Managing fertiliser in a grazing system – putting principles into practice

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Abstract: *This paper presents the key principles underpinning the calculation of phosphorus (P) application rates that has been developed in the Five Easy Steps approach. Whilst shortcomings are noted, we find that it is best to accept the recommended P application rates as a first approximation which can then be modified using the results of regular (annual) soil testing. A strong case is made for annual, effective soil testing – particularly to avoid the extreme high and low P values that we have found on clients' properties. Considering client data – three lessons are highlighted: soil P values are variable between and within properties; when carefully carried out soil testing can provide repeatable values; and fertiliser history is no guide to current soil P levels. Our current approach to managing soil P on farm is outlined – it includes annual testing, application of the Five Easy Steps methodology and the development of a farm-based geographical information system as an aid to data management and visualisation. In addition, we contrast pasture-based enterprises with cropping enterprises and suggest that a measure of paddock productivity – i.e. livestock production, would be of great benefit in determining the effectiveness of soil P management.*

Key words: Pasture, superphosphate, management strategies, legume component

Introduction

On the face of it, managing phosphorus-based fertiliser for improved pastures should be simple – there has never been as much information on soil fertility status, critical values, response of pasture and likely returns. Recent P soil test results from 464 paddocks we sampled in 2014 are extremely variable – from acute deficiency right through to luxuriant excess. This suggests that either the tools are not up to the job and/or our ability to devise and implement adequate management strategies is at fault. In this paper we will first revise the key principles of P management. Then we will focus on some lessons learnt from monitoring the paddocks of our clients over the past two years. Strategies to manage fertiliser to achieve optimal outcomes will be discussed and compared to approaches taken in cropping enterprises, particularly with respect to the complex but integral issue of stocking rate. This will lead to the conclusion that fertiliser management can be improved by consistently applying simple principles and further improved if the producer can measure the outcome of this management in terms of paddock output.

Principles

There are three key principles that underpin the methodology used to calculate the amount of P fertiliser required in grazing system (e.g. Simpson *et al.* 2009). They are:

1) Determine the response to soil P by pasture. The potential response of the legume component is predictable and can be related to potential pasture yield. A mathematical description of the relationship allows us to set a critical level and then target that critical level. Unless the level of P in the soil is known, all fertiliser decisions will have to be made using rules of thumb.

2) Calculate the approximate amount of soil P required to maintain soil P levels, taking into account a number of factors, including loss factors associated with soil type, landscape and grazing management (originally calculated by Cornforth and Sinclair 1982; later, Cayley and Saul 2001; Simpson *et al.* 2009). These can be used to determine the rate of application per dry sheep equivalent (DSE) required to maintain soil P levels. It is also possible to calculate the amount of P required to increase soil P levels if the target

is set and the phosphorus buffering index (PBI) of the soil is known (Simpson *et al.* 2009).

3) There is no point in fertilising pastures unless it results in either an increase in animal production or maintenance of desired levels of animal production. Growing more feed without utilising it is little more than a cosmetic exercise. (Here we refer to animal production rather than stocking rate *per se* but the two are often strongly associated. Some confusion arises when an increase in stocking rate is confined to running more stock per hectare – this is usually true but increases in stocking rate can also occur by running growing stock for longer periods before sale.)

Considering the principles – a practical perspective

Each of these principles needs to be considered before developing a fertiliser program for a property. The main aim of soil testing should be to acquire a representative and repeatable indication of soil P status. Soil sampling should ensure that:

- sampling of the paddock is representative of the paddock landscape – avoid sheep camps, steep sections, waterlogged areas, etc.;
- transect(s) or points where samples are obtained are marked so that future sampling can take place along the same transect(s)/point – thus reducing the impact of spatial variability of soil P values;
- at least 30 samples to 10 cm depth are taken;
- the sampling takes place at approximately the same time every year, ensuring that some months have passed since fertilising; and
- the sample is sent to an accredited lab and that a PBI is obtained for the initial sample – calculating the critical value for the paddock will depend on this.

