Sulphur fertiliser and sheep grazing capacity

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Abstract

Sheep grazing capacities over 15 years from two long-running high country trials in a moderate rainfall zone and under 30 different annual sulphur and phosphorus fertiliser combinations are presented. With time, the sheep grazing capacities became increasingly related to the rate of S fertiliser input, and largely independent of P fertiliser rate. The implication for grazing capacity, fertiliser purchase, transport and spreading costs is the very large cost benefit that could accrue from further development of methods for handling and spreading elemental S fertiliser.

Keywords: fertiliser, grazing, high country, phosphorus, sulphur

Introduction

Nitrogen, which makes 1–4% of living organisms, is generally the most limiting nutrient for plant and animal production. New Zealand agriculture is largely based on superphosphate fertilisation of legumes to stimulate nitrogen fixation. However, sulphur (S) is the other important constituent of proteins, making up 0.1–0.4% of plants and about 0.4% of woolly sheep. Superphosphate contains more S than phosphorus (P), with the S component becoming increasingly important as rainfall decreases. In the South Island there are a range of commercial superphosphate fertilisers augmented with elemental S additions, up to a total of 50% S content.

The relationships for the relative effectiveness of S and P fertiliser have been largely determined from pasture response trials (e.g., Boswell 1994; Boswell 1997; Boswell & Friesen 1993; Sinclair *et al.* 1994; Sinclair *et al.* 1997) and have been assumed to carry over into corresponding responses in animal production. Sulphur is known to be limiting for sheep production on native tussock in New Zealand (Dryden & Archie 1980).

With the importance of wool production to the South Island high country, an opportunity was taken to measure directly the effect of different S and P fertiliser combinations and rates on the sheep grazing capacity on developed pastures, and the implication of that for fertiliser management.

Methods

Two trials were combined in the study. Both were adjacent to each other at the AgResearch Mt. John trial site, Lake Tekapo (820 m altitude, 520 mm annual rainfall, Tekapo soil series). They were established by partial over-drilling of hieracium-infested fescue tussock grassland in 1982 with a common mixtures of 25 different legume and grass species, before fencing and imposition of management treatments (Scott & Covacevich 1987).

One trial was of a response surface design of 27 combinations of S fertiliser (as elemental S-modal size 0.5–1 mm) and P fertiliser (as triple superphosphate of 20% P) of nominally 0, 5, 10, 20, 50 or 100 kg element/ha/year. Four of the combinations were repeated with additional potassium and micro-nutrients. Each fenced combination was 12.5 × 12.5 m.

The second trial had 24 different management regimes, being combinations of main treatment blocks with two spatial replications of nominally five fertiliser/growth regimes of 0, 50, 100, or 250 kg superphosphate/ha/year. The superphosphate was fortified with elemental S to 20 or 50% at the 50 and 100 kg/ha/year rates respectively. Within the main fertiliser treatments were further grazing treatments of three stocking rates (low:moderate:high in ratios of 2:3:4 sheep/pen) by two stocking methods (mob stocking – high number for few days, or sustained stocking – low number for long duration). Each fenced treatment combination was 8 × 50 m. In both trials the fertiliser rates were doubled in the initial year with half the S applied as gypsum. The fertiliser was applied annually in early spring.

The plots were given nearly two growing seasons to establish before the start of the grazing treatments in the second autumn. Grazing was from November to June each year with 2-tooth Merino wethers. Grazing decisions, as for most farmers, were based on visual assessment of feed-on-offer, stock condition, and herbage residual. An attempt was made to maintain the same criteria for pre-grazing herbage bulk and pasture residual over the years. There was an element of self-correction over time, with underestimation in one occasion leading to greater residual and greater regrowth and hence greater estimation of stocking rate on the next occasion.

The plots of the first trial were mob-stocked on two or three common occasions each year for 5–10 days each. In the second trial the number of grazings varied with fertiliser rate. The plots were grazed in groups of three for the different stocking rate treatments within each fertiliser by stocking method treatment. The decisions were based on the moderate stocking rate plots, with the differential stocking rate applied to the other two treatments for the same period. The number of sheep grazing days for each plot was recorded.

