PHOSPHORUS

Key points

- Phosphorus (P) is one of the most critical and limiting nutrients in agriculture in Australia.
- Phosphorus reactions in soils are complex, and agronomic advice is recommended when interpreting soil test results.
- Only 5–30% of phosphorus applied as fertiliser is taken up by the plant in the year of application.
- Phosphorus losses via runoff and drainage under dairy production can be high in Tasmania.

Background

Ancient and highly weathered soils with very low levels of natural phosphorus (P) dominate much of Australia. Many of our agricultural soils are therefore among the most acutely phosphorus deficient in the world, and profitable crop production has only been possible through significant applications of P-fertilisers.
Phosphorus is an essential element for plants and animals for cell division and growth. Complex soil process influence the availability of phosphorus applied to the soil, with many soils able to "tie up" phosphorus, making it unavailable to plants. Your soil's ability to do this must be accounted for when determining requirements for crops and pastures.

Deficiency

Phosphorus deficiency can at first be difficult to see in many field crops because while growth is slowed and the crop somewhat stunted, it still looks a healthy colour. Phosphorus is concentrated at the young growth tips, meaning deficiencies are first visible on lower (older) parts of the plant. A purple or reddish colour associated with accumulation of sugars, is often seen in deficient plants, especially when temperatures are low. Leaf distortion, chlorotic (yellowed) areas and delayed maturity are all indicators of phosphorus deficiency in more mature plants-. Deficient cereal crops are often poorly tillered.

Visual symptoms other than stunted growth and reduced yield are not as clear as are those for nitrogen and potassium. At some growth stages, phosphorus deficiency may cause the crop to look darker green. The role of phosphorus in cell division and expansion means crop establishment and early growth is highly dependent on sufficient sources of the nutrient. Trials have shown significant agronomic penalties from applying phosphorus more than 10 days after germination. Most of these phosphorus timing trials indicate the optimum time for P-fertiliser application is before or during seeding.

Fate of applied fertiliser

Phosphorus fertiliser is mostly applied in a water-soluble form which can be taken up by plants, retained by soil and lost through erosion and leaching (Figure 2). In the water-soluble form phosphorus rapidly reacts with iron, aluminium and calcium in the soil) to form insoluble compounds. Therefore, competition between the soil and plant roots for water soluble phosphorus arises, with only 5% to 30% of the phosphorus applied taken up by the crop in the year of application. At low pH (<5.0), the soil's ability to fix P rises dramatically, thereby decreasing the amount available to plants, but less soluble reactive phosphate rock (RPR) can be used as an alternative slow release P fertiliser in high rainfall districts (> 1000 mm/year) as this requires acidic conditions to dissolve the mineral P.

Measuring a soil's ability to fix phosphorus

Knowing the soil's ability to fix phosphorus is vital in determining the rates of fertiliser application. A high fixing soil will require significantly more P-fertiliser to raise levels of plant-available P. A Phosphorus Buffering Index test (PBI) (Burkitt *et al.* 2002) has been developed to determine P fixation capacity and is used in conjunction with a test for plant-available soil P to optimise fertiliser P requirements. For example, target levels for the Colwell P test, a measure of plant-available P, depend on the soil's PBI (Table 1), with high PBI Ferrosols having higher optimum levels than the other soils which all have lower PBI.

The alternative test of plant available P in soils, the Olsen P soil test, has been assessed in trials to be a reliable indicator of available P for pastures on all soil types, independent of PBI.

Table 1. *Tasmanian optimum agronomic soil phosphorus* levels (0 – 75 mm depth).

Colwell P (mg/kg)	Ferrosols (PBI > 200)	Cropping	100 - 200
		Pastures	70 - 120
	Chromosols Kurosols Podosols Sodosols Tenosols	Cropping	50 - 80
		Pastures	10 - 40
	Dermosols Vertosols	Cropping	50 - 100
		Pastures	30 - 70
Olsen P (mg/kg)	All soils under pasture	Very low	0 – 10
		Low	10 – 20
		Optimum	20 – 30
		High	30 – 60
		Excessive	> 60

Phosphorus retention and removal

Phosphorus that is not removed from the soil system remains adsorbed by the soil or in organic matter. These sources all supply some P for plant uptake and thus maintain a residual fertiliser value. A long term regime of applying P fertiliser decreases the capacity of the soil to adsorb phosphorus, giving increased effectiveness of subsequent applications. Each crop species will remove different amounts of phosphorus from soil following harvest (Table 2), and this must be accounted for during nutrient budgeting. Nutrient budgets and whole farm nutrient distribution maps are both essential tools for improved fertiliser management.

