CATION STUDIES ON A TYPICAL SOIL OF THE NATAL MIDLANDS

By R. LUDORF and P. CHANNON

Abstract

1. The changes in cation content of a ferrallitic soil were determined and studied over a period of two years.
2. Highly significant results were obtained with calcium which gave the major responses to both soil, percolate and crop content.
3. The antagonism of calcium to magnesium and potassium are well illustrated.

Introduction

In the soil survey carried out of the Tugela Basin many of the soils occurring in the Natal midlands were encountered and recognised.

From publications of G. D. Darby[1], J. J. van der Eyk[2], C. N. Macvicar[3] and J. M. de Villiers[4] the need for further study was clearly indicated.

The soil chosen for this work was the Balmoral series, a leached ferrallitic soil type derived from dolerite. The soil is dark reddish brown (5 YR/3/3) in colour, is friable and has a moderately developed fine sub-angular blocky structure and is a silty clay in texture. The base saturation (34%) of the topsoil is higher than is normally expected for this series and is due to organic matter accumulation, the immediate subsoil, however, falls into the regular pattern for the Balmoral series (<20%).

The design of the experiment is a 4^3 factorial, using improved Mitscherlich pots as micro-lysimeters. The pots were filled with 6,000 gms. air-dry soil.

TABLE 1

The weight of nutrients used at the various levels

Treatments	Amount in Lbs/Morgen	Grms. Per Pot	Indication
$CaCO_3$ (Added as a solid) .	0	0	Ca_0
	2,000	3.3274	Ca_1
	8,000	13.3096	Ca_2
	18,000	29.9466	Ca_3
$MgCO_3$ (Added as a solid) .	0	0	Mg_0
	1,000	1.6637	Mg_1
	2,500	4.1593	Mg_2
	4,000	6.6548	Mg_3
K Cl (Dissolved in distilled water)	0	0	K_0
	50	0.0832	K_1
	200	0 3327	K_2
	450	0.7487	K_3

Basic nitrogen and phosphorus
N $H_4H_2PO_4$ at 308 lbs/morgen
= 1,000 lbs super/morgen
= 83 lbs P/morgen
Also = 180 lbs $(NH_4)_2SO_4$/morgen
= 37.5 lbs N/morgen

During the growing season all water requirements were derived from rain except in time of drought, when it was supplemented with de-ionized water to approximately 75 per cent of the total water holding capacity of the soil.

All percolates were measured and analysed for Ca, Mg and K.

The lucerne was cut at 10% flowering stage, and dried, weighed and analysed for Ca, Mg and K.

The soil was analysed before the study and after every season for pH, exchangeable Ca, Mg, K and total exchange capacity.

The following methods were used to determine the cations:

The soils were leached with neutral N Ammonium Acetate buffered at pH 7. The exchangeable Ca, Mg, and K were determined on these filtrates with a Beckman DU Flame photometer. The pH was determined with a Beckman model N pH meter.

The percolates of the pots were determined directly with the same flame photometer.

The plant material was ashed and then digested with 1 + 4 HCl and taken up in a volumetric flask with distilled water. The cation determinations were made on these solutions.

Discussion

The effect of calcium, magnesium and potassium on the soil

(*a*) *Calcium content*

Applied calcium significantly increased the calcium content of the soil during the period of the experiment. The calcium content at the first sampling was much higher than that of the second, as shown in Table 2.

Further it is interesting to note that approximately 50% of the available calcium in the soil was lost irrespective of the amount applied as shown in Table 3.

(*b*) *Magnesium content*

Higher rates of magnesium application increased the magnesium content of the soil. Analysis results of the first sampling compared with those of the second showed a lower magnesium content in the second sampling, Table 2.

(*c*) *Potassium content*

With increasing amounts of applied calcium, the potassium content of the soils decreased significantly. This was more marked at the second sampling, as shown in Table 2.

