STUDIES ON LEACHING LOSSES OF SULPHUR FROM PUMICE SOILS, YELLOW BROWN LOAMS AND SANDS

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AT the 1963 New Zealand Grassland Association Conference, I. L. Elliott gave a short description of a new laboratory technique for determining the ability of soils to retain nutrients against leaching. At that time, only a very few soils had been examined and since no comparable evidence from field trials was available, the value of the test was largely a matter of conjecture. The technique was applied to measure the ability of soils to retain potassium, phosphorus and sulphur. This paper is particularly concerned with sulphur. Following the examination of a larger number of samples, some clear patterns of leaching losses are now emerging and a better position exists to predict where sulphur deficiency is likely to arise.

Description of the Laboratory Technique

This has been described and illustrated elsewhere (Hogg, 1962) so a brief mention here will suffice. Soils to be studied are packed into polythene cylinders. Potassium chloride (potash) and superphosphate at the rates of 2 cwt and 4 cwt per acre respectively are then placed on the surface of the soil. Distilled water applied to the top, percolates through the soil and the solutions are collected for analysis. This leaching is then followed by a drying phase, the cycle of leaching and drying being repeated weekly for a month. The total application of water is equivalent to 16 in. rainfall of which 4 in. is collected in drainage, the balance evaporating in the drying phase. By analysing the water draining through, it is possible to compare weekly and total losses of nutrients from various soils.

It is found that only rarely does phosphate appear in the drainage; there is some potassium, but the main nutrient leaching out, and probably the most important, is sulphur.

Leaching Lasses of Sulphate from Yellow Brown Pumice Soils

In the field, the predominant phosphatic fertilizer used on these soils is superphosphate and at the rates applied (normally 2 to 3 cwt per acre) it has been generally assumed that sulphur needs would in consequence be met automatically. However, occasional responses to spring applications of gypsum have been reported on pastures topdressed with superphosphate the previous autumn, suggesting considerable leaching of sulphate from the superphosphate during the winter period. It was decided to examine a number of pumice soils by the laboratory leaching technique for their ability to hold sulphate.

A summary of the results from 41 pumice soils examined is set out in Table 1. The total amount of sulphate leached during the 4-week period has been calculated and expressed as a percentage of that applied. In all cases, controls were run and the sulphate from these deducted from that leached from the superphosphate-treated soil. The resulting values thus represent sulphur leached from the applied superphosphate.

TABLE 1: SULPHATE LOSSES FROM PUMICE SOILS
SUMMARY OF RESULTS

% *Applied S leached*	*No. in Group*	% in *Group*
<30	nil	nil
30 -39	5	12
40 -49	3	7
50 -59	4	10
60- 69	8	20
70 -79	7	17
80 -89	7	17
90-100	7	17

Of forty-one pumice soils examined (representing 29 soil types) nearly three-quarters showed high sulphate leaching losses, i.e., 60% or more of the sulphate present in the superphosphate was leached out in the 4-week period. Highest leaching losses tended to occur in the younger and coarser soils.

Evidence from Field Trials

To determine whether appreciable losses of sulphur were actually occurring in practice, M. R. Toxopeus laid down eight field trials with gypsum in spring, 1964, on pumice

soils under pasture which had been topdressed with 2 to 3 cwt of super-phosphate per acre the previous autumn. Soils selected were those showing high leaching losses of sulphate in the laboratory test. In every case, there was a response to the spring-applied gypsum.

The response could in theory be due to either calcium or sulphur or both. However, numerous analyses from both grasses and clovers from pastures on the pumice soils have consistently shown normal calcium levels but frequently low sulphur levels. Further, a field trial on Galatea sand, a coarse pumice soil, comparing 3 cwt superphosphate with 3 cwt superphosphate + 20 lb elemental sulphur has shown a clear response to the additional sulphur, so that it may be concluded with some certainty that the gypsum responses found are due to the sulphur and not the calcium.

Leaching Losses of Sulphate from Yellow Brown Loams

These soils, which are best represented in those areas where the landscape is mantled with fine volcanic ash — e.g., Taranaki, Waikato and the Bay of Plenty (C. G. Vucetich, pers. comm.) are more weathered than the pumice soils, and, as will be shown in Table 2, behave quite differently in their ability to retain sulphate.

Only seven samples, each representing a different soil type, have so far been examined by the leaching procedure. Results are shown below.

TABLE 2: SULPHATE LOSSES FROM YELLOW BROWN LOAMS

Soil Type	*Locality*	*% Applied S Leached*
Horotiu sandy loam	Hamilton	3
Mahia fine sandy loam	Mahia	37
Waitekauri sandy loam	Tauranga	nil
Tirau sandy loam	Tirau	6
Egmont black loam	New Plymouth	nil
Stratford sandy loam	Stratford	2
Te Anau brown loam	Te Anau	nil

With the exception of the Mahia fine sandy loam, sulphate losses are very small indeed and the explanation probably lies in the kind of clay mineral present. Fieldes (1955) distinguishes two types of the clay mineral allophane, A and B. Leaching experiments with allophane A, present in the yellow brown loams, indicate that this material retains sulphate strongly and this may be the dominating factor in

sulphate retention by the yellow brown loams. It is interesting to note that the one South Island yellow brown loam examined, the Te Ana.u brown loam, falls into line.

As far as the writer is aware, no cases of sulphur deficiency have been reported from field trials on yellow brown loams which have had normal topdressings with superphosphate.

