

---

# LIME AS AN AMENDMENT FOR THE ACID LATERITIC RICE SOILS OF CEYLON

F. N. PONNAMPERUMA

(Chemist, Department of Agriculture, Ceylon)

---

THE mineral rice soils of the low country wet zone of Ceylon are strongly acid in reaction and deficient in bases. The adjoining highland is invariably ferruginous laterite. The productivity of these soils is low. Also the physiological disease of rice known as "bronzing" occurs frequently on these soils.

The results of an investigation reported elsewhere (1), showed that: (i) symptoms very similar to those of bronzing were associated with a high concentration of ferrous iron in the soil solution; and (ii) lime prevented the appearance of these symptoms. Lime as an amendment for acid lateritic rice soils was therefore tested on an imperfectly drained, strongly acid, clay loam at the Rice Research Station, Panagoda.

The soil had the horizon sequence,

A<sub>1</sub>pg/A<sub>12</sub>g/Bg/BG/G, after Kanno's notation (2) and the following chemical analysis:

pH	4.4
Organic matter	4.35 per cent.
Nitrogen	0.17 per cent.
Total exchangeable bases	0.72 m. e./100 gm.
Cation Exchange Capacity	7.10 m. e./100 gm.
Available P <sub>2</sub> O <sub>5</sub> (Olsen)	12.5 ppm.
Available SiO <sub>2</sub>	32 ppm.
Free Fe <sub>2</sub> O <sub>3</sub>	1250 ppm.

The levels of lime were 0, 3, and 6 tons slaked lime per acre. The plots were pegged out but not separated by ridges. Lime was applied in April 1956, only. The following fertilizer mixture was applied every season:

ammonium sulphate	100	} lb./acre
concentrated superphosphate	50	
muriate of potsh	50	

Rice was grown on these plots for six seasons in succession with the results shown in Table I.

TABLE I  
Mean Yields of Paddy lb./acre

<i>Slaked lime (tons/acre)</i>				<i>S. E.</i>	<i>Mean response to 6 tons</i>
	<i>0</i>	<i>3</i>	<i>6</i>		
<i>Season</i>					
April, 1956-September, 1956	.. —	.. —	.. —	.. —	.. —
October, 1956-March, 1957	.. 2,093	.. 2,332	.. 2,829	.. 46	.. 736
April, 1957-September, 1957	.. 1,789	.. 2,259	.. 2,594	.. 83	.. 805
October, 1957-March, 1958	.. 1,297	.. 1,624	.. 2,019	.. 101	.. 722
April, 1958-September, 1958	.. 2,415	.. 2,498	.. 2,755	.. 133	.. 340
October, 1958-March, 1959	.. 1,638	.. 1,849	.. 2,056	.. 179	.. 419

The responses to lime were very highly significant and linear in the range 0-6 tons per acre during the first three seasons for which the yields are available. A yield increase of over 700 lb. paddy per acre was obtained for three seasons in succession for one application of lime at 6 tons per acre.

The changes in pH value of the soil are shown in Table II.

TABLE II  
pH value of the Dry Soil at the beginning of each Season

<i>Season</i>	<i>Slaked lime in tons/acre</i>		
	<i>0</i>	<i>3</i>	<i>6</i>
April, 1956*	.. 4.4	.. 6.5	.. 7.6
October, 1956	.. 4.9	.. 5.9	.. 6.6
April, 1957	.. 4.9	.. 5.2	.. 5.9
October, 1957	.. 4.8	.. 5.1	.. 5.4
October, 1958	.. 4.9	.. 5.0	.. 5.3

\* Two weeks after liming.

The decline in pH of the lime plots is due partly to loss of calcium by leaching and partly to diffusion and mass movement of calcium from the limed to the adjoining unlimed plots which were not separated by ridges.

LIME AS AN AMENDMENT FOR THE ACID LATERITIC RICE SOILS OF CEYLON

In view of the linear response to lime in the range 0-6 tons per acre a fresh experiment was laid down with an additional level of lime, viz, 9 tons per acre. The results are summarized in Table III.

TABLE III  
Mean Yields of Paddy in lb./acre in four-level Liming Trial

Slaked lime (tons/acre)	0	3	6	9	S. E.	Mean response to 6 tons
April, 1957	.. 1,458	.. 1,693	.. 2,111	.. 1,385	.. 69	.. 653
October, 1957	.. 1,017	.. 2,029	.. 1,978	.. 1,874	.. 202	.. 1,007
April, 1958	.. 2,171	.. 1,969	.. 1,978	.. 2,056	.. 129	.. — 175
October, 1958	.. 2,153	.. 2,797	.. 2,949	.. 2,783	.. 115	.. 796

Slaked lime at 9 tons per acre was injurious in the first two seasons. The responses to 6 tons per acre slaked were 653, 10,007, and 796 lb. per acre paddy during the first, second and fourth seasons respectively. In the third season there was no response to lime, probably because of unfavourable weather.

