THE RELATIONSHIP BETWEEN EXCHANGEABLE POTASSIUM AND SOIL MOISTURE IN SOME IMPORTANT NATAL SOILS

(Met opsomming in Afrikaans)

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Abstract

To assess the significance of K release/fixation fourteen important Natal soils were analysed for K at several stages during the air-drying process and after oven drying. Air drying resulted in some K release in all the soils examined, the greatest release being equivalent to 0,20 me%. Oven drying resulted in further release in the case of eight soils, but to varying degrees of reversion in the other six. The suggestion is made that release/fixation phenomena should receive closer attention in fertility evaluation studies designed to establish critical soil K levels.

Introduction

The phenomenon of K release/fixation in soils on drying is well known. It may not be important under field conditions, since soils do not normally dry to the extent necessary to cause release or fixation (Leubs, 1954; Leubs, Stanford & Scott, 1956). However, it is probably of considerable significance in soil fertility evaluation. There are soil testing laboratories in the United States which go to considerable lengths to inhibit K release/fixation in soil samples received for analysis, either by the use of polar liquids with a low vapour pressure (Scott, Hanway & Stickney, 1957) or by prevention of drying. Nelson (1967) has, in fact, described the use of moist samples as 'one of the greatest breakthroughs in soil testing in recent years'. Soil-test laboratories in South Africa have paid little attention to this problem, due largely to the absence of K responses in many major cropping areas. Where K responses do occur, however, relation of soil test values to crop requirement has not proved easy. In recent years this has resulted in considerable research activity into alternative soil test procedures. Surprisingly, few attempts have been made to evaluate the influence of drying South African soils on the predictive value of established techniques. In other parts of the world air drying soils has been observed to result in both release (Reitemeier, Brown & Holmes, 1951; Leubs *et al*, 1956; Ahmad & Davis, 1971) and fixation (Wood & De Turk, 1942; Attoe & Truog, 1946; Vasco da Gama, 1964) of exchangeable K. McEwan & Matthews (1958) concluded that release or fixation depended on the degree of K saturation. Matthews & Sherell (1960) subsequently showed that an inverse relationship held for Ontario soils. These workers found that regardless of soil type, release of K to the exchangeable form was likely to occur with drying if the percentage K saturation was less than 1,11 and that fixation was likely to occur if the percentage saturation was greater than 1,11. Dowdy & Hutcheson (1963) suggested that release was likely to occur when the level of exchangeable K was $< 0{,}5$ me% and that fixation was likely at values $> 0{,}5$ me%. Vasco da Gama (1964) demonstrated both release and fixation on air drying eight Portuguese soils, but was unable to establish a causal relationship.

Several workers have shown that, depending on moisture conditions, various states of equilibrium may be attained among the different forms of K in soils, each characterised by a particular level of exchangeable K. In certain soils reversion of K to the nonexchangeable form may occur on rewetting dried soils (Leubs, 1954; Hanway & Scott, 1957). Both fixation and release appear to be manifestations of reversible reactions involving particular types of K-bearing minerals. Reactions which may occur simultaneously (De Membrum & Hoover, 1958; Bates & Scott, 1964). It appears that mica-like zones may be responsible for K release, and vermiculite for K fixation (Rich, 1968).

The objects of the work reported here were to determine the significance of release/fixation in a range of important Natal soils and to attempt to establish a causal relationship.

Material and methods

Topsoil (0–15 cm) samples were collected from 14 profiles representing a wide range of important Natal soils (see Table 1). Soil samples were collected in the field-moist state, thinly spread in a constant temperature room ($20° \pm 1°C$) and allowed to dry. After air drying sub-samples were oven dried at 110°C. At hourly intervals during the air-drying process and after oven drying duplicate samples were collected and analysed for K by shaking with neutral $\underline{N}$ NH_4OAc for 30 minutes using a 1:10 soil to solution ratio. K was determined flame spectrophotometrically in filtered extracts. Moisture determinations were conducted simultaneously on other samples. The exchangeable K content, expressed on an oven-dry basis, was then plotted against moisture percentage at the time of sampling. After thorough air drying cation exchange capacities were determined by alkali distillation of soil leached with neutral $\underline{N}$ NH_4OAc. Clay analyses were performed on dry soil using the hydrometer method. Quantitative vermiculite and mica analyses were conducted on air-dried soil using the wet chemical method of Alexiades & Jackson (1966). All analyses were conducted in duplicate.

