CHAPTER 6

LIME REQUIREMENT OF SOILS

6. LIME REQUIREMENT OF SOILS

The soils of entire Manipur state are acidic and the productivity of the crops is affected severely. Liming is essential for the management of acid soils. Many lime requirement methods have been suggested from time to time (Brown 1943; Woodruff 1948; Lin and Coleman 1960; Shoemaker *et al.* 1961; Pratt and Bair 1962; Kamprath 1970 and Brown and Cisco 1984) but there seems to be no universally suitable and acceptable procedure for determining the lime requirement of acid soils. The availability and uptake of most of the nutrients are known to be affected by liming. Poor or no response or even negative effect of liming has been, some times, observed. This may be due to injudicious liming of the soils and improper selection of the method for lime requirement. In this chapter efforts have been made to assess different methods of lime requirement for their suitability to the acid soils of Manipur. Association of different soil properties with lime requirement and correlation between different forms of soil acidity and lime requirement have also been worked out.

6.1 MATERIALS AND METHODS

Lime requirement of these soils have been estimated by various methods as outlined below:

6.1.1.SMP Buffer Method (Shoemaker *et al.* 1961)

Buffer mixture :	Para nitrophenol	1.8 g
	Triethanolamine	2.5 mL
	Potassium chromate	3.0 g
	Calcium acetate	2.0 g
	Calcium chloride dihydrate	53.1 g

All these reagents were dissolved in water to make 1000 mL solution and pH of the buffer was adjusted to 7.5 with NaOH. 5 g soil was mixed with 5 mL distilled water. 10 mL of above buffer mixture was added and the contents were shaken continuously for 10

minutes. pH of the suspension was then recorded immediately. Lime requirement was directly read from the table of Shoemaker *et al.* (1961)

6.1.2.Pratt and Bair (1962)

Buffer mixture :	Para nitrophenol	1.8 g
	Triethanolamine	2.5 mL
	Potassium chromate	3.0 g
	Calcium acetate	2.0 g
	Calcium chloride dihydrate	40 g

The buffer was prepared by dissolving the above mixture in about 800 mL distilled water adjusting the pH to 7.5 with NaOH or HCl and diluting to 1000 mL. 20 mL of the above buffer was added to 10 g of soil. The mixture was shaken for 10 minutes and pH was recorded. Lime requirement was directly read from the table as given by Pratt and Bair (1962).

6.1.3. Woodruff (1948)

Buffer mixture :	Para nitrophenol	8 g
	Calcium acetate	40 g
	Magnesium oxide	0.625 g

The above mixture was dissolved in water and volume was made up to 1 litre. The pH was adjusted to 7.0 with HCl or MgO. 5 g soil, 5 mL distilled water and 10 mL buffer are equilibrated in 50 mL beaker with stirring and allowed to stand for 30 minutes and then the pH was recorded.

$$LR\ [cmol\ (p^{+})\ kg^{-1}] = 10\ (7.0\text{-}pH)$$

LR in tonne/hectare was calculated by multiplying the above LR value with 2.2.

6.1.4. New Woodruff Buffer (Brown and Cisco 1984)

Buffer mixture :	Para nitrophenol	12 g
	Calcium hydroxide	4 g

Calcium acetate	10 g
Salicylic acid	10 g

Calcium acetate and calcium hydroxide were dissolved in 500 mL cool distilled water. 200 mL distilled water was heated to 70^{0}C and para nitrophenol was dissolved in it. Salicylic acid was added to acetate-hydroxide solution and mixed vigorously for 2 minutes. Then para nitrophenol solution was poured in this and mixed immediately. Volume was made to 1000 mL and pH was adjusted to 7.0±0.05 by HCl or NaOH. 10 g soil, 10 mL 0.01 *M* $CaCl_2$ and 10 mL buffer were equilibrated in 100 mL beaker with stirring periodically and allowed to stand for 30 minutes and the pH was, then, recorded to 0.01 units. Calculation was done as in case of Woodruff buffer.

