Critical external phosphorus requirements of pasture legumes

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Key findings

» *Ornithopus sativus* (French serradella) was capable of yielding as much as *Trifolium subterraneum* (subterranean clover) with 30% less phosphorus (P).

» *Ornithopus compressus* (yellow serradella) required 30% less P than *T. subterraneum* to produce the maximum yield, however its maximum yield was often lower than that of *T. subterraneum*.

Introduction

This research aimed to determine the external critical phosphorus (P) requirement (i.e. the soil extractable-P concentration required to achieve 90% of maximum yield) of a range of pasture legume species under field conditions. This information can be used as a benchmark for soil testing and soil P fertility management on farms.

Sites

Four sites were established near Yass (340 56′54.02″ S and 1480 55′48.02″ E), Burrinjuck (340 52′11.80″ S and 1480 40′ 21.45″ S), Belfrayden (350 06′58.06″ S and 1460 59′34.51″ E) and Beckom (340 12′10.56″ S and 1470 01′59.22″ E) in southern NSW.

Procedures

Phosphorus was applied by hand from two pre-weighed bags per plot to establish six equal P fertility levels. Rates included 0, 15, 30, 45, 60 and 80 kg P/ha at Yass (2012) and Burrinjuck (2013) with slightly different rates of 0, 15, 30, 50, 65 and 85 kg P/ha at Belfrayden and Beckom (2014). P was applied as triple-superphosphate (P = 20.7%, S = 1.5%). Basal nutrients (potassium sulfate 100 kg/ha, magnesium sulfate 60 kg/ha, molybdenum trioxide 0.07 kg/ha, boric acid 1.75 kg/ha, copper sulfate 1.75 kg/ha and zinc sulfate 3.5 kg/ha) were applied at each site through a boom spray at 100 L/ha of water carrier.

Varieties tested in 2014 were inoculated with their appropriate rhizobia strain before sowing (Table 1). At peak spring growth, shoots were cut from three quadrats (200 × 500 mm) in each plot. Shoots were dried at 70 °C for 72 hours and weighed to provide an estimate of the dry matter production for each plot.

Soil P levels were determined at the time of the peak spring growth by sampling 24 cores (0–10 cm depth) from each plot. Soils were then homogenised and dried at 40 °C. Once dry, the soil samples were again homogenised and subsampled to determine the Colwell P extractable-P concentration (Colwell 1963).

Experimental designs were generated using DiGGer® (Coombes 2009) to produce a design that avoids row, column and diagonal treatment duplicates with three replicates, six P rates and 12 varieties. Where results for fewer than 12 varieties are shown (Table 1), it highlights variety failure at that specific location. Results were analysed using R version 3.3.1.1. Dry matter and soil test data were first analysed using Asreml and the fixed model applied as cultivar plus P rate with testing for linear column and row effects, which were checked for significance using the Wald test. The random model included row, column, rep and rep.plot effects with testing for auto-regressive correlations using loglik differences greater than 3.84. This analysis showed that P rate and cultivar effects were significant ($P > 0.05$), but not P rate × cultivar effects. Estimates of l.s.d. values at the 5% level were calculated for Colwell P and dry matter measurements. Fitted data from Asreml at the plot level was then used to fit Mitscherlich equation [$y = a - b^*(-cx)$] where y is the shoot dry matter (kg/ha) and x is the soil Colwell P (mg/kg) to provide an estimate of critical Colwell P (i.e. the Colwell P concentrations coinciding with 90% of maximum dry matter).

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Results

Subterranean clover (cvs. Leura, Narrikup, Izmir) was used as a benchmark/control species as it is the most commonly grown legume in permanent pastures and mixed crop-pasture systems in southern Australia. It is also known to have a high critical external requirement for P, which is the basis of the soil test P benchmarks that are currently used for pasture management in southern Australia (Gourley et al. 2007; Moody 2007). Results for 2014 are presented below.

Table 1. Critical Colwell P requirements (mg P/kg soil) of pasture legumes determined as the soil test P (STP) concentration required to achieve either 90% of maximum herbage yield (kg dry matter/ha) for peak spring growth. Parameters were derived by fitting a Mitscherlich response (yield = a – b *(e – c*Colwell P)) to data collected from the Yass, Burrinjuck, Beckom and Belfrayden sites. Maximum yield is predicted by a, the asymptote; responsiveness to P is reflected in c, the curvature parameter; and the intercept (a-b) is an extrapolation reflecting yield at a theoretical Colwell P value of zero.

