4R Approach to Nutrient Best Management Practice

PHOSPHORUS APPLICATION on Wheat in Southeastern Australia

Collated by Dr. Rob Norton, Director, International Plant Nutrition Institute (IPNI) Australia/New Zealand Program, on behalf of the project collaborators and supporters.

IPNI Regional website: http://anz.ipni.net

Project Collaborators:
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Note:
Use of the monetary symbol $ refers to Australian dollars.

Abbreviations:
P = phosphorus; S = sulphur.

Summary – the Elements of P Best Management

- *Soil testing and budgeting of P removal and additions can help plan P inputs.*
- *Placing P close to the seed at sowing is the most efficient way to deliver this vital nutrient.*
- *PBI can give you a guide as to how much P the soil is likely to tie up in forms that are unavailable to the crop.*
- *There are a range of different sources of P fertiliser available and they should always be considered in terms of individual soil type and individual budget.*
- *Highest yielding does not always mean highest profits — consider how management decisions will affect the bottom line, as well as yields, for a variety of rainfall and price scenarios.*

Fertiliser represents a major financial investment in modern cropping systems and so it makes sense to gain the maximum value from this decision. Recent research supported by the Grains Research and Development Corporation in conjunction with the University of Melbourne and the Victorian Department of Primary Industries and others has found that there are a number of ways that farmers can maximize the return from their fertiliser investments.

This publication provides a summary of the latest research and uses the "4R" approach to nutrient stewardship in describing current best management practices for P.

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What happens to P fertiliser?

Most of Australia's cropping soils have a long history of P application, but only a small proportion of this P is available to the current crop.

When P is applied to soil, up to 70% will be adsorbed by the soil into forms that are unavailable to the current crop.

The crop will access some P from the fertiliser as well as from slowly available pools built up over time.

The problem is that it is very difficult for plants to access P that is locked up in the 'soil bank'. This is particularly true on soils with a high P buffering index (PBI). For this reason, in most cases annual applications of P at sowing are needed to meet the crop's P requirements.

Where P application has built up a large P bank, a stable response can be obtained with the use of maintenance P dressings – where P input as fertiliser balances P removal in grain.

The Global "4R" Nutrient Stewardship Framework

Fertiliser best management practices (BMPs) can be aptly described as the application of the right source (or product) at the right rate, right time, and right place. Under the Global "4R" Nutrient Stewardship Framework, the four "rights" (4Rs) comprehensively convey how fertiliser applications can be managed to achieve economic, social, and environmental goals. The framework ensures that fertiliser BMPs are developed with consideration of the appropriate focus on all three areas of sustainable development (see **Figure 1**).

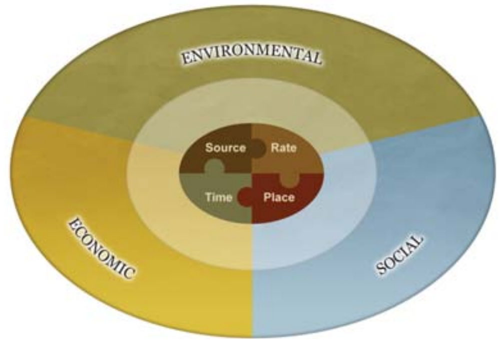


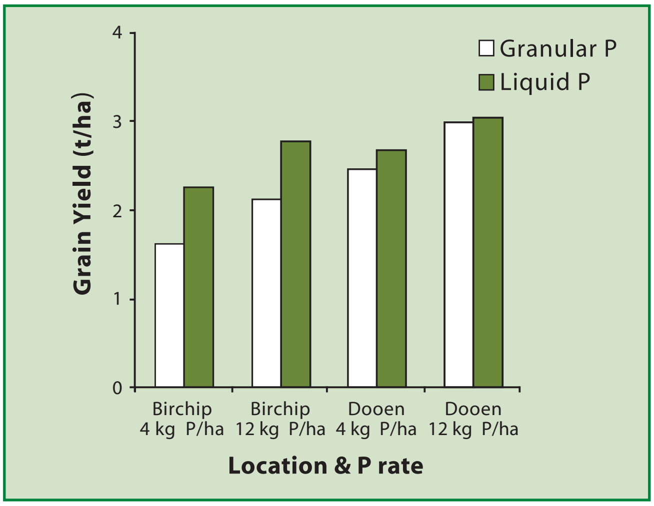
Figure 1. The 4R approach to nutrient best management practice, to meet environmental, economic, and social demands.

