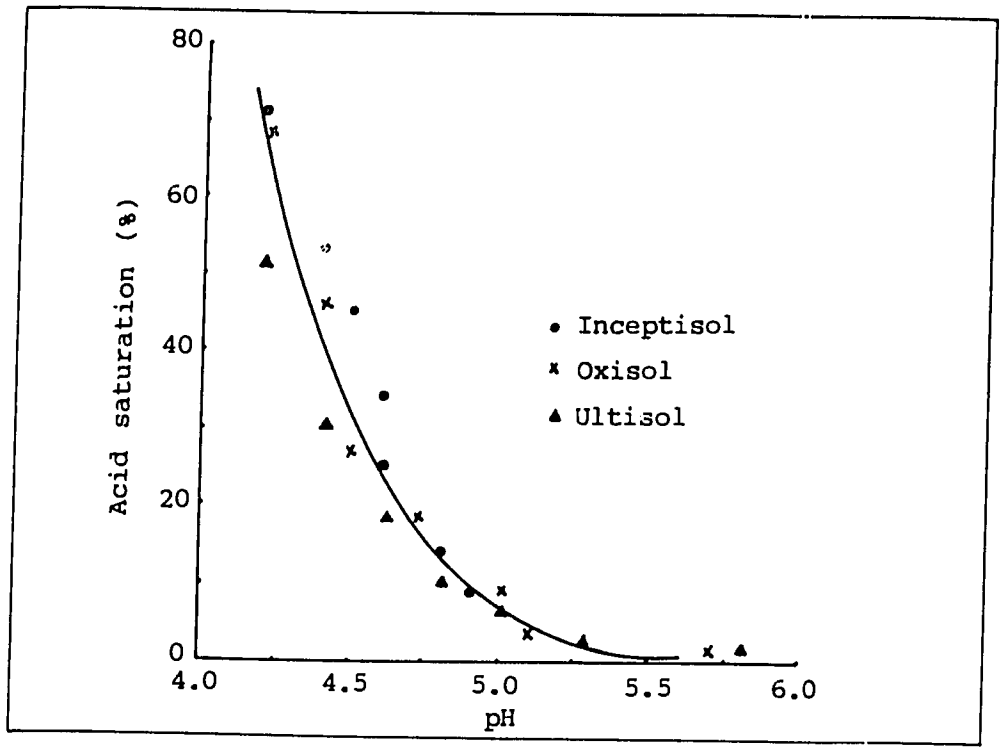

Figure 3. Relationship between pH and acid saturation for three soils (Wade and Al-Jabri, 1986)

Efficiency of the lime for reducing soil acidity (Al+H) was similar for the three soils studied, i.e. 2 me Ca required to reduce 1 me of (Al+H) when AS >10% (Figure 4). For these soils the following lime recommendation (LR) is proposed :

$$LR = 1.5\ ((Al+H) - (RAS*ECEC))$$

where LR is lime requirement (ton/ha), RAS is required acid saturation (>10%), and ECEC is effective cation exchange capacity (Al+H+Ca+Mg+K in me/100 g), by assuming a bulk density of 1.0 and a depth of tillage of 15 cm.

SOIL PHOSPHORUS AVAILABILITY AND MANAGEMENT

Acid upland soils in Indonesia are commonly very responsive to P fertilizer. An experiment was initiated on a Typic Dystropepts, selected for its very low extractable P and high P sorption. The purpose was to quantify fertilizer management for sustained high crop production on such a P deficient soil. Ten days prior to crop initiation, six rates of P:0, 20, 40, 80, 160, and 320 kg P/ha were broadcast and

