Phosphorus efficient pastures: response of alternative legumes to fertiliser application

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Abstract
There is interest in pastures that require less phosphorus (P) fertilizer because P costs have risen. This objective requires legumes that yield as well as *Trifolium subterraneum*, but with lower critical P requirements (rate of fertilizer for 90% of maximum yield).

Two field sites were sown near Yass (autumn, 2012) and Bookham (2013). Yass was re-sown in 2013 to ensure establishment did not limit dry matter (DM) responses to P. The experiments included 12 pasture species (monocultures) at 6 P rates (0-80 kg P/ha, as triple superphosphate), (n=3 replicates). Maintenance P (0-31 kg P/ha) was applied at Yass in 2013. Lime and basal nutrients were applied to ensure only P and nitrogen were limiting. Legumes were inoculated with appropriate rhizobia. Herbage DM was determined in spring. Mitscherlich equations fitted to the DM data after Linear Mixed Model analysis were used to compare P requirements.

Some species proved unsuited to the soils and climate. Of those that established and grew well, only the grasses (*Phalaris aquatica, Dactylis glomerata*) and three legumes *(Ornithopus sativus* [pasture type], *T. incarnatum, T. purpureum* [forage types]) had DM yields equivalent to, or better than *T. subterraneum* whilst also having lower P-fertiliser requirements. *O. compressus* required less P, but did not yield as well. The critical *P requirement* of Medicago sativa was not reached over the P range used.

The experiments demonstrated that the P requirements of pasture legumes can differ. A few species yielded as well as *T. subterraneum* with lower critical *P requirements*.

Key words
Pasture legumes, critical phosphorus, *Ornithopus, Trifolium, serradella*, subterranean clover

Introduction

The phosphorus (P) balance efficiency of fertilised pastures in Australia is low with approximately 5 units of P applied as fertiliser to produce 1 unit of P in animal products (McLaughlin *et al*. 1992; Weaver and Wong 2011). The most common reason for low efficiency is accumulation of P in soil (McLaughlin *et al*. 2011) although other P losses (erosion, leaching, runoff) can also occur, particularly from sandy soils with low P sorption capacity. Pasture legumes that achieve equivalent yields at lower soil test P concentrations (i.e. lower critical P requirements) than *Trifolium subterraneum* (the most widely-used pasture legume) may reduce the amount of P fertiliser needed for productive pastures because fertilising soils to lower soil test P concentrations is expected to reduce the rate at which P accumulates in the soil (Simpson *et al*. 2014). Considerable resources have now been invested in the development of numerous alternative pasture legumes, mainly to address gaps in the areas where subterranean clover cannot be used reliably (Nichols *et al*. 2012). Little is known about the P requirements of these species. Here we report initial results from field experiments examining the growth during spring of a number of alternative legumes and two grasses in response to the application of P fertiliser. One objective of the work was to determine if any of the legumes could yield as well as *T. subterraneum* but at lower rates of applied P.

Methods

Field sites were sown near Yass (autumn, 2012) and at Burrinjuck near Bookham, (autumn, 2013) on the Tablelands of southern NSW. The initial choice of species was guided by evidence that a species may have a low P requirement; subsequent sowings were guided by field performance. Consequently, the alternative legume now known to have the most promise (*Ornithopus sativus*), was first sown at the Burrinjuck site in 2013. Species were re-sown at Yass in 2013 to ensure establishment did not limit dry matter (DM) responses to P. Each experiment included 12 pasture species grown as monocultures with six rates of applied P (0, 15, 30, 45, 60 and 80 kg P/ha.); (n = 3 replicates). P was applied as triple superphosphate (20% P and 1.5% S). Maintenance P (0, 4, 10, 16, 24, 31 kg P/ha) was added to the six original P treatments, respectively, at Yass in autumn 2013. Lime and basal nutrients were applied to ensure only P and nitrogen were limiting. Legumes were inoculated with an appropriate rhizobium strain. Perennial grasses received a total of 80 kg/ha/yr of nitrogen in four equal applications during May, July, August, and October. Herbage DM yields were determined in spring.

Herbage yields were analysed using GenStat version 16.1 by applying Linear Mixed Models (LMM) with Rep+Row.Column as random effects. The yields generated from LMM at plot level were subsequently used to fit Mitscherlich equations for all species except Medicago sativa, where a linear fit was used. The relative critical P requirements of each species were estimated for each season and site as the rate of P application that corresponded with 90% of maximum herbage yield in spring.

