How do I ...

better manage phosphorus for pasture growth in light sandy soils?

The issue:	Light sandy soils with extremely low Phosphorus Buffering Index (PBI) values also have lower critical phosphorus (P) requirements for pasture production. They can have a poor ability to hold P in the surface soil after fertiliser has been applied and often have other co-occurring nutrient deficiencies. These findings present opportunities and challenges for effective management of soil fertility in sandy soils.
The impact:	High pasture production can be achieved at lower soil test P levels. However, nutrients may leach to depth in some of these soils and may not be identified by surface soil (0–10cm) testing. Other nutrient deficiencies (if present and unrecognised), can constrain the impact of P fertiliser application.
The opportunity:	Thousands of producers are farming areas with light sandy soils, including large tracts of Western Australia and coastal areas, localised patches and whole districts in all states. Increased use of soil testing and interpretation of the results will lead to more appropriate fertiliser recommendations and applications. Testing for P in the surface soil, and at depth to account for P which has moved deeper in the soil profile after fertiliser applications, and for other co-occurring nutrient deficiencies, can lead to more effective use of existing P stocks and applied fertiliser. There is also value in using deep-rooted pasture legumes, such as serradellas. Serradella is well-adapted to deep sandy soils as it handles soil infertility better than some legume options and has the capacity to use deep soil nutrients (P, potassium (K), sulphur (S) and nitrogen (N)) if present. This can potentially be financially and environmentally rewarding for grazing and mixed farming enterprises.

Producers and agronomists discussing fertiliser responsiveness of serradella growing on a deep sandy soil. Research indicated P soil test interpretation is different for these soils compared to more loamy ones. Image courtesy of Bob Freebairn.

Critical P benchmarks for pastures growing in light sandy country

The critical soil test P requirement of pastures in Australia is defined as the soil test value (using 0–10cm depth soil samples) which can support 95% of the pasture's maximum growth rate. It is a useful benchmark on which to build a soil fertility management program.

If you are using the Olsen P soil test, the critical value is believed to be 15mg P/kg of soil for all soil types. However, the critical soil test P value for the Colwell P test varies with the PBI value of your soil. The relationship between PBI and the critical Colwell P value is shown in Figure 1. Using the PBI test value allows a grower to work out the critical Colwell P value for high pasture production.

Sandy soils can have low capacity for P buffering and can have a lower Colwell P value for maximum pasture growth.

A combination of field trial data and soil fertility modelling has been used to re-evaluate the critical P requirements of clover-based pastures growing on very sandy soils where the PBI is less than ~15 (Gourley et al. 2019). The newly understood relationship between PBI and critical Colwell P in the very sandy soil range is shown in the inset to Figure 1. This means producers can fertilise these soils to lower soil test P levels and still expect to achieve high production.

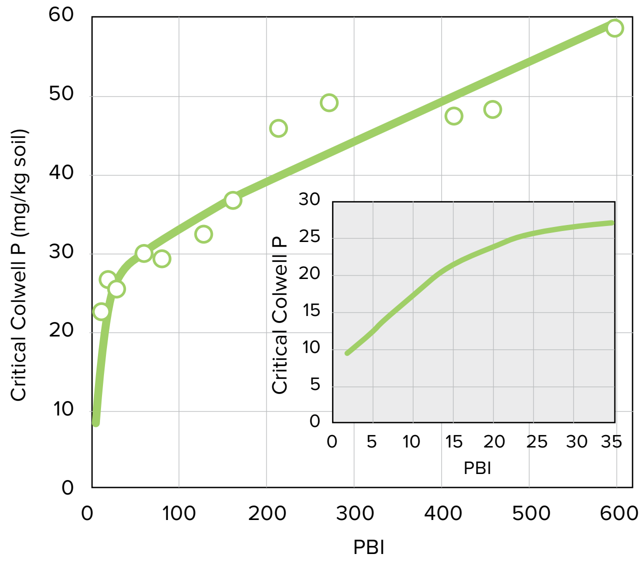

Figure 1. Relationship between PBI and 'critical' Colwell P for soil samples taken at 0–10cm depth. The critical Colwell P shown here is the soil test P concentration (mg P/kg soil) which support 95% of maximum yield by sub-clover and white clover-based pastures. It is also applicable to most other legume-based pastures, but there are a few exceptions (see FACTSHEET xxxxxx). This relationship between PBI and critical Colwell P was derived from a dataset of ~650 experiments conducted between 1955 and 2006 (Gourley et al. 2019). Producers can use the relationship to predict the critical P value which applies to their soil type if they have undertaken a PBI soil test. The inset to the figure is an expanded view of the relationship which applies to soils with very low to moderate PBI values (e.g. very sandy soils).

