How do I ...

grow more phosphorus-efficient pastures?

The issue:	Phosphorus is globally important for the production of food, including red meat. It is an expensive input and forecasts are for pressure on world supplies as the population increases. Currently, producers can use phosphorus (P) fertiliser most effectively by using soil tests to guide and monitor their application. However, if livestock producers can grow highly productive winter annual legumes with a lower soil P requirement, further savings and reduced fertiliser inputs are possible.
The impact:	P fertilisers (mineral and/or organic) should be applied to pastures at rates appropriate for efficient production. Applying the appropriate amount of fertiliser can minimise the risk of adverse off-site impacts, which can occur when fertilisers are applied in excess of agronomic requirements. Producers also have the opportunity to select pasture types which require less soil P, while being highly efficient at producing quality livestock feed.
The opportunity:	Legume species, such as serradella, have been identified as P efficient, highly productive and nutritious. Two species, yellow serradella and French (or pink) serradella, are available for use in Australian pastures. They provide an opportunity to grow high-performing pastures with lower fertiliser input costs. Growing these legumes may help reduce pressure on fertiliser supplies and supports positive environmental outcomes.

Soils in the grazing and mixed farming areas of southern Australia are commonly low in natural fertility, especially phosphorus (P). The growing of more P-efficient pastures may improve the feedbase and profitability over millions of hectares.

Serradella (pictured right) has been identified by research, supported by MLA, as being substantially more P efficient than the most widely grown annual winter legume, sub-clover, and more P efficient than many other winter legume species including medics. The serradellas typically have a lower 'critical' soil test P requirement for maximum yield (Figure 1). This is also the soil test P level likely to ensure maximum growth of a mixed legume–grass pasture.

When grown in well-drained soils with a pH_{Ca} of 4.2–7.0 and well established and managed, serradella was found to be as or more productive than sub-clover. In situations not suited to sub-clover (for example, very low pH, high aluminium soils) serradella proved successful.

TOP TIP

A comprehensive guide for implementing best practice when fertilising sub-clover-based pastures can be found at: mla.com.au/extension-training-and-tools/tools-calculators/phosphorus-tool/

Why serradella?

Serradella offers:

- improved phosphorus efficiency when grown in soils to which it is suited
- low bloat risk
- lower plant disease risk
- tolerance to very acid soils (pH_{Ca} 4.2–7.0 with exchangeable aluminium (Al) of 10–40%)
- improved tolerance to some pests
- drought tolerance
- high feed quality
- adaptation to low to high-rainfall environments when using an appropriate cultivar
- very low phytoestrogen content (to avoid oestrogen levels which cause ewe fertility issues, a problem with some older sub-clover varieties)
- the ability to build soil nitrogen
- the ability to put down a deep root system
- hardseededness (in most cultivars) to support regeneration after a dry period.

However, serradella is not suited to soils:

- prone to persistent water logging
- with high clay content
- of high pH (above pH_{Ca} 7)
- of low pH where manganese (Mn) toxicity is likely to occur.

Is serradella my only option for P-efficient pastures?

While commonly grown winter legumes have similar P requirements to sub-clover and white clover, they do not have serradella's ability to thrive on soil with lower P fertility (Figures 1 and 2). However, there are a few forage-type legumes (e.g. arrowleaf clover) which also have lower critical P requirements, similar to that of the serradellas (Figure 2).

