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# SPECIES, AND FERTILISER EFFICIENCY - A HIGH COUNTRY EXAMPLE

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**Abstract**

Species dominance and sheep grazing days relative to fertiliser costs are given for the first 6 years of 2 trials at Lake Tekapo. Both were sown in a multiple species mixture. Trial I examined 27 different annual P and S levels; Trial II examined 30 combinations of 5 superphosphate levels, 3 sheep grazing intensities and 2 stocking methods. Pastures were mostly legume dominant, and species differences were related to P fertiliser and stocking method. Perennial (Russell) lupin (*Lupinus polyphyllus*) dominated at all low to medium fertiliser rates, alsike clover (*Trifolium* hybridum) at intermediate rates, and cocksfoot (*Dactylis glomerata*) and white clover (*T. repens*) at high fertiliser rates. The stocking rate achieved was related to both S and P rates. Greatest fertiliser efficiency (returns v. costs) was at low annual rates of 4-5 kg P plus 16-25 kg S/ha.

**Keywords:** lupin, cost-benefit. cocksfoot, alsike clover. phosphate, sulphur, sheep grazing management, fertiliser efficiency.

## INTRODUCTION

The ideal measure of the efficiency in any farming system is the additional income generated relative to the money expended. This paper describes the relative returns from two long term grazing trials in which the principal treatment is variation in P and S fertiliser levels, and where vegetation composition and the number of grazing days were measured.

## METHODS

The two trials at Mt John Station, Lake Tekapo, were set up to determine the most appropriate pasture species for a range of fertiliser, stocking rate and stocking methods appropriate to the high country. The site was dominated by mouse-ear hawkweed (*Hieracium pilosella*) with low to moderate amounts of fescue tussock on rolling moraine soils of the Pukaki set, with an annual rainfall of 650 mm. In 1962 species mixtures of 27 legumes, grasses and herbs were sown across the area using the NZAEI rotary-hoe drill (Scott & Covacevich 1987). Soil tests gave pH = 5.5-5.6, Olsen P = 1 O-22, P retention = 26; S = 1-2, K = 6, Ca = 4; and Mg = 13.

The Trial I treatments were 27 combinations of P and S fertiliser at annual rates of 0, 5, 10, 20, 50 and 100 kg element/ha as elemental S or triple phosphate (2 1% critic acid soluble P)). Four of the combinations were repeated with micro-nutrient additions. The fenced plots were 12.5 m x 12.5 m and mob stocked as required.

Trial II (previously described by Scott & Covacevich 1987), had combinations of:

(i) 5 fertiliser levels (0, 4P+16S, 8P+19S, 20P+48S, and 45P+55S kg/ha.yr using sulphur superphosphate-based products with a decreasing proportion of elemental S augmentation; and irrigation at the highest level);
(ii) 3 grazing intensities (low, moderate and hard grazed);
(iii) 2 stocking methods (mob and sustained);
(iv) 2 replications. The fenced plots were 50 m x 8.3 m.

Double the treatment fertiliser rate was used on both trials in the establishment year. Gypsum was also used in preference to elemental S for this initial application on Trial I. The trials were allowed a year and half to establish before sheep grazing began. The number of sheep grazing days on each plot was recorded; stock movements were based on visual assessments of available herbage. The decision on duration of grazing was made independently for each 3 plot fertiliser x stocking method set.

Grazing did not start until early November of each year to give a common spring growth period for vegetation sampling. The contribution of each species to the total pasture yield of plots was estimated independently by 3 or 4 observers, and the treatment means of these were used to construct Figs 1 and 2.