TABLE 2

The effect of calcium, magnesium and potassium on the soil

	Calcium content in me%			Magnesium content in me%			Potassium content in me%			Total exchange capacity in me%
	Effect of Ca	Effect of Mg	Effect of K	Effect of Ca	Effect of Mg	Effect of K	Effect of Ca	Effect of Mg	Effect of K	Effect of Ca
First Sampling	Ca0=2.02	Not significant	Not significant	Not significant	Mg0=2.36	Not significant	Ca0=0.57	Mg0=0.53	K0=0.46	Ca0=14.76
	Ca1=3.16				Mg1=2.24		Ca1=0.52	Mg1=0.52	K1=0.45	Ca1=14.37
	Ca2=7.04				Mg2=3.02		Ca2=0.45	Mg2=0.49	K2=0.50	Ca2=14.75
	Ca3=11.49				Mg3=3.86		Ca3=0.44	Mg3=0.46	K3=0.57	Ca3=15.74
Second Sampling	Ca0=1.02	Not significant	Not significant	Not significant	Mg0=1.55	Not significant	Ca0=0.59	Not significant	Not significant	Not significant
	Ca1=1.59				Mg1=1.98		Ca1=0.52			
	Ca2=3.15				Mg2=2.51		Ca2=0.38			
	Ca3=6.00				Mg3=3.13		Ca3=0.21			

TABLE 5

The effect of calcium, magnesium and potassium on the leachates

	Calcium in milligrams leached			Magnesium in milligrams leached			Potassium in milligrams leached		
	Effect on Ca	Effect on Mg	Effect on K	Effect on Ca	Effect on Mg	Effect on K	Effect on Ca	Effect on Mg	Effect on K
First Season	Ca0= 44.93	Not significant	Not significant	Ca0= 85.16	Mg0= 56.53	Not significant	Not significant	Not significant	K0= 93.35
	Ca1= 60.08			Ca1= 78.64	Mg1= 85.99				K1= 99.96
	Ca2=191.50			Ca2=111.86	Mg2=107.04				K2=110.03
	Ca3=315.82			Ca3=106.28	Mg3=132.38				K3=124.68
Second Season	Ca0= 0.09	Not significant	K0=10.39	Ca0= 9.98	Mg0= 2.78	K0= 2.92	Ca0=45.88	Mg0=33.12	K0=21.06
	Ca1= 1.18		K1=15.01	Ca1= 5.49	Mg1= 5.84	K1= 4.46	Ca1=34.98	Mg1=31.56	K1=23.27
	Ca2= 6.31		K2=12.35	Ca2= 3.43	Mg2= 8.08	K2= 6.71	Ca2=17.19	Mg2=26.07	K2=29.49
	Ca3=58.58		K3=28.39	Ca3=11.03	Mg3=13.22	K3=15.83	Ca3=13.94	Mg3=21.24	K3=38.18

Application of increasing amounts of magnesium significantly decreased the potassium content of the soil at the first sampling but not at the second sampling, Table 2.

As might be expected increase in applied potassium raised the soil potassium content significantly at the first sampling (Table 2) but not at the second.

(d) Total exchange capacity

Calcium was the only element that had any significant effect on the T.E.C. of the soil at the first sampling, and caused an increase in the T.E.C. This increase although very small did achieve significance (Table 2).

(e) pH

For the first nine weeks the pH values were taken *in situ* at three weeks intervals and averages of these readings were taken and analysed biometrically, and the following was found:

TABLE 3

Mean calcium content at the various levels of application

	Calcium content of soil in me%		
	First Sampling	Second Sampling	Loss of Ca
Ca0	2.02	1.02	1.00
Ca1	3.16	1.59	1.57
Ca2	7.04	3.17	3.87
Ca3	11.49	6.00	5.49

TABLE 4

The effect of calcium, magnesium and potassium on the pH of the soil

	Effect of Calcium	Effect of Magnesium	Effect of Potassium
pH *in situ* . . .	Ca0=5.57	Mg0=5.88	Not significant
	Ca1=5.76	Mg1=6.02	
	Ca2=6.14	Mg2=6.11	
	Ca3=6.74	Mg3=6.21	
pH of Second Sampling	Ca0=5.10	Mg0=5.13	Not significant
	Ca1=5.16	Mg1=5.31	
	Ca2=5.29	Mg2=5.35	
	Ca3=5.69	Mg3=5.45	
pH of First Sampling	Ca0=5.54	Not significant	Not significant
	Ca1=5.53		
	Ca2=5.78		
	Ca3=6.16		

Applied calcium increased the pH significantly.