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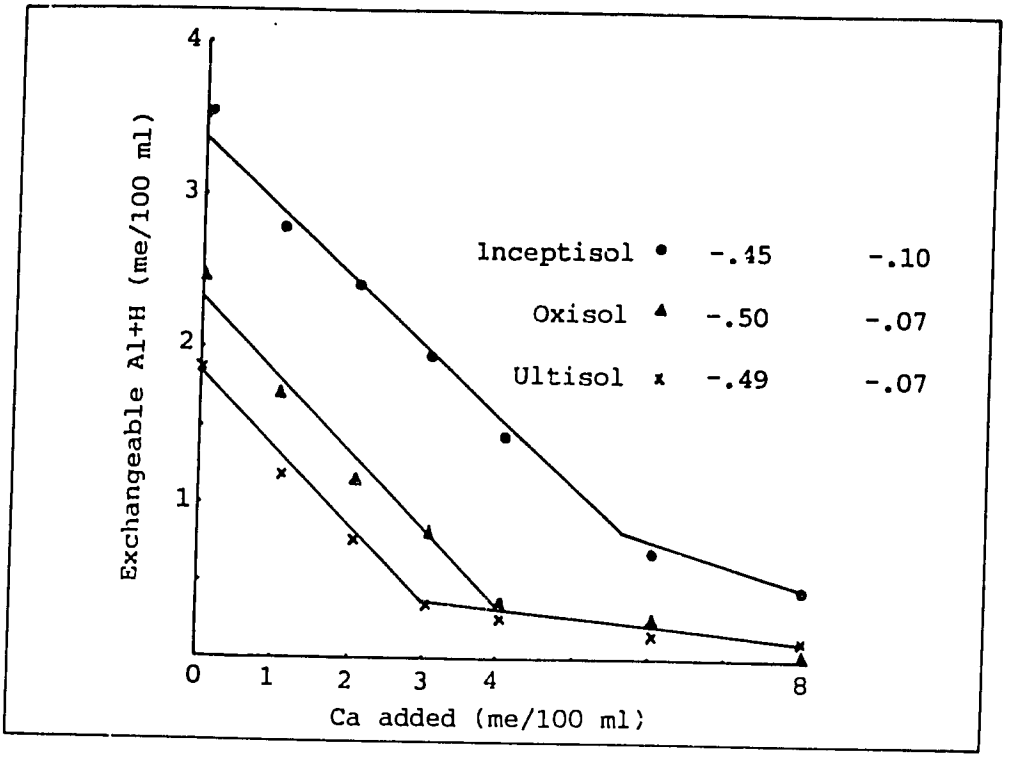

Figure 4. Effect of added Ca,as lime, on exchangeable acidity of three soils (Wade and Al-Jabri, 1986)

incorporated. Plus "maintenance" treatments of 20 kg P/ha banded, 20 kg P/ha broadcast and no additional P were combined factorially with all initial rates, except for the highest, and applied at planting of each crop. Crops grown were two cycles of an annual maize-soybean rotation (Wade and Widjaja-Adhi, 1986).

Crop yield were increased 2-3 fold by the initial rates, with approximately 2/3 of the response achieved by 40 kg P/ha, although 160 kg P/ha was required for plateau yields (Figure 5). The residual of the initial P rates was very strong, as the response curve was similar for all four crops. The plus-maintenance (per crop) treatments increased, rather than maintained, soil P and crop yields. By the third and fourth crops plus-maintenance treatments were at plateau yields (Figure 5). Banding and broadcasting of the maintenance doses were equally effective (Table 3).

Total applied P, regardless of whether initial or per-crop, regressed very well with each crop (Figure 5), further indicating that applied fertilizer P was remaining available in the soil. Mehlich I-extractable soil P increased linearly with added P with a slope of 1 mg P/l per 22 kg fertilizer