Table 2: *Phosphorus removed in various crops.*

Crop	Phosphorus removed (kg)
Wheat	3 / T grain
Barley	3 / T grain
Lupins	5 / T grain
Canola	7 / T grain
Oaten hay	3 / T dry matter
Grass pasture	3 / T dry matter
Potatoes	0.5 / T tubers
Milk	1 / T liquid

Runoff losses

Phosphorus movement in soil varies depending on soil type, although it generally stays very close to where it is placed. Because fertiliser P is mostly applied on or near the soil surface, most P is found near the surface and concentrations decrease with depth. However, sandy pasture soils used for milk production in high rainfall parts of Tasmania have been found to lose large amounts of fertiliser applied P in surface runoff or surface drainage (Broad and Corkrey 2011). Rates of 11 kg P/ha/year were found, but this loss can be minimised by applying P fertiliser during drier periods when the risk of surface runoff or drainage are minimal, i.e. during summer. Elevated concentrations of nutrients in water draining agricultural catchments, particularly N and P, have been associated with environmental problems such as eutrophication and algal blooms.

Placement of phosphorus

Agronomic benefits of banding P fertiliser on high P-fixing soils have been found in trials with potatoes and lupins, with this attributed to less soil coming in contact with the fertiliser. Wheat and canola have not responded to banded phosphorus on high P-fixing soils. Placing high rates of phosphorus less than 2 cm from the seed can reduce germination and establishment. Nitrogen-containing fertilisers (e.g. DAP) have been found to be more damaging than superphosphate fertilisers.

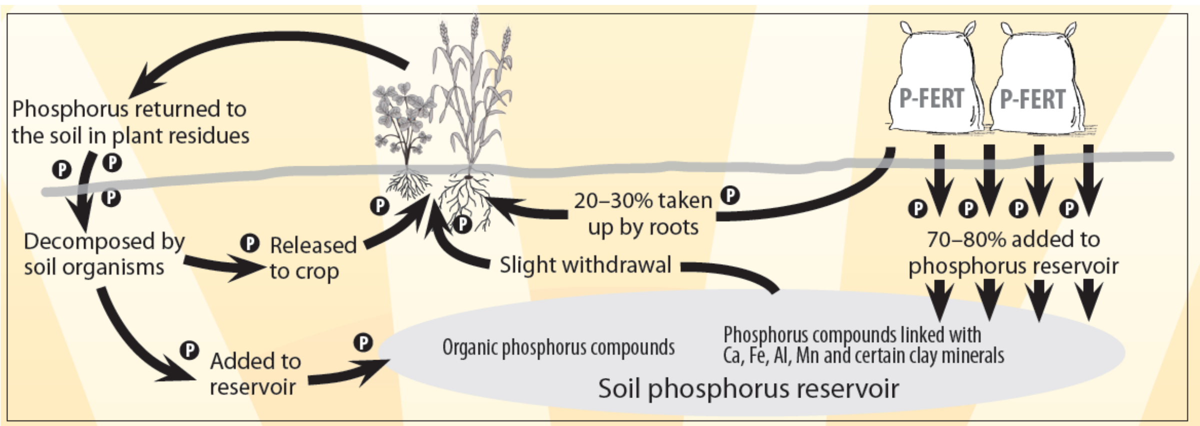

Figure 2: *The phosphorus cycle in a typical cropping system is particularly complex, where movement through the soil is minimal and availability to crops is severely limited (from Glendinning, 2000).*

Further reading and references

Broad ST and Corkrey R (2011) Estimating annual generation rates of total P and total N for different land uses in Tasmania, Australia. Journal of Environmental Management 92, 1609-1617.

Burkitt LL, Moody PW, Gourley CJP, Hannah MC (2002) A simple phosphorus buffering index for Australian soils. *Australian Journal of Soil Research* 40, 1-18.

Glendinning JS (2000) Australian Soil Fertility Manual. Fertiliser Industry Federation of Australia Inc. (CSIRO Publishing).

Peverill KI, Sparrow LA and Reuter DJ (1995) Soil Analysis an Interpretation Manual. (CSIRO Publishing).

Snowball K and Robson AD (1988) Symptoms of Nutrient Deficiencies in Subterranean Clover and Wheat. (The University of Western Australia).

Authors: **Richard Quinlan** (Planfarm Agricultural Consultancy), **Andrew Wherrett** (Department of Agriculture and Food, Western Australia) and **Bill Cotching** (Tasmanian Institute of Agriculture)