ffective upto 3 cm. The least effective oil of *E. alba* ould inhibit the test organism upto 1cm only Table 3).

Result of the pot experiment revealed that all e essential oils used as well as formaldehyde were ble to control the damping-off disease of tomato and illi. Essential oils of *O. canum* and *C.lanceolatus*, owever, were much better than other chemicals used. Table 4 and 5).

The present study clearly indicates the ssibility of effective exploitation of higher plants the management of damping-off disease of tomato d chilli.

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Lime requirement methods for lateritic soils of Orissa

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Abstract : The lime requirement of fourteen acid soils from Orissa as determined by calcium carbonate incubation method showed significant correlation with pH, product of increase in pH value due to liming and the organic matter content, clay content, exchangeable aluminium and exchange acidity but not with organic matter content or cation exchange capacity. Four lime requirement (LR) methods were evaluated regarding their suitability to these soils. Except Peech's method, the lime requirement as determined by the laboratory methods showed highly significant correlation with that obtained by $CaCO_3$ incubation. The New Woodruff did slightly better than Woodruff and SMP in estimating lime requirement and hence the New Woodruff may be recommended for adoption in routine soil testing work. ***(Key words : Lime requirement, Lateritic soils)***

Lateritic region soils of Orissa are acidic and the productivity of the crops is affected severely. Judicious application of lime is essential for the management of these soils. Laboratory procedure using various buffer solutions for rapid determination of lime requirement was developed by Woodruff (1948), Shoemaker *et. al.* (1961), Peech *et. al.* (1962) and Brown and Cisco (1984) but there seems to be no universally suitable and acceptable procedure for determining the lime requirement of acid soils. In the present study, an attempt has therefore been made to investigate the suitability of a few LR methods already used in many laboratories and to find out the effect of different soil properties in LR recommendation in acid lateritic region soils of Orissa, as very little information is available in this regard.

Materials and Methods

In the lateritic tract of Orissa one catena around Badchana and Tangi P.S. area in Cuttack district of Orissa was selected for the present investigation. In this catena three pedons were studied, one in the upland, second in the middle of the slope and the third at the bottom of the slope in the upper valley. The physicochemical properties of the soils are reported in the Table 1.

Samples of the soils were thoroughly mixed in glass beakers (in triplicate) with varying quantities of calcium carbonate corresponding to 0.8, 1.6, 3.2, 4.8, 6.4, 8.0, 9.6 and 12.8 cmol(+) kg^{-1}. These were incubated at room temperature at approximately field moisture capacity for one month; thereafter the samples were air-dried and pH was determined. From the pH vs lime (added) curve, the amount of lime needed to attain pH 7.0 was obtained. The estimate of lime requirement was put in terms of cmol(+)kg^{-1} instead of the traditional Mg of $CaCO_3$ per hectare furrow of the soil. 1 cmol(+)kg^{-1} is equivalent to 1.12 Mg $CaCO_3$ per hectare. Beyond one month of equilibration, the change in pH was negligible. Diagnostic lime requirement for the soil was determined according to the following standard procedures : barium chloride-triethanolamine at pH 8.0 (Peech 1965) and buffer methods (Woodruff, New Woodruff and SMP) outlined by Brown and Cisco (1984). Relationships were established amongst the lime requirement assessment methods also with different physicochemical characteristics of the soils following standard statistical methods.

Results and Discussion

Lime requirement by the $CaCO_3$ incubation and other diagnostic methods

Lime requirements (LR) are generally determined for the plough layer, in which lime can be incorporated. However, acidity in the subsoil is also important because it restricts root development and hence limits the potential for crops to absorb water and nutrients (Farina and Chanon 1988; Ritchey *et. al.* 1980).

Lime requirement of the various soil profiles as determined by the $CaCO_3$ incubation and other diagnostic methods are indicated in Table 2. It is evident from the data in Table 2 that various methods showed a great disparity in the lime requirement value of a particular soil. The lime requirement determined involved equilibration with $CaCO_3$ incubation as well as buffer salt solutions which reacted with various fractions of the acidity and gave widely different values. The estimate of lime requirement (LR) using the different methods were put into terms cmol(+)kg^{-1} as a common basis of comparison instead of the traditional Mg of $CaCO_3$ per hectare furrow of the soil.