Site and species	Cultivar	90% Critical STP concentration (mg/kg)		Parameter		
		Colwell P	Intercept	a	b	c
Yass 2014						
Ornithopus compressus	Avila	20	-1305	3984	-5289	0.8801
Ornithopus compressus	Santorini	19	-977	5976	-6953	0.8784
Ornithopus sativus	Margurita	17	-2461	6987	-9448	0.8572
Trifolium subterraneum	Leura	31	-2095	6715	-8810	0.9200
T. subterraneum+ Lupinus albus	Leura + Luxor	19	-3293	5518	-8811	0.8663
Trifolium purpureum	Electra	25	-1898	5652	-7550	0.9015
Burrinjuck 2014						
Trifolium incarnatum	Dixie	20	-17915	10726	-28641	0.8502
Trifolium subterraneum	Leura	27	-5472	9489	-14961	0.9037
Ornithopus sativus	Margurita	17	-29840	9267	-39107	0.807
Trifolium michelianum	Bolta	22	-5474	11903	-17377	0.8836
Beckom 2014						
Trifolium spumosum	Bartolo	21	512	3542	-3030	0.902
Biserrula pelecinus	Casbah	18	-1764	2549	-4313	0.8524
Trifolium incarnatum	Dixie	19	1552	3618	-2066	0.9127
Trifolium hirtum	Hykon	19	-284	3117	-3401	0.8804
Trifolium subterraneum	Izmir	25	1052	2591	-1539	0.9323
Ornithopus sativus	Margurita	10	-1336	2576	-3912	0.7580
Trifolium subterraneum	Narrikup	26	746	3488	-2742	0.9234
Trifolium glanduliferum	Prima	33	296	2467	-2171	0.9356
Ornithopus compressus	Santorini	7	-102963	2009	-104972	0.385
Medicago truncatula	Sultan-SU	30	410	3631	-3221	0.9303
Trifolium vesiculosum	Zulu II	12	-2838	2945	-5783	0.7792
Belfrayden 2014						
Trifolium spumosum	Bartolo	39	460	7518	-7058	0.9436
Biserrula pelecinus	Casbah	42	1215	7012	-5797	0.9515
Trifolium incarnatum	Dixie	41	2518	9120	-6602	0.9531
Trifolium hirtum	Hykon	29	-3649	7421	-11070	0.9103
Trifolium subterraneum	Izmir	48	-52	6053	-6105	0.9528
Ornithopus sativus	Margurita	24	-1927	5054	-6981	0.8976
Trifolium subterraneum	Narrikup	48	2143	7489	-5346	0.9598
Trifolium glanduliferum	Prima	46	280	5694	-5414	0.9526
Ornithopus compressus	Santorini	24	534	4331	-3797	0.9125
Medicago truncatula	Sultan-SU	47	2508	6642	-4134	0.9617
Trifolium vesiculosum	Zulu II	24	-459	5694	-6153	0.9057
	l.s.d. (P = 0.05)	8.0				

