Sulphur and phosphorus in balanced pasture nutrition

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Abstract

Clover-based pastures frequently require both sulphur (S) and phosphorus (P) fertilisers for near-maximum growth. Fertilisers with a wide range of S:P ratios are commercially available. Selection of fertilisers to provide well-balanced pasture nutrition requires criteria to judge nutritional balance. In the work described in this paper, the effects of various combinations of S and P fertilisers on clover growth and herbage chemical composition were investigated in a field trial. There were large clover dry matter responses to both nutrients and a large positive interaction between them, emphasising that balanced nutrition is essential for efficient use of both nutrients. The ratio of S:P in clover herbage appeared to be a useful indicator of nutritional balance. For data combined over the experimental period (16 months), treatments more deficient in S than in P had clover S:P ratios less than 0.72 and *vice versa.* However, because S fertiliser costs much less than P fertiliser, a higher S:P ratio in clover, approximately 0.76, corresponded to an economically optimal balance of S:P in fertiliser.

Keywords: clover, fertiliser, nutrient ratios, pasture, plant analysis, phosphorus, sulphur

Introduction

Multiple nutrient deficiencies are common in New Zealand pastures. In particular, many pastures require both sulphur (S) and phosphorus (P) fertiliser for near maximum growth. Because fertiliser P is much more costlythan fertiliser S, it is important that the potential benefit of expensive P fertiliser is not restricted by S deficiency. Fertilisers with a wide range of S:P ratios and nutrient release rates are now generally available and widely used. For cost-effective fertiliser use, the fertiliser chosen for a particular situation must ensure a good balance of S to P in plants. Fertiliser recommendation schemes use nutrient models and soil tests to predict the requirement for individual nutrients, but there are no simple criteria for assessing whether balanced nutrition has been achieved. The objective of the work presented here was to examine the interaction between S and P fertilisers on pasture clover growth and to evaluate the use of S:P ratios in plant tissue as an index of S/P nutritional balance in pasture. A brief report on early data from this work has been published (Sinclair *et al.* 1994); this paper presents a fuller account.

Methods

A P by S factorial fertiliser trial was established on a low fertility site at Dipton in Southland. The soil was a Mataura silt loam which is classified as a recent alluvial soil (NZ Soil Bureau 1968), with mean annual rainfall of 800 mm. Over the five years prior to starting the trial no fertiliser was applied. The trial was fenced to exclude grazing stock. After site selection, the area was sprayed in October 1992 with Roundup (3 l/ha) and Buster (7.5 l/ha) to kill existing low fertility species. Six days later it was direct drilled with ryegrass (Grasslands Nui, 23 kg/ha) and white clover (Grasslands Huia, 4 kg/ha). Fertiliser treatments were applied in early December 1992 after pasture establishment. Treatments were P (0, 10, 20, 40 and 80 kg/ha as monocalcium phosphate) and S (0, 7.5, 15, 30 and 60 kg/ha as gypsum) in a full factorial design with three replicates. Basal treatments included potassium chloride (100 kg/ha), copper chloride (15 kg/ha), sodium molybdate (200 g/ha), sodium tetraborate (11.25 kg/ha), calcined magnesite (30 kg/ha), and zinc chloride (15 kg/ha). Diazinon (3 l/ha) was applied in March 1993 to prevent possible grass grub or porina attack. Fertilisers were reapplied after 12 months. P treatments were at the original rate and S treatments at half the original rate.

Pasture was harvested during the period December 1992 to March 1994 with a rotary mower when yield was 1000-2500 kg DM/ha. All clippings were removed from the plots to encourage the rapid development of responses to S and P fertiliser. Herbage sub-samples on a plot basis were taken for DM analysis and for dissection into grass and clover components. Clover samples from 4 harvests (February, March and December 1993 and March 1994) were analysed for N, P and S.