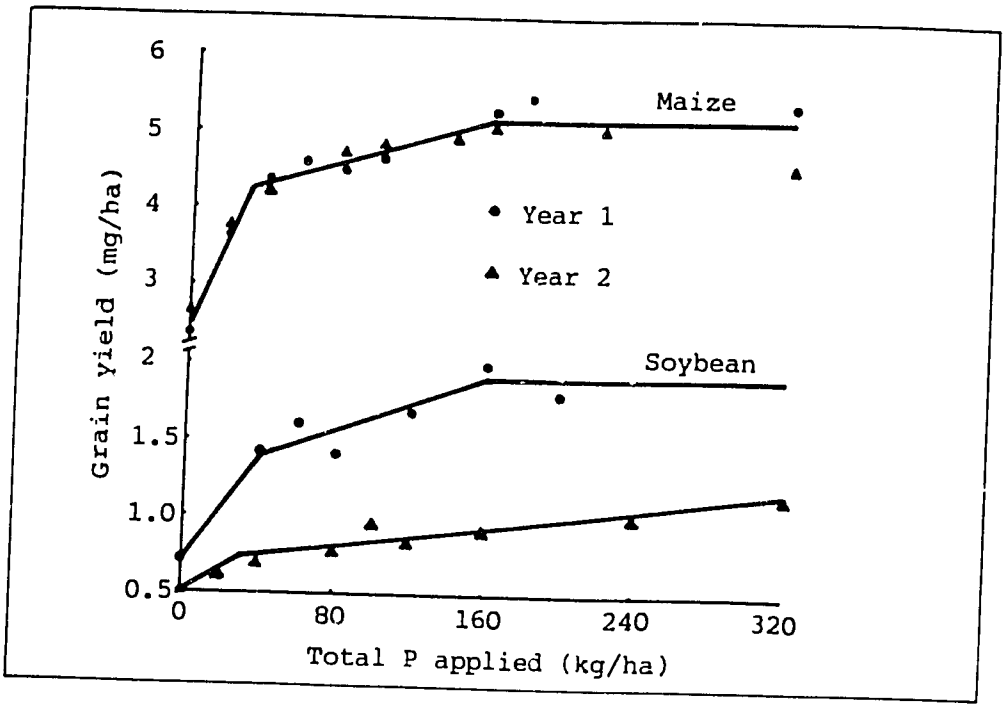

Figure 5. Maize and soybean response to total analised (Wade and Widjaja-Adhi, 1986)

P/ha, but did not consistently change over time. The soil apparently does adsorp great amounts of phosphorus, but much of it remains labile. The soil is very high in kaolinitic clay, but low in amorphous material and free iron. Thus the clay surface may adsorp P, but it remains exchangeable with soil solution, thereby providing long residual of applied fertilizer and requiring relatively low rates to achieve and

Table 3. Effect of banded and broadcast maintenance applications (20 kg P/ha per crop) in addition to initial broadcast rates of P fertilizer on grain yields of two cycles of a maize-soybean rotation

Initial P rates	Crop							
	Maize-1		Soybean-1		Maize-2		Soybean-2	
	+band	+broad	+band	+broad	+band	+broad	+band	+broad
kg/ha	Mg/ha							
0	4.3	3.3	1.6	1.3	4.5	4.3	0.9	1.0
20	4.2	4.3	1.7	1.4	5.1	4.8	0.9	1.0
40	4.1	4.9	1.4	1.4	4.8	4.6	0.9	0.8
80	4.6	4.7	1.8	1.6	4.8	5.0	1.0	0.8
160	5.1	5.7	1.7	1.9	4.8	5.2	1.0	1.0

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maintain good crop yields. The rates are 40 kg P /ha and less than 20 kg P/ha for maintenance.

Calibration curves, using linear plateau (LP) models, show a well-defined critical level for both the maize and soybean data (Figure 6), i.e. 8 and 12 mg P/l soil, respectively. These values are much lower than the commonly used critical level of 20 mg P/l soil for the Mehlich-I extract.