6.1.5.Brown (1943)

2.5 g soil in 25 mL 1 *N* ammonium acetate solution of pH 7.00 was shaken intermittently for one hour and, then the pH of the suspension and original solution were determined to 0.01 units.

LR [cmol(p^+) kg^{-1}] = (7.00-pH suspension) X 22

LR in tonne/hectare was obtained by multiplying the above value by 2.2.

6.1.6.Peech *et al.* (1947)

10 g soil was equilibrated for 30 minutes with 25 mL of buffer solution consisting of 0.5 *N* $BaCl_2$ and 0.2 *N* triethanolamine adjusted to pH 8.1. The suspension was, then, filtered and the residue was washed once with 25 mL of buffer solution. The residue was again leached with 100 mL of 0.5 *N* $BaCl_2$ solution containing 2.5 mL of buffer per litre. The extracts were pooled and titrated with standard 0.1 *N* HCl using methyl red-bromocresol green mixed indicator. The difference between the titre of a blank consisting of 50 mL of buffer solution and 100 mL of 0.5 *N* $BaCl_2$ solution and the titre of the soil extract is equivalent to the lime requirement in cmol(p^+) kg^{-1}. It was multiplied by a factor of 2.2 to get the LR in tonne / hectare.

6.1.7.Kamprath's Exchangeable Al Method

The method of Kamprath (1970) was used to determine the LR based on neutralization of exchangeable Al.

$$LR\ [cmol(p^+)\ kg^{-1}] = 1.5\ X\ Exchangeable\ Al^{3+}.$$

It was converted to tonne/hectare by multiplying the above value with a factor of 2.2.

6.1.8. Incubation Method (Bhumbla and Mclean 1965)

The reference LR was determined by laboratory incubation of 100 g soil samples with graded doses of $CaCO_3$ (0,0.8, 1.6, 3.2, 6.4, 12.8 and 25.6 $cmol(p^+)\ kg^{-1}$) for 90 days at room temperature with alternate wetting and drying. The pH of these incubated soils was, then, determined in 1:2.5 (soil:water) suspension. The lime requirement was calculated as the amount of $CaCO_3$ required to raise the pH of the soil to 6.5 from the graph plotted between pH versus $CaCO_3$ doses.

6.1.9. pH Dependent Sites

pH dependent sites on organic matter and clay were calculated as outlined by Pionke *et al.* (1968).

pH dependent sites on organic matter = $(6.5 - pH_w)$ X (percent organic matter)

pH dependent sites on clay = $(6.5 - pH_w)$ X (percent clay)

and $6.5\text{-}pH_w$ was denoted as $\triangle pH$.

6.2. RESULTS AND DISCUSSION

6.2.1. Lime Requirement of the Soils

Lime requirement of the soils was estimated by six buffer methods *viz.*, those of Shoemaker *et al.* (1961), Pratt and Bair (1962), Woodruff (1948), Brown and Cisco (1984), Brown (1943) and Peech *et al.* (1947) and exchangeable Al method of Kamprath (1970). The laboratory incubation method of Bhumbla and Mclean (1965) was taken as reference LR method to standardize the buffer methods for their suitability to these soils. The LR data are

Table 6.1. Lime requirement of acid soils of Manipur by different methods (t $CaCO_3$ ha^{-1})