Researchers taking samples at depth during the trials on sandy soils in NSW. Image courtesy of Suzanne Boschma.

P movement in deep sandy soils

A complicating factor when managing soil P in very sandy soils is their low capacity to adsorb phosphate (i.e. low P buffering capacity). This means P can also leach from the topsoil to depth and may also be lost to watercourses, where it can be a significant pollutant leading to eutrophication (excessive algal growth which disrupts aquatic ecosystems). The consequences for soil P management are:

- over-fertilising, which may result in off-farm environmental impact
- P which moves below the topsoil layer will not be detected by standard surface soil testing methods; this can mean surface soil tests (0–10cm) may be a less reliable indicator of soil P fertility
- P from previous fertiliser applications, which has accumulated in a sandy subsoil, is often still available for plant uptake and can offset the need to apply P as fertiliser.

As a guide, if the PBI of surface soil samples (0–10cm depth) is less than about PBI 35 it can be useful to check whether the soil you are managing has deep P reserves.

Figure 2 shows Colwell P concentrations in deep sandy soil profiles on farms in northern NSW and south-western Western Australia. The soils at Boggabri and Purlewaugh, NSW, retained P in the topmost soil layers and can continue to be managed using surface soil testing (0–10cm depth). However, those from Broomehill and Grass Patch, WA, accumulated P at depth. The deep P should be taken into account to ensure the soil profile is not over-fertilised.

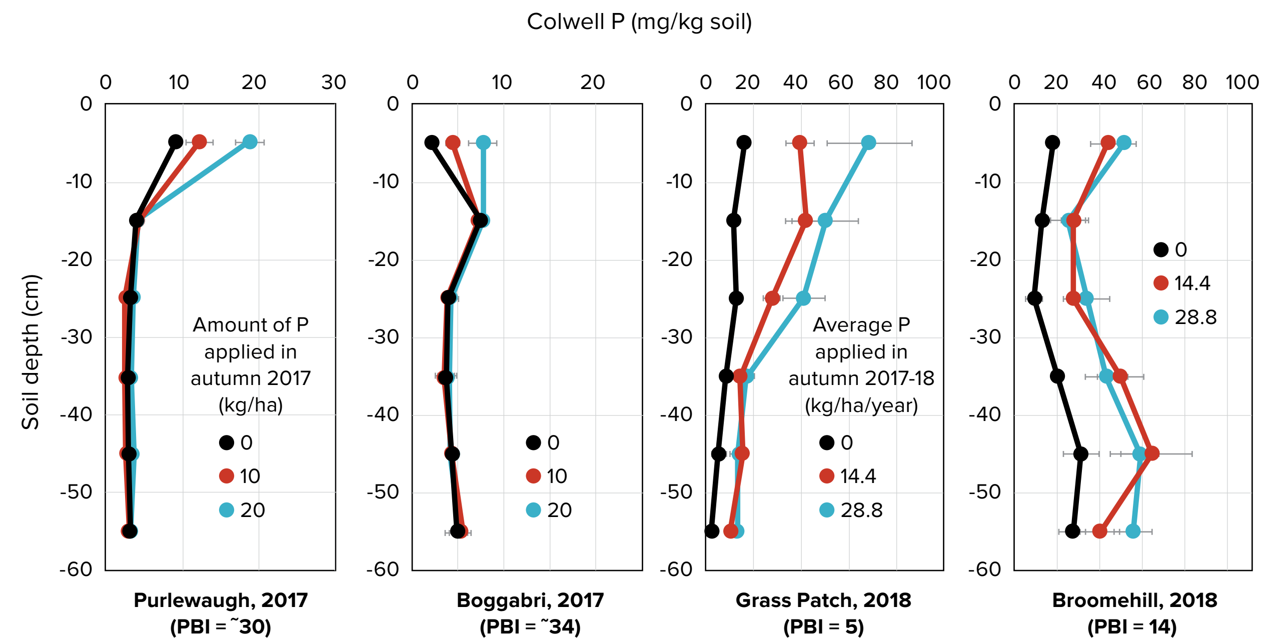

Figure 2. Colwell P profiles at farm sites in northern NSW (Boggabri and Purlewaugh, local farmer groups) and Western Australia (Broomehill and Grass Patch, ASHEEP and Southern Dirt farm groups) which were part of a national program to assess serradella's ability to grow well at lower soil P levels than species like sub-clover. These sites are typical of deep, sandy textured soils with very low to low PBI levels in the surface soil. The very low PBI values indicate it is wise to check the soil profiles for P at depth. This was observed at Broomehill and Grass Patch where P moved readily to depth in the soil profile after application of P fertiliser. Data was provided courtesy of the farm groups, Brad Nutt (Murdoch University), Bob Freebairn (agricultural consultant) and Suzanne Boschma (NSW Department of Primary Industries).