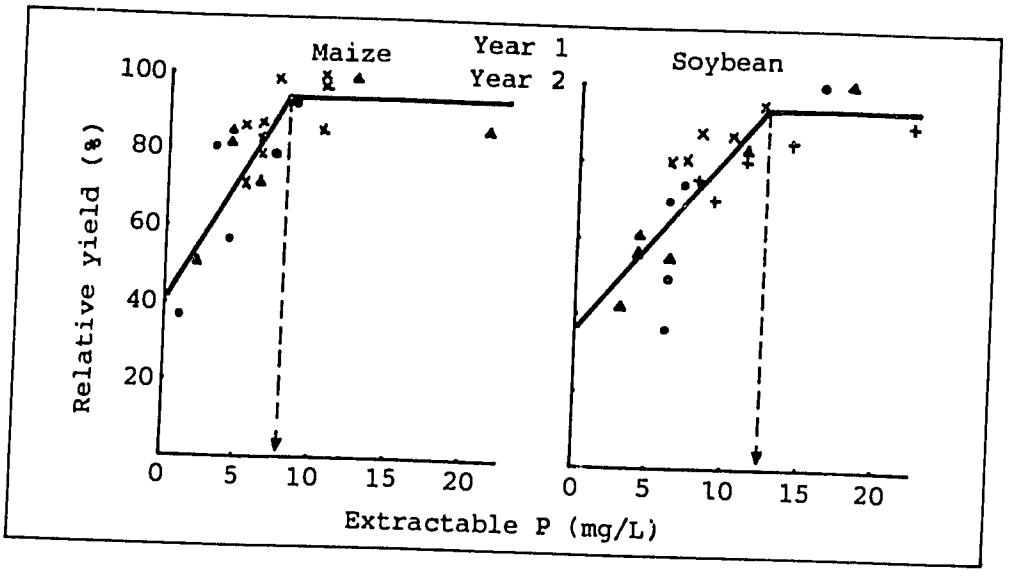

Figure 6. Relationship between relative yield of maize and soybean and Mehlieh I (Wade and Widjaja-Adhi, 1986)

POTASSIUM, MAGNESIUM AND SULPHUR

Experiments were conducted on Typic Dystropepts and Typic Haplorthox, with objectives: (1) to examine the effects of rates of K at three levels of Al or base saturation on crop yield and uptake of K and other basic cations, and (2) to study the effect of different levels of base saturation on retention and movement of K applied at various rates (Gill et al, 1985a, b; Gill and Kamprath, 1985a, b).

Under high yield environment, with most exchangeable Al netralized (5 ton lime/ha), a yield response up to 80 and 120 kg K was obtain for soybean and rice, respectively on a Typic Haplorthox (Figure 7a). On a Typic Dystropepts a large response of maize was observed up to 20 kg K/ha and a smaller one up to 120 kg K/ha. Peanuts did not respond as strongly to K as did the maize on this soil (Figure 7b). A low level of K (20 kg K/ha) is sufficient fcr growing peanuts in this area.

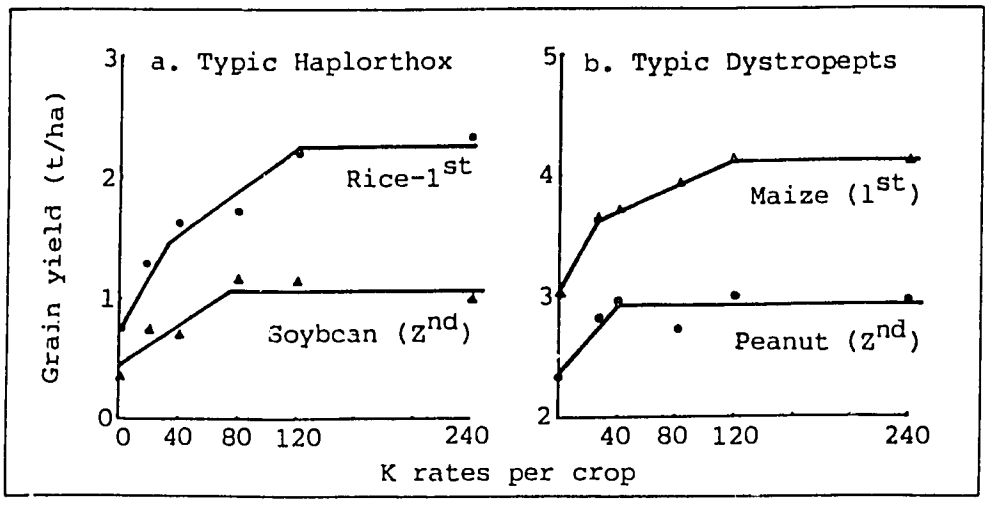

Figure 7. Effect of K fertilizer (KCl) on food crop yield (Source a. Gill et al, 1985a; 1985b; and b. Gill and Kamprath, 1985a; 1985b)