Results

Very large responses in clover DM to both S and P occurred throughout the trial period, and there was a strong positive interaction between S and P ($P<.001$), with responses to P being much enhanced by S, and *vice versa* (Table 1). The largest responses were to P in year 1 and to S both in year 2 and for years combined.

Table 1 Effects of rates of S and P fertilisers on clover DM production (t/ha) over the whole experimental period.

P (kg/ha)	S (kg/ha)					
	0	11.3	22.5	4.5	90	Mean
0	2.70	4.91	5.54	5.51	5.77	4.89
20	3.62	5.24	7.29	7.21	7.66	6.20
40	4.26	6.73	7.95	a.43	8.16	7.10
80	3.54	6.30	8.02	8.71	11.18	7.57
160	4.75	6.59	9.04	10.22	10.53	6.23
Mean	3.77	5.97	7.57	8.02	8.67	6.60
SED (treatments)		0.52				
SED (means)		0.23				

A response surface was fitted to the total clover DM data using a 2-variable Mitscherlich-related equation (Sinclair et al. 1994):

$$DM\ (kg\ ha^{-1}) = \{a+b[t+s(x+1)^{-1}]^{y}\}\ \{c+d[r+q(y+1)^{-1}]^{x}\} \quad \ldots\ldots\ldots\ldots (1)$$

where x and y were application rates of P and S fertiliser respectively and the other parameters were constants selected to give a best fit to this data set. 95.7% of the variation in total clover DM production over the experimental period was accounted for by this equation.

From the best-fit equation, response curves were generated relating clover DM production to expenditure on fertiliser applied at various S:P fertiliser ratios (Figure 1). Costs of S and P in fertilisers were taken as $0.27/kg and $1.75/kg respectively, these costs being calculated from current prices of a range of S+P fertilisers. The fertiliser S:P ratio giving the greatest DM response depended on how much was being spent on fertiliser. This relationship was explored by plotting the yield response for a given expenditure against the ratio S:(S+P) in fertiliser (Figure 2). At the lowest expenditure ($50/ha over 2 years), maximum response was achieved with S/(S+P) = 0.71, i.e. S:P = 2.5:1. With increasing expenditure the optimum fertiliser S:P ratio declined and was close to 1: 1 when the expenditure was $200/ha. Yield data for year 1, in which P gave the larger response, produced a similar pattern (not shown), i.e. a high S:P ratio in fertiliser giving most response at low expenditure and the optimum at high expenditure being about 1: 1.

The S:P ratio in clover herbage, meaned over the four chemically analysed cuts, was also modelled using equation 1, which gave a best fit accounting for 98.8% of the variation in the ratio. S:P ratios calculated from the best-fit equation for various fertiliser treatments have been inserted

Figure 1 Effect of fertiliser S:P ratio on the relationship of modelled total clover DM yield to expenditure on fertiliser.