Applied magnesium increased the pH significantly.

Calcium increased the pH of the soil at both samplings.

Magnesium increased the pH of the soil at the second sampling only (Table 4).

The effect of calcium, magnesium and potassium on the leachate

(a) Calcium content

As might be expected. The calcium content of the leachates increased significantly with increase in calcium applied to the soil. Although the first season was only six months, calcium lost during this period was much higher than that lost during the second season of 12 months. Table 5.

Potassium applied significantly increased the calcium content of the leachate. Table 5. This increase took place in the presence or absence of added calcium.

(b) Magnesium content

During the first season the magnesium content of the leachates increased with increase in applied calcium. During the second season the magnesium content of the leachates decreased with increased calcium application, but increased again at the highest level. Table 5.

During both seasons applied magnesium significantly increased the magnesium leached. The total magnesium leached during the first season was much higher than that of the second season (Table 5).

Applied potassium significantly increased the amount of magnesium leached at all levels of magnesium and all levels of calcium.

TABLE 6

The effect of calcium, magnesium and potassium on the yield

	Effect of Calcium	Effect of Magnesium	Effect of Potassium
First cut . . .	Ca0=5.12	Mg0=5.56	Not significant
	Ca1=8.29	Mg1=7.26	
	Ca2=7.84	Mg2=7.52	
	Ca3=7.00	Mg3=7.91	
Second cut . . .	Ca0= 6.36	Mg0= 9.61	Not significant
	Ca1= 9.43	Mg1=10.24	
	Ca2=12.45	Mg2=10.58	
	Ca3=14.44	Mg3=12.25	
Third cut . . .	Ca0= 5.78	Mg0=14.79	Not significant
	Ca1=13.11	Mg1=15.65	
	Ca2=23.77	Mg2=18.80	
	Ca3=27.75	Mg3=21.17	

Yields is given in gm/pot wet material.

TABLE 7

The effect of calcium, magnesium and potassium on the plants, composition

	Calcium content in me%			Magnesium content in me%			Potassium content in me%		
	Effect of Ca	Effect of Mg	Effect of K	Effect of Ca	Effect of Mg	Effect of K	Effect of Ca	Effect of Mg	Effect of K
First cut . .	Ca0=13.38 Ca1=23.79 Ca2=38.72 Ca3=48.88	Mg0=33.50 Mg1=33.13 Mg2=31.43 Mg3=26.72	Not significant	Ca0=27.52 Ca1=22.36 Ca2=16.76 Ca3=14.47	Not significant	Not significant	Ca0=50.04 Ca1=46.11 Ca2=45.23 Ca3=48.87	Mg0=49.85 Mg1=47.81 Mg2=46.56 Mg3=46.03	K0=46.15 K1=45.61 K2=46.08 K3=51.68
Second cut .	Ca0=16.79 Ca1=24.55 Ca2=31.84 Ca3=39.59	Not signficant	Not significant	Ca0=34.63 Ca1=20.18 Ca2=11.69 Ca3= 9.65	Not significant	Not significant	Ca0=40.05 Ca1=40.86 Ca2=40.40 Ca3=35.98	Not significant	Not significant
Third cut . .	Ca0= 3.57 Ca1= 7.31 Ca2=20.17 Ca3=27.14	Not significant	Not significant	Ca0=14.73 Ca1=13.87 Ca2=11.69 Ca3= 9.86	Mg0=11.45 Mg1=11.72 Mg2=12.54 Mg3=14.44	Not significant	Ca0=62.50 Ca1=58.71 Ca2=51.95 Ca3=49.41	Mgo=57.06 Mg1=56.81 Mg2=55.38 Mg3=53.33	K0=53.33 K1=54.91 K2=55.51 K3=58.82

(*c*) *Potassium content*

Applied calcium significantly decreased the potassium content of the leachates during the second season, as shown in Table 5.

Applied magnesium decreased the potassium content of the leachates during the second season whether or not potassium was also applied (Table 5).

Applied potassium significantly increased the potassium leached. The figures of total potassium leached during the first season are much higher than those for the second season, as shown in Table 5.

