Profitable Use of Phosphorus Fertiliser for Temperate Pastoral Australia

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ABSTRACT: The phosphorus (P) fertiliser required to maximise profit from spring-lambing fine wool Merinos over a range of stocking rates (SR) at Hamilton, Victoria can be expressed as kg of P/dry sheep equivalent (P/DSE). The P/ha required for maximum profit calculated from this ratio can be related to P/ha for maintenance predicted by the New Zealand model of Cornforth and Sinclair. This corresponds to the P required if the SR is 96% of the potential carrying capacity (CC) of the site when pasture utilisation (PU) is set at 90%. To apply this approach elsewhere, the model is used to assess the P required if SR is 96% of CC with 90% PU, and the P/DSE to achieve this is computed. This varied from about 0.8 kg P/DSE for areas with a mean annual rainfall of 700 mm to 0.5 kg P/DSE for a rainfall of 500 mm.

Key Words: Phosphorus, Superphosphate, Stocking Rate, Sheep, Pasture, Gross Margin

INTRODUCTION

The dynamics of Phosphorus (P) in grazed pasture systems can be described by diagrams of varying complexity which represent the P cycle. The P lost from any such system must be replaced with fertiliser in order to maintain the P status of that system and hence its productivity. Cornforth and Sinclair (1982) provided a simplified P cycle (Figure 1), and proposed that the quantity of P/ha required to maintain the P status of a soil-plant-animal system (PM) should equal the estimated losses of P due to animal (ALF) and soil factors (SLF). Their model (Eqn 1) uses the loss factors together with the stocking rate (SR), carrying capacity (CC) and the percentage of pasture utilisation (PU) to predict PM. Here, SR, ALF and CC are in N.Z. stock units. (One N.Z. stock unit is equivalent to a 55 kg ewe at mating with 1.0 lambs weaned.)

For sheep and beef cattle, the ALF varied from 0.7–1.1 kg P/N.Z. stock unit, the higher figure being used for very steep country, as animal camps are more localised on hilly terrain than flat areas. The SLF is the kg P lost per kg P uptake of pasture maintained at 90% of relative yield: the yield, expressed as a percentage, of the maximum pasture yield with P non-limiting. Cornforth and Sinclair (1984) provide a table of SLFs for a wide range of New Zealand soils and rainfalls. These SLFs were calculated from a nation-wide network of P fertiliser mowing trials.

In Australia, the unit for SR in common use is the dry sheep equivalent (DSE). This represents a 45 kg wether that maintains its liveweight (White and Bowman, 1981). DSE equivalents for sheep during pregnancy and lactation can be calculated from the metabolisable energy requirement of these animals (Foot, 1983). If it is assumed that a N.Z. stock unit is equivalent to 1.6 DSE, Cornforth and Sinclair’s ALF for beef cattle or sheep on flat to ‘rolling’ country is 0.44 kg P/DSE.

If the loss of P per animal due to removal in product and transfer to camps is constant, then, for a given soil and climate, the loss of P per hectare will vary with the number of animals. This leads to the notion of a fixed amount of P being required per animal to account for losses; suggested by Cornforth and Sinclair (1982) for cases where the stocking rate is close to the CC. This approach was adopted by Keys (1996), who recommended 1 kg P/DSE for all situations and Fleming (1997), who recommended between 1–1.5 kg P/DSE depending on the likelihood of the P being leached.

This paper discusses how research in New Zealand and at Hamilton, Victoria can be used to help producers make decisions about how much P to apply in order to maximise profitability and maintain the productivity of pastoral systems.
METHODS

Results from a long-term experiment at Hamilton (Cayley et al., 1999) were used to assess the effects of varying amounts of P fertiliser and SR on the productivity of continuously stocked, spring-lambing fine wool Merinos. Equations from this work predicted the quantity and fibre diameter of wool produced per ewe, the weaning weight of lambs and amount of supplement fed. These equations were incorporated in a computer spreadsheet in order to assess the effects of wool and fertiliser price on the amount of fertiliser required to maximise gross margins at a range of SRs. The variability of the ratio of P/ewe required to achieve maximum profitability was also examined. The range of 75 predictions consisted of five wool prices (400-600 cents/kg) in factorial combination with five fertiliser costs (200-400 $/tonne for superphosphate) and three SRs (10.2, 12.6 or 18.2 ewes/ha). The predictions were made using the following assumptions: variable cost/ewe $11.50; cost of oat grain supplement $150/tonne; lambs sold at weaning for $0.75/kg liveweight; minimum lambing percentage 90%; lamb survival 85%; and lambing percentage increasing by 1.75% for each extra kg of ewe liveweight at mating (Morley et al., 1978).

The P/DSE required for maximum profitability at the Hamilton site was assessed from the range of predictions. An estimate of the amount of fertiliser to apply per hectare was made by multiplying the P/DSE ratio by the SR. This estimate was then compared to predictions of PM made using the model of Cornforth and Sinclair’s model, or the linear model derived by multiplying the SR with the estimated P/DSE for maximum profit at the 700 mm rainfall site, were compared graphically in order to establish where both methods would predict the same amount of P/ha.