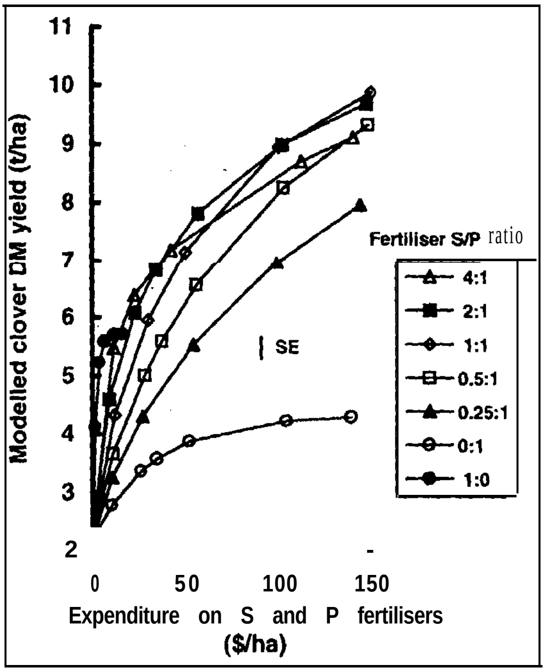
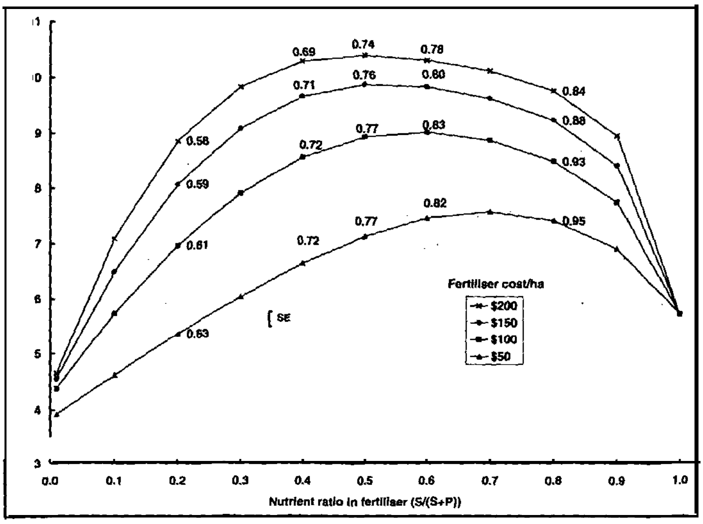


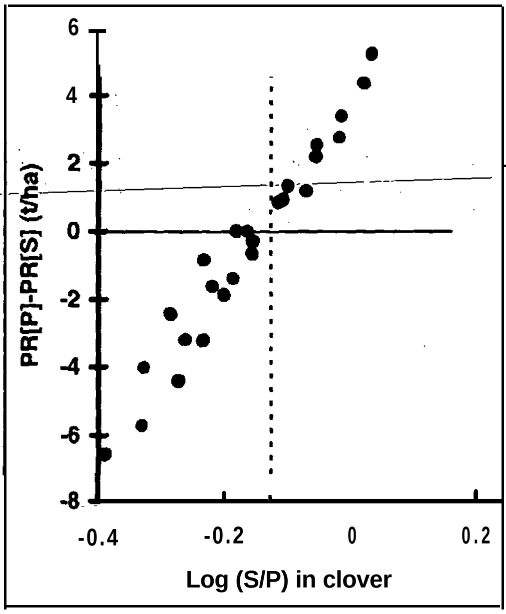
Figure 2 Predicted relationships of total clover DM yields and clover S:P ratios to S/(S+P) in fertiliser at different levels of expenditure. Clover S:P ratios are shown on curves.



in Figure 2. With expenditure of $50/ha the S:P ratio in clover at maximum yield was 0.88 and this ratio declined to 0.74 with expenditure of $200/ha.

For each treatment, the maximum additional yields obtainable with more Pat the same rate of S, designated the potential response to P, (PR[P]), and with more S at the same rate of P, (PR[S]), were calculated using the best-fit equation for total clover DM production. The difference between PR[P] and PR[S] was plotted against the log of the mean S:P ratio in clover herbage for that treatment (Figure 3). Log (S/P) = -0.14, i.e. S/P = 0.72, gave the best separation between treatments with positive values for PR[P] - PR[S] and those with negative values, i.e. between those more deficient in P and those more deficient in S. (Actual mean concentrations ranged from 0.182% S and 0.274% P in the control treatment to 0.266% S and 0.407% P in the high S+P treatment.)

Figure 3 Relationship of the difference between potential clover responses to P and to S (PR[P]-PR[S]) and clover S:P ratio. Treatments with S/P>0.72 (i.e. log(S/P) >-0.14, dotted line) are more deficient in P than in S, and vice *versa.*



Discussion

The results illustrate the importance of applying sufficient S to ensure that response to P fertiliser is not limited by S deficiency. The low cost per kg of S relative to P and the generally lower quantities required to achieve maximum yields led Sinclair & Saunders (1984) to suggest that an S fertiliser recommendation policy should be more generous than that used with P and should be designed to almost eliminate S deficiency while avoiding unnecessary application. Results presented here strongly support that conclusion. Economically, there is very little to be saved through a miserly S fertiliser policy and much to be lost by inadequate use of S (Figure 1). When both S and P are deficient a fertiliser with a high S:P ratio will give the best clover response for a low expenditure. With increasing expenditure, the optimum S:P fertiliser ratio declines because, with S requirements well supplied, the best return for further expenditure comes from meeting P requirements.