On the basis of the mean lime requirement values by different methods, the pedons for all these methods except that of $CaCO_3$ incubation are arranged in order as Pedon B - mid-upland > Pedon C - lowland upper valley > Pedon A - upland. Thus the similar sequence of pedons observed for different diagnostic methods of lime requirement suggests the intimate relationship of various methods of lime requirement with each other.

Irrespective of pedons, grand mean of lime requirement by different methods as expressed in cmol(+)kg^{-1} was in the the order: Peech 7.5 > SMP 5.7 > New Woodruff 4.5 > Woodruff 4.4 > incubation 1.95.

Correlation between lime requirement by $CaCO_3$ incubation method with various soil factors

Correlations between several soil factors with lime requirement by $CaCO_3$ incubation method are presented in Table 3. The pH of the soil measured in water had a significant negative correlation with lime requirement. The pH value, no doubt, is one of the major factors on which the amount of base required to neutralise the acidity should depend, but more important are the degree of base saturation and soil buffering. This result is in close agreement with those reported by Sharma and Tripathi (1989) and Dadhwal and Tripathi (1986). The lime requirement decreased linearly with the soil pH. Soil pH is the most common reference for the measurement of the degree of soil acidity and lime requirement is defined on the basis as the amount of liming materials which must be applied to a soil to raise its pH from an initial acid condition to a desired value, supposed by sufficient for optimal plant growth. With this usage, soil pH is considered an intensity factor and the total acidity is a capacity factor so that lime requirement depends essentially on the capacity factor with pH serving as an indirect reference value. Although pH is a well-defined electrochemical measurement for solutions, it lacks chemical significance in aqueous soil

Table 1. Physicochemical properties of soils

Location	Horizon	Depth (cm)	pH(1:2:5) water	EC dSm⁻¹ (1:5) water	Organic matter (%)	Mechanical separates(%) Sand	Silt	Clay	C.E.C.	Exchange able Aluminium	Exchange acidity
									Cmol(+)kg⁻¹		
Pedon A					Loamy mixed hyperthermic udic ustochrept						
Upland	A	0 - 10	5.2	0.34	0.95	75.5	6.6	17.8	8.0	0.07	9.9
	B	10 - 34	5.5	0.06	0.77	63.3	8.8	27.9	8.8	0.10	11.3
	C	34 - 55	5.9	0.07	0.77	67.0	10.1	22.8	8.0	0.03	6.8
Mean			5.5	0.16	0.83	68.6	8.5	22.8	8.3	0.07	9.3
Pedon B					Fine loamy mixed hyperthermic udic rhodustalf						
Mid-upland	A	0 - 10	4.7	0.09	0.74	54.6	7.5	37.8	12.0	0.92	15.2
	B_1	14 - 32	4.9	0.06	0.72	49.9	7.5	42.5	14.2	0.94	14.8
	B_{21t}	32 - 50	5.2	0.01	0.72	48.6	17.1	34.3	11.8	0.15	12.2
	B_{22t}	50 - 88	5.4	0.07	0.64	46.4	21.5	32.2	11.2	0.10	9.9
	B_{23t}	88 - 120	5.2	0.01	0.52	52.1	21.3	26.6	8.5	0.04	9.3
	C	120 - 150	5.2	0.10	0.43	51.3	22.8	25.4	7.8	0.07	7.8
Mean	5.1	0.06	0.63	50.5	16.3	31.1	10.9	0.37	11.5		
Pedon C					Fine loamy mixed hyperthermic typic plinthaqualf						
Lowland upper valley	A	0 - 15	5.3	0.08	0.48	52.9	19.9	27.2	8.5	0.45	10.1
	B_{21t}	15 - 36	4.8	0.09	0.69	67.6	10.8	21.5	7.2	0.38	9.9
	B_{22t}	36 - 67	5.1	0.07	0.62	57.9	18.4	23.7	8.3	0.61	8.0
	B_{23t}	67 - 95	5.1	0.05	0.46	57.3	17.0	25.7	8.0	0.64	8.0
	B_{24t}	95 - 150	5.1	0.05	0.34	51.0	18.0	31.0	7.8	0.40	9.9
Mean			5.1	0.07	0.52	57.3	16.8	25.8	7.9	0.49	9.2

