both cowpea cultivars is as high as 60 percent when chemical fertilizer is not applied in the second season (Fig. 28). But, with moderate rate of fertilization, the critical level of Al saturation is reduced considerably, and the 2 cowpea cultivars show differential response to soil acidity, i.e., 30 percent for VITA-4 and 43 percent for VITA-1 (Fig. 29).

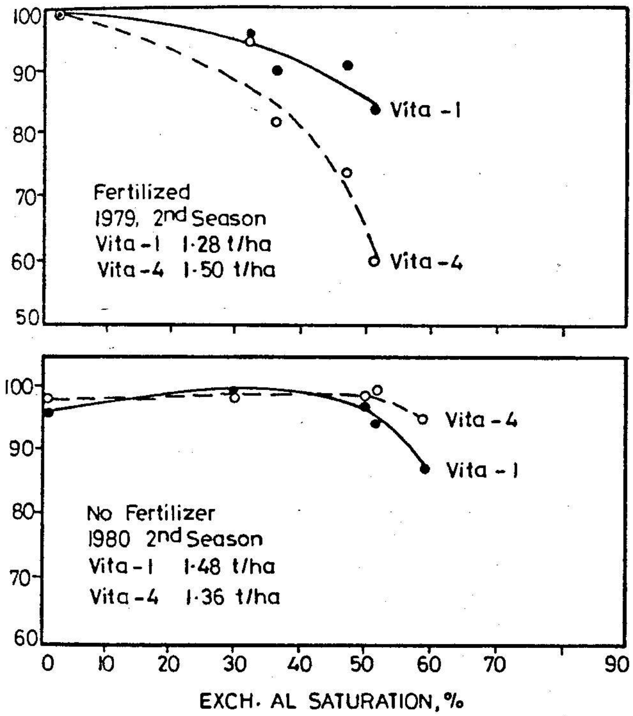

Fig. 29. Relative yield of cowpea as affected by percent exchangeable Al saturation in the soil.

Thus, liming is not necessary unless the exchangeable Al saturation of the soil has reached a level beyond the critical level of the crop to be grown. The critical level of exchangeable Al saturation in such coarse-textured, kaolinitic Ultisols depends to some extent upon the rate of fertilizer to be applied. The variability in the critical level of exchangeable Al saturation is because of the large increase in soluble Al in the soil solution after fertilization. Such effects have not been taken into account because soil sampling is normally done before planting. The effect of fertilizer salts on soil solution Al is shown in Table 38.

Residual effect of lime

Because lime is scarce in many parts of the humid tropics such as southeastern Nigeria, it is necessary to know what minimum rates of lime are needed for optimum crop production and what residual values may be expected. Results from an Onne trial are summarized as follows:

Relatively low rates of lime would be adequate to sustain crop yields under a maize/cowpea rotation system. It is interesting to point out that with balanced fertilization, respectable levels of maize and cowpea yields were maintained for 5 years in the unlimed plots (pH 4.3) where no severe Al toxicity effects were observed. Both cowpea cultivars nodulated well with indigeneous acid-tolerant rhizobia, and nodulation was only slightly reduced without liming.

Applied Ca in the form of lime leached readily from the surface layer, which is accompanied by the subsequent reappearance of exchangeable Al (Table 39). The increase in CEC values due to liming is also short-lived. The downward movement of Ca has little effect on the subsoil pH and exchangeable Al, suggesting that Ca leached in the form of neutral salts. The vertical distribution of exchangeable Ca in the field profile measured 3 years after lime application follows the theory and formulation of ion-exchange chromatography (Fig. 30). This is in agreement with a previous laboratory leaching study using undisturbed soil columns. Over 90 percent of the applied Ca may be found between 0-90 cm depths 3 years after liming because of the strong subsoil acidity (pH 4.3 and greater than 50 percent Al saturation). Recovery of the subsoil Ca, however, would require deep-rooting species tolerant to high exchangeable Al levels.

Moreover, because a high lime rate in the surface soil has little effect on the subsoil acidity, there would be no advantage of applying a rate of lime more than required to reach the exchangeable Al levels for the crop to be

Table 38. Concentration of Al in soil solution of a Ultisol (Typic Paleudult) as affected by fertilization (Onne, 1980).

	Soil pH (H_2O)	Exch. Al saturation %	Al in saturation extract ug/ml
Unfertilized	4.3	60	2.7
Fertilized and incubated 6 weeks at field capacity	3.9	46	17.1

Table 39. Changes in soil properties in the surface layer (0-15 cm) 5 years after lime application (IITA Onne substation, 1980).

Initial lime rate (1976) t/ha.	pH (H_2O)		Exch. Ca, meq/100g		Exch. Al, meq/100g		ECEC, meq/100g	
	Initial #	5 Yrs.	Initial	5 Yrs.	Initial	5 Yrs.	Initial	5 Yrs.
0	4.7	4.2	0.57	0.27	1.26	1.51	2.77	2.47
0.5	5.0	4.3	1.37	0.31	0.82	1.43	3.08	2.40
1	5.2	4.4	1.58	0.42	0.45	1.27	2.77	2.36
2	5.6	4.5	2.36	0.61	0.06	1.01	3.10	2.28
4	6.3	4.8	5.71	1.03	0.04	0.40	6.53	2.12

#Initial soil samples taken one month after lime application.