On the very poorly drained humic soils of Labuduwa, Karapincha, and Bombuwela, there was no significant response to lime.

In view of the marked and sustained benefits of lime on the acid lateritic soils at Panagoda, liming trials were set down on the moderately well drained to imperfectly drained acid lateritic soils of the low country wet zone of Ceylon.

### LIME AND NITROGEN EXPERIMENTS

*Object* : To study the response of rice to slaked coral lime with and without nitrogen over a basal dressing of 40 lb.  $P_2O_5$  per acre as conc. superphosphate and 50 lb.  $K_2O$  per acre as muriate.

*Design* : Randomized blocks of 4 plots replicated at several locations.

*Plot size* : 33'  $\times$  16½'.

*Treatments* :  $L_0N_0$ —No lime, no nitrogen.

$L_0N_1$ —No lime, 40 lb. N. per acre as ammonium sulphate.

$L_1N_0$ —6 tons lime per acre, no nitrogen.

$L_1N_1$ —6 tons lime, 40 lb. N per acre as ammonium sulphate.

*Soils*: Strongly acid, moderately well drained to imperfectly drained brown clay loams.

*Results*: The limed treatments were characterized by their deep green colour, profuse tillering, and vigorous growth. The lime-plus-nitrogen treatment lodged badly. The individual plots yields in lb. per acre are presented in Table IV.

TABLE IV  
Yields of Paddy (lb./acre), Mirigama Range

Location	$L_0N_0$	$L_1N_0$	$L_0N_1$	$L_1N_1$	S. E.
1	1,713	3,084	2,090	3,038	
2	526	2,764	1,041	1,840	
3	1,381	1,556	757	1,462	
4	1,150	1,913	1,209	1,698	
5	2,326	2,768	2,627	2,703	
6	2,517	3,665	2,339	2,377	
7	1,651	1,958	1,254	1,934	
8	2,842	2,962	2,593	2,891	
9	1,329	2,475	1,715	2,410	
10	2,157	2,990	2,814	2,590	
11	2,035	3,313	2,272	3,088	
12	1,806	2,855	2,014	2,227	
13	2,854	3,931	3,410	3,588	
Mean	1,868	2,788	2,010	2,452	83

The figures show that lime in the absence of fertilizer nitrogen unerringly produced an increase in yield at every one of the 13 locations. The mean response to 6 tons per acre slaked lime in the absence of nitrogen was 920 lb. paddy per acre. The response to nitrogen in the absence of lime was a non-significant increase of 142 lb. paddy per acre. The lime plus nitrogen treatment was highly significantly better than the control ( $L_0N_0$ ) but highly significantly inferior to the lime-only treatment ( $L_1N_0$ ) owing to a severe lime and nitrogen interaction.

LIME AS AN AMENDMENT FOR THE ACID LATERITIC SOILS OF CEYLON

The same trial on a similar soil type in Kamburupitiya Range gave the results shown in Table V.

TABLE V  
Individual plot yields of paddy (lb./acre), Kamburupitiya Range

Location	$L_0N_0$	$L_1N_0$	$L_0N_1$	$L_1N_1$	S. E.
1	1,922	2,121	2,090	2,389	
2	1,935	2,204	2,066	2,227	
3	1,590	1,937	1,217	1,590	
4	1,358	1,784	1,314	1,918	
5	1,672	2,505	1,981	2,275	
Mean	1,697	2,111	1,734	2,079	79

As in the Mirigama Range, lime increased the yields over the unlimed treatment at every single location although there was hardly any response to nitrogen. There was no lime x nitrogen interaction. The mean response to 6 tons per acre slaked lime was 382 lb. per acre paddy.

These trials show that on the strongly acid lateritic soils of Mirigama and Kamburupitiya lime produced marked increases in yield while 200 lb. of ammonium sulphate per acre gave an insignificant increase in yield. The benefits of liming cannot therefore be associated with increased mineralization of organic nitrogen that liming no doubt would have brought about. The inferiority of the lime-and-nitrogen treatment ( $L_1N_1$ ) to the lime alone treatment ( $L_1N_0$ ) in Mirigama Range probably reflects the adverse effects of excess nitrogen.

A pH near neutrality accelerates the liberation of phosphate from organic residues just as it favours the mineralization of organic nitrogen. Increased availability of phosphate might therefore be one of the benefits of liming. This was tested in lime and phosphate trials set down on the strongly acid lateritic soils of Mirigama Range.