The only significant interaction noted was between calcium and magnesium during the second season. Although applied magnesium in general decreased the amount of potassium leached, this effect was diminished with increasing levels of applied calcium (Table 5).

The effect of calcium, magnesium and potassium on the yield

In general calcium increased the yield significantly. This increase was not so marked for the first cut, but the yield increased at all levels of calcium with each cut (Table 6).

Magnesium applied in increasing amounts increased the yield significantly during all three periods of growth. The results of each cut were successively higher in turn, as shown in Table 6.

The effect of calcium, magnesium and potassium on the plant composition

(*a*) *Calcium content*

Calcium application increased the calcium content of the lucerne significantly during all three periods of growth, but the figures were lower at nearly all levels of calcium application for each consecutive period, as shown in Table 7.

Applied magnesium decreased the calcium content in general, but this effect was only significant during the first growth period (Table 7).

(*b*) *Magnesium*

The application of increasing amounts of calcium caused a considerable decrease in the magnesium content of the plants during all three periods of growth (Table 7).

Applied magnesium increased the magnesium content of the plants significantly during the growth period between the second and third cut only (Table 7).

(*c*) *Potassium*

Applied calcium decreased the potassium content significantly during all three periods of growth, but the results from the analyses of the three cuts vary greatly, as shown in Table 7.

In general magnesium had a depressing effect on the potassium content of the plants but this effect was only significant for the results of the first and third cuts (Table 7).

Applied potassium increased the potassium content of the plants in general. This effect was significant for the first and third cuts only, and the results of the first cut were lower than those of the third cut (Table 7).

Summary

The addition of an element as a nutrient, as might be expected, raised the soil content of that element in all cases. The effect of an added element on the others present was small and not significant, except in the case of potassium, where a general decrease of the amount of potassium present in the soil was noticed.

Increasing amounts of applied calcium caused an increase in calcium and magnesium leached, but a decrease in potassium. When the amount of magnesium applied was increased, the amount of magnesium leached increased, the potassium leached decreased and no effect was noticed on the calcium.

Potassium applied in increasing amounts increased the amounts of calcium, magnesium and potassium leached.

Calcium and magnesium increased the yield significantly.

The addition of an element as a fertilizer raised the content of this element in the plants. Calcium and magnesium decreased the content of each other in the plant material, potassium having no effect on the content of the others.

References

Darby, G. D. (1954). The Characteristics of South African Wattle Soils.

van der Eyk, J. J. (0000). The Soils of the Tugela Basin.

Macvicar, C. N. (1962). Soil Studies in the Tugela Basin.

de Villiers, J. M. (1962). A Study of Soil Formaton in Natal.

Mr. Lintner: Each soil series presents its own problems and difficulties, and Mr. Ludorf is to be congratulated on presenting a paper which takes into consideration not only genetic problems, but also the important chemical and plant physiological features associated with each of the series. It is essential that all factors should be taken into consideration when interpreting experiments such as those presented in this paper, in order that a true explanation can be obtained.

There is nothing contradictory about this paper, but I was particularly interested to note the speed with which calcium, in particular, disappears from the soil. The effect of calcium on the uptake and retention of other minerals bears out standard knowledge.

This paper is a valuable contribution and the writer is to be commended on his approach to the problems of soil fertility, particularly in his alignment of research with soil series.

Mr. du Toit: The application of lime apparently increased the yield enormously. I am referring to your graph on the board, which is not in your paper. No increase in the first year, slight in the second but an enormous increase in yield in the third year.

Mr. Ludorf: This was a pot experiment and I cannot say that the same results would be found in the field, although there would be some increase.

Mr. Coignet: When the potash is high in the soil, sugarcane will absorb large amounts. This is known as luxury consumption and leads to difficulties in juice processing in the factory and is reflected in the molasses. In the case of many Natal Estates soils, where the fields are very high in calcium due to previous heavy applications of carbonatation filter cake, has a lower content of potash been noted in the molasses?

Mr. du Toit: Natal Estates molasses is no lower in potash than, for instance, Tongaat or Illovo, despite the enormous applications of lime on the Natal Estates sandy soils.

Dr. Sumner: A healthy plant has a certain composition to enable it to grow and give a good yield. The only effect any particular nutrient in the soil will have will be on yield and not significantly on the plant composition.