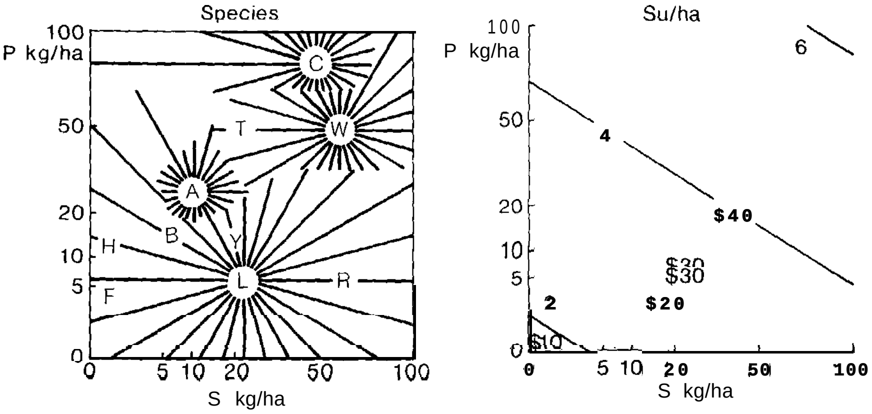


**Figure 1: Species composition, stocking rates achieved and fertiliser efficiency in relation to 27 combinations of P and S fertiliser (square root scale). On left species composition in sixth spring (1987). L = perennial lupin, A = alsike clover, W = white clover, C = cocksfoot. R = red clover, T = Caucasian clover, Y = Yorkshire fog, B = birdsfoot trefoil, F = fescue tussock, and H = mouse-ear hawkweed. Symbol in position where species reaches greatest Individual dominance, while radial shading gives regions where species reaches greater dominance than all other species.**

**On right stocking rates achieved w/ha/year = mean 1983-88 grazing days/365*2.5. Optimum fertiliser combinations indicated assuming net income of $10 to $40/su.**

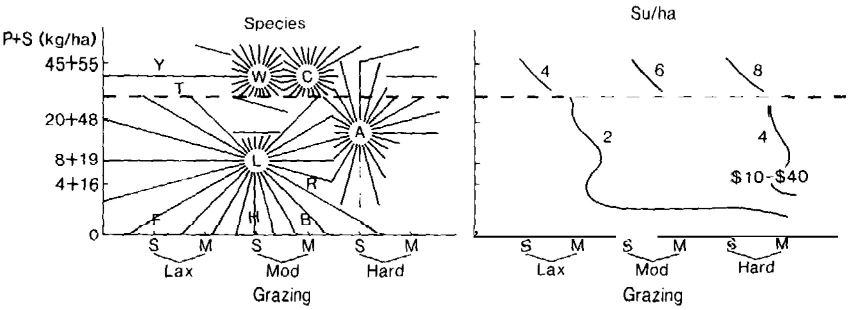


**Figure 2: Species composition, stocking rates achieved and fertiliser efficiency in relation to fertiliser level, grazing Intensity (lax. moderate and hard) and method of stocking (mob and sustained). Coding as in Fig. 1.**

Herbage chemical analyses were made in Trial I in the second year and soil analysis on both experiments in the autumn of the sixth year.

## RESULTS

Over the first 6 years the principal pasture species in both trials were, in decreasing importance: perennial (Russell) lupin (*Lupinus polyphyllus*), alsike clover (*Trifolium hybridum*), red clover (*T. pratense*), white clover (*T. repens*), birdsfoot trefoil (*Lotus corniculatus*), cocksfoot (*Dactylis glomerata*), Yorkshire fog (*Holcus lanatus*), chewing fescue (*Festuca rubra*) and ryegrass (*Lolium perenne*).

**Trial I**

Species Relative species dominance was related more to P fertiliser rates than to S fertiliser rates.

Alsike clover was most dominant at intermediate P and S levels by the sixth year (Fig. 1, left), having also been dominant at all but the lowest P levels in the second and third year. Perennial lupin was conspicuous only at the lowest P levels in the second year, but improved to become the dominant species at all except the highest P level by the fourth year. It remained dominant at below 10 kg P/ha in the sixth year. The contribution of white clover has fluctuated over the years: it was common in many of the fertiliser combinations in the second year, decreased in the third to fifth years, and achieved overall dominance only at some of the highest P and S level combinations in the sixth year. Red clover has been common over a wide range of fertiliser combinations but without overall dominance in any combination to date. Birdsfoot trefoil was a common legume at intermediate P and S levels in the second and third year but has decreased subsequently. Caucasian clover was a minor species but is increasing at the higher fertility levels. The early legume dominance at the highest P rates was replaced by overall cocksfoot dominance in the fifth and sixth year. The original hawkeed and fescue tussock remained at the lowest fertility levels.

