SOIL ACIDITY FACTORS AFFECTING MAIZE YIELD IN RHODESIA*

(Met opsomming in Afrikaans)

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Abstract

The importance of the soil acidity factors, aluminium toxicity, manganese toxicity, molybdenum deficiency and magnesium deficiency, as limitations to maize yields in Rhodesia is considered, and the relation to soil parent material is discussed.

Introduction

Field experiments on dryland maize in Rhodesia have shown that the soil parent material, and thus the soil type, determines the threshold value of soil pH at which increased yields are obtained with lime. Maize is tolerant of moderate soil acidity and it appears that the differences in response to lime is associated with the occurrence of various soil acidity factors: magnesium deficiency, molybdenum deficiency and manganese toxicity together with aluminium toxicity are the only important acidity factors affecting maize yields in Rhodesia.

Procedure

The methods of analysis used are as follows:

(1) Soil pH is determined electrometrically on 15 g soil shaken with 75 ml 0,01 M $CaCl_2$ for 1 hour.

(2) Soluble aluminium was determined in the filtrate from the 0,01 M $CaCl_2$ suspension for the pH determination. The aluminium method of Chenery (1955) was used.

(3) 'Exchangeable' aluminium was extracted with N $CaCl_2$ at pH 5,5 and determined by the aluminon method.

(4) Exchangeable bases and manganese were extracted with neutral N ammonium acetate and determined by atomic absorption spectrophotometer of flame photometer.

(5) Molybdenum was determined colorimetrically by a modified KCNS method after wet digestion (Madziva, unpublished data).

(6) Leaf samples were analysed by the normal methods of the Branch of Chemistry and Soil Science.

(7) Details of field trial procedure were given in previous reports (Grant, 1971).

Results and Discussion

On light-coloured soils, – pale grey, brown or yellow-brown, – derived from granite, triassic sands and some metasediments yields decrease when soils are strongly acid at pH 4,2 and less, and liming is recommended for maize if the soil pH is below 4,5. On the heavier reddish-brown and yellow-red soils derived from basic igneous rocks and some banded-ironstone complexes the threshold pH value is about 4,8 but response to lime has been obtained on some sites at pH 5,0; on red soils liming is therefore recommended to maintain soil pH at 5,2 or over. These groupings by pH range cover liming to correct the specific nutrient deficiencies, i e magnesium and molybdenum, in certain soils.

Aluminium toxicity

Reduction in yield when the soils are strongly acid, pH 4,2 or less, is ascribed to aluminium toxicity, and the crop response on liming is associated with a decrease in available aluminium resulting from the rapid rise in pH which occurs when lime reacts with moist soil. It appears that at pH values 4,5 and over the amount of soluble aluminium, extracted by 0,01 M $CaCl_2$, present in both the red and the pale coloured soils is negligible, (see Figure 1). A regression equation for the relation of soluble aluminium concentration (y) to the soil pH (x) calculated for samples of both groups of soil was $\log y = 8{,}48 - 1{,}94x$; at pH 4,5 the calculated aluminium concentration of the solution would be 0,6 ppm Al. The 'exchangeable' aluminium content (determined by extraction with N $CaCl_2$) was similarly related to soil pH on both red and pale-coloured soils, (see Figure 2).

The release of aluminium, which is primarily dependent on acidity, is not dependent on soil type. On the pale-coloured soils derived from siliceous parent material crop performance and the threshold pH value for liming are consistent with aluminium concentration occurring at varied pH; however, the response on red soils to liming at pH values of 4,8 and over, where the concentration of 'exchangeable' aluminium is low and soluble aluminium is negligible, must be atrributed to some other factor. It appears that the occurrence of manganese toxicity/molybdenum deficiency is responsible for reduced yields on the red soils in the mildly-acid pH range.

Manganese toxicity

The red clay-loam soils derived from basic rocks are rich in manganese, containing 0,3–0,5 per cent total Mn, and much of this is chemically active. There are marked differences