There are uncertainties about every step of the decision process in managing fertilisers on farm. The calculation of the critical value relies on simple relationships between soil test values (either Olsen or Colwell) and relative yield sourced from a large database of fertiliser trials (Gourley *et al.* 2007). The results are statistically valid but there is considerable variation around the prediction that is not emphasised. For instance, the relationship between Olsen P and relative yield (Figure 3 in Gourley *et al.* 2007) shows that in many instance 95% of maximum pasture yield was achieved at less than the critical value. However, the fitted line is statistically valid and, importantly, there are few instances beyond the critical value of 15 ppm (Olsen) where relative yield is low. The variation in response is impossible to avoid especially given the range of conditions and methodologies used on the trials from which the data is derived. There are instances where soil test has been no guide to response of the pasture to fertiliser at all (e.g. Curll and Smith 1977) *but* when all the available data is considered there is a robust relationship between soil P test values and relative yield and that is *the best that we have got*.

Determining the amount of fertiliser required to reach the critical value or maintain soil P levels at a certain value should be approached with caution. The methodology of Cornforth and Sinclair (1982) taken up by Cayley and Saul (2001) and used in Five Easy Steps (Simpson *et al.* 2009) ties the amount of P to be added to the stocking rate. In broad terms this would appear to make sense – the more productive systems that run higher stocking rates would require more fertiliser. The derivation of the amount of P to be added per DSE depends on soil and animal loss factors. It is difficult to comprehend why soil loss factors are not independent of stocking rate. Conceptually it would make more sense if the two were separated but this would require a very different approach and it is unlikely to be taken up. Such as it is, the estimates of P required to maintain productivity should be viewed as approximations which need to be verified on a paddock by paddock basis by soil testing – see below.

The third issue that arises from the key principles is that of stocking rate itself. The methodology of Cornforth and Sinclair (1982) requires that maintenance applications of P be tied to stocking rate. In managing a paddock to near critical levels of soil P, the Five Easy Steps approach is to derive a linear relationship between soil P and stocking rate under unimproved, current and potential (i.e. the desired level) conditions. The potential carrying capacity is set according to growing season weighted for apparent level of utilisation (small versus large paddocks). As a starting point there is nothing wrong with this but at a practical level it would be vastly improved if data on paddock productivity were included. For instance, most producers could not nominate the current stocking rate of a paddock and have to use a property average, as suggested by Cayley and Saul (2001).

The absence of paddock by paddock production data highlights a major deficiency in the management of improved pastures which is in stark contrast to the management of cropping systems. The grain farmer has always had the capacity to analyse the agronomic and financial outcomes of management by monitoring inputs (fertiliser, herbicide, etc.) and outputs (yield and quality). Furthermore, with the development of precision agriculture, the analysis can be performed at the sub paddock level. In contrast, in grazing systems inputs are managed at the paddock level but outputs are commonly only measured at the property level. Imagine a wheat farmer with 20 paddocks who could only report the average yield across the property! Of course, the reason the farmer can so readily measure outputs on a paddock basis is output from the header with or without yield monitor, it has always been thus even when the measurement of yield was in bags per acre.

This presents a considerable challenge for the grazier – obtaining data which can be used to measure the efficiency with which inputs are utilised at the paddock level. This would require the development of a system that records stock movements, stock class, etc. through the year, and then calculating the number of livestock supported in each paddock on a DSE/ha basis. Such a system would have to also take into account supplementary feeding. We are well aware that commercial applications are available to help producers do this – we have even developed our own spreadsheet system to the same end – *but*, in our experience, very few producers either record or use such data. Even when collated, the estimate of paddock output (DSE/ha) would only represent an approximate gauge of paddock productivity as utilisation of pasture grown in the paddocks would still be an unknown. In addition, estimates of DSE loadings are problematic when liveweight of stock fluctuates. Hence, the results of paddock monitoring of carrying capacity should be approached with caution.

For all its apparent shortcomings, the current system of calculating the amount of fertiliser required in grazing systems provides an objective guide that can be used to make justifiable decisions. The investment analysis that underpins the fourth of the 'Five Easy Steps' (Simpson *et al.* 2009) would encourage the use of fertiliser on the basis of internal rate of return in most circumstances, where soil P is under or near the critical value and improvements in stocking rate can be made. In addition, benchmarking data from the Holmes and Sackett series clearly shows that the most successful producers in terms of profit per DSE and profit/ha/100 mm of rainfall spend more on fertiliser per DSE in beef, prime lamb and wool enterprises (J Francis pers. comm.). So, there is a robust method that underpins decisions on fertiliser application in grazing systems that is straightforward to apply and there is a clear profit motive.