Another experiment was conducted on an Orthoxic Tropudults high in Al and low in bases, especially K, to study crop and soil response to K fertilization with and without returning previous crop residues (Gill et al, 1986). Strong response to K application was also obtained for both rice and soybean crops when crop residues were removed at harvest (Figure 8).

A study on crop response to Mg fertilization for a low input system of rice and peanut rotation and a high input system of maize and soybean rotation was carried out on a Typic Dystropepts (Wade et al, 1986). The location was cleared from virgin forest by bulldozers in 1976, abandoned to grass and bush fallow since 1978.

Early growth of maize was strongly influenced by the Mg fertilization (Figure 9). A strong response to Mg rates up to 32 kg Mg/ha was observed. The unfertilized maize had leaves with severe yellowing and intervenal chlorosis, a characteristic visual symptom of Mg deficiency. Progressive rates of Mg reduced the deficiency, but only at rates of 32 and 64 kg/ha were the leaves completely normal. The rice however, showed only modest response to Mg, and no visual symptoms were apparent in the field (Fig. 9).

Two experiments on sulfur responses and reactions in soils were conducted, one on a recently cleared soil and the other on a soil which has been cultivated for more than 5 years (Kamprath et al, 1985). The results showed that no response to S fertilizer on maize, soybean or mungbean on either recently cleared or 5-year cultivated soil.

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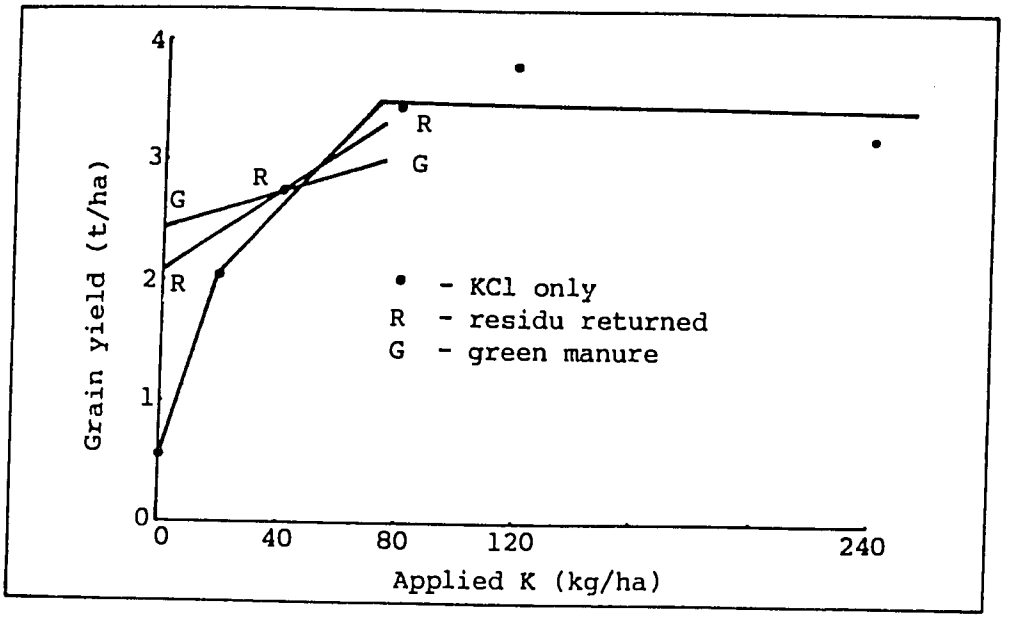