The Right Source of P

All phosphorus fertilisers are labeled to show the amount of water soluble P and citrate soluble P, which are forms available to the plant. Total P content is also given, and the difference between that figure and the available P is the amount in the material that is not available in the short term. The process of fertiliser manufacture transforms low solubility P in rock phosphate to the water and citrate soluble forms.

Phosphorus source comparisons over 3 years in the Wimmera, Mallee, and Western District showed that monoammonium phosphate (MAP) was generally the best P source tested. In certain areas, particularly on highly calcareous soils, growers are moving towards supplying P in fluid form.

Figure 2. Granular and fluid P at two rates at two sites (Vic DPI).



Fluid P sources such as ammonium polyphosphate could provide around a 10% benefit over MAP and these fluid responses were most common on alkaline soils. Across all sites in the Victorian Wimmera and Mallee, we found that fluid P sources were never less efficient than MAP. The presence of free lime is often a good indicator of where fluid P sources will be better than granular P sources, and a "fizz" test with a strong acid can help identify these soils.

In our trials, MAP fortified with S present as both sulphate and elemental sulphur forms, showed a 10% improvement over MAP in two trials. It is not certain if this is due to improved S nutrition or the formulation of the P source itself.

Fluid P sources can help to reduce the amount of P that is tied up in high PBI soils. **Figure 2** shows the improved yields that can come from using fluid P sources. It also shows that this effect varies with soil type. When considering a change to fluid P, factors such as PBI, pH, soil type, and Colwell P status should be taken into account.

Changing to fluid fertilisers requires a change in equipment to allow for the delivery of the fluid to the seeding

bar and into the soil along with the seed. These costs can be quite significant.

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The source of P that you choose should be specific to the soil characteristics, and the potential for losses. For example, even though P is relatively rapidly bound to soil particles, using soluble P sources on light soils could result in losses through leaching or surface water draining P away.

Conversely, the use of lower solubility P sources such as reactive phosphate rock, calcined phosphate rock or partially acidulated phosphate rock can build up low solubility P pools increasing the size of the lower availability pools (**Figure 3**). These sources have value where there is low soil pH, high soil organic matter, low soil calcium and high PBI.

As with all nutrient management decisions, any changes to the source of P being supplied to the crop should be considered in the context of the fertiliser budget for the farm (see financial considerations).

The Right Time and Right Place for P

Because P is relatively immobile in the soil, fertiliser P should be placed as close to the seed as possible, especially where soil P test levels are low. Because MAP is relatively safe near the seed, this fertiliser can be placed quite near the seed ... unlike urea which should be located away from the seed row, especially at high rates or in wide rows. Care should be taken with the placement of some fluid P sources as they can be corrosive to machinery and should be kept away from the seed row.

Also, because of its poor mobility, top-dressing P after sowing rarely shows a crop response. In virtually all cases, the right time and place for P is at seeding and near to the seed for maximum efficiency.

Crop demand for P peaks during crop establishment, early in the season, and most importantly, early P supply sets up the roots to better access both water and nutrients. Later application using any of the currently available P sources is unlikely to produce economic responses. In drier years, crops are relatively more dependent on applied P because of a reduced ability to exploit soil P.