Table 2. Lime requirement by incubation and other diagnostic methods

Location	Horizon	Depth (cm)	Cmol(+)kg⁻¹				
			Incubation	SMP	Wood ruff	New Wood ruff	Peech
Upland	A	0 - 10	1.4	4.9	5.0	5.0	3.1
Pedon A	B	10 - 34	0.7	5.5	4.3	4.0	6.2
	C	34 - 55	0.6	5.2	3.0	2.5	6.2
Mean			0.9	5.2	4.1	3.8	5.2
Mid-upland	A	0 - 14	4.0	8.4	5.5	6.0	8.3
Pedon B	B_1	14 - 32	4.3	6.8	5.5	5.5	10.4
	B_{21t}	32 - 50	1.6	5.4	4.5	4.5	5.2
	B_{22t}	50 - 88	0.8	5.6	4.0	4.0	10.4
	B_{23t}	88 - 120	1.4	5.9	4.0	4.0	8.3
	B_3	120 - 150	0.8	5.3	3.8	4.0	9.4
Mean			2.2	6.2	4.5	4.7	8.7
Low-land	A	0 - 15	1.9	3.5	4.0	4.0	7.3
Upper valley	B_{21t}	15 - 36	3.4	6.9	4.7	5.5	6.3
Pedon C	B_{22t}	36 - 67	2.2	5.5	4.0	4.5	7.3
	B_{23t}	67 - 95	2.0	5.3	4.5	5.0	7.3
	B_{24t}	95 - 150	2.2	5.6	4.5	4.0	9.4
Mean			2.3	5.4	4.3	4.6	7.5
Grand Mean			2.0	5.7	4.4	4.5	7.5

suspensions (Bache 1988; Sposito 1989). Nevertheless almost all characterizations for soil fertility purposes rely on pH so that it is the most frequently performed chemical measurement on soil.

Organic matter did not significantly correlate with lime requirement. This appears unusual since the organic matter content influences the lime requirement by providing the positively charged hydrogen ions through hydrolysis. It is to be noted however that there was not a wide range in organic matter values among the soils used.

The relationship between LR and the product of the increase in pH value due to liming and the organic matter content, that is (pH at which LR was calculated - initial soil pH) × organic matter gave a significant correlation with $r = 0.57$ significant at 5% level. The result is important since lime requirement of acid soils can be evaluated from the pH and organic matter content which are routinely estimated in all soil testing laboratories. It is to be admitted, however, that this will be true only when exchangeable aluminium is low, since its contribution in lime requirement has not been taken into account. This is in agreement with the findings of Keeney and Corey (1963) and Roy and Dolui (1974).

Clay per cent in soil was significantly related to lime requirement. Such correlation is expected since clay being an important colloidal constituent in most soil, should contribute a significant share to the buffer capacity and lime requirement of acid soils.

Cation exchange capacity was not significantly correlated with lime requirement. This needs experimentation with a large number of soils to conclude whether or not the relationship is valid.

A very close correlation was found between exchangeable aluminium and lime requirement. The role of exchangeable aluminium is closely tied up with the pH since at low pH (less than 5.0) aluminium occupies a lot of the base unsaturated charge sites and with the clay content because it is the clay minerals that supply the aluminium which remains exchangeable at the low pH. This follows from that fact at low pH when exchangeable Al^{3+} bounds, soil organic matter has no negative charge (Coleman *et.*

Table 3. Correlation between lime requirement by $CaCO_3$ incubation method and other soil factors

