

Soil nutrient status of the Bay of Plenty region and the implications to pasture productivity and fertiliser requirements

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Abstract

The soil nutrient status of sheep and beef, and dairy farms in the Bay of Plenty region was examined using results from over 4700 soil samples analysed by MAF between 1988 and 1991. The proportion of farms in various soil test categories was determined and related (using known relationships) to the potential responsiveness of pastures to fertiliser nutrient additions. About 70% of farms had soil phosphorus (P) tests below optimum values, indicating that pasture production would be increased by addition of P fertiliser on these farms. Similarly, about 50% of farms had below-optimum levels of sulphur (S) and potassium (K). Pasture production on most farms was limited by more than one nutrient and a relatively high proportion of pumice soils had low levels of P, S and K. Pumice soils are prone to large leaching losses of added sulphate S and field experimental results indicated that elemental S (in sulphur superphosphate) was more efficient at increasing pasture production on these soils than sulphate S (in superphosphate). Soil test data was also used to indicate that about one-third of sheep and beef, and one-half of dairy farms were suitable for use of slow-release reactive phosphate rock (RPR) as a source of P, as indicated by soil pH ≤ 6.0 and MAF fertiliser P requirements at or above maintenance levels.

Keywords soil test, fertiliser requirement, phosphorus, sulphur, potassium, slow-release fertiliser

Introduction

Fertiliser use within the Bay of Plenty (BOP) region has fluctuated greatly during the past decade and was low during 1986-88. This is likely to have influenced productivity of farms where fertiliser use had decreased or stopped for a number of years (e.g. O'Connor *et al.* 1990).

Soil testing is the simplest and most cost-effective procedure for determining the requirements for major

fertiliser nutrients and lime to maintain or increase pasture production. In New Zealand, the MAF soil tests have been calibrated using a large number of field experiments. Thus the pasture responsiveness to addition of a fertiliser nutrient or lime is known for a given soil test level (Edmeades *et al.* 1984; Edmeades *et al.* 1988; Sinclair *et al.* 1985).

This paper reports soil test levels on almost 1500 sheep and beef (hereafter called sheep) and dairy farms in the BOP, and discusses their implications to pasture productivity relative to potential and to the applicability of various fertiliser forms.

Methods

A database of soil tests analysed by the MAF Soil Fertility Service between 1988 and 1991 for the BOP and North Island was compiled. Soil samples from the BOP had been submitted from an area encompassing Tauranga, Whakatane and Rotorua and included 1557 samples from 531 sheep farms and 3228 samples from 966 dairy farms.

Soils had been submitted for analysis by farmers, consultants (MAF and private) and fertiliser company representatives. They were analysed for pH, Olsen P, K, S, Ca and Mg (Comforth & Sinclair 1984).

Table 1 Optimum soil test values for sheep/beef and dairy farms. These are based primarily on achieving approximately 90 and 95% respectively of biological maximum production.

	Sheep/beef	Dairy
P ¹	15-20	25-30
S	7-10	6-12
K	6-6	8-10
Mg ²	7-10	9-12
pH	5.7-6.0	5.8-6.0

¹ Optimum is lower for low P retention soils and higher for high P retention (e.g. ash) soils.

² Optimum for pasture growth only.

For each farm type (sheep and dairying), soil test results were classified by soil type and the proportion of samples within specific ranges of soil test values

were obtained. These ranges of soil test values were related to the expected level of pasture productivity relative to the potential, using known relationships (Table 1; Comforth & Sinclair 1984; Edmeades *et al.* 1988; Sinclair *et al.* 1985). The suitability of slow-release fertilisers was also examined using soil data for reactive phosphate rock (RPR) and using research results for elemental S.

Results and Discussion

Soil analyses

Most samples from the BOP region were from yellow-brown pumice ('pumice'), recent and yellow-brown loam ('ash') soils (Table 2). A small proportion of samples was from dairy farms on organic ('peat') soils.

Table 2 Percentage of soils sampled from the Bay of Plenty between 1988 and 1991 with MAF test values below optimum.

Sheep and beef farms:						
Soil	No.	P<17	S<6	K<5	Mg<6	pH<5.6
pumice	975	87	70	52	12	14
ash	279	60	34	57	10	30
recent	171	30	41	12	0	8
all	1548	71	57	46	9	16
Dairy farms:						
Soil	No.	P<26	S<8	K<8	Mg<9	pH<5.7
pumice	2073	93	53	71	35	32
ash	246	61	12	50	9	38
recent	555	53	52	49	2	29
peat	216	55	25	88	6	36
all	3198	76	47	66	24	31

Table 1 summarises desirable optimum soil test levels based on field trial results and Table 2 identifies the proportion of farms in the BOP below optimum levels. Farms within these categories are likely to show increases in pasture production from addition of nutrient(s) in fertiliser.