**Herbage yields** From capacitance probe measurements before each grazing, annual yields ranged from 4.6 t DM/ha without fertiliser to 12.0 t DM/ha at the highest fertiliser levels. The regression between yields and fertiliser rates was

$$\text{t DM/ha} = 5.2 + 0.033\sqrt{P} + 0.322\sqrt{S} \qquad R^2 = 0.61$$

indicating a preferental respones to S at low rates.

**Grazing capacity** The mean stocking rates of the pastures were estimated from the annual grazing days achieved over the last 5 years divided by 365 to give approximate stock units. Because procedure was considered to overestimate the annual stocking rate, a further division of 2.5 was used.

There was a 3- to 4-fold difference in mean stocking rate achieved. A notable feature was the marked response to S as well as P, the fitted regression being a additive relationship with the square root of P and S levels.

$$\text{SU/ha} = 1.7 + 0.28\sqrt{P} + 0.17\sqrt{S} \qquad R^2 = 0.75$$

The stocking rate achieved was related mainly to the increased herbage yield at higher P and S fertiliser rates, and also to the greater grazing time achieved per unit of available herbage.

**Fertiliser efficiency** Mid 1988 fertiliser prices were used based on citric acid-soluble P contents. The alternatives considered were: the actual fertilisers used (high cost triple superphosphate and elemental S); the cheapest commercially available blends giving the same elemental S; or the cheapest blends giving the same total S. All costs included \$40/ha for transport and \$6/ha for spreading.

The differences between fertiliser costs and grazing returns per stock unit were estimated assuming a constant net margin/su for other management factors and after deducting the mean carrying capacity without fertiliser.

At an assumed \$20/su net return, profit was greatest from an annual fertiliser rate of 5 kg P + 25 kg S/ha corresponding to about 90 kg/ha sulphur superphosphate extra (Fig. 1, right). At this level fertiliser costs would be about $25/ha, returns $33/ha, i.e. a profit of $8/ha. For an assumed $40/su the corresponding costs would be $60/ha, returns $1 05/ha and a profit $45/ha.

Trial II

**Species** This showed similar results to Trial I, although grazing intensity and method differed as well as P and S fertiliser levels. Most treatments were again legume dominant for 6 years except in the highest fertilisers plus irrigation treatment where white clover and cocksfoot became dominant (Fig. 2, upper). Perennial lupin was generally dominant in most years with low fertiliser, particularly under sustained lax grazing. Alsike clover was co-dominant with lupin and white clover in the intermediate fertility and sustained stocking. Fig. 2 shows the conditions in which other species reached their highest ranking though none reached general dominance over the four above.

**Grazing capacity** Grazing days doubled in the irrigated high fertiliser treatments compared with the next highest dryland fertiliser treatments (Fig. 2, right). No importance should be attached to the differences between mean stocking rates of 2.0, 3.2 and 4.4. su/ha for the low, moderate and hard grazing intensity, as they were features of experimental design rather than response. Slightly higher stocking rates were achieved on mob-stocked treatments than in sustained-stocked treatments.

There were very slight difference between the stocking rates achieved at the three intermediate fertiliser levels. Five of these six fertiliser x stocking methods combinations achieved the highest stocking rate where perennial lupin dominated at the low rate of 4P + 16S kg/ha.

**Fertiliser efficiency** In calculating the difference between costs and grazing capacities the high fertiliser treatment was omitted because the cost of the associated irrigation could not be estimated. The greatest fertiliser efficiency was in the 4 kg P + 16 kg S treatment (=50 kg/ha.yr sulphur super extra) and was unaffected by the assumed net return/su.