Figure 8. Sentani rice response to applied K without returing residu, with residu incorporated and with green manure applications (Gill et al, 1986)

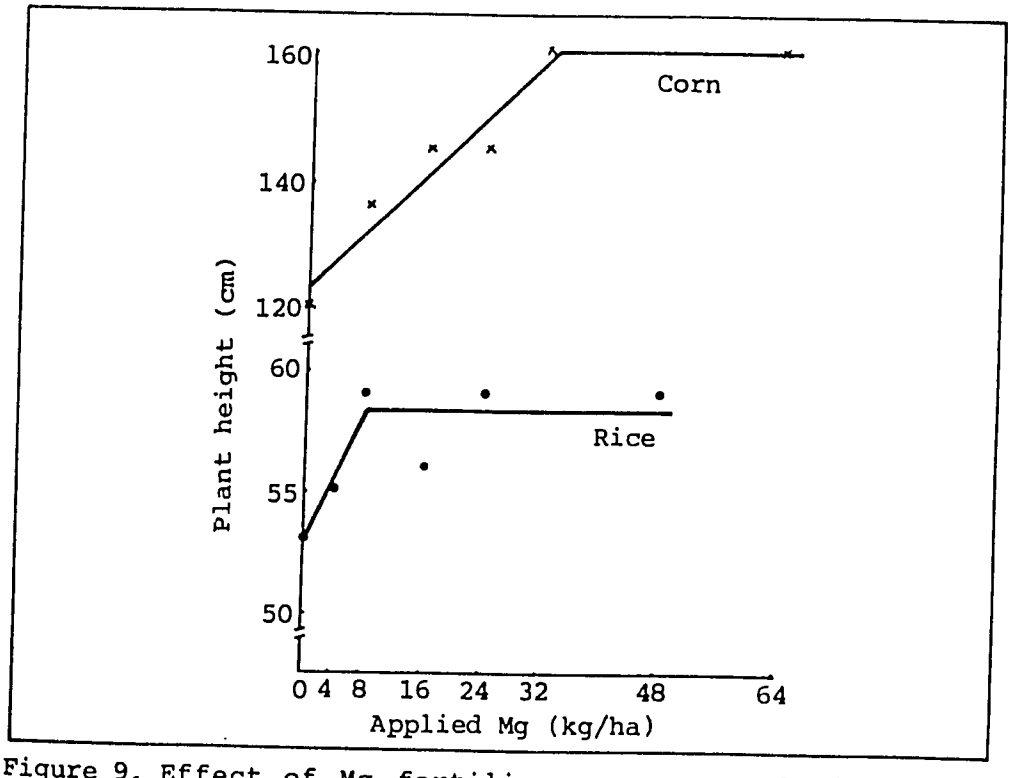

Figure 9. Effect of Mg fertilizer on corn and rice plant height at 36 days after planting (Wade et al, 1986)

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ORGANIC MATTER MANAGEMENT

Post land clearing management

Effects of post land clearing managements (burning, liming and tillage) were studied on a newly cleared Ultisol (Agus et al, 1986). No consistent response to lime was observed, the same as showed by the other experiment on liming at this newly cleared site (Wade and Al-Jabri, 1986). The fresh organic matter of this soil apparently reduced the toxicity of the KCl-extractable acidity.

Burning, partly or completely, increased crop yields and also soil pH, exchangeable Al (Table 4). Since the difference of the effects of partly and completely burning exists only for a short period, partly burning (branches and twigs) is recommended.

Table 4. Some soil chemical characteristics before and after land clearing (Agus et al, 1986)

Soil depth	Sampling time[a]	pH	Al+H	Ca+Mg	K Mehlich-I
cm			-------- me/100 ml soil ------		
0 - 10	BB	4.2	2.87	0.55	0.12
	BO	3.9	2.76	1.20	0.14
	B1	4.4	1.72	3.80	1.15
	B2	6.6	0.16	9.70	2.07
10 - 20	BB	4.5	2.15	0.50	0.03
	BO	4.0	2.08	1.50	0.13
	B1	4.4	1.82	1.60	0.28
	B2	5.1	0.92	2.40	0.52

[a] BB : before land clearing
BO : post land clearing, no burning
B1 : post land clearing, partly burnt
B2 : post land clearing, completely burnt.