What then is the current state of affairs in growers' paddocks? Over the last two years we have been engaged by a number of clients to perform systematic sampling of most managed (potentially fertilised) paddocks on their properties. Considering this data and experiences along the way, a number of lessons have been learnt.

Lesson 1 – Soil phosphorus varies widely between and within properties: In 2013, 209 paddocks were sampled and in 2014, 464 paddocks were sampled for Colwell P and PBI. Critical levels were calculated for each paddock and compared with the current level (Fig. 1). In

2014, the soil test value was more than 5 units (mg/kg) below critical for 48% of paddocks. On the other hand, there were some paddocks with very high soil P values (13% of paddocks in 2014 had values greater than 20 units over critical). There are biases in the data – the samples are from our clients and represents paddocks that are targeted for management, and paddocks that the property holder had no intention of fertilising were not tested. It is interesting to note that Burns *et al.* (2014) found that in areas dominated by grazing enterprises (Central and Southern Tablelands) median soil P values were below critical.

Within properties there was considerable variation in soil P (Fig. 2). The properties used for this analysis include only those that had 10 or more paddocks sampled. With the exception of one, every property had paddocks that were either well above and/or well below the critical value. While we are more likely to be thinking about correcting deficiencies in soil P, it is important to remember that paddocks with very high soil P (well above critical) represent excessive use of fertiliser for no apparent gain and, hence, a poor (zero?) return on investment. The wide distribution of soil test values between paddocks suggests that individual paddocks must be monitored if management of soil P is to be targeted and efficient.

One excuse to avoid soil testing is that it is too expensive – due to the high cost of analysis. This is not right and reflects a tendency to submit samples to analytical laboratories for repeated comprehensive tests. In managing soil P, after an initial comprehensive test (which should include at least soil P, PBI, pH, sulphur, potassium and, depending on pH, exchangeable cations), only the soil P values need be obtained in following years. It would be advisable to verify the PBI value as well in one or two following years (R Simpson pers. comm.) but apart from that, managing the P input requires no detailed analyses. An important further consideration would be monitoring sulphur levels in paddocks where P is excessively high and/or superphosphate has not been the major source of fertiliser P.

Lesson 2 – Soil test results can be repeatable: When all the precautions listed above are taken, reasonably reliable soil test results can be obtained. On one property that had all paddocks sampled in 2013 and 2014, we found a close relationship between the soil P values in both years. In this data set, the paddocks that had low values in 2013 were fertilised at higher rates, those with high values (above 45 g/kg in 2013) were not fertilised at all. Given the temporal (e.g. Simpson *et al.* 2011) and spatial variability in soil P, the results give some confidence in the sampling and analytical

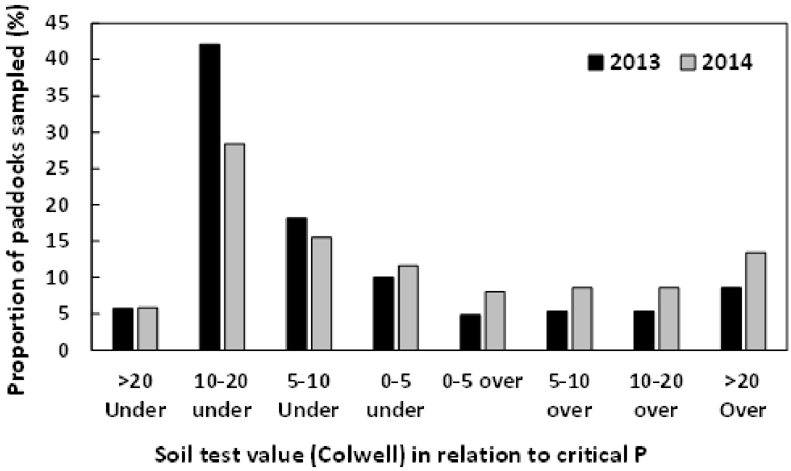

Figure 1. Level of soil P (Colwell) in paddocks sampled in 2013 and 2014 in relation to the critical value calculated for each paddock.

regimes. Further, if soils were tested on an annual basis, it would prevent over-reliance on a result from a single test, which is subject to variation beyond the operator's control.