The annual grazing capacity of each treatment combination was the sum of products of sheep number by number of days, expressed as grazing days/365/ha. For this paper the results of the two trials were combined relative to their rates of S and P fertiliser and with adjustment for the stocking rate and stocking method treatments in the second trial. There were no direct measurements of liveweight gains or wool production.

Initial soil P tests for the undisturbed top soil were high, but decreased rapidly with depth (P 0–5 cm =40, 5–10 cm =10, and 10–20 cm =5). There would have been partial soil mixing with the rotary hoe drill used. The initial sulphate S soil test was 5. Soil sampling of the 0–7.5 cm layer was done on all plots in the 10th year, and for the zero fertiliser treatments the Olsen P and sulphate S levels were 30 and 9 respectively.

Results

Grazing capacity

The changing relationship between sheep grazing capacity and S and P fertiliser rates is given for three successive periods (Figure 1). The plots were grazed only from October to May. The derived sheep grazing capacities of grazing day/365/ha/yr for the different fertiliser combinations are relative and need dividing by a further common factor of about 2.5 to convert to annual stock units.

During the first period (3rd to 6th year following initial development), the mean grazing capacities ranged from 3 grazing days/365/ha/year with zero fertiliser, to 20 under combined high S and P fertiliser rates. The grazing capacities increased with both increasing S and P fertiliser rates, but that increase was greater with P fertiliser rates than with S fertiliser rates. There tended to be a plateau in grazing capacities at low to intermediate S and P fertiliser rates before further increase at higher rates. The plateau was associated with success of perennial lupin as a grazing legume at those lower fertiliser rates.

The grazing capacities were generally lower during the second period of the 7th to 10th year from development, but were related to a series of dry years rather than fertiliser response. However, there was a changing relationship in the relative response to S and P fertiliser. During that period the general response to fertiliser was more uniform, with S response similar or slightly greater than P rate response.

By the third period of the 11th to 15th year following development, the response with increasing S fertiliser rates was generally greater than with increasing P fertiliser rates. At moderate S fertiliser rates, there was negligible response with increasing P fertiliser.

The 10th year soil test measurement showed that Olsen P values ranged from about 40 ppm for the zero fertiliser treatments to over 200 ppm at the highest P fertiliser rates. The sulphate S levels ranged from 7 ppm for the zero fertiliser treatments to about 100 ppm from the highest S fertiliser rates. At many of the fertiliser rates used, the soil test values were exceptionally high by conventional standards. However, relationship between mean grazing capacities and soil test values showed that while there was some plateauing of grazing response in the sulphate test range of about 40–60 ppm, it continued to increase for all S soil test values covered by the data (Figure 2). There was no trend with soil P test values.

Figure 1 Changing relationship between mean sheep grazing capacity (grazing days/365 /ha/year) and annual S and P fertiliser rates (kg element/ha/year expressed on a square root scale). Mean for 3rd–5th, 6th–10th, and 11th–15th year from initial development.