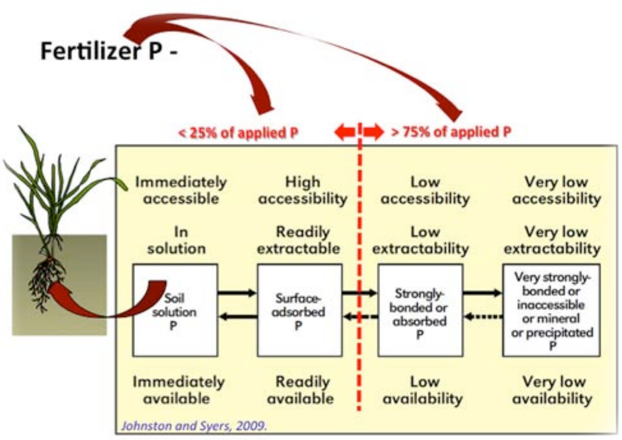
What is the Right Rate for P?

Know how much P is in your soil?

Phosphorus in soils present in a range of forms some of which are readily available to plants, others which are less available. There can also be a large pool that is not able to be used. **Figure 3** gives a representation of the links between these pools and the fate of applied P fertilisers.

These pools are in balance with each other, but the movement between each is very slow. Even so, some P moves into the available pool from the unavailable pools, and if the unavailable pool is large, then this may supply adequate P

Figure 3. Summarizes the pools of P in the soil.



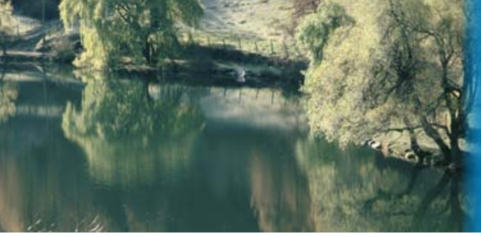


Table 1. Minimum or critical Colwell P values for various soils.

Soil type	Critical Colwell P mg/kg
Wimmera Clay	15 to 35
Mallee Sandy Clay	20 to 25
Loam Acid Soils (high rainfall zone	25 to 30

to meet part of the crop demand. On the other hand, when fertiliser P is added, some of it enters the low availability pool. The PBI indicates how much can get shifted to the low availability pool.

Estimating soil P supply largely relies on the use of a carefully calibrated soil test. There are many tests for P and these use different methods of extraction to estimate how much of the P in the soil is available to the crop.

The Colwell P test uses an extractant that frees some of the P absorbed on the soil, but does not consider less accessible forms of P. The critical Colwell P value is interpreted from the soil PBI value so both values are need to evaluate the potential response to added P fertiliser.

Periodic testing for Colwell P in the top 10 cm of your soil is a good way to estimate soil P levels. However, this soil test even with PBI adjustments to cricitcal values, does have limitations and in the future new tests such as the Diffusive Gradients on Thin-Films (DGT) P test may become available, but at present Colwell is the most widely used test for soil P status.

Sampling for P should be done at about the same time of year and careful selection of sampling sites and depths will provide the best estimate of the sample to be submitted for testing.

Colwell P alone is not always the best test to determine the rate of P to apply to a crop. Rather, it is best used over time in conjunction with other methods to judge soil P requirements. After initial testing, Colwell P can be used to estimate P levels for the next 4 to 5 years (see P budgeting below). However, after this time it is best to retest the paddock.

What Colwell P level is best?

Minimum or critical Colwell P soil test values vary widely depending on soil type. **Table 1** shows the general rules – using a range of values that are accepted as ideal for a range of soils.

If the soil test reveals Colwell P levels equal to or higher than these values, you may only need to apply enough P fertiliser to replace what the crop takes out (see P budgeting).

However, if Colwell P levels are lower than the critical value, consider applying 'capital' inputs of P over and above maintenance requirements to 'build up' soil P levels over time.

It is recommended that Colwell P figures be analyzed over a period of years and taken in context with crop yields over that time. By tracking Colwell P over time in comparison with crop yields and fertiliser inputs, growers can gain an in-depth understanding of the Colwell P levels that they should be targeting for their individual paddocks.

Any decisions to alter P rates should be considered in terms of financial impact – higher yields do not always equal higher profit (see financial considerations).

Table 2. What constitutes a high or low PBI value?

PBI Value	Category
Less than 150	Low
150-300	Moderate
More than 300	High

What about PBI?