Over all soils on sheep farms, P was the main nutrient limiting pasture production (about 70% below optimum soil P levels). About half of these soils had low S and K soil tests, while only a small proportion had below-optimum levels of Mg and pH. The relative importance of nutrients varied with soil type. The most obvious differences were a larger proportion of pumice soils low in P and S, few recent soils low in K, and a larger proportion of ash soils with low pH.

Dairy farms showed similar results to those for sheep farms, although a larger proportion of dairy farms were below optimum for K and a smaller proportion were below optimum for S. Potassium was

limiting on a larger proportion of peat soils on dairy farms than for other soil types.

In general, the proportion of farms below optimum soil test levels in the BOP was similar to that for the whole of the North Island (compare Tables 2 and 3). However, in the BOP there was a relatively higher proportion of samples with below-optimum soil P, S and K tests on sheep farms and below-optimum S tests on dairy farms. This was largely due to the high component of pumice soils in the BOP, which had lower P, S and K test values on average than most other soils.

Table 3 Percentage of soils sampled from the North Island between 1988 and 1991 with MAF test values below optimum.

Sheep and beef farms:						
Soil	No.	P<17	S<6	K<5	Mg<6	pH<5.6
pumice	2295	83	76	47	11	13
ash	2511	60	16	30	3	20
recent	705	22	37	16	2	15
all	11349	40	42	26	3	23
Dairy farms:						
Soil	No.	P<26	S<8	K<8	Mg<9	pH<5.7
pumice	2506	93	51	77	42	30
ash	7089	62	8	67	9	17
recent	1503	54	45	61	10	30
peat	1218	48	35	87	15	50
all	17385	65	26	67	13	24

Potential responsiveness to added nutrients

Table 4 indicates the potential increases in pasture production that can be expected for 3 categories of soil test values for the 3 major nutrients, and the proportion of farms in these categories. Farms in the first category for each nutrient are essentially in the 'development phase' of soil nutrient status. These farms are highly responsive (increase of 10-30% expected) and nutrient addition in fertiliser should be very profitable within the year of application (e.g. Ledgard *et al.* 1991; Roberts *et al.* 1991). although this may require an increase in stocking rate to ensure high utilisation of extra feed grown due to fertiliser. The second category is moderately responsive and nutrient additions should also be profitable in the short-term (1-3 years), particularly on dairy farms. The third category represents the 'maintenance phase' of soil nutrient status where responses to fertiliser addition are small (0-10%) and fertiliser is applied to sustain productivity. Thus, on sheep farms in this category the economics of P application must be considered in the longer-term with the 'break even' time for profitability being about 3-6 years (Clark *et al.* 1990). However, on dairy farms in this third category, fertiliser addition can

be economically worthwhile with it the year of application on intensively managed farms (Roberts *et al.* 1990).

Table 4 Percentage of farms in the Bay of Plenty within various soil test ranges categorised according to the expected responsiveness to nutrient addition in fertiliser.

Nutrient	Soil test values	Approx. increase in production (%)	% of farms sampled	
			Sheep	Dairy
P	<3	15	55	30
	13-17	10	15	20
	17-25	5		20
S ¹	<4	15	35	15
	4-6	10	30	25
	7-9	5		10
K	<3	15	10	10
	3-4	10	40	20
	5-6	5		40

¹ Sites with rainfall <1500 mm. In higher rainfall sites on pumice soils, large (e.g. 20-50%) pasture responses to S are common and soil S test may not be a good indicator (B.S. Thorrold, unpublished data).

P is the most expensive of the major nutrients (e.g. about 5x cost per kg S and 3x cost per kg K). Thus, a larger increase in production from P is required for profitability relative to the other nutrients. Levels of P, S and K can be varied to obtain the most economic response from all nutrients.

Clearly, more farms are in the very responsive category for P than for S or K. Thus, about 50-70% of farms are in the combined categories (1 and 2 for sheep and 1-3 for dairying) where application of P, S or K (depending on individual soil tests) can be economically worthwhile in the short-term (1-2 years).