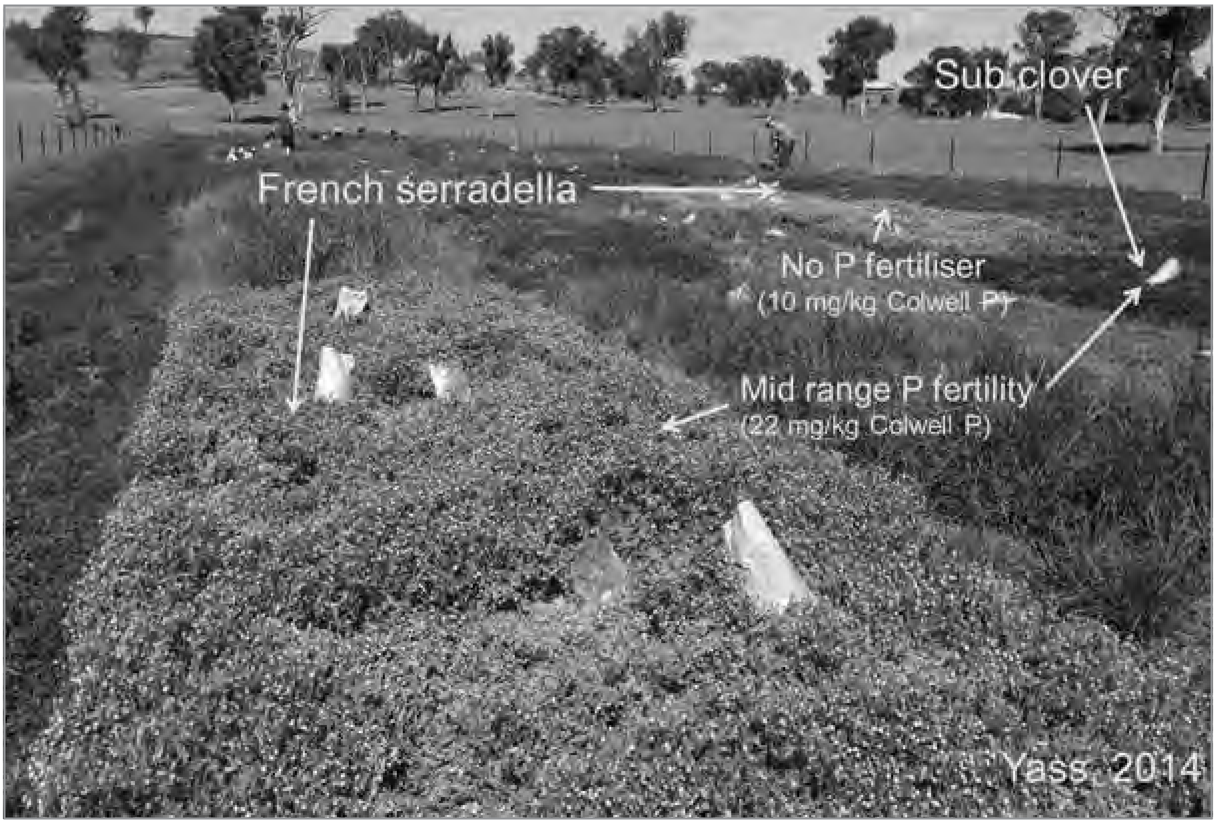

Figure 1. French serradella grown at 22 mg/kg Colwell P (foreground) and subterranean clover (back right) also grown at 22 mg/kg Colwell P.

Yass

The critical Colwell P requirement of subterranean clover was 31 mg P/kg. Yellow serradella (cvs. Avila: 20 mg P/kg, Santorini: 19 mg P/kg) and French serradella (cv. Margurita: 17 mg P/kg) had critical Colwell P requirements approximately 60% of that for subterranean clover and yielded as well as subterranean clover (with the exception of cv. Avila). The mixture of white lupin and subterranean clover had a lower critical Colwell P requirement, but also a lower yield than the subterranean clover.

Burrinjuck

The critical Colwell P requirement for subterranean clover was 27 mg P/kg. French serradella (cv. Margurita) yielded as well as subterranean clover but had a critical Colwell P requirement of 17 mg P/kg. Crimson clover (cv. Dixie: 20 mg P/kg) and Balansa clover (cv. Bolta: 22 mg P/kg) yielded more than subterranean clover, but did not differ in critical P requirement.

Belfrayden

The critical Colwell P requirement of subterranean clover (cvs. Izmir and Narrikup) was 48 mg P/kg. Bladder clover (cv. Bartolo), Biserrula (cv. Casbah), gland clover (cv. Prima), crimson clover (cv. Dixie) and barrel medic (cv. Sultan-SU) had critical P requirements that did not differ from subterranean clover. Rose clover (cv. Hykon: 29 mg P/kg), French serradella (cv. Margurita: 24 mg P/kg), yellow serradella (cv. Santorini: 24 mg P/kg) and arrowleaf clover (cv. Zulu II: 24 mg P/kg) had critical P requirements up to half that of subterranean clover. Serradella species yields were not significantly different from subterranean clover cv. Izmir, but were lower than that of cv. Narrikup.

Beckom

Dry matter yields and critical P requirements were lower than those measured at Belfrayden. The critical Colwell P requirement of subterranean clover (cvv. Izmir and Narrikup) was 25–26 mg P/kg. French serradella (cv. Margurita: 10 mg P/kg), yellow serradella (cv. Santorini: 7 mg P/kg) and arrowleaf clover (cv. Zulu II: 12 mg P/kg) had critical P requirements less than half that of subterranean clover. The French serradella yield was not significantly lower than that of subterranean clover. The remaining clover species, barrel medic (cv. Sultan-SU: 30 mg P/kg) and biserrula (cv. Casbah 18 mg P/kg) had similar critical P requirements and yields to subterranean clover (25–26 mg P/kg).

Conclusion

The field experiments have identified for the first time that French serradella (cv. Margurita) has a significantly lower critical P requirement

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than subterranean clover and is also capable of producing equivalent peak spring biomass. This result, similar to that for yellow serradella, confirmed the substantial differences in critical STP requirements of the serradella species relative to subterranean clover. These differences in external P requirement occurred whilst roots of all species were highly colonised by arbuscular mycorrizhal fungi, despite their reputed role in P nutrition of pasture legumes. The results indicate that the serradella species could potentially be used to achieve productive, low P-input pasture systems.

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