S.No.	Sampling site	Lime requirement methods							
		SMP	Wood-ruff	New Wood-ruff	Pratt & Bair	Brown	Peech	Kamp-rath	Laboratory incubation
1		2	3	4	5	6	7	8	9
1.	Khukthar	5.63	5.61	7.26	6.25	11.08	16.00	5.30	9.19
2.	Leikun	4.67	5.28	6.60	4.77	7.63	19.70	0.33	10.31
3.	Liwa Sarai	2.88	4.07	5.94	3.77	8.62	16.00	0.77	7.17
4.	Thamnapokpi I	5.63	5.39	7.15	4.46	10.34	18.47	2.75	8.29
5.	Boungyang	4.95	5.06	6.93	5.98	8.87	22.17	1.65	10.98
6.	Sinam	0.00	0.77	1.10	0.43	5.15	2.45	0.11	0.00
7.	Lamkhai	10.86	8.14	10.23	11.17	11.08	28.32	3.19	20.17
8.	Thamnapokpi II	5.63	5.39	6.66	6.98	10.34	20.93	1.32	6.94
9.	Karong	1.90	3.19	2.18	2.11	8.62	11.08	0.00	3.81
10.	Leirouching	0.68	2.86	3.30	1.11	7.14	11.08	0.00	2.02
11.	Maram	0.96	2.42	3.30	1.88	6.71	11.08	0.22	2.69
12.	Tadubi	1.58	0.99	1.21	2.43	4.92	3.68	0.00	2.02
13.	Mao-I	4.53	4.51	6.49	6.25	7.39	12.30	1.32	8.29
14.	Mao-II	3.71	4.29	5.28	8.87	8.87	14.77	0.22	6.27
15.	Maram Centre	9.07	8.36	9.79	11.89	11.08	24.62	5.50	14.34
16.	Makhan Centre	3.71	4.18	5.50	7.29	6.65	13.53	0.44	6.50
17.	Kathiko	6.18	5.72	7.70	6.98	8.62	17.23	0.66	8.74
18.	Keithelmanbi	8.52	5.94	7.92	7.94	8.87	17.23	3.30	11.21
19.	New Keithelmani	16.55	14.18	10.67	15.87	10.21	17.28	7.98	20.80
20.	T.Kasam	3.02	6.60	4.07	3.81	10.84	12.92	0.88	7.84
21.	Sakpao	13.33	8.36	7.56	14.59	11.82	15.38	5.50	23.53
22.	Lambui	8.66	5.72	7.81	7.95	7.88	17.85	5.28	11.21

23. Hundung	8.38	6.05	6.93	9.95	10.84	23.39	0.66	12.10
24. Upper Hundung	4.26	6.71	4.18	5.29	9.11	18.45	0.00	4.71
25. Pherung	4.40	3.30	2.29	7.81	9.85	14.77	0.22	5.38
26. Lamlang Gate	12.20	3.74	3.96	12.33	7.14	12.30	0.22	6.27
27. Khulan Juhui	0.41	2.20	2.09	0.88	7.14	11.08	0.00	0.67
28. New Heaven	5.08	4.07	4.84	7.29	11.08	16.00	0.48	8.07
29. Mahadeo	7.83	5.72	6.49	6.47	12.81	18.47	4.84	9.41
30. Lamjang	7.28	3.96	4.62	7.29	6.65	11.08	1.76	4.93
31. Singnhat	10.72	6.71	8.14	10.64	10.10	19.70	4.40	15.02
32. Muallum	3.71	3.30	3.63	4.33	7.88	11.08	0.11	4.48
33. Muallum Centre	7.42	5.61	3.16	8.26	10.10	12.30	5.72	2.24
34. Zezaw	1.78	2.86	2.97	2.84	6.40	8.62	0.11	3.58
35. Jaumun	0.41	2.31	1.98	0.88	4.92	6.15	0.11	3.58
36. Tualnuam	2.20	2.20	2.97	3.29	5.10	7.38	0.22	5.83
37. Molnam	0.00	0.77	0.76	0.88	4.18	6.15	0.11	0.00
38. Khengjang	3.16	3.41	3.63	2.84	13.55	8.62	0.33	5.38
39. Lukhambi-I	10.31	10.52	9.02	10.56	7.26	11.26	6.65	16.06
40. Awangkhul-I	2.00	0.00	1.98	3.21	4.15	6.21	1.37	4.07
41. Awangkhul-II	6.05	7.21	6.05	6.26	3.87	6.16	2.31	10.00
42. Irong	5.08	6.10	5.50	6.15	4.12	4.38	1.76	10.23
43. Sangphen Khullen	9.15	6.31	6.82	7.21	6.56	9.81	0.55	15.84
44. Noney	3.16	2.00	4.18	3.26	1.28	4.18	0.22	4.51
45. Tupul-I	9.70	7.76	7.37	10.53	7.29	9.26	1.65	14.96
46. Tupul-II	7.56	5.20	6.93	8.25	6.73	8.16	2.31	10.90
47. Lukhambi-II	9.62	6.19	8.69	9.26	7.61	10.16	6.72	10.56