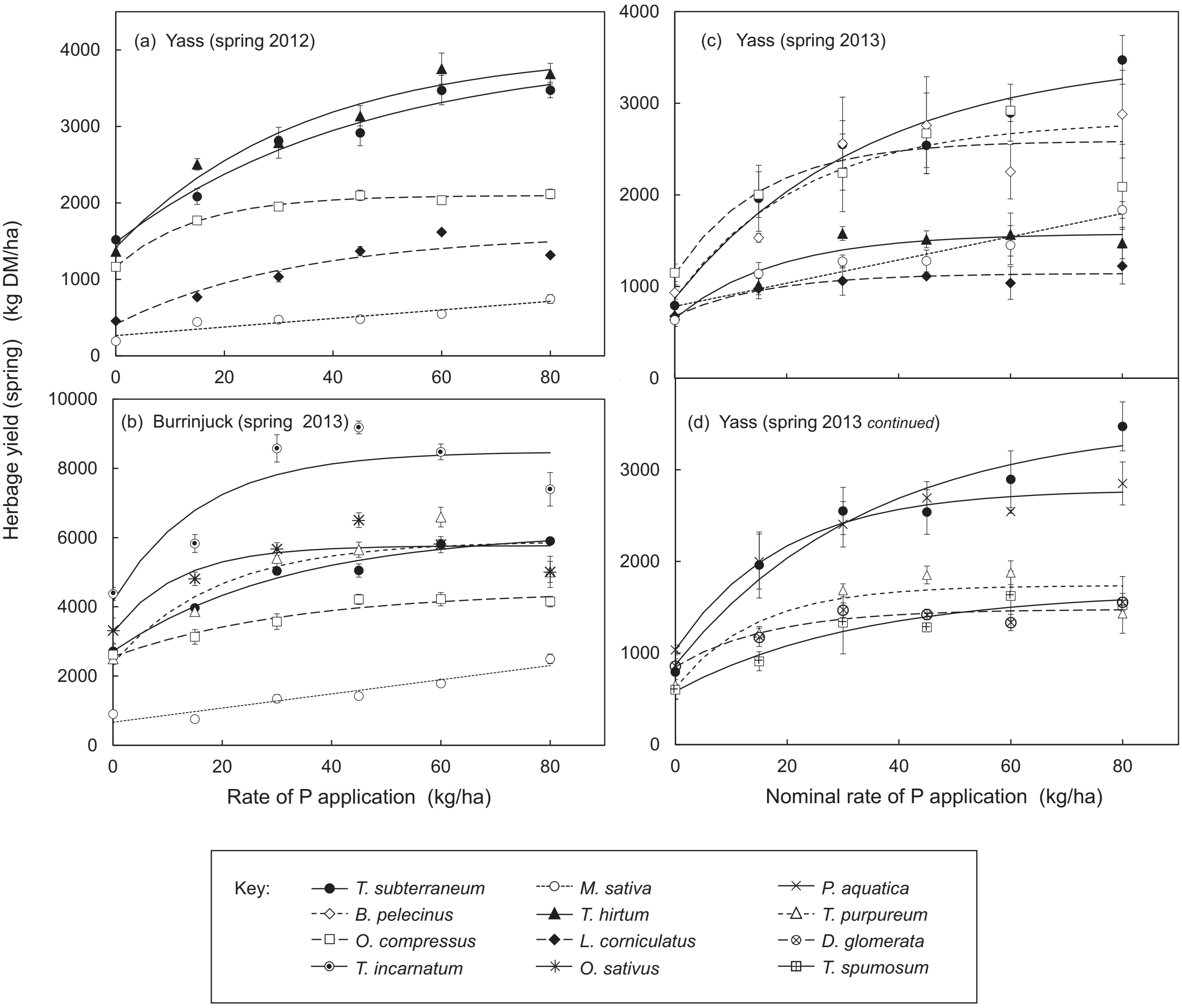

Figure 1. Yield of herbage DM grown in spring by species that had established adequately at the Yass (a, c and d) and Burrinjuck (b) sites. The result for *T. subterranean* is repeated in panels (c) and (d) for easy comparison with the other species. The Mitscherlich asymptotic function was fitted to the data using GenStat. For the year of establishment at each site, pasture yields are plotted relative to the P application rate. In the subsequent year (at Yass), soil P levels were topped up by adding a maintenance dressing of P and yields are plotted relative to the original P application rates, now designated (panels c and d) as the "nominal rate of P application". Error bars = 2xSE.