Fertiliser requirements

Major nutrients

Soil test data from BOP farms were used in the MAF fertiliser recommendation models and the results indicated that few farms required only one of the major nutrients P, K or S (Table 5). Only 5% of farms had no requirement for fertiliser. Thus, most farms required combinations of fertiliser nutrients e.g. about one-quarter required P + S on sheep farms whereas P + K was relatively more important on dairy farms. About one-half of all farms had a recommendation for P + S + K.

Average rates of nutrients required for the current year's production and for longer-term maintenance of production are summarised in Table 6. Current requirements were calculated from maintenance requirements using an adjustment for measured soil test values relative to desirable values (Cornforth & Sinclair 1984). Thus, on sheep farms, the relatively low soil P test values (Table 2) have resulted in current requirements for P being, on average, 16% above the longer-term maintenance requirements over all soils. On pumice soils, this value was over 40% (Table 6).

Table 5 Percentage of farms in the Bay of Plenty with recommendations for various combinations of P, S and K according to MAF fertiliser recommendation models.

Nutrients recommended	Sheep/beef	Dairy
No fertiliser	5	5
P only	6	3
S only	7	5
K only	3	10
P and S only	22	6
P and K only	6	30
P, S and K	56	47

Table 6 Average rates of P, S and K recommended for the current year and for long-term maintenance for the grazing area¹ of farms on pumice soil and on all soils in the Bay of Plenty, determined using MAF fertiliser recommendation models.

Soil	Nutrient	Sheep and beef				Dairy			
		Maintenance (kg/ha)	Current			Maintenance kg/ha	Current		
			kg/ha	% nil ²	kg/ha (-nil) ³		kg/ha	kg/ha	% nil ²
Pumice	P ⁴	16	23	7	25	23	25	14	29
	S	24	26	10	30	26	17 ⁵	38 ⁵	29
	K	25	23	30	32	66	64	12	71
All soils	P	16	21	19	24	25	21	27	29
	S	21	21	22	20	25	14	42	27
	K	22	19	41	33	62	61	16	73

¹ Hay and silage areas need additional inputs.

² Percentage of samples with no nutrient recommended.

³ Mean rate recommended, excluding samples with nil nutrient recommendations.

⁴ Recent trial data (B.S. Thorrold, unpublished data) indicates that these rates are underestimates.

⁵ See subnote of Table 4.

Trace elements

Requirements for trace elements cannot be determined accurately using soil testing and must be assessed using plant or animal tissue testing. Unfortunately it was not possible to produce a database of trace element analyses for the BOP. Nevertheless, Ledgard *et al.* (1991) summarised plant analyses by MAF for the whole of the North Island and showed essentially no deficiencies of molybdenum, zinc, iron and manganese for pasture growth. However, 20-30% of samples showed low levels of cobalt, copper and selenium which could affect animal health. Pumice soils are renowned for being relatively low in cobalt and selenium, and supplementation (directly to animals or in fertiliser) is often required (A. Frazer, MAF Animal Health Laboratory, pers.comm).

Suitability of slow-release fertilisers

RPR

RPRs are currently the cheapest form of P fertiliser per kg P but they must dissolve in soil before the P becomes plant-available, and the rate of dissolution is influenced by soil and climatic conditions. Thus, they are not recommended for use on soils with pH above 6.0 and where annual rainfall is below 800 mm. They are also considered most appropriate as a maintenance fertiliser and not for short-term increases in soil P status and hence in production (Edmeades *et al.* 1990).

The summary of soil tests for the BOP showed that 91% of sheep farms and 86% of dairy farms had soil pH values 5.6.0, with little difference among soil types. Average annual rainfall in all areas of the BOP exceeds 800 mm and therefore this is not a limitation for the use of RPR.

Approximately one-third of sheep and one-half of dairy farms in the BOP have soils with pH 6.0 and have current P requirements equal to or less than maintenance requirements (Table 7). The latter criterion of moderate to high P status, and therefore low P responsiveness, means that the 'lag' in P availability from RPR (e.g. Sinclair 1990) is less evident in pasture production.

The largest cost-benefit from RPR is obtained where there is no S requirement. This occurs because RPRs contain negligible S, in contrast to the more soluble P fertilisers (e.g. superphosphate with 11% S), and S must be added to RPR where both P and S are required.

The soil summary for the BOP indicated that about one-eighth of sheep farms and one-quarter of dairy farms met the combined criteria (including no S requirement) for greatest cost-benefit from RPR use (Table 7). These proportions were similar to those for the whole of the North Island for sheep/beef farms, but were lower for dairy farms.

