Impact of phosphorus fertiliser on tropical pasture legume production

Justin P. Macor[1*], Gavin Peck[2], **Louise Newman**[2], Bradley Taylor[2], and Andrew Mclean[2]

[1] Central Queensland University, Rockhampton North, QLD 4702, Email: j.macor@cqu.edu.au
[2] Department of Agriculture and Fisheries, 203 Tor Street, Toowoomba, QLD 4350

Abstract
The application of phosphorus (P) fertilisers during legume establishment can substantially increase yields, however the P requirements of many tropical legumes has not been defined. A trial was established on low P soils near Wandoan in southern Queensland to investigate the effect of P fertiliser on tropical legume production during establishment and the three years post sowing, with early results reported in this paper. The trial consisted of single cultivars of three tropical legume species (*Desmanthus leptophyllus*, *Desmanthus virgatus* and *Stylosanthes seabrana*) with five rates of P fertiliser applied. No significant difference between the three species was identified, suggesting the three legumes responded to P fertiliser similarly. Across the three species a 20% increase in yield was achieved with P application. The critical soil P level, defined as 95% of maximum yield, ranged between 12 and 14 mg/kg. The addition of P fertiliser on low P soil during tropical legume establishment results in greater legume productivity which is expected to increase livestock production.

Keywords
Stylosanthes, *Desmanthus*, Colwell P.

Introduction
Approximately 30% of northern Australia's beef herd occurs within the Brigalow Belt bioregion which comprises extensive areas of sown grass pastures but very few legume-based pastures (Peck et al. 2015). Although these sown grass pastures are highly productive compared to most of northern Australia, their productivity has declined dramatically since first established due to 'pasture rundown' (Peck et al. 2015). Sown pasture rundown is the decline in grass growth due to a decline in available nitrogen (N) in the soil with increasing age of the pasture stand as N is 'tied-up' in soil organic matter (Peck et al. 2015).

Pasture legumes have been identified as the best long-term option to increase the productivity and returns from both rundown sown grass pastures and native pastures through their ability to biologically fix atmospheric nitrogen (Peck et al. 2011). Successful legume adoption levels, however, remain very low in the Brigalow Belt, commonly a result of poor establishment (Peck et al. 2011). Within this region P is often the most limiting nutrient for legume growth (Peck et al. 2015) therefore, the application of P fertilisers during legume establishment has the potential to substantially increase yields. Little is known about the effect of fertilisation with P on legume establishment and production in this region.

This paper reports early results of a trial aimed at investigating the impact of P fertiliser when establishing tropical pasture legumes on low P soils.

Methods
Trial sites
This experiment was conducted on an alkaline Vertosol soil located near Wandoan, Queensland. The initial soil test results for P levels (BSES and Colwell) and for Phosphorus Binding Index (PBI) are shown in Table 1.

Table 1: Initial soil test for P BSES, P Colwell and PBI at the experimental site at Wandoan

Depth (cm)	PBI	P Colwell (mg/kg)	P BSES (mg/kg)
0-10	66	5.9	6.4
10-30	93	<5.0	6.2
30-60	72	<5.0	7.1
60-90	37	<5.0	11

Trial Design
The trial has a factorial design comprised of three species (*D. leptophyllus* cv. JCU7, *D. virgatus* cv. JCU2 and *S. seabrana* cv. Unica) with five rates of P fertiliser (0, 5, 10, 25 and 100 kg of P/ha). The trial has three replicates in a randomised complete block design with 5 x 10 m plots as experimental units.

Fallowing, fertilisation, and sowing dates

Starting October 2017, a fallowing period was used to kill the existing pasture, store soil moisture, reduce the amount of weed seed in the ground, incorporate the fertiliser treatments and prepare a suitable seedbed. A combination of cultivation and herbicide were used during the fallow period.

Fertiliser was applied to the trial in January 2018. Triple superphosphate was used as the P source to minimise other nutrients being applied. The fertiliser treatments were applied at an approximate depth of 7cm using a research planter with three tool bars of cultivating tynes producing 250mm row spacing with following harrows to provide good mixing of fertiliser with the surface soil.