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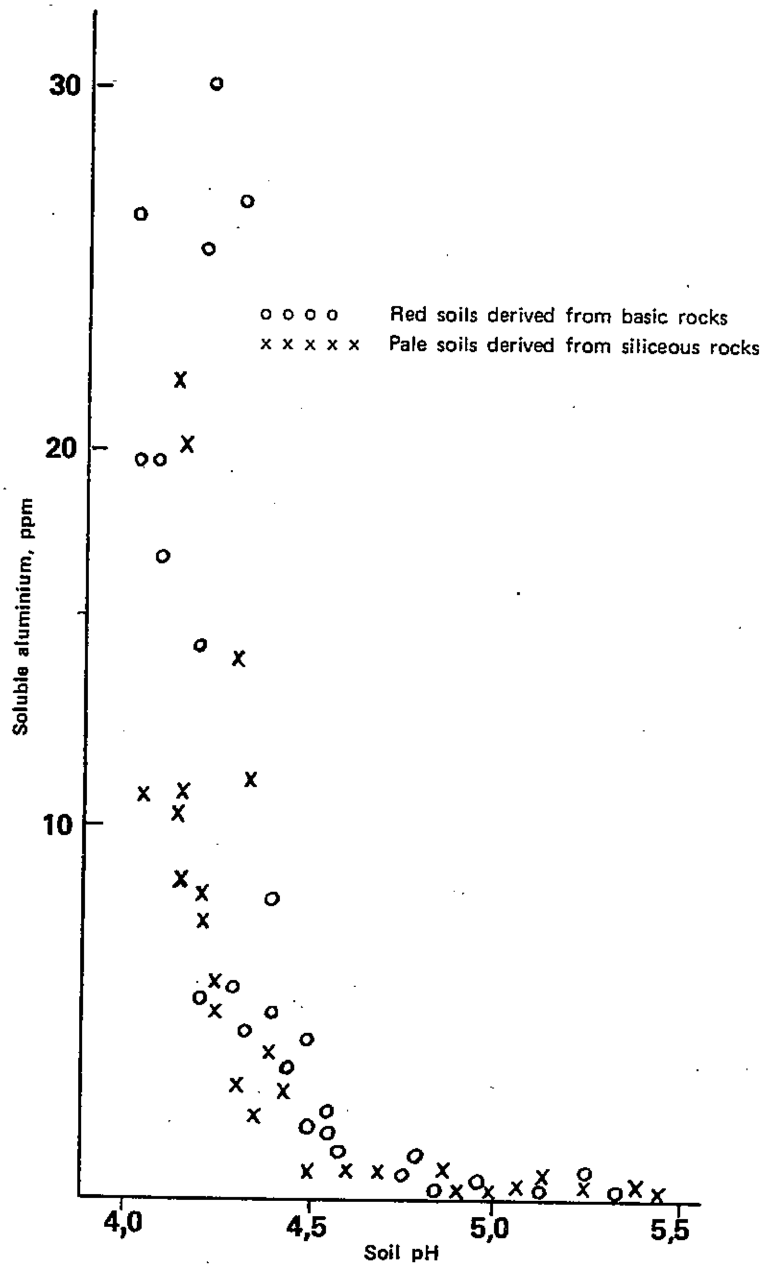

Fig 1 The relationship of soil pH and aluminium extracted by 0,01 M $CaCl_2$

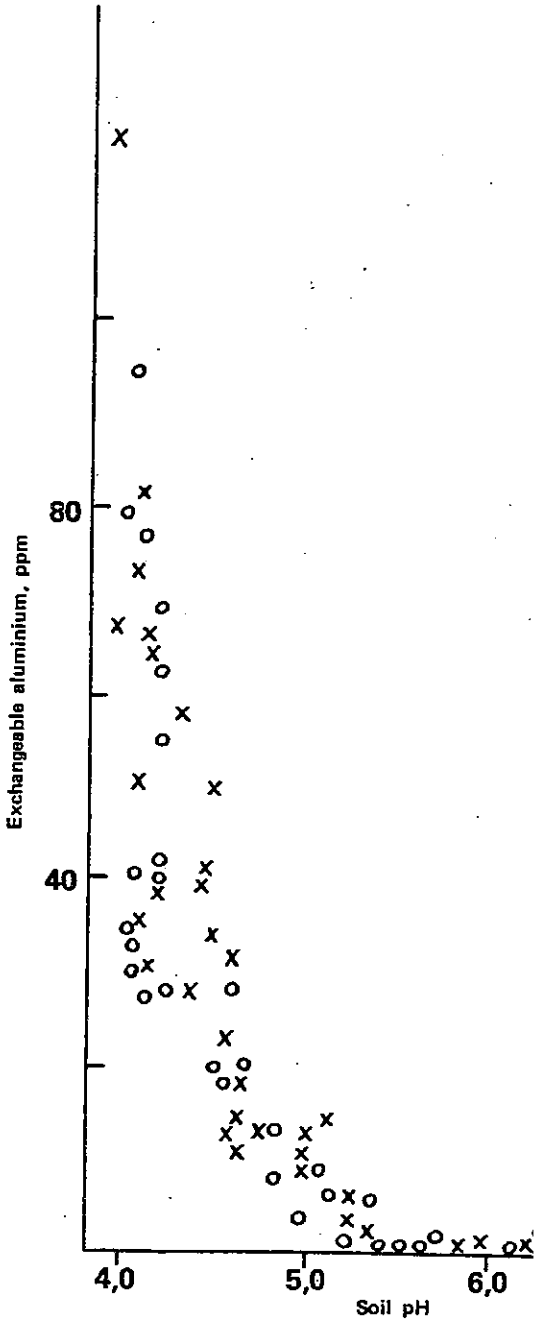

Fig 2 The relationship of soil pH and exchangea[ble] aluminium extracted by N $CaCl_2$