Result

Some of the pasture species that were sown proved to be poorly adapted to the Yass and Burrinjuck sites. For example: Bituminaria bituminosa ssp. abomarginata was susceptible to frost (sown at Yass only); Trifolium hirtum, in the year subsequent to its establishment, showed significant cold and waterlogging stress; Lotus corniculatus, Trifolium ambiguum and Trifolium tumens did not persist well over the dry summers (sown at Yass only); and Trifolium spumosum senesced prematurely during spring at Yass (2012 and 2013). The grasses were selectively grazed by wombats at Burrinjuck in early 2013 until additional fencing measures could be implemented. These issues reduced the opportunities to benchmark the critical P requirements of some of the species (Table 1). Some species (e.g. T. hirtum and T. purpureum) yielded as well as T. subterraneum in one season or at one site, but subsequently did not yield as well (Fig. 1).

The critical P requirement of a species can be yield dependant so two precautions were taken to minimise the chance of confounding yield or persistence issues with estimates of critical P requirements: (i) the species were oversown with fresh seed in the second year at Yass to ensure adequate densities of plants in all treatments and (ii) less credence was given to apparently-low critical P requirements that occurred in seasons when herbage yield was also significantly lower than that of T. subteraneum. When all of the potential comparisons from both sites were considered, four legumes and the two grasses appeared to have lower critical P requirement than T. subterraneum (Fig. 1, Table 1). Only one 'pasture type': Onithopus sativus had a lower critical P requirement whilst yielding as well as T. subterraneum. The critical P requirement of O. compressus was also consistently lower than that of T. subterraneum. However, it did not achieve equivalent yield to that of T. subterraneum. Two 'forage types' had lower critical P requirements and equivalent (T. purpureum) or higher (T. incarnatum) yields than T. subterraneum at Burrinjuck. Of these two, only T. purpureum was sown at Yass where it again had a low critical P requirement but did not yield as well as T. subterraneum. There has been no evidence that the maximum yield of Medicago sativa was achieved even at the highest soil P fertility levels in these experiments (~60 mg P/kg; Colwell 1963).

Table 1. Critical P application rates (kg P/ha) for 90% of maximum yield of pasture legumes and grasses grown in monocultures at Yass and Burrinjuck. It was not possible to estimate a critical P value for all species in some years or at both sites because some species had either failed to persist (due to pest/disease, frost, waterlogged soil) *(f)*; outcompeted by subterranean clover that germinated from the seed bank after or with the test species *(o)*; or was not sown at the site in that year *(ns)*. The critical P requirement of *Medicago sativa* was not reached over the P range used. Letters used in 'Relative P requirement column are L = low, M = medium, H = high.

Test species (cv.)	Yass 2012	Yass 2013#	Burrinjuck 2013	Relative P requirement	Yield relative to sub. clover
	Critical P application rate (kg P/ha)				(Yass district)
Dactylis glomerata (Porto)	*(f)*	25	*(f)*	L	lower
Phalaris aquatica (Advanced AT)	*(f)*	35	*(f)*	L	equal
Ornithopus sativus (Margurita)	*(ns)*	*(ns)*	18	L	equal
O. compressus (Santorini)	22	27	49	L	lower
Trifolium purpureum (Electra)	*(ns)*	27	34	L	lower
T. incarnatum (Dixie)	*(ns)*	*(ns)*	26	L	higher
T. subterraneum (Leura)	83	70	55	M	---
T. spumosum (Bartolo)	*(f)*	62	*(f)*	M	lower
Biserrula pelecinus (Casbah)	*(f,o)*	44	*(f)*	M	equal/lower*
Lotus corniculatus (LC07AUYF)	66	23	*(ns)*	L/M?	lower
T. hirtum (Hykon)	64	32	*(o)*	L/M?	equal/lower
Medicago sativa (SARDI 10)	---	---	---	H	---

critical P rate in this year at Yass is determined relative to the "nominal" P application rate applied during 2012; these rates were topped up with a maintenance dressing of P in 2013 (see Methods). * Lower based on failure in some years.

Discussion

Acclimation of species, or cultivars of species to farming districts is a critically important attribute for persistence and yield in pastures. The present observations are among the few available for some of the alternative legumes when grown in Tableland environments. They indicate that wider examination of species performance should be considered if alternative legumes are to be promoted in these areas. The experiment demonstrated that there are at least some alternative pasture legumes that can yield as well as or higher than *T. subterraneum* with substantially lower critical P requirements. For example, the amount of P applied for equivalent yield by *O. sativus* at Burrinjuck was less than half that needed for *T. subterraneum*. However, it was also very clear that many of the alternative species were poorly suited to the cool, wet Southern Tableland's seasonal, or soil conditions. This, more than any other factor, restricted the comparisons of P requirements that could be made. The most promising species have now been grown for a further season at a wider range of sites confirming the observations made here. Soil samples are being tested for Olsen P and Colwell P to facilitate specification of critical soil test P levels.

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