Table 6.2. Range and Mean values of lime requirement of different methods and their correlation with standard LR method.

Method	Lime Requirement (t ha^{-1}) Range	Mean	Correlation coefficient
Shoemaker *et al.*	0.00-16.55	05.63	0.8548**
Woodruff	0.00-14.18	04.92	0.8478**
Brown and Cisco	0.76-10.67	05.40	0.8729**
Pratt and Bair	0.43-15.87	06.29	0.8324**
Brown	1.28-13.55	08.05	0.4046**
Peech	2.45-28.32	13.17	0.5137**
Kamprath	0.00-07.98	01.91	0.6409**
Laboratory incubation	0.00-23.53	8.32	

** represents significant at 1% level.

presented in tables 6.1 and 6.2. The lime requirement by these methods ranged between 0 and 16.55, 0.43 and 15.87, 0 and 14.18, 0.76 and 10.67, 1.28 and 13.55, 2.45 and 28.32, 0 and 7.98 and 0 and 23.53 t $CaCO_3$ ha^{-1} respectively. The mean value of LR determined by the buffer methods of Shoemaker *et al.*, Woodruff, Brown and Cisco and Pratt and Bair were in a close range of 4.92-6.29 t ha^{-1} but lower than the reference LR. The mean LR determined by Brown was very close to the reference LR. However, the mean LR value by Kamprath method was too low (1.91 t ha^{-1}) and that by Peech *et al.* was the highest (13.17 t ha^{-1}).

6.2.2. Assessment of Suitability of Buffer Methods for LR Determination

Laboratory incubation method is very time consuming and combursome. As such, it can not be used for testing the LR of the soils as a routine method. Therefore, it is necessary to test the rapid buffer methods for their suitability for LR determination of these soils. This was achieved by correlating LR values determined by different methods with those by laboratory incubation method (Table 6.2). The SMP, Woodruff, Brown and Cisco and Pratt and Bair LR values had very high positive correlation with reference LR (r = 0.8548**, 0.8473**, 0.8729** and 0.8324** respectively). Sharma and Tripathi (1989) also reported high degree of correlation coefficient with Pratt and Bair, SMP and Woodruff methods with reference LR for some Indian soils. Brown, Peech and Kamprath LR were also positively correlated with reference LR but the magnitude of correlation was of lower degree (r=0.4046**, 0.5137** and 0.6409** respectively).

SMP, Woodruff, Brown and Cisco and Pratt and Bair buffer methods were almost equally effective for LR determination of these soils and were superior to those of Brown, Peech or Kamprath. Brown and Cisco buffer method having highest degree of correlation was adjudged to be the best buffer method for LR determination of these soils.