TABLE 1a *Manganese extracted in various fractions from red-brown sandy clay-loam derived from banded ironstones with epidiorite near Salisbury. (Exchangeable manganese was determined on samples as received, taken before and after the rains)*

	Manganese ppm					
	Total	Oxalate extract	Exchangeable at various dates			
			6/10	22/10	23/11	15/2
Site 0; pH 4,5	2700	2000	85	20	7	3
Site 0; pH 5,1	2700	–	63	10	4	1
Site K; pH 4,7	3600	2700	47	–	5	2

TABLE 1b *Changes during incubation in the exchangeable manganese content of a red-brown, sandy clay-loam with moisture at field capacity or saturation*

Days	Acid soil pH 4,2		Limed soil pH 5,4	
	Field capacity	Water-logged	Field capacity	Water-logged
0	143	143	98	98
4	30	275	14	262
8	6	375	2	327
12	2	405	1	370

TABLE 2 *Effect of liming on exchangeable manganese and manganese concentration in cob leaves*

Site and parent material	Lime t/ha	Soil pH	Exch Mn ppm	Leaf Mn ppm
Salisbury:				
Epidiorite with	0	4,6	85	100
banded ironstone	4	5,0	62	80
Concession:	0	4,6	22	195
Meta-sediment	4	5,7	6	160
Macheke:	0	4,7	16	56
Granite/dolerite	4	5,5	6	50
Gwebi:	0	4,9	7	90
Epidiorite	2	5,4	1	70
Rusape:	0	4,4	8	100
Granite	2,5	4,9	5	95

between the red and the pale-coloured soils in the amount of active manganese, for example extracted by Tamm's acid oxalate reagent; in one batch of samples the mean value for red soils derived from basic rocks was 1400 ppm Mn, for soils from granite and light-coloured meta-sediments was 120 ppm Mn and for soils from contact zones was 670 ppm Mn.

There is considerable difficulty in establishing a relationship between soil pH and any measure of available manganese because the latter varies (a) seasonally with the wetting of the soil after the long dry winter, (b) intermittently with short periods of water-logging or bursts of micro-biological activity and (c) with localised variations in chemical factors such as fertilizer phosphate, (see Table 1).

The hazard of Mn toxicity should be decreased by liming, since in general manganese availability and uptake by plants decrease as soil pH rises but the effect is not great in the normal soil pH range, (see Table 2).

It is notable that the manganese content of leaf samples at tasselling and also at four weeks old are less than the toxic levels reported in the literature and are no greater than the concentrations found in maize on granite sandveld where manganese toxicity is not expected (Table 2). The possibility of a manganese/molybdenum imbalance rather than a true manganese toxicity must therefore be considered.

Molybdenum deficiency

Marked symptoms of molybdenum deficiency have been observed when the maize is two or four weeks old on some acid red soils. In the field trials the affected plants frequently died so that the stand on acid plots was reduced. The manganese content of the young maize surviving at four weeks has been found to be 150–200 ppm Mn, which is not abnormally high. The surviving plants showed no symptoms at later stages, and at tasselling there was little difference in manganese or molybdenum contents of the leaves on acid or limed plots; loss of yield was related to reduction in plant and cob numbers more than to cob masses (see Table 3).

The effect of lime in increasing availability of molybdenum is well-known, and has been clearly demonstrated by the interaction of lime and molybdenum application on yellow-brown clay-loams on meta-sediments. (R Peacock, unpublished data; P D Tanner). These clay-loams, for example in the Glendale district, are thought to be inherently deficient in molybdenum without the complicating factor of manganese toxicity. Symptoms of molybdenum deficiency, death of young plants, and decreased yields have been recorded on acid plots. When molybdenum deficiency has been corrected by seed treatment or spraying there has been no additional response to liming (see Table 4).

Control yields were very highly significantly lower than treatment yields. The differences between treatment means were not significant by the Duncan multiple range test.

Magnesium deficiency

The correction of the remaining acidity factor, magnesium deficiency, may be considered more in terms of a fertilizer application than of liming practice since the small amount of dolomite commonly needed has little effect on soil pH. Magnesium deficiency occurs mainly on pale-grey, coarse-grained sands derived from granite after exhaustive cropping without application of magnesium carriers such as manure or lime. If the deficiency occurs on moderately acid soils, about pH 4,4, the curve for yield increase with increasing magnesian lime is exponential with only small responses with more than 30 kg Mg/ha, (see Table 5). Even smaller amounts of lime may be used when the dolomite is cupped into the planting hole. If the deficiency occurs in combination with aluminium toxicity on very highly acid soils, pH 4,2 or less, normal heavy dressings of lime must be applied to decrease acidity and eliminate aluminium and the use of a magnesium-rich lime ensures that the deficiency is corrected.