Sowing was delayed by one year due to drought. The trial was sown into dry soil January 2019 with germinating rain not occurring until late March 2019.

Measurements

Harvest was unable to occur in the first growing season due to late germinating rain. The first harvest occurred during the second growing season in March 2020. Tropical legume biomass was harvested using a small tractor-mounted forage harvester for the length of the plot. Fresh weight was measured in the field and subsample taken to determine dry weight.

Soil samples were collected from within each plot. Soil and plant samples were analysed for nutrient content by CSBP Soil and Plant Analysis Laboratory in Western Australia.

Results

Dry matter response to applied P fertiliser for the three species is shown in Figure 1. High variability in the dry matter response was found and consequently there was a low percentage variance accounted for by the response curve (R^2=25.9). No significant difference (P>0.5) was present between the three species. When averaged across the three species, yield increased by approximately 20% with P fertiliser application.

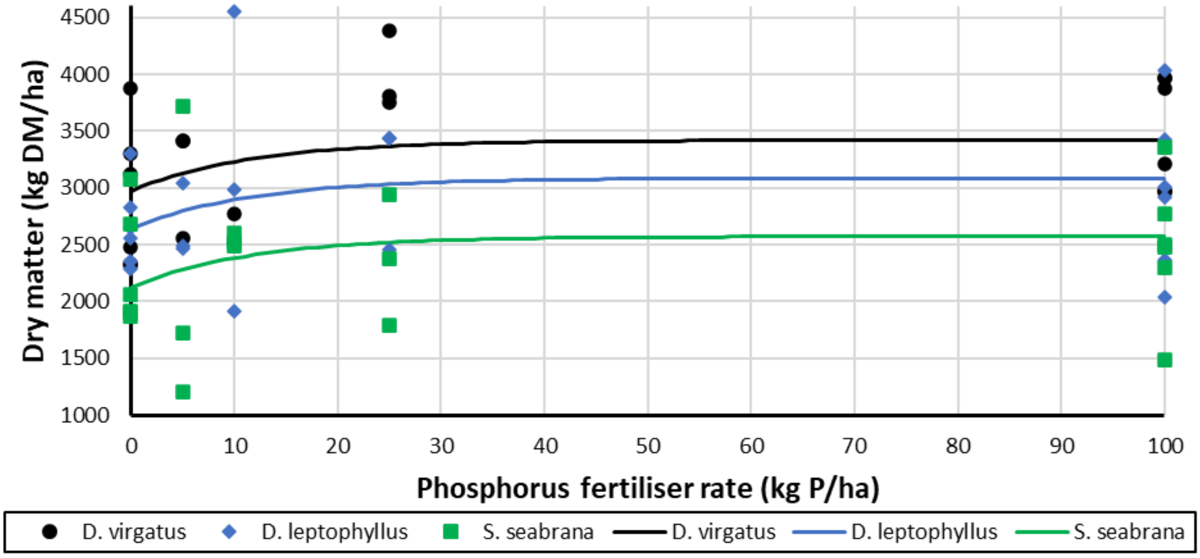

Figure 1. Relationship between tropical legume yield (kg DM/ha) and applied phosphorus fertiliser rate (kg P/ha) for three species of legume. (R^2 = 25.9)

Dry matter response curves to soil P levels for the three legume species are shown in Figure 2. There is a lot of variability in responses and therefore a low percentage variance accounted for by the response curve (R^2=25.1). The critical P levels defined as 95% of maximum yield for the three varieties are shown in Table 2.