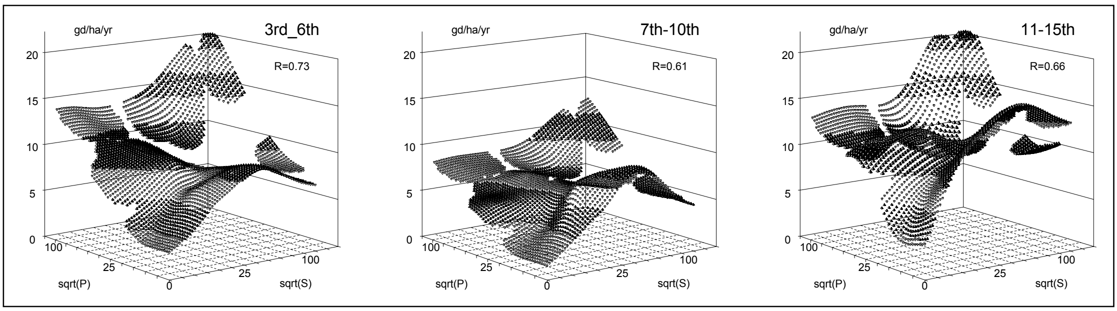
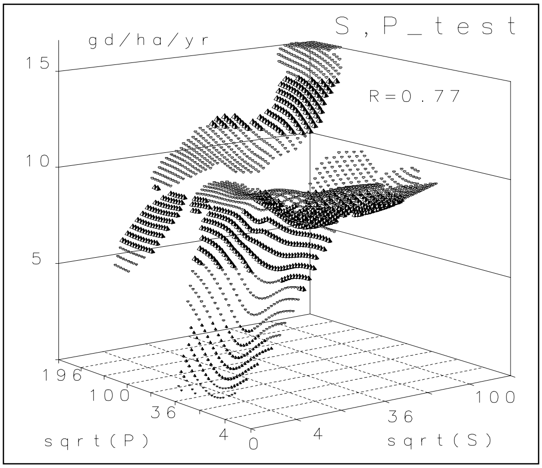


Figure 2 Relationship between mean grazing capacity of treatments for 3rd–15th year relative to 10th year S and P soil test values expressed on a square root scale.



Cost effectiveness of fertiliser

These empirical determinations of the response in sheep grazing capacities over a full range of S and P fertiliser rates, allow estimation of the cost effectiveness of different fertiliser combinations.

In a simplified economic analysis the following cost values were used (Burt 1998): superphosphate costs ex works at $156/t for superphosphate, through to at $166/t for 50% S "maxi super"; agricultural elemental S, if it could still be brought, at $220/t; bulk fertiliser transport at $70/t for 130 km; spreading cost $14/ha; with any S requirement first satisfied by any associated P requirement from superphosphate; mean grazing capacity without fertiliser at 1.2 su/ha; and net profit margin at $36/su increase.

These were applied to the mean grazing capacity of each treatment and the net profit determined. The optimum S and P fertiliser combination giving maximum net profit was determined from bivariate spline fitting to the combined treatment data.

Assuming an annual fertiliser application the analysis showed that the optimum fertiliser mixture and rate was elemental S fertiliser alone (Table 1). For the greatest net return the optimum was 53 kg S/ha/year, and for the greatest increase in net return per $ spent on fertiliser the optimum rate was 24 kg S/ha/year. While the actual net return was highly dependent on the net $/su assumed, the actual optimum fertiliser rate of elemental S was relatively insensitive to the level of other cost factors within their likely range of values. This efficiency for the use of elemental S as fertiliser is contrasted with the case when the same investment is spent on annual superphosphate application (Table1).

The calculations highlighted a number of general points. The first is that the on-the-ground cost of fertiliser includes the transport and spreading costs as well as the ex works costs. Most fertiliser contractors do not separate the transport and spreading components. The first should be related primarily to distance travelled, while the second to the area to be covered and be relatively independent of the spreading rate. The two components need to be separated especially where spreading rates are low. As the first two examples show, spreading at low rates make this the dominant factor in the overall cost.

The allied factor is the difficulty of applying low fertiliser rates. Even with precision spreaders the useful working range is from 80 to 400 kg/ha, with the best accuracy about 200 kg/ha (R. Horrell pers. comm.). Thus it is desirable if fertiliser requirements can be accumulated over time so that spreading rates can fall within this desirable range.

All these features focus on the properties of elemental S as a fertiliser. Elemental S is a pure fertiliser; every kilogram carried uphill can be used, and is reflected in the transport component. The slow oxidation of elemental S will result in the fertiliser having a residual value over a number of years. Also, elemental S has the advantage that it is acceptable to "organic" farmers. However, because of its proneness to electrostatic discharge and toxic flammability its use is currently limited to 23% in dry mixes with superphosphate, and 50% in wet mixes. Elemental S requires oxidation to become available to pastures. Part of the cost of agricultural elemental S is for grinding or sieving to get fine particle sizes. The reasons given for the present recommendation of fine grinding is that particles are sufficiently small to become oxidised within a year or so of application.