6.2.3. Relation between LR and Soil Properties

The results of simple correlation studies of soil properties with lime requirement are given in table 6.3. Organic carbon, exchangeable and extractable Al^{3+} had significant positive correlation with LR values. Mclean *et al.* (1965) explained the relationship between

Table 6.3. Coefficients of correlation (r) between lime requirement and soil properties

Soil properties	Lime requirement methods	
	Laboratory incubation	New Woodruff buffer method
pH	-0.6116**	-0.6905**
Organic carbon	0.5089**	0.4576**
Exchangeable Al	0.5957**	0.6321**
Extractable Al	0.7367**	0.6429**
Base saturation	-0.4867**	-0.5626**
ECEC	-0.3548*	-0.4302**
Exch. $Ca^{2+} + Mg^{2+}$	-0.4551**	-0.5378**
(△ pH X OC)	0.8455**	
(△pH X Clay)	0.4758**	

** represents significance at 1% level

Table 6.4. Correlation (r values) between lime requirement and different forms of CEC

Forms of CEC	Lime requirement
Neutral salt CEC	-0.3638*
pH dependent CEC	0.5176**
pH dependent CEC due to OM	0.1726
pH dependent CEC due to Al, Fe	0.7661**
Total CEC	-0.1521
ECEC	-0.3548*

* and ** represent significance at 5% and 1% level respectively.

Table 6.5. Correlation coefficients between different forms of acidity and lime requirement method

LR Method	Different Forms of Acidity				
	Total acidity	pH dependent acidity	Exchangeable acidity	EB-H^+ acidity	EB-Al^{3+} acidity
Shoemaker et al.	0.4974**	0.3597*	0.5875**	0.4443**	0.6359**
Woodruff	0.5434**	0.3769**	0.5965**	0.3082*	0.3278*
Brown and Cisco	0.5609**	0.4505**	0.5447**	0.3071*	0.5156**
Pratt and Bair	0.4902**	0.3548*	0.5817**	0.4102**	0.5870**
Brown	0.0321	-0.0816	0.1683	0.2708	0.1987
Peech *et al.*	0.1575	0.0506	0.1588	0.0660	0.1717
Kamprath	0.5186**	0.2598	0.8003**	0.5501**	0.8703**
Laboratory incubation	0.6239**	0.5209**	0.5646**	0.4696**	0.5530**

LR and organic carbon content of the soils due to the fact that greater is the organic matter, more will be the accumulation of acidic cations on the exchange sites of organic matter. Organic matter chelates the cations in the forms not readily displaced by ordinary exchange sites but reacts with lime on addition. The exchangeable and extractable Al^{3+} contribute to the exchangeable and pH dependent acidities respectively and are, therefore, directly correlated with the lime need of the soils (Table 6.3). The relationship of exchangeable and extractable Al^{3+} with LR is in confirmity with the findings of Sharma and Tripathi (1989).

Soil pH, base saturation, ECEC and exchangeable Ca^{2+} + Mg^{2+} were negatively correlated with LR. pH dependent sites on organic matter and clay showed significant direct correlation with reference LR. Association of pH dependent sites on organic matter with reference LR was of higher degree (r = 0.8455**) than those on clays (0.4758**). This may be due to more contribution of organic matter towards pH dependent CEC in these soils. The importance of pH dependent sites on organic matter in determining the LR has also been professed by Pionke *et al.* (1968). Lime requirement had direct correlation with pH dependent CEC and pH dependent CEC due to Al/Fe. However, it showed negative correlation with neutral salt CEC and ECEC (Table 6.4).

6.2.4. Correlation between Different Forms of Acidity and Lime Requirement

The data on correlation (r values) between different forms of soil acidity and lime requirement as estimated by different methods are presented in table 6.5. It is evident that the lime requirement determined by Shoemaker *et al.*, Woodruff, Brown and Cisco and Pratt and Bair methods was significantly correlated with all kinds of soil acidities. LR determined by Peech and Brown methods did not show any correlation with either forms of soil acidity which again confirms nonsuitability of these methods for these soils. Kamprath LR had very high correlation with exchangeable acidity and EB-Al^{3+} acidity (r=0.8003** and 0.8703** respectively) as it is based on the neutralization of exchangeable Al^{3+}. Reference LR determined by incubation method also showed significant high correlation with all forms of soil acidities.