Lesson 3 – Fertiliser history is not a reliable indicator of current fertility: Can fertiliser history provide a guide to the Colwell P of paddocks today? Counter-intuitively, the answer to this question appears to be – No. Some loss factors, especially those associated with landscape and soil type may be relatively constant. However, long-term shifts in pH are known to influence soil P fixation. In addition, animal loss factors may vary through time – changes to grazing management could also influence camping behaviour and associated losses. There is also the problem of how representative the sample is of the paddock as a whole. In practical terms, fertiliser rates are calculated as if the test value is representative,

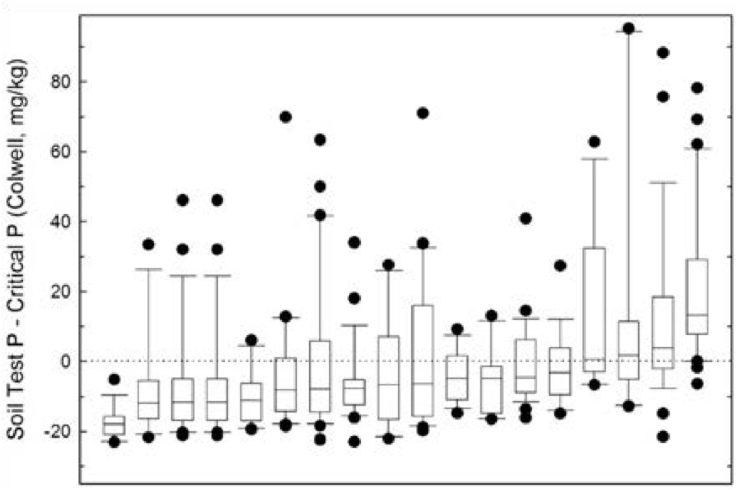

Figure 2. Box plots of soil P test values in relation to the critical value from properties with 10 or more paddocks. Each box plot represents the soil test results from a single property. The line in the middle of each box represents the median, the upper and lower edges of the box represent the 75th and 25th percentiles, respectively (i.e. the central 50% of all values are within the box). The upper and lower whiskers represent the 90th and 10th percentiles, respectively and the points represent outliers – i.e. the extreme values from any paddocks outside the 90th and 10th centiles.

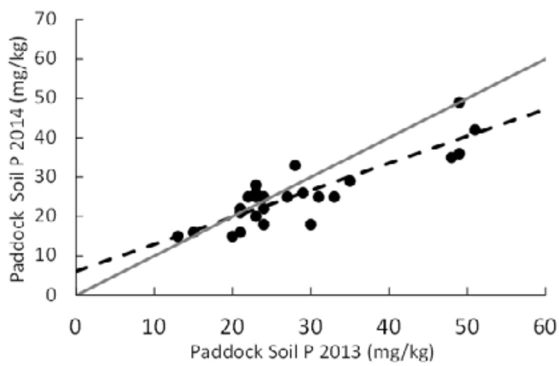

Figure 3. Soil P (Colwell) levels on a single property for 2013 and 2014. The solid line represents the 1:1 relationship and the dashed line is the line of best fit (r2 0.75).

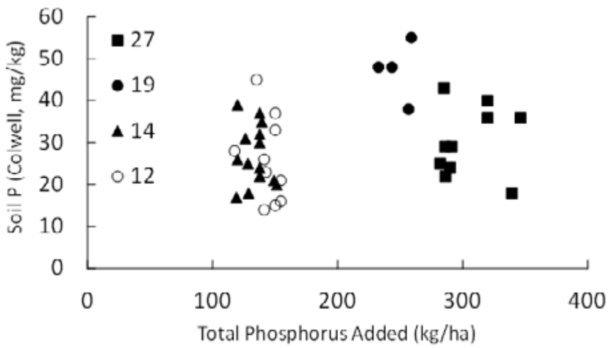

Figure 4. Soil P (Colwell) test values versus total P applied as fertiliser. The different symbols signify the number of years since the property was purchased. Note 2 points were omitted from this graph as they had extremely high soil P values and made interpretation of the data difficult due to scale.

however, obtaining a truly representative sample would be extremely time consuming and expensive. One of our clients had four properties with a fertiliser history going back to the date of purchase of each. When current soil P values are plotted against the amount of P added as fertiliser since purchase – there is no relationship between the two (Fig. 4). Admittedly the starting point for each paddock is not known but even for the two properties held for over 20 years, the absence of a relationship is clear.