Soil factor	Value of r	Regression equation
pH	- 0.84**	Y = - 3.4X + 19.53
i) Organic matter	0.08	
ii) (7.0 - original soil pH) x Organic matter	0.57*	Y = 1.93X - 0.25
Clay %	0.52*	Y = 0.09X - 0.60
CEC	0.47	
Exchangeable Aluminium	0.88**	Y = 3.27X + 0.81
Exchange acidity	0.68**	Y = 0.33X - 1.41

* Significant at 5% level. ** Significant at 1% level. N.B. Y = Lime requirement, X = Soil factor

Table 4. Correlation between lime requirement by $CaCO_3$ incubation and other diagnostic lime requirement methods

Diagnostic LR methods	Value of r	Regression equation
New Woodruff	0.81**	Y = 0.60X + 3.29
Woodruff	0.79**	Y = 0.44X + 3.52
S.M.P.	0.68**	Y = 0.63X + 4.47
Peech	0.24	Y = 0.42X + 6.68

** Significant at 1% level. N.B. Y is diagnostic lime requirement and X the incubation LR

al. 1959). From experiments carried out in lime requirement studies of various acid soils. Kamprath (1967) concluded that liming recommendations should be based on the amount of exchangeable aluminium which is replaced by a neutral unbuffered salt such as KCl. Significant correlation between lime requirement and exchangeable aluminium found in the present study is thus explained.

With exchange acidity also lime requirement had a significant correlation. Exchange acidity in a soil is the sum total of replaceable hydrogen ions together with aluminium which hydrolyses to give rise to acidity and those others which may dissociate to contribute to acidity in the soil. Exchange acidity therefore should have a direct relation with the lime requirement, as has been obtained in the present case.

Relationship between LR as determined by $CaCO_3$ incubation and by other diagnostic method

The incubation method with $CaCO_3$ served as the reference method. Since this method is subject to some arbitary influences such as incubation time, moisture content, Co 2 levels and air pollutants, another method was sought to lend support to the validity of this method as the standard method. For this purpose, diagnostic lime requirements as determined by buffer methods of New Woodruff, Woodruff, SMP and Peech were used. The resulting values were then compared to those from the incubation method using correlation coefficient and regression equation.

The methods are listed in order of decreasing values for the correlation coefficient, (Table 4). It will be noted from regression analysis of the results obtained that the correlation coefficients (r) are relatively high for all methods, except Peech, involving the 14 soils of lateritic region of Orissa. However, r values for data from the SMP and Woodruff buffers are somewhat lower than that of New Woodruff method indicating higher predictability of New Woodruff method.

The regression coefficients utilized diagnostic lime requirement for each method as the dependent variable and the lime requirement from the incubation method as the independent variable. If all methods, including the incubation method, accurately reflect lime need, the intercept of the regression equations should be zero and the slope should be one. However, for all buffer methods the intercepts are substantially greater than zero and slopes much less than one.

The regression coefficients i.e., coefficients of x, reflect increasingly flatter slope of the lines for the various methods as follows : SMP > New Woodruff > Woodruff > Peech. The near-zero Y intercept of the line for data from the New Woodruff method would make this method ideal for adjustment to correct LR values indicating highly increased predictability of New Woodruff method using the regression equation.

Examination of the regression data of Table 4 indicates that the widely used New Woodruff method is probably the most satisfactory compromise between simplicity of determination and reasonable accuracy of values for soils of wide range in LR. The New Woodruff method appears to be the most promising vehicle for providing the desired LR method. To obtain the correct total amount of LR, the buffer indicated LR values simply have to be converted to actual values from $CaCO_3$ incubation by using the regression equation to solve for x (actual LR) in terms of y, i.e. $x = 1.1y - 2.95$. Relatively small errors of estimate make the New Woodruff an improve method, over Woodruff and SMP methods, of lime requirement determination in the soils of lateritic region in Orissa.

In conclusion for the present group of soils, the New Woodruff buffer did slightly better than Woodruff and SMP at estimating lime requirements as measured by $CaCO_3$ incubation and hence the New Woodruff procedure may be recommended for routine soil testing.

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