In an attempt to isolate a causal relationship for observed K release/fixation, the degree of release/fixation was correlated with exchangeable K content of moist soil, C E C, percentage K saturation of the exchange complex, clay content, and mica and vermiculate content, both individually and jointly.

Results and Discussion

Most of the soils examined released significant quantities of exchangeable K on air drying (see Figs 1 & 2). In seven of these soils considerable further release occurred on oven drying (Fig 1). Six soils, however, exhibited varying degrees of reversion on oven drying (Fig 2).

Attempts to identify a causal relationship were unsuccessful. None of the parameters considered were significantly correlated to the degree of release/fixation observed. (See Table 1).

Notwithstanding the evidence presented by Matthews & Sherell (1960), Dowdy & Hutcheson (1963) and others, there did not appear to be any simple relationship between percentage K saturation of the exchange complex and the degree of release/fixation (see Table 1). Certainly, the critical K levels which have been reported in the literature (Matthews & Sherell, 1960; Dowdy & Hutcheson, 1963) did not appear to be operative in this study. Several of the soils under examination had percentage K saturation values considerably in excess of 1,11 and exchangeable K contents greater than release (see Table 1). It is probable that the presence of pH-dependent charge resulted in C E C values somewhat higher than values which would have been obtained with the use of unbuffered solutions, but lower C E C values would have increased rather than decreased

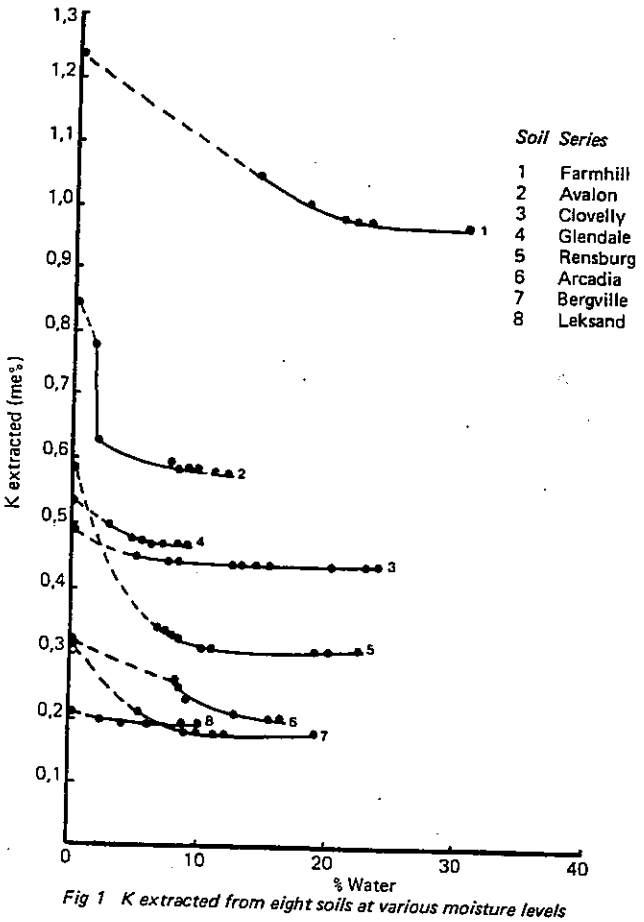

Fig 1 K extracted from eight soils at various moisture levels

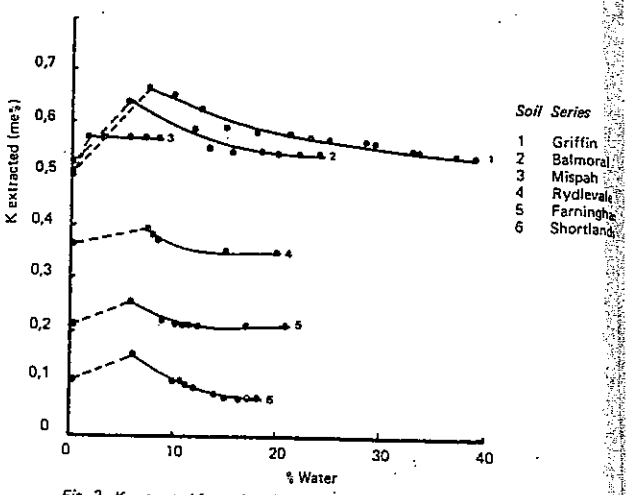

Fig. 2 K extracted from six soils at various moisture levels.

the discrepancies. This does not preclude the validity of some such relationship, however, as it was observed in preliminary work that soils of the same series consistently exhibited greater release at lower K saturations.