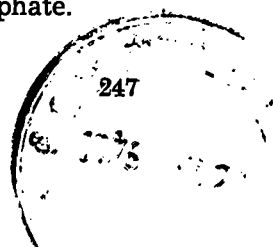
### LIME AND PHOSPHATE TRIALS

**Object :** To study the response of rice to lime in the presence and absence of phosphate.

**Design :**  $3 \times 2$  factorial.

**Levels :** Lime—0, 3, 6 tons per acre slaked lime.

Phosphate—0 and 40 lb. per acre  $P_2O_5$  rock phosphate.



*Basal dressing* : 50 lb.  $K_2O$  per acre as muriate of potash.

*Season* : April-September, 1958.

The limed plots stood out by its dark green colour and luxuriant growth. But during this very wet season there was severe lodging and loss of crop owing to rat damage. No response was revealed to lime or P during this season.

The same experiment was continued at 10 locations in October, 1958 to March, 1959 to test residual effects of lime. No lime was applied but the phosphate and potassium dressing were given. The results are summarized in Table VI.

TABLE VI  
Mean yields of Paddy in lb./acre

Rock phosphate lb./acre $P_2O_5$	Slaked lime (tons/acre)			S. E.
	0	3	6	
0	.. 2,313	.. 2,861	.. 2,815	89
40	.. 2,594	.. 2,712	.. 2,650	

There was a highly significant response to lime, a significant lime x phosphate interaction but no significant overall response to phosphate. The figures show, however, that there has been a significant response of 279 lb. paddy to 40 lb.  $P_2O_5$  in the absence of lime while the responses to phosphate at the higher levels of lime are non significant.

A fresh 3 x 2 factorial experiment in the same season in the same Range with 0, 4 and 8 tons per acre ground coral limestone and 0 and 40 lb.  $P_2O_5$  per acre as rock phosphate revealed highly significant responses of 460 and 657 lb. paddy per acre to 4 and 8 tons per acre ground limestone, respectively. There was no significant response to phosphate nor a significant lime x phosphate interaction.

The results are summarized in Table VII.

TABLE VII  
Mean Treatment Yields in lb./acre

Rock phosphate lb./acre $P_2O_5$	Ground limestone in tons per acre			S. E.
	0	4	8	
0	.. 2,073	.. 2,473	.. 2,703	100
40	.. 1,911	.. 2,412	.. 2,596	

## LIME AS AN AMENDMENT FOR THE ACID LATERTIC SOILS OF CEYLON

A form of lime trial was set down in the same Range with the following objectives: (a) to determine the best form of lime for this Range, and (b) to elucidate the mechanism of the action of lime.

Slaked coral lime, ground coral limestone and ground dolomite at a lime equivalent of 6 tons per acre slaked lime were tested at 14 locations in the Mirigama Range over a basal dressing of 40 lb.  $P_2O_5$  per acre as rock phosphate and 50 lb.  $K_2O$  per acre as muriate of potash, during the season October, 1958-March, 1959.

The mean yields in lb. per acre are shown below—

<i>No. lime</i>	<i>Slaked coral lime</i>	<i>Ground coral limestone</i>	<i>Ground dolomite</i>	<i>S. E.</i>
2,445 ..	3,151 ..	2,930 ..	2,764 ..	72

The responses to slaked coral lime, ground coral limestone and dolomite were 707, 486 and 319 lb. of paddy per acre respectively. All these forms of lime gave highly significant increases in yield. Slaked lime was significantly superior to both ground coral limestone and ground dolomite. Ground coral limestone was better than ground dolomite. The superiority of slaked lime to the ground carbonate forms is no doubt due to its strong chemical nature and the extreme fineness of the particles. It could also be due to the peptizing action of slaked lime on soil organic matter on which Japanese workers (3) lay so much emphasis. But that this effect is relatively unimportant may be inferred from the fact that even in the fourth season from the first slaked lime application the response to the first lime application remains undiminished.

### LEVELS OF LIME

The rate of liming should vary with (a) and pH, (b) the clay content, and (c) the organic matter content of the soil. The optimum lime dressing will, therefore, have to be determined for each soil type. This is being done.

The results available so far suggest that, generally speaking, a dressing of 5-8 tons per acre ground coral limestone is necessary on the strongly acid clay loam of the low country wet zone for a response of the order of 500 lb. paddy per acre. On the less strongly acid loams of the mid country wet zone adressing of 2.7 tons per acre ground limestone produced the same response.

## MECHANISM OF THE ACTION OF LIME

The increase in yield brought about by the application of lime to acid lateritic soils may provisionally be attributed to :

- (i) decrease in concentration of ferrous iron in the soil solution ;
- (ii) decrease in the concentration of organic acids formed during the anaerobic decomposition of organic matter ;
- (iii) decrease in concentration of  $\text{CO}_2$  ;
- (iv) increased supply of Ca and Mg ;
- (v) increased supply of N and P ;
- (vi) increased absorption of N by rice roots ;
- (vii) increased availability of silica and Molybdenum ;
- (viii) improvement in physical condition of soil.