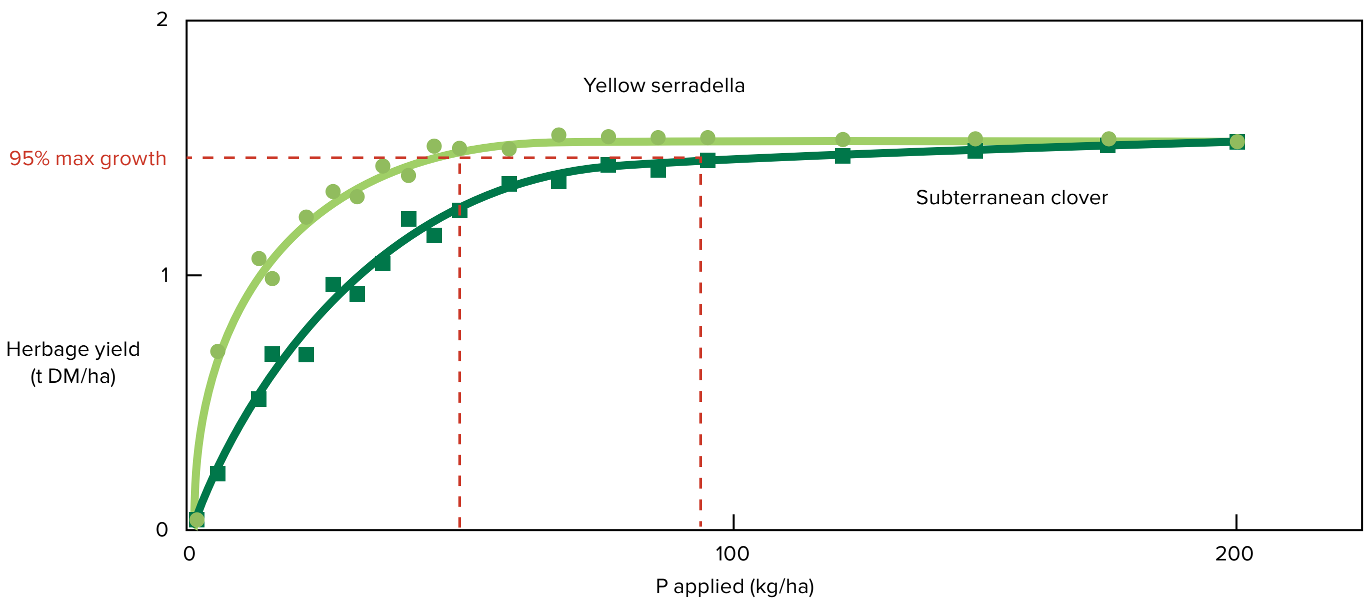

Figure 1. The effect of phosphorus application on serradella herbage yield (t DM/ha) compared with sub-clover. (Bolland and Paynter 1992)

Pasture species	Cultivar	No. of assessments
Caucasian clover *(Trifolium ambiguum)*	KuratasΦ	1
Barrel medic *(Medicago truncatula)*	Sultan-SUΦ	2
Subterranean clover *(T. subterraneum)*	5 x Leura 2 x IzmirΦ 2 x NarrikupΦ	9
Gland clover *(T. glanduliferum)*	Prima	2
Rose clover *(T. hirtum)*	Hykon	4
Biserrula *(Biserrula pelecinus)*	2 x Casbah 1 x MauroΦ	3
Bladder clover *(T. spumosum)*	Bartolo	3
Cocksfoot *(Dactylis glomerata)*	Porto	2
Crimson clover *(T. incarnatum)*	Dixie	4
Balansa clover *(T. michelianum)*	Bolta	1
Phalaris *(Phalaris aquatica)*	Advanced ATΦ	2
Arrowleaf clover *(T. vesiculosum)*	Zulu II	3
Yellow serradella *(Ornithopus compressus)*	6 x Santorini 1 x Avila	7
Birdsfoot trefoil *(Lotus corniculatus)*	LCO7AUYFΦ	2
French serradella *(O. sativus)*	MargaritaΦ	5
Purple clover *(T. purpureum)*	Electra	3