Our approach

The results presented above, coupled with the lessons learnt, suggest that implementing an annual soil sampling regime will provide data that will be useful in assuring efficient use of P-based fertiliser. Initially, the methodology of Five Easy Steps and its predecessors can be used to help guide fertiliser decisions. These should be viewed as approximations – the effect of which can be gauged with further soil testing. Such a regime would ensure that paddocks are managed to desirable levels and reduce poor decision making that (as has been shown) can result in either excessively high or low levels of soil P. This, at least, is what we have urged our clients to do.

In order to manage the data from soil testing and fertiliser records and as an aid for spreading contractors, we have developed Geographical Information Systems (GIS) for each property. A GIS is simply a system that allows data to be associated with spatial features, such as paddocks, or soil transect lines. It allows us to map the location of paddock boundaries, soil sampling transects, current P status, recommended fertiliser rates, etc. A demonstration will be presented in the talk. This sounds a lot more difficult than it actually is. Today there are free GIS programs that can be downloaded and used in combination with spreadsheets to help in the management task. Typically we will use the GIS to produce a map with fertiliser rates and total tonnages for each paddock. In doing so, we have also ensured that the fertiliser information has been stored and will hopefully be used at some time in the future to analyse progress. We have found the programs QGIS and MapWindow to be the best of the free GIS software available.

Finally, it is worth reiterating the ambition to collect output data on a paddock by paddock basis. By this we mean some measure of animal and/or pasture production from the paddocks. The use of satellite data to derive pasture growth rates at an acceptable scale would potentially trump the need to collect stock movement data – but at this stage, a cost-effective and accurate method of using satellite data is not available.

Conclusions

A rational approach to managing P-based fertiliser applications must include a regular and effective soil testing regime. The resulting data can be tracked through time to adjust fertiliser rates and ensure that applications are economically and environmentally efficient.

In grazing enterprises, while we manage a property on a paddock by paddock basis with respect to inputs, it is very common that outputs (livestock production) can only be gauged on a whole property basis. If this were to change and paddocks were to be monitored for livestock production then the management of pasture-based livestock enterprises would be able to approach that of cropping enterprises – and that would be a good thing!

Acknowledgments

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difficult to translate the 'back of the envelope calculations' into the impact a decision has on the farm system.

The 5 Easy Steps P Tool is an excellent programme for setting and matching fertility to stocking targets. In my previous 12 years as a farmer I had never been asked the question: 'what percentage of potential would you like to be stocking this paddock at?'. There are many reasons why I hadn't targeted every paddock to be performing at 95% of potential and yet every agronomist I had spoken with assumed this to be the case.

Monaro Farming Systems has a sub group called 'Soils Club', which has been instrumental for me to hone the theory and gain a better understanding of what works for other farmers. It is a group of 40-plus farm businesses on the Monaro who collect soil tests once a year in a two week window so that they can be submitted as a bulk sample. This gives the group the power to analyse paddock, farm or district scale information. Another important part of being in this group has been the structure and discipline it has provided around the soil testing process. It has meant I have set up monitor paddocks that get tested every year, I test at the same time every year and I am doing more testing than I might have otherwise done.

Results

As this is not a replicated trial nor does it have a control, the result should be taken as observations.

The farm has doubled its carrying capacity and tripled profitability from 2002 until now. I put a lot of this down to fertiliser but there are other influences such as introduced pasture, more watering points, improved genetics, improved infrastructure, etc.

I am of the opinion that 80% of the profits coming from fertiliser are attributed to the 2002–10 period where the plan was all about getting it roughly right. The further 20% has come from the detail of aligning soil potential with stocking rate at a paddock scale. This has been through reduced input in some paddocks and increased input in others.

Another observation is that the pasture is faster to respond at the break in season, more water efficient and more resilient to extreme conditions. This doesn't help in a severe drought but it does help bridge the gap when the normal dry spells occur.

Conclusion

For my farm system fertiliser and grass utilisation are the number one profit drivers. For this reason I feel it deserves detailed attention and I am keen to explore variable rate spreading within a paddock. The hard part is proving to be the cost of identifying the parts of the paddock that will economically respond to more input and those that are getting too much. Watch this space.

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