Similarly, although it is reasonable to assume that the principle source of released K is mica and that vermiculite would provide a 'sink' for K fixation, no relationship appeared to exist between release/fixation and mica or vermiculite content in this study (see Table 1). It is possible that a more complete separation and quantitative analysis of the clay fraction would have proved more meaningful. Furthermore, alkali extractable amorphous aluminosilicates are present in relatively large amounts in the clay fraction of especially highly-weathered Natal soils (Le Roux, 1973). It has been shown that synthetic amorphous aluminosilica gels can fix potassium against replacement by common alkaline earth cations (van Reeuwijk & de Villiers, 1968). A marked increase in capacity to fix K was shown to result from drying gels prior to K–saturation. Drying presumably increased the rigidity of channels in the gel structure which would otherwise restrict the passage of larger hydrated cations. This finding could partly explain potassium fixation and release in soils occurring under alternate moist and dry conditions.

The fact that five of the soils studied exhibited both release and fixation (see Fig 2) lends support to the theory that both may occur simultaneously (De Membrum & Hoover, 1958, Bates & Scott, 1964). The degree of nett release or fixation probably depends on several independent and related factors. It is probable that a generally applicable causal relationship will only be established by joint consideration of a greater number of parameters than has hitherto been used.

To the soil fertility evaluator a causal relationship *per se* is of secondary importance. It is the effect of release/fixation on the predictive value of soil tests and the establishment

TABLE 1 *Selected physical and chemical properties of several Natal soils and the effects of drying on exchangeable K*

Soil Series	Soil Form	% Mica	% Vermiculite	% Clay	C E C (pH 7)	K Content, moist (me %)	% K saturation	% K Release, air dry	% K Release, air dry
Balmoral	Hutton	4,39	3,35	49,3	16,3	0,54	3,31	20	−2
Farningham	Hutton	0,50	1,77	17,9	20,6	0,21	1,02	20	0
Griffin	Griffin	2,06	1,36	22,6	26,0	0,54	2.08	23	−7
Farmhill	Griffin	1,17	7,61	46,7	17,1	0,97	5,67	8	27
Clovelly	Clovelly	3,99	5,52	35,6	14,9	0,44	2,95	2	10
Glendale	Shortlands	2,58	1,06	28,7	9,9	0,47	4,75	7	13
Shortlands	Shortlands	1,20	1,93	38,6	18,7	0,08	0,43	106	40
Mispah	Mispah	2,71	0,53	13,2	4,7	0,57	12,13	2	−12
Leksand	Avalon	1,30	0,68	10,5	3,1	0,19	6,13	5	10
Avalon	Avalon	0,75	0,89	11,2	5,7	0,58	10,18	35	45
Bergville	Avalon	4,12	4,80	52,2	15,0	0,18	1,20	16	80
Rensburg	Rensburg	2,31	2,27	39,9	30,9	0,31	1,00	17	97
Rydlevale	Arcadia	1,60	1,89	41,1	34,0	0,35	1,03	13	4
Arcadia	Arcadia	1,74	1,78	44,2	34,6	0,20	0,58	30	60

of satisfactory threshold values that is of primary importance. Evaluation of the effects of K release/fixation on plant availability of K was not an objective of this study. However, the significant shifts in K equilibrium observed, suggested that efforts currently being made to calibrate important soil-crop systems in South Africa may be frustrated by failure to give due consideration to this phenomenon.

Opsomming

DIE VERBAND TUSSEN UITRUILBARE KALIUM EN GRONDVOG IN SOMMIGE BELANGRIKE NATALSE GRONDE

Om die betekenis van K-vrystelling/vaslegging te bepaal is veertien belangrike Natalse gronde vir K ontleed by verskillende stadia tydens die lugdrogingsproses en ná oonddroging. Lugdroging het by alle gronde geringe K-vrystelling veroorsaak, met 'n grootste vrystelling van 0,20 me%. Oonddroging het verdere vrystelling by agt van die gronde veroorsaak, maar variërende grade van hervaslegging by die ander ses. Dit word voorgestel dat die vrystelling/vaslegging verskynsel meer aandag geniet wanneer navorsing in verband met die evaluering van vrugbaarheid en die vasstelling van kritiese grond-K-waardes gedoen word.

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