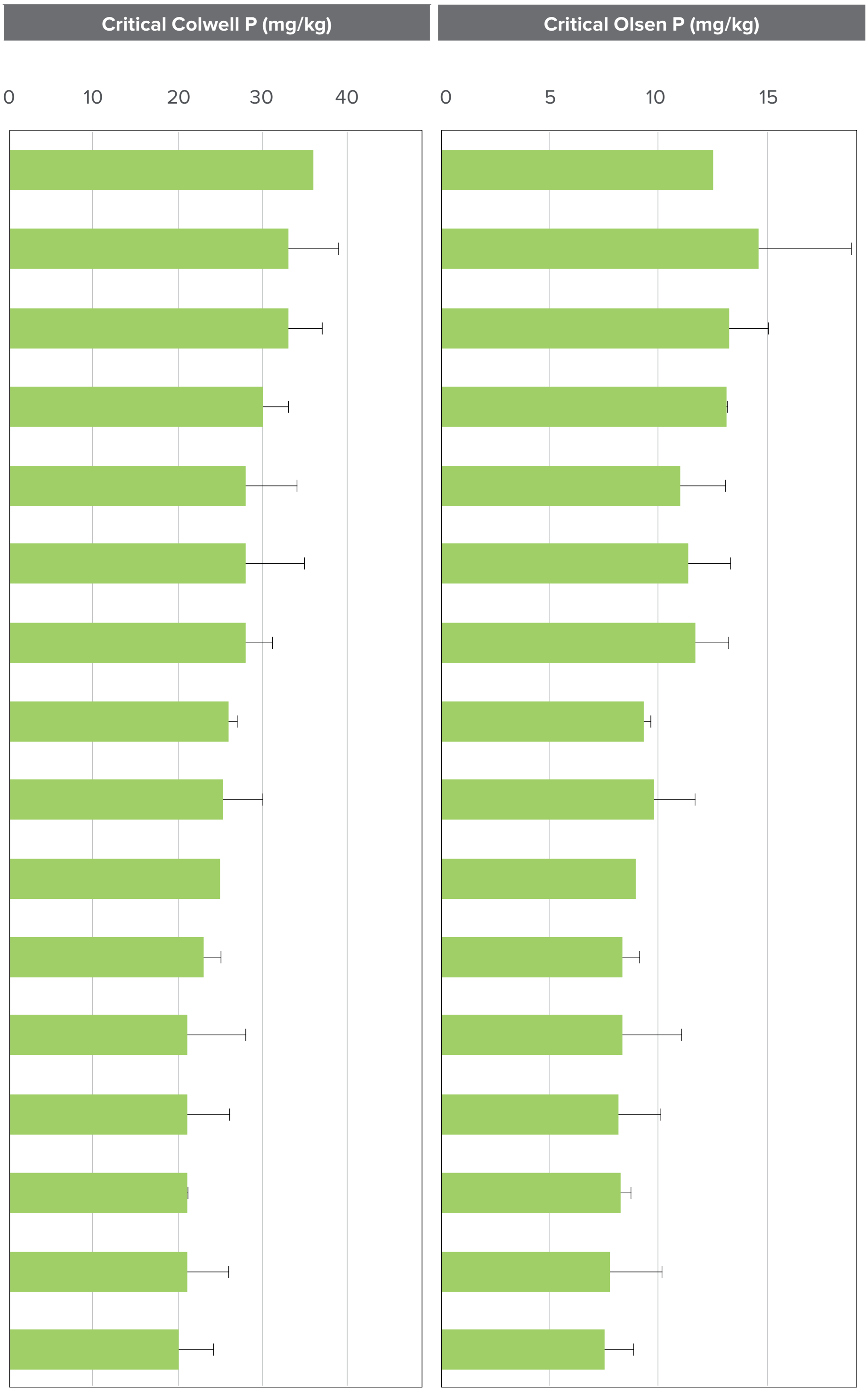

Figure 2. The critical soil test P concentration (corresponding to 95% of maximum yield; mg P/kg soil using 0–10cm depth soil samples) of various pasture legume and two perennial grass varieties grown at up to four sites (PBI range: 40–80) over a three-year period (in total, seven site-year experiments). The critical Colwell P concentrations only apply to soils within this Phosphorus Buffering Index (PBI) range because critical Colwell levels are known to vary with soil PBI levels. Herbage growth responses to increased soil P availability were measured in spring. There were no significant differences in the critical P requirements among cultivars from a single species. Bars indicate 1x standard deviation. They provide a measure of the repeatability of the critical P estimate. If error bars are not shown the variety was evaluated only once. Lucerne (cv. SARDI 10) as also assessed on six occasions, but its critical P requirement often exceeded the highest P levels in the experiments. On this basis it is suspected that its critical P requirement was greater than Colwell P 45–50mg/kg, or Olsen P 15.5–21.4mg/kg. These graphs are drawn using data from Sandral et al. 2019, *Crop & Pasture Science* 70, 1080–1096, https://doi.org/10.1071/CP19014

How much phosphorus does my soil need?

The critical soil P value is the value at which 95% of maximum production is likely to be achieved providing other resources (e.g. other nutrients and moisture) are not limiting. The critical soil test P level (typically reported in mg Olsen P, or mg Colwell P/kg soil for a 0–10cm depth soil sample) is a good guide to the target levels to which soil P fertility can be increased without wasting money and resources.

Table 1. Phosphorus buffering index (PBI) categories and corresponding Colwell P 95% critical soil test values

PBI category		Critical value (mg/kg) for midpoint of PBI category (range)+
≤5	Extremely low	10 (9–12)
>5–10	Very low	15 (12–17)
>10–15	Low	20 (17–21)
>15–35	Moderately low	26 (21–28)
>35–70	Medium	29 (28–31)
>70–140	Moderately high	33 (31–35)
>140–280	High	39 (35–42)
>280–840	Very high	55 (42–68)
≥840	Extremely high	n/a#

\+ Critical Colwell P value at the midpoint of PBI class. Values in parentheses are critical Colwell P values at the lowest and highest PBI values within the range.

\# Insufficient data to derive a response relationship.

Provided attention is given to other potential production constraints (suitable variety and species, other soil deficiencies, suitable grazing management) maintaining soil test P concentrations close to the critical P level should deliver high production per hectare and the most effective use of P fertiliser.