Phosphorus buffering index (PBI) is a soil test done in association with soil P testing that measures how strongly a soil locks up P into forms that are unavailable or only very slowly available to a crop.

Soils with a high PBI (see **Table 2**) will generally require higher rates of P each year because much of the P applied is tied up in forms that are not available to the crop.

PBI needs to be measured only once for each soil type and it can be used every year when considering P rates. Soils with a higher PBI will require more applied P to raise the Colwell P test value.

High PBI values are generally associated with highly alkaline 'calcareous' soils often found in the Eyre Peninsula of South Australia. However, high PBI soils can be found in a broad range of areas.

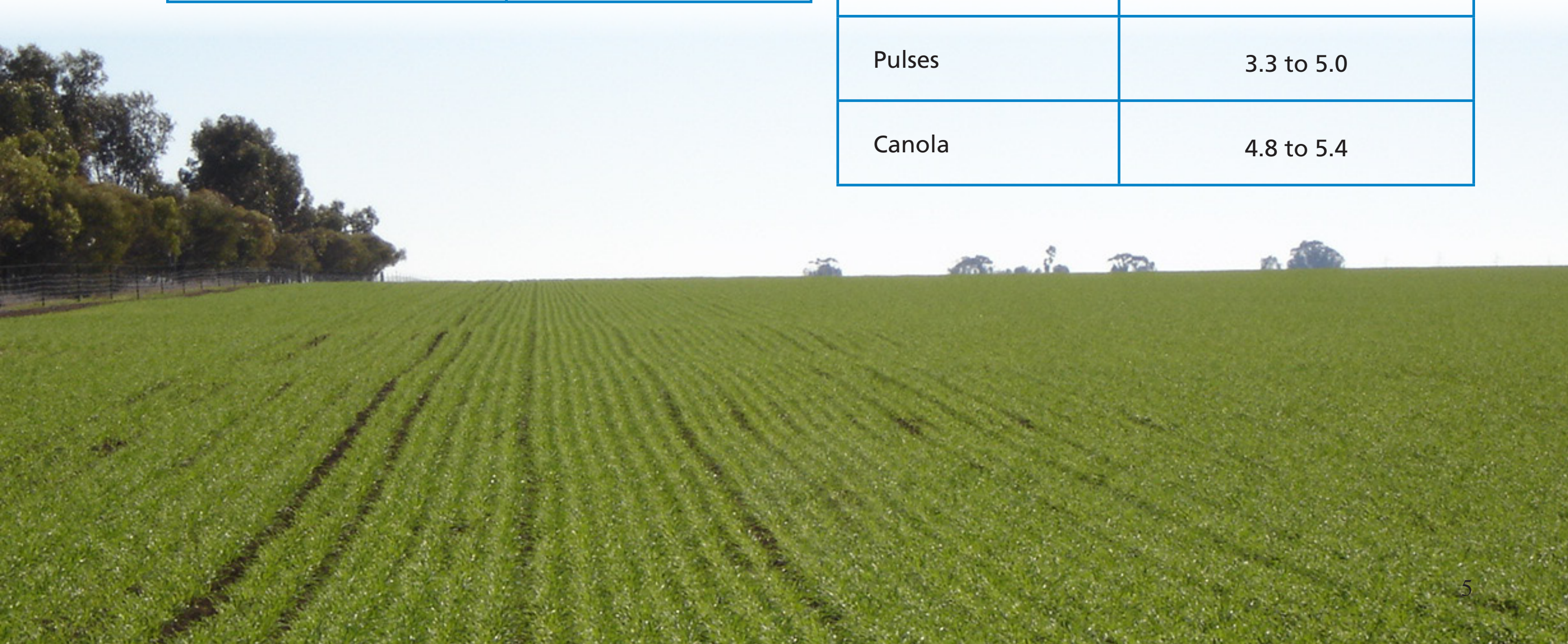
Recent research has suggested that liquid sources of P may assist with managing high PBI soils. See 'different sources of P' above.

P budgeting — tracking P over time

For most cropping regions, the soil has had a strong P application history and so balancing input and output ... rather that supplying long-term soil P pools ... can be a useful approach.