**Decrease in Concentration of  $\text{Fe}^{+2}$ .** Although a pH near neutrality favours the reduction process in a submerged soil, it prevents the build up of a high concentration of ferrous iron. This is shown in Table VIII.

TABLE VIII  
Changes in Concentration of  $\text{Fe}^{+2}$  in the Soil Solution from a submerged Acid Lateritic Soil

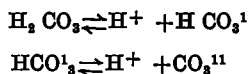
Days from submergence		pH		$\text{Fe}^{+2}$ in ppm								
Slaked lime (tons/acre)				0	30	60	90	120				
0	..	4.4	..	0.3	..	7.3	..	40	..	122	..	243
3	..	5.9	..	0.3	..	0.5	..	37	..	48	..	80
6	..	6.7	..	0.3	..	0.3	..	32	..	26	..	45

Excess iron is toxic to rice (1). The decrease in concentration of ferrous iron is one of the benefits of liming.

**Decrease in Concentration of Organic Acids.** It is not known to what extent organic acids present in the soil inhibit growth. But in solution culture certain organic acids are known to be injurious to rice (6).

A high pH favours the destruction of organic acids with the formation of  $\text{CH}_4$  and  $\text{CO}_2$  (7).

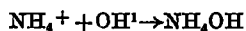
**Decrease in Concentration of CO<sub>2</sub>.** A decrease in concentration of CO<sub>2</sub> is favourable to the growth of rice because CO<sub>2</sub> in concentrations exceeding 15 per cent is toxic to rice (4, 5). The decrease in concentration of CO<sub>2</sub> may be attributed to (i) the diluting effect of CH<sub>4</sub> from the decomposition of organic acids at high pH, and (ii) to the lowering of the concentration of the species "H<sub>2</sub>CO<sub>3</sub>" at high pH values, according to the equilibria,



**Increased Supply of Ca and Mg.** This is probably one of the chief benefits of liming, for strongly acid lateritic soils are extremely deficient in bases. A dressing of 6 tons of slaked coral lime per acre supplies approximately 9,500 lb. Ca and 200 lb. Mg O per acre.

**Increased Supply of N and P.** Lime accelerates the mineralization of organic nitrogen and phosphorus under anaerobic conditions because a pH near neutrality favours the activity of anaerobic bacteria. The peptizing action of a high pH on soil organic matter is another reason advanced by Japanese workers, (3) for the benefits of liming. This explanation, however, does not account for, (a) the long term effects of lime, and (b) the effect of carbonate forms of lime.

**Increased Absorption of N by Rice Roots.** A high pH favours the absorption of nitrogen as ammonia because the protoplasmic membrane of the cells of rice roots is more permeable to the un-ionized NH<sub>4</sub> OH molecules than to NH<sub>4</sub><sup>+</sup> ions. An increase in pH favours the change.



**Increased Availability of Silica.** Lime favours the reduction of a submerged soil. As reduction proceeds silica is released (8) probably from ferri-silica complexes.

**Improvement in Physical Condition.** This view was commonly advanced by the farmers in whose fields liming trials were carried out. They referred to a loosening of heavy clay soils by the increased fermentation that went on in the limed plots. It may be mentioned in support of this that root system of rice plants in the limed plots was very well developed.

### GENERAL SUMMARY

Liming of strongly acid lateritic soils in Ceylon has given striking increases in yield. A single six-tons-per-acre application of slaked

lime gave an increase of over 700 lb. per acre paddy for four seasons in succession on an imperfectly drained acid lateritic clay at Panagoda Rice Research Station. In cultivators' fields average responses as high as 920 lb. paddy were obtained on similar soils to lime at 6 tons per acre. Residual effects a year later were of the order of 500 lb. paddy per acre. In Mirigama Range nitrogenous and phosphatic fertilizers appeared to be superfluous in the season of liming. The responses to forms of lime at a lime equivalent of 6 tons per acre  $\text{Ca}(\text{OH})_2$  were in the following descending order: slaked coral lime, ground coral limestone, ground dolomite. The optimum level of limestone was about 6 tons per acre for the strongly acid soils of the low country wet zone and about 3 tons per acre for the less acid soils of the mid country wet zone.

## LITERATURE CITED

1. *Nature* 175 : 265, 1955.
2. *Soil and Plant Food* 2 : 148—157, 1957.
3. *Inorganic Nutrition, Fertilization and Soil Amelioration of Lowland Rice*, 1954.
4. *Plant Physiology* 19 : 33—51, 1944.
5. *Plant Physiology* 20 : 221—232, 1945.
6. *Journal Science of Soil and Manure* 24 : 45—50, 1953.
7. *Biochemical Journal* 29 : 528—541, 1955.
8. *Journal of Ecology* 29 : 280—329, 1941.