Conclusion

It may prove possible eventually, when the nutrient deficiencies and imbalances associated with soil acidity are separately corrected, to predict lime requirements solely on the aluminium toxicity hazard of the soil. At present however, the soil type and parent material must be considered in assessing the optimum pH range for maize and other crops.

TABLE 3 Effects of liming on acid red-brown clay-loam derived from dolerite near Marandellas

	Control	Limed
Lime applied, kg/ha	Nil	6000
Soil pH	4,60	5,60
Exch Mn, ppm	62	28
Leaf Mn, ppm	86	68
Leaf Mo, ppm	0,20	0,18
Yield, t/ha	5,32	6,92
Stand, plants/ha	21 900	30,000
Grain/plant,g	250	235

TABLE 4 Effect of lime and molybdenum on yield of maize on a yellow-brown clay-loam at Glendale

Molybdenum treatment	Grain yield in t/ha at different lime treatments		
	No lime Soil pH 4,6	2 000 kg lime/ha Soil pH 5,0	4 000 kg lime/ha Soil pH 5,3
Nil	7,09	7,76	8,37
On seed	7,79	8,04	8,37
Speed + spray	8,69	8,47	8,23

Standard error of mean of 4 plots = 0,30

TABLE 5 Effect of magnesian limes on magnesium status of acid granite sands

Lime applied kg/ha	Soil pH	Exch Mg me %	Leaf Mg %	Yield t/ha
Pale grey sand in Que Que T T L				
Nil	4,3	0,06	0,14	4,16
400 Mg Lime, (5% Mg)	4,5	0,11	0,16	4,59
400 Mg Lime + 800 calcite	5,2	0,12	0,19	4,75
Yellowish-grey loamy sand in Holdenby T T L				
Nil	4,0	0,04	0,05	1,26
2000 liming slag, (2% Mg)	4,8	0,25	0,15	3,50

Opsomming

GRONDSUURHEIDSFAKTORE WAT MIELIE-OPBRENGS IN RHODESIË BEÏNVLOED

Mielies aard in matige suur gronde en reaksies op kalk in Rhodesië is slegs verkry by pH-waardes (gemeet in 1:5 suspensie met 0,01 M $CaCl_2$) van 5,0 en minder op rooi klei- en kleileemgronde, en van minder as pH 4,5 op vaal en bruin sand en sanderige leem. Uit veldproefresultate en grondontledings van die afgelope paar jaar is aluminiumtoksisiteit, mangaantoksisiteit, magnesiumgebrek en molibdeengebrek geïdentifiseer as die faktore wat òf afsonderlik òf gesamentlik die opbrengs verlaag. Die verband tussen grondtipe en dominante suurheidsfaktore is bepaal.

Aktiewe aluminium word slegs in toksiese hoeveelhede vrygestel as die pH laer as 4,3 is, met die gevolg dat aluminiumtoksisiteit self 'n belangrike suurheidsfaktor is; dit kom hoofsaaklik op ferralitiese sandleem en sandkleileem voor waar bekalking om ander suurheidsfaktore by hoër pH-waardes te elimineer, nie nodig is nie. Magnesiumgebrek ontstaan deur onafgebroke gewasverbouing op sand- en sandleemgronde by pH-waardes van 4,5 en laer. Bekalking met 200–300 kg/ha dolomitiese kalk, wat voldoende is om die magnesiumgebrek reg te stel, is onvoldoende vir die bevordering van gesonde mieliegroei as die pH te laag is.

Die mangaanhoudende rooigronde wat van basiese stollingsgesteentes en metasedimente afkomstig is kan mangaan by pH-waardes van laer as 5,0 vrystel. Rooigronde word dus bekalk om 'n pH van bokant 5 te handhaaf om te verseker dat toksiese mangaan nie gedurende die droë winterperiode of tydens versuiptoestande vrygestel word nie.

Hoewel dit aangeneem word dat die invloede van mangaantoksisiteit en molibdeengebrek op die oes nou gekoppel is, is daar aanduidings dat daar op sekere bruin leemgronde, afkomstig van skalies en grint, 'n absolute molibdeengebrek is sonder dat oormaat mangaan teenwoordig is. Op hierdie gronde is bekalking om die toeganklike mangaan te verlaag, nie nodig nie; toediening van 'n klein hoeveelheid molibdeen sal gesonde mieliegroei by pH 4,5 verseker.

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