**Herbage and soil analysis** Spring foliage analyses in the second year gave the highest N content to lupin (4.4%) followed by white clover (4.2%) red clover (3.7%) and alsike clover (3.5%). Lupin had the highest N to S ratio, lowest N to P ratio. Other analysis also showed lupin to have very high Mn and Cu contents but low S and Na.

Soil analysis in autumn of the sixth showed that for both trials the most Cost efficient fertiliser combination gave Olsen P tests in the range 10 - 25, with very high values, indicating accumulation, at higher fertiliser rates (e.g. P = 182 in 100 kg P/ha combination). For S, the most efficient fertiliser combinations gave soluble S test in the range 5 - 7 and only moderate values at higher S rates (S = 28 and 21 at 45 and 100 kg S/ha respectively). Effects on soil pH were only minor even under very high elemental S rates. There was a slight trend of higher values of S, K and Mg under hard grazing.

## DISCUSSION

This paper descibes fertiliser efficiency in terms of the grazing that can be achieved in relation to fertiliser rates, ratio of P to S, and the choice of pasture species. Only a few other fertiliser trials have measured grazing achieved, as the main response.

Both experiments were sown in the same mixture of species, and showed similar rapid sorting out of species according to fertiliser inputs. The clear implication is pasture species should be chosen to best utilise the fertiliser rates used. Multi-species mixtures were used as a research method to determine these species - fertiliser matches. Farmers need sow only those species most suitable for the fertiliser rates used.

The general concept of species suitability according to the environmental conditions of moisture, temperature, fertility and management has already been described by Scott et a/. (1985). The present trial shows that multi-species mixtures can be used to determine the matching of species with fertiliser and management at particular sites.

Perennial lupin in both experiments became the dominant species at the lower fertiliser rates and is maintaining itself under the various stocking rates and methods, particularly the laxer sustained grazing management. The success of perennial lupin in acid, low P and high Al soils as well as its low P accumulation rates and preferential accumulation of Mn without toxic effects has also been reported by Davis (1981). The present trial has also shown its value on low S soils.

For this particular soil at least, greatest net returns were at lower fertiliser rates and with a high S to P ratio. The three ranges of fertiliser options considered made little difference in determining the best S to P ratio but did make a large difference to the actual costs. For the S to P ratio there was a similar trade off when decreasing P costs by considering superphosphate relative to triple super, and the often cheaper S costs in some combinations using ammonium sulphate or bentonite sulphur in some superphosphate blends. There could be a bonus of nitrogen in the ammonium sulphate option.

Most current fertiliser recommendations are based on the CFAS model of Cornforth 8 Sinclair (1982) which is based principally on pasture cutting trials from the more developed parts of New Zealand. In the present study, fertiliser application rates to give the soil test values of Olsen P = 1 O-25 and S = 5-7 were the most cost efficient as indicated by the CFAS model. However, there were differences between the actual and expected animal use factor (AUF) and change in soil test value for fertiliser rates applied. For P the change in test values is best described by an AUF = 2.2. and P test change per net kg applied = 0.28 for this trial as compared with the corresponding expected values of 1.1 and 0.1. The present soil test shows accumulation of soluble P, but only moderate increase in S values, which can be interpreted as either very slow mineralisation of applied elemental S or high subsequent loss. As the trial has been established for 6 years, then perhaps the mineralisation of elemental S in these high country environments is slower than commonly believed, indicating the need for soluble S during the early years of development. Such sulphate and element S combinations will benefit initial legume establishment and also reduce fertiliser costs. The apparent slow mineralisation of elemental S would also cast doubt on the efficacy of rock phosphate - sulphur combinations as a fertiliser source, in these cold high country sites.

## CONCLUSIONS

For high country sites similar to Lake Tekapo, fertiliser efficiency, in terms of stocking rates versus fertiliser costs, can be increased by using lower rates of fertiliser with high S to P ratios.

The pasture species best able to utilise the lower fertiliser rates must also be chosen. In this trial perennial lupin was the best species.

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