Investigations on Raw Peat

Leaching studies on raw peat showed very high sulphate losses (85 to 100% of that applied). Subsequent field trials by F. C. C. H. van der Elst have confirmed the laboratory findings.

Leaching Losses of Sulphate from Sands

Sands would not be expected to retain sulphate and studies in the laboratory show high leaching losses from samples so far examined. Typical figures are shown in Table 3.

TABLE 3: TYPICAL SUPHATE LOSSES FROM SAND

Soil Type	*% Applied S Leached*
Te Kopuru sand	85
Patea sand	91
Whananaki sand	100
Pinaki sand	100

Only on the Te Kopuru sand have there been any extensive field trials and these have failed to support the laboratory findings, no advantage being found from sulphurized superphosphate. There are two possible reasons for this:

(1) In the laboratory, one looks only at samples taken from the 0 in. to 3 in. profile. It is possible that in some cases the sulphate may be carried down and retained by soil in a lower horizon where it can be tapped by plant roots.

(2) The Te Kopuru sand trials at Dargaville are fairly close to the coast and prevailing winds from the west may provide enough sulphate for adequate plant growth.

In a small number of Patea sand samples analysed in the laboratory, 0 in. to 3 in. soil samples have shown low sulphur tests. However, in view of experiences at Dargaville, one would be rash to predict that sulphur responses are probable, and suitable field trials need to be laid down to settle the question.

Forms of Sulphur

In several field trials in the South Island, Walker (1964) has found gypsum to be superior to elemental sulphur, when applied at equivalent rates of sulphur. On the pumice soils, the opposite situation appears to apply, elemental sulphur being superior to gypsum. Workers have often been puzzled by the fact that soil tests on samples taken six months after laying down a rates-of-gypsum trial have shown uniformly low sulphur levels. Field trials with rates of gypsum on pumice soils have in the main been unsatisfactory, responses from even the highest rates having faded after the lapse of a few months.

Recently a laboratory leaching study with rates of gypsum (Cooper and Hogg, 1966), was made on Waipahihi sand, a pumice soil with little ability to retain sulphate. In this study, which was carried out over a six-weeks period, it was found that losses of sulphate were proportional to the amounts applied. Results are shown in Table 4.

TABLE 4: SULPHUR LEACHED FROM GYPSUM TREATMENTS

Rate per Acre (cwt)	*Fraction (mesh)*	*% Applied S Leached*
1	16 -30	94
	30 -60	100
	60-120	100
2	16 -30	94
	30-60	96
	60-120	98
4	16 -30	96
	30-60	99
	60-120	96

Losses were unaffected by particle size of gypsum over the ranges 16 to 30, 30 to 60 and 60 to 120 (B.S.S.) except in the first leaching. It is suggested that on soils not retaining sulphur and where rainfall exceeds about 40 in. per year, field trials with finely ground gypsum, aiming at the determination of optimum sulphur dressings, are of little value and may even be misleading. Trials incorporating elemental sulphur (finely ground flowers of sulphur) are much more likely to give reliable information in such cases. Since there is a time lag of 6 to 12 months before elemental sulphur reacts with the soil (because of the necessity for bacterial oxidation), field trials with this fertilizer should not be judged too hastily and should run for a minimum of two years.

REFERENCES

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DISCUSSION

Hnve you considered the effect of phosphate on sulphur retention?

One would expect a soil with a long phosphate topdressing history to have a lower sulphate retention than the same soil where little phosphate had been applied. The only evidence we have is from the examination of two local soils, Hamilton clay loam and Horotiu sandy loam. On the Hamilton clay loam, 3% tons of superphosphate applied over a 17 year period appeared to reduce sulphate retention (3% and 22% of the applied sulphur being leached from the no-phosphate and high-phosphate plots respectively). However, a similar examination from low- and high-phosphate (5 tons superphosphate in 10 years) plots on Horotiu sandy loam-a yellow brown loam -showed no difference in the amount of sulphur leached, this being very small in both cases.

In the yellow brown loams, did Mr Hogg find that sulphur was retained in the union form in the soil?

I think the sulvhur would mainly be retained by these soils as sulphate. It is unlikely that much of the SO, would be converted from an inorganic to an organic form over the 4-week period of the laboratory test.

All the experiments have been carried out by leaching the soil samples with the equivalent of 16 in. *of rain over a* four-week *period. Have any experiments been carried out with less rainfall and would rainfall intensities alter results in anv wav?*

With the technique used, the equivalent of 4 in. of rain per week results in 1 in. or 50 ml passing through the soil. This is the minimum amount of solution required for analyses, so smaller applications have not been tried. Higher water applications would probably increase the amount of sulphate appearing in the first and second weeks but would have little effect on the total amount leached over the 4-week period. Too high a leaching rate can result in dispersion of the clay fraction with the subsequent appearance of colloidal material in the percolate. The method adopted is empirical and its main value lies in comparing losses from various soils under standardized conditions.

Has Mr Hogg any views as to how sulphur can be retained more efficiently in the soil?

COMMENT (G. L. BANFIELD): Is not the use of elemental sulphur the answer to the question? Sulphur oxidation to sulphate is slow. This gives the plant a better chance to utilize sulphate as oxidation proceeds and reduces the risk of large leaching losses.

COMMENT (T. E. LUDECKE) : Professor T. W. Walker and A. F. R. Adams have looked into this problem in a 35-m. rainfall area in the Rakaia Gorge and have found that very little sulphate is held by anion absorption, Work is at present under way with radioactive sulphate in an attempt to confirm this,