Green manuring

Effects of green manuring on food crop response to lime and P fertilization were studied on a Typic Haplorthox, cleared by bulldozers six years ago, with annually cropping of upland rice since clearing . Soil analytical data showed pH 4.1, Al+H 2.6 me /100 ml, Ca+Mg 0.5 me/100 ml and acidity saturation 82%, and Olsen-extractable P 5 ppm (Heryadi and Wade, 1984).

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It seems apparent that the green manure has largely altered the influence of soil acidity (Figure 10a) and possibly available P (Figure 10b) on the growth of upland rice. However, the green manure has not affected the Al-saturation nor Olsen-extractable P. A further investigation is required to clarify our knowledge and understanding of the usefulness of green manure as a potential lime substitute.

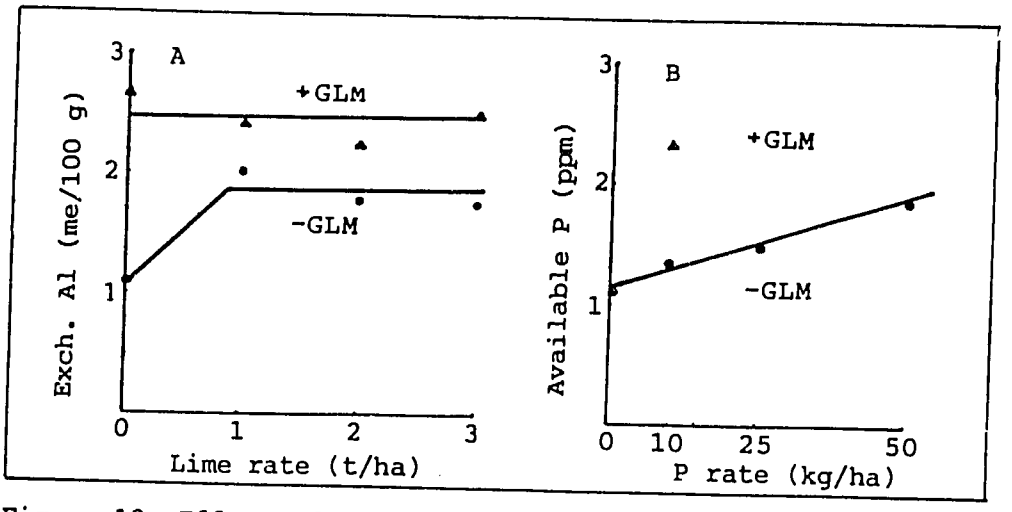

Figure 10. Effect of GLM (green leaf manure) on response of rice to lime and P (Heryadi and Wade, 1984)

Use of crop residues also dramatically improved yields at low rates of K application and decrease crop requirements for K fertilizer to obtain optimum yield (Figure 8). Green manure applications of 10 ton/ha of fresh Calopogonium were very effective in increasing crop yield, primarily because of the relatively high levels of organic K being applied (Gill et al, 1986).

Alley cropping

An alley cropping trial was conducted on a Typic Paleudults, with the objectives : (1) to determine N, leaf, wood production, and Al tolerance of three legume tree species, (2) to measure the effects of green leaf manure additions on rice and soybean (or cowpea) yields, (3) to measure effects of these organic matter additions on soil chemical properties and their interaction with crop growth, and (4) to select an appropriate legume tree species and liming level for farmer testing (Evensen and Yost, 1985). Albizzia falcataria and Caliandra calothyrsus prunings alleviated lime response of rice and improved fertility. The trees tolerate poor soils and soil acidity and also tolerate frequent pruning.

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