Table 3. Typical P removal rates for various crops.

Crop	P removed per tonne of product, kg/ha
Cereal grain	2.6 to 4.0
Cereal hay	1.3 to 2.0
Cereal straw	0.7 to 0.9
Pulses	3.3 to 5.0
Canola	4.8 to 5.4



When considering how much P to apply, it can be useful to look at the recent history of the paddock and estimate how much P has been both applied and removed (**Table 3**). The values in **Table 3** are a range and this is because at high soil P levels crops will take up more P than under low P supply states. Despite that, P budgeting allows an estimate the amount of P required to be applied to the paddock to achieve your target yield.

Example P budget for a single year:

Crop: Wheat

Yield: 2.0 t/ha

Fertiliser input: 60 kg/ha MAP (21.9% P)

P removed in grain: 2.0 t x 3.0 kg = 6 kg P/ha

P added in fertiliser: 60 kg x 21.9% = 13.1kg/ha

Net balance: + 7.1 kg P/ha

In an ideal situation, you would aim to have a slight positive net balance of P over a 4 to 5 year period, after which soil tests such as the Colwell P would provide guidance about the direction of this strategy. If Colwell P levels decline over this period, then additional P may be needed to maintain the soil P status at the critical level.

Some growers use yield maps to estimate the pattern of P removal across their paddocks. Variable rate fertiliser applicators, or simple paddock zones, are then used to match the removal patterns identified in the yield map.

The major limitation with P budgeting is that it does not consider P that is locked up in the soil. So that for soils with a high PBI, P budgeting may be somewhat less accurate due to tie-up of applied P.

Can you cut back on P when finances are tight?

With volatile fertiliser prices and following a string of below average years, this was a question that many were asking at the start of the 2008 season. Given the uncertainty of weather, the lessons from that season should be remembered for the future.

Research conducted during 2007 investigated the effects of skipping a year of P on wheat yields on a Wimmera grey cracking clay at Kalkee. This experiment showed that following a failed crop in 2006 there was very little carry-over of P from the previous year, except at high P rates (20 kg P/ha).

In general, provided that a paddock has a good history of P application, it may be possible to skip P application following a failed crop. (A good P history is generally typified by a high Colwell P figure – see **Table 1**). As usual, this decision must be weighed against the risk that the season unfolds as an exceptional year and the yield potential of the crop may not be realized.

Financial Considerations

As with any management decision, the choices associated with P management carry with them a certain amount of financial risk and return.

The aim of P management is to minimize risk by minimizing financial outlay early in the season while still being able to capture the potential should the season be a good one.

Changes to P strategies should be fully costed (including capital costs) and balanced with the likely changes to yield over several years.

In particular, realistic assessments of the yield potential of individual paddocks are vital to ensure that the correct decisions are made. Because fertiliser use is an economic, as well as an agronomic, decision, consideration of commodity prices will indicate the return on the fertiliser investments.

Soil Testing Tips for Measuring Colwell P

In order to gain a representative sample, it may be necessary to take up to 20 soil cores from across the paddock. Try to sample at about the same time each year, and make sure the samples are taken from areas that have not been fertilised in the current season.

Take samples from within and between rows in the same ratio as the rows represent to the paddock. For example if on 30 cm rows with 3 cm sowing row spread, take 1 in-row sample for each 10 inter-row samples.

In paddocks with multiple soil types, try to sample from the dominant soil type. If you are going to manage these soils differently then sample them separately.

Mix the samples thoroughly in a clean bucket and keep them in a cool place until dispatch.

Use a testing service that participates in Inter Laboratory Proficiency Programs such as the program undertaken by the Australian Soil and Plant Analysis Council.

Remember that a bag of soil submitted, in the lab becomes only a tablespoon of soil that will represent an entire paddock! ■

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This nutrient management guide was adapted from an earlier version titled "Matching Phosphorus (P) Supply and Demand on a Range of Soil Types" produced by the Victorian Department of Primary Industries.

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