Table 7 Percentage of farms in various soil test categories for use of RPR as a form of P fertiliser.

	pH \leq 6.0 & current P \leq maintenance P	pH \leq 6.0 & current P \leq maintenance P & no S required
Bay of Plenty		
Sheep/beef farms	36	12
Dairy farms	46	23
North Island		
Sheep/beef farms	37	13
Dairy farms	56	39

Elemental S

Elemental S is a slow-release form of S fertiliser which must be oxidised by soil bacteria to sulphate S before it can be utilised by plants. Potentially, elemental S can be more effective than sulphate as a source of S on low S-retentive pumice soils where sulphate is readily leached (Hogg 1965). Pumice soils predominate in the BOP and a relatively high proportion of farms is on pumice soils with a below-optimum soil S test (Table 3).

To date, few experiments in the North Island have examined the efficiency of elemental S and sulphate S fertilisers at similar rates of S application. One experiment was on a pumice soil near Rerewhakaaiti (A.G. Sinclair & W.M.H. Saunders unpublished; Figure 1) and the results showed that sulphur superphosphate (which contained 70% of its S as elemental S) was more effective at increasing pasture production over 1 to 2 years than superphosphate (which contains sulphate-S only).

These results indicate that fertiliser containing elemental S (e.g. S super) is desirable as a source of S for pastures on pumice soils so that S does not become limiting within the year of application, and to avoid large S losses. It may also be the preferred source of S on peat soils where leaching losses of sulphate S can also be large (Hogg 1965). The form of S fertiliser is unimportant on ash soils because little leaching of sulphate S occurs on these soils.

Conclusions

The soil test summary clearly showed that a high proportion of sheep and dairy farms in the BOP have low levels of P, S or K in soil which would limit pasture production. It was estimated that economically worthwhile increases in production through application of fertiliser P, S and K would occur on about 50-70% of farms in the short-term (1 to 2 years).

Pasture production on most farms was limited by more than one nutrient. On an individual farm, soil testing should be used to identify the main limiting

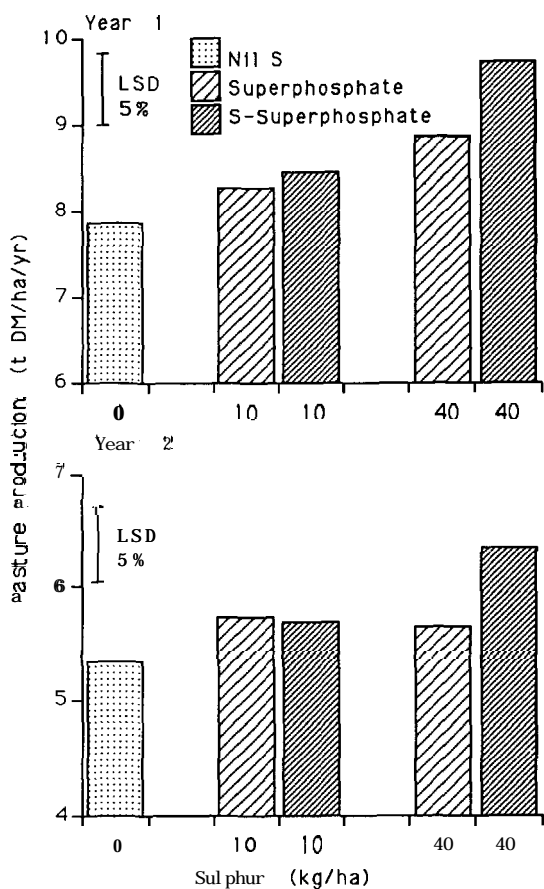


Figure 1 Effect of form and rate of sulphur on pasture production on a pumice soil near Rerewhakaaiti (A.G. Sinclair and W.M.H. Saunders unpublished). Superphosphate contained all of its sulphur as sulphate whereas S-superphosphate contained 2/3 elemental S and 1/3 sulphate S. All plots received adequate P.

nutrient(s) and ensure cost-effective use of fertiliser. Soil testing should also be used if RPRs are being considered, to check that soil pH and P status are appropriate and to check whether S addition is required.

A larger proportion of pumice soils, compared with other soil types, had low soil test levels for P, S and K, indicating the important need for these nutrients in fertiliser to maintain production. On pumice soils, leaching of sulphate S can be large and fertilisers containing elemental S (a slow-release form) are preferable for ensuring that plants have an adequate supply of S throughout the year.

ACKNOWLEDGEMENTS

We thank the MAF Soil Fertility Service for use of data from soil analyses, and Drs A. G. Sinclair and

W.M.H. Saunders for permission to use unpublished trial data.

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