Other nutrient deficiencies

Soils used for pasture production across Australia can have other nutrient deficiencies, most commonly potassium (K), sulfur (S) and/or molybdenum (Mo) in very acid soils.

Mo deficiency is usually addressed by applying molybdised superphosphate at five to six-year intervals.

Critical soil test values have been determined for K and S (Table 1). As a general rule, the most deficient nutrient in your soil determines the pasture production level you will achieve. So if K and S are more deficient than P, they will reduce or stop the pasture responding to P fertiliser applications and to existing soil P stocks. The chance of this happening is now much greater than before because producers have been improving the P status of soils by applying superphosphate over many years.

Table 1. Critical soil test potassium (K) and sulfur (S) concentrations for surface soil testing (0–10cm) of soils that support clover-based pastures in Australia. Critical soil test values can support 95% of maximum yield, provided other nutrient deficiencies or soil constraints are not present. (Gourley et al. 2019).

Critical Colwell K (mg/kg soil)	
Sand	126
Sandy loam	139
Sandy clay loam	143
Clay loam	161
Clay	insufficent data
Critical KCl40 sulfur (mg/kg soil)	
All soils	8

Sandy soils are particularly prone to multiple nutrient deficiencies. For example, research currently underway in Western Australia to validate critical soil P levels for sandy soils, found that at least 11 sites, out of 19 farm sites, tested as deficient in K and/or S. (Fifteen of the 19 sites responded to a basal fertiliser application containing N, K, S and micronutrients). Only five of the farm sites were still responsive to P fertiliser. (Rogers et al. 2021).

K and S are also more prone to leaching to depth in a soil profile than P, and this is particularly the case in deep sandy soils. If surface soil testing indicates K and/or S deficiencies, it is worthwhile considering deep soil testing to check whether there are reserves of K and/or S deeper in the soil profile.

Nutrients at depth can be factored into your fertiliser calculations and will ensure more cost-effective fertiliser decisions which do not inadvertently over-fertilise the soil profile.

Alternative pasture legumes for deep sandy soils

Pasture species like serradellas (*Ornithopus* spp.) are capable of rooting faster and deeper (up to 1.5m depth or more) than sub-clover (0.45–0.8m depth) in deep sandy soils. Serradella also has extensive fine roots and longer root hairs which allow it to access soil P more efficiently than sub-clover. They are ideally suited to – and often thrive in – acidic, deep sandy soils. Read more about the beneficial agronomic features of serradellas in xxxxx Factsheet xxxx.

The P efficiency of the serradella root system enables it to achieve maximum yields at a lower critical P level than sub-clover.

Serradella's deep root system can access nutrients such as P, K, S and N when they have leached to depth in a soil profile.

Critical soil test guidelines for the serradellas are limited because they are still gaining wider acceptance and have not been studied as much as species like sub-clover. However, field experiments on soils across a PBI range of 40–80 found the critical soil test level for serradella was about 20mg Colwell P/kg soil (7.5–10mg Olsen P/kg), whereas that for sub-clover was about 30mg Colwell P/kg soil (~15mg Olsen P/kg) (see also Figure 1). More information on the research in relation to P efficiency of serradellas and critical P requirements of various pasture legumes can be found in xxxxx Factsheet xxxx.

Yellow serradella pasture thriving in a deep sandy soil. Image courtesy of Bob Freebairn.

Acknowledgements

Research to increase the effectiveness of phosphorus use was conducted under the 'RnD4P-15-02-016 Phosphorus Efficient Pastures' project. The project was supported by funding from the Australian Government Department of Agriculture and Water Resources as part of its Rural R&D for Profit program, Meat & Livestock Australia, Dairy Australia and Australian Wool Innovation Ltd.

The research by Rogers et al. in WA was funded through Royalties for Region's Healthy Estuaries WA and the Australian Government's National Landcare Program.

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Serradella thriving in a Premier digit grass stand in sandy soils. Image courtesy of Bob Freebairn.

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First published in 2021