For two reasons, I would argue that we should give more serious consideration to coarser grinding. The first is that if there is a need to accumulate elemental S

Table 1 Cost effectiveness of three different fertiliser strategies for a high country example.

	Optimum annually	Equivalent super	Optimum 5 yearly
On-ground fertiliser			
Total cost ($/ha/yr)	$29	$29	$12*
% – bulk, transport, spread	40, 13, 47	36, 17, 47	64,20,16
S & P rates (kg/ha/application)	53, 0	8, 6	250, 0
Net profit at $36/su/yr	$160	$53	$103*

* Assuming 5% discount rate

requirement until the total reaches an efficient spreading level, then it would be necessary that particle size be coarse enough to be supplying adequate sulphate over the whole of the intervening period.

The second reason is that in the normal ups and downs of farm economics, particularly in the high country, coarse particles may be a very useful strategy for allowing fertiliser to be applied in the good years, then coasting through the lean years.

The best long-term fertiliser strategy could be estimated using the fertiliser response function and cost factors given above, and the decay function for elemental S particles of different sizes determined from the present trial. From these, the available S rate in each year could be determined, and the effect evaluated of continuation of the different rates and frequency of elemental S fertiliser over a long time frame under different assumed discount rates.

The modelling calculations indicate that the most cost efficient particle size is between 2.1 and 2.6 mm diameter with a cumulative 20-year rate of 900–1000 kg S/ha. Table 1 gives the estimates for a 5-yearly rate. As the assumed discount rate is increased, the most cost effective strategy is towards the more frequent but lower application rates of the smaller particle size.

Discussion

These empirical results suggest there may be some major difference between the manner in which grazing capacities respond and pastures respond to different S and P fertiliser combinations. The indications are that we are getting a greater increase in grazing capacity with S fertiliser than would be indicated by the pasture response. In this same study the discrimination of the relative effectiveness of the different pasture species was more explainable in terms of different soil P levels than soil S levels. Yet the longer-term sheep grazing capacities, as presented here, were more clearly related to S fertiliser and soil S test levels. Even though there was increasing soil acidification and soil aluminium at the highest S fertiliser levels the trend was for grazing capacity, as measured by grazing days, to be increasing rather than decreasing at the high elemental S fertiliser rates. The sulphate soil test values of 40+ ppm for optimum grazing capacity, are well above those of the recommended biological optimum of 10 ppm for pasture production (Roberts *et al.* 1994).

The basis for the greater effect of S fertiliser over P fertiliser on grazing capacity is not obvious, but may be related to protein production. A partial answer is that contrary to general perception, a good proportion of high country soils, such as in the zone where the trial was done, has reasonable natural P levels. These need only a few years of fertiliser application, at even low P input rates, to bring soil P levels up to good working levels.

But the same logic and processes do not explain why grazing capacity responses were continuing to the highest S levels used. Elemental S requires time to oxidise to become available, but for the particle sizes used this would be of the order of 1–3 years rather than the decade or so covered by the results. Neither is it likely to be owing to S leaching. There is probably nil or low leaching in the rainfall zone used and measurements of soil sulphate profiles to depth also indicated that it was unlikely to be occurring.

Both the empirical results on grazing capacity, and their implications in terms of fertiliser costs and efficiencies, suggest there is need for other reappraisals of the importance of S fertiliser to stock grazing capacities.

Conclusions

The paper has made three points. Firstly, S fertiliser may be equally or more important than P fertiliser in determining the long-term grazing capacities of pastures – at least for the mid-rainfall developed tussock grasslands from which the results derive. Secondly, in terms of fertiliser efficiency and economics, elemental S fertiliser has many advantages. Thirdly, in view of these advantages we should be encouraging the fertiliser industry in the further development of procedures for handling and applying elemental S fertilisers.

ACKNOWLEDGEMENTS

To Ravensdown Fertiliser Ltd for fertiliser, Defence Dept. for use of land, Mr H. Hunter Weston and Mr A. Simpson for stock, and Mr L. A. Maunsell and Mr J. Robertson for technical assistance.

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