In order to apply these findings to another site, the CC was computed from R and an appropriate SLF and ALF chosen. Predictions of PM at different levels of PU were then made using Cornforth and Sinclair’s model, and the point where PM bore the same relationship to the linear model at Hamilton established. The P/DSE for the new site was computed by dividing this value of PM by the SR at this point.

RESULTS AND DISCUSSION

A set of predictions showing the effect of fertiliser and SR on profitability is shown in Figure 2. In this case, the wool price was assumed to be 450 cents/kg and superphosphate $250/tonne. The amount of P/ewe at maximum gross margins was 1.13, 1.15 or 0.99 kg for the low, medium or high SR respectively. Variation in the kg P/ewe over the 75 predictions from the long-term experiment is shown in Figure 3. For the low and medium SRs, the ratio was mostly between 1 and 1.2. For the high SR the ratio was mostly below 1, but above 1 when the cost of superphosphate was less than $250/tonne. The ratio was insensitive to the price of wool.

Given the response curves in Figure 2 are relatively flat, it is not possible to estimate with...
precision the P/ewe required to give maximum profitability. A value of 1 kg/ewe (0.8 kg/DSE) is therefore assumed for the fine wool Merinos at Hamilton.

At the 700 mm rainfall site, the P/ha calculated by multiplying the SR by 0.8 P/DSE gives a value, at 22.5 DSE/ha, equivalent to the PM at 90% PU. This SR is 96% of CC700, the predicted CC at the 700 mm rainfall site (Figure 4a).

If it is assumed that the amount of P required can always be assessed by calculating PM at 96% of CC with 90% PU, the P/DSE can be computed for any site. At a drier site, for example (Figure 4b), an R of 500 mm/year, a SLF of 0.10 and an ALF of 0.44 kg P/DSE were assumed. The P/DSE for this site was calculated by predicting CC500 (13.0 DSE/ha), assessing the PM at 96% of CC500 with 90% PU, and dividing this by 0.96CC500, i.e. 6.7/12.5 = 0.54. Predictions of P/ha for each site made by multiplying the SR by 0.8 (the ‘Hamilton standard’) and 0.54 are also shown in Figure 4.

Predictions of PM from Cornforth and Sinclair’s model for the 700 mm rainfall area correspond to those of P required for maximum profit using a P/DSE ratio of 0.8, provided that the efficiency of utilisation is increased with increasing SR. A P/DSE ratio of 0.8 overestimates the PM at the drier site, where the ratio of 0.54 appears to be more appropriate.

Experience at Hamilton shows that it is necessary to have efficient pasture utilisation in order to fully derive the benefits associated with larger applications of fertiliser. It is also apparent from the long-term experiment that it is not possible to have a high degree of utilisation if inputs of P are less than 8 kg/ha annually. The poor nutritive value of these pastures prevents them from being grazed short, because sheep grazing these areas are fed a supplement
if their body condition falls below a pre-determined level.

The effect of topography and rainfall on the P/DSE required for maximum profitability of sheep or beef cattle grazing improved pastures for a medium SLF (0.25) is provided in Table 1. The ALFs corresponding to the ‘Flat-rolling’, ‘Easy hill’, and ‘Steep’ classifications of topography are 0.44, 0.56 and 0.69 kg P/DSE, respectively.

**Table 1.** Effects of rainfall and topography on predicted fertiliser-P/DSE (kg).

<table>
<thead>
<tr>
<th>Topography</th>
<th>Mean annual rainfall (mm)</th>
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<tbody>
<tr>
<td></td>
<td>500</td>
</tr>
<tr>
<td>Flat-rolling</td>
<td>0.69</td>
</tr>
<tr>
<td>Easy hill (&lt;25°)</td>
<td>0.84</td>
</tr>
<tr>
<td>Steep (33% &gt; 30°)</td>
<td>0.96</td>
</tr>
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The 0.8 kg P/DSE for maximum profit established at Hamilton was derived from continuously stocked pasture. While it is possible in rotational grazing situations to estimate the overall annual SR of paddocks, such estimates can give rise to serious bias for areas that are ‘mob-stocked’ several times each year. In addition, as the transfer of nutrients to stock camps is less marked with rotational grazing, it is advisable to adopt a lower ALF. For example, Cornforth and Sinclair (1984) used a very low ALF (0.5 kg P/NZ stock unit) to account for losses in intensive rotational grazing systems.

**CONCLUSIONS**

Whereas a simple model can be used to estimate the P requirements of pastures, there is little information about SLFs as defined by Cornforth and Sinclair (1982) for southern Australian conditions. The even simpler approach of multiplying the SR by an appropriate P/DSE ratio appears sufficient to give a useful estimate of the amount of P fertiliser required for profitable animal production over much of southern Australia. A suitable P/DSE ratio can be estimated from a set of predictions with Cornforth and Sinclair’s model, which can then be compared with the SR multiplied by a P/DSE ratio. It is also necessary to estimate the SLF for the chosen site, using the table of SLFs provided by Cornforth and Sinclair (1984) as a guide.

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