The relative S and P requirements of pastures differ from paddock to paddock and cannot be precisely predicted. Therefore it is important to be able to assess whether current fertiliser policies are providing S and Pin the ratio which gives best yield response for money spent. The ratio of S:P in clover herbage appeared to be a useful index of economically well-balanced nutrition. For the lowest expenditure on fertiliser considered in Figure 2 ($50/ha), the clover herbage S:P ratio for highest clover yield was 0.88; this optimum ratio declined to 0.74 for the highest fertiliser expenditure ($200/ha). Thus in a well-maintained pasture where both S and P fertiliser are required, an S:P ratio in clover herbage of close to 0.76 would indicate an economically optimal ratio of S:P in the fertiliser.

It is important to distinguish between economically optimal and physiologically balanced S:P ratios in clover herbage. The latter may be defined as the ratio corresponding to equal deficiency of S and P, and is determined by plotting PR[P] - PR[S] against the S:P ratio in the herbage (Sinclair et al. 1994) as in Figure 3. The difference between the physiologically balanced S:P ratio (0.72), which appeared to be independent of the level of fertilisation, and the economically optimal ratio, which varied from 0.74-0.88 depending on the level of fertilisation, results from S fertiliser being very much cheaper than P fertiliser.

From the first analysed cut of this experiment, Sinclair *et* al. (1994) derived a value of 0.64 for the physiologically balanced clover S:P ratio. This lower value may reflect a high P requirement by young clover plants. Analysis of data from the second season alone gave a value of 0.74, similar to the over-all value.

Most other work on interpretation of clover herbage analysis has focussed on defining concentrations of individual elements necessary for near maximum growth (McNaught 1970). However these critical concentrations can vary considerably with environment and plant age (McNaught 1970, Sinclair & Jones 1991). McNaught (1970) gave critical ranges of S and P in white clover as 0.25-0.30 and 0.30-0.40, respectively. The ratio of the means of these ranges (S:P) is 0.79. Sinclair & Jones (1991) reported critical concentrations of 0.32% S and 0.43% P in clover in a lowland trial and 0.16% S and 0.22% P in a high country trial. In contrast to the large differences in critical concentrations, the ratios of critical concentrations (S:P) within trials were very similar, 0.74 and 0.73. Sinclair &Jones (1991) derived a DRIS norm of 0.72 for S:P ratio in clover. DRIS norms are mean values from high-yielding field plots and are considered to be optimal. Thus earlier work, although not directly determining optimal clover S:P ratios, generally supports the values derived in the present work.

Herbage analysis is not an alternative to nutrient modelling and soil testing for calculating fertiliser requirements. Its role could be to determine the effectiveness of current fertiliser programmes in achieving optimal nutrient balance in pastures and thus provide the basis for either confirming or modifying fertiliser policies. Because of its key role in providing nitrogen, it is the clover component of pasture which should be analysed; more research is required to define optimum season and frequency of analysis.

Conclusions

Serious production losses and inefficient use of P fertiliser can result from inadequate application of S fertiliser on S-deficient pasture. Since fertiliser P costs about 6 times as much per kg as fertiliser S, S:P ratios in fertilisers should be high enough to virtually eliminate S deficiency. The S:P ratio in clover herbage could be a useful indicator of the adequacy of current fertiliser policies to supply S and P in economically optimal ratios. An S:P ratio of close to 0.76 in clover indicates economically well-balanced fertiliser use in productive pastures requiring both S and P fertiliser.

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