What is considered the ideal soil test level of P for maximum legume production can depend on the Phosphorus Buffering Index (PBI) of the soil. Soils with medium PBI levels (for example, a soil with a PBI between 36 and 70) have lower critical Colwell P levels than soils with higher PBI levels. In this PBI range, near-maximum production by sub-clover would require the soil to have around 30mg Colwell P/kg (or 15mg Olsen P/kg soil).

However, for serradella the Colwell soil test level for maximum herbage production is around 20mg Colwell P/kg (or 7.5–10mg Olsen P/kg) (Figure 2).

While soil P tests taken in the top 0–10cm soil layer provide a good guide for determining appropriate soil P levels for maximum pasture production for most soil types, this is not necessarily the case for deep sandy soils. P leaching to depth can occur in these soils and a surface soil test may not be a reliable indicator of the P available to a pasture. Producers on deep sandy soils should seek further local agronomic advice. Deep soil testing may be required. Serradella, being a far more deep-rooted species than many other annual legumes, can be more efficient at capturing this deep soil P than most other species.

Serradella's potential in new environments

A national project which featured on-farm trials, part-funded by MLA, indicated productivity of selected serradella cultivars can, in many cases, be equivalent to sub-clover in areas where serradella is currently hardly ever grown. This includes the NSW Tablelands and Slopes.

Research across the NSW Southern Tablelands found variety choice was a vital aspect of likely serradella success in newer environments. While many cultivars were capable of high herbage yields, their persistence in a pasture could be problematic. The yellow serradella cultivar Avila was (in three years of study) outstanding for seedling regeneration and was one of the more stable flowering types studied. It is of late-season maturity, similar to sub-clover cultivars Goulburn and Leura, and suited to high-rainfall areas. However, in a few locations it did not yield as well as the subterranean clover. The exact reason for lower yield in some locations is not yet understood.

Hardseededness is essential for the persistence of serradellas in a pasture. Soft-seeded cultivars (e.g. French serradella cultivar Cadiz⁽ᴾ⁾) will not persist more than a few years as they are not protected against a false summer break or prolonged drought.

However, most yellow and the newer French serradella cultivars have high levels of hard seed. The yellow serradella cultivar, Avila, is an older hardseeded variety. Typically, it produces seeds which are 80–90% hard at the beginning of summer, but the seeds soften slowly by comparison with the equivalent late-maturing sub-clover varieties (Goulburn and Leura). By the autumn break, there may only be 20–30% of seeds which have softened and are ready to germinate. High hardseededness and slow seed softening are unlikely to be detrimental once seed banks of serradella are established, but growers establishing new serradella pasture should be aware it can sometimes be associated with low regeneration of seedlings in the year after pastures were sown, especially if the initial season was relatively dry.

In a permanent pasture, this may result in a low legume content and provide an opportunity for weeds to invade the newly sown pasture. In cropping areas, producers are encouraged to sow a fodder crop in the year after serradella establishment to counter this issue, but this is not a practical solution when establishing a mixed, permanent pasture. Nevertheless, in the research experiments good stands of Avila serradella often regenerated in the second year after establishment.

This highlights the importance of following good pasture establishment practices, especially good weed control, when establishing a new pasture. Further research is underway to address low serradella densities in the year after pasture establishment.

It is also critically important to remember to inoculate serradella seeds with the right rhizobium strain (Group G/S). Some manufacturers only produce Group G (used on lupins) and if it is the only product available, it can be used on serradella. The inoculant groups used on serradella are different to those used for other pasture legumes. Failure to do this may compromise nodulation and serradella pasture establishment.

Once established, it is expected the slow seed softening attributes of many serradella cultivars will result in good levels of residual hard seeds for carryover into future years and protection through droughts.

In the areas where serradella is currently grown, for example over wide areas of WA where soils are sandy and acidic and in NSW central, southern and central west light soil areas, earlier maturing hard-seeded yellow and French cultivars are used. New knowledge of their improved P efficiency has the potential to further increase the uptake of serradella in these environments.

Long-term pasture fertiliser trial. Image courtesy of Bob Freebairn

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More information

Richard Simpson and Rebecca Haling, CSIRO Agriculture and Food, Canberra, ACT
E: richard.simpson@csiro.au
E: rebecca.haling@csiro.au

Richard Hayes, NSW Department of Primary Industries, Wagga Wagga, NSW
E: richard.hayes@dpi.nsw.gov.au

Robert Freebairn, Agricultural Consultant Coonabarabran NSW
E: robert.freebairn@bigpond.com

MLA's Feedbase Hub: mla.com.au/extension-training-and-tools/feedbase-hub/

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MEAT & LIVESTOCK AUSTRALIA

Meat & Livestock Australia
Level 1, 40 Mount Street
North Sydney NSW 2060
Ph: 02 9463 9333
mla.com.au

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