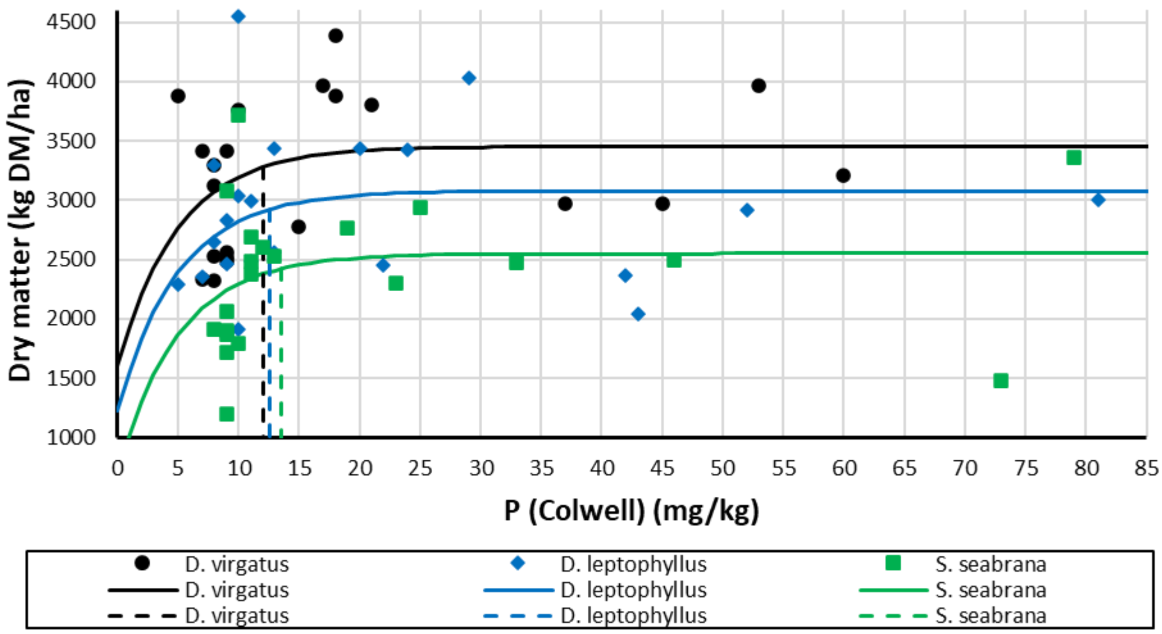

Figure 2. Relationship between tropical legume yield (kg DM/ha) and the soil phosphorus level (Colwell P kg/ha) at 0-10cm for three legume species. (R^2 = 25.1)

Table 2: Yield at 95% of the maximum yield and corresponding critical soil phosphorus (Colwell P mg/kg) to achieve this yield for three tropical legume species.

Legume species	**Cultivar**	**Yield (kg DM/ha)**	**Critical Colwell P (mg P/kg)**
Desmanthus virgatus	**JCU2**	3278	12.0
Desmanthus leptophyllus	**JCU7**	2923	12.6
Stylosanthes seabrana	**Unica**	2422	13.5

Discussion and Conclusion

The results obtained from this trial suggested the tropical pasture legume species *D. leptophyllus*, *D. virgatus* and *S. seabrana* have a relatively low soil P requirement. The critical Colwell P value of 12-14mg/kg calculated from these trial results are comparable to previous studies conducted on *S. hamata* and S. *scabra* species where critical values of 10-12mg/kg and 8mg/kg respectively were found to achieve 80% of maximum yield (Gilbert & Shaw 1987; Probert & Williams 1985; Hall 1993).

Critical soil P requirements vary with the buffering capacity of the soil. As the buffering capacity decreases so too does the critical P requirements (Moody, 2007). Phosphorus buffering capacity of soils is measured as the PBI. As the PBI of the soils in this trial was low (PBI 66) compared to other clay soils in the Brigalow Belt bioregion, the findings may be at the lower end of critical soil P value range for the region.

Whilst the critical values are comparable to previous work, the average increase in yield from the application of P fertiliser of 20% is lower than expected. Another trial also located near Wandoan, with *D. virgatus*, *D. leptophyllus* and *D. pubescens* growing in combination with grass resulted in a 100% increase in yield with the application of P fertiliser on a soil with lower P level (Colwell P <1 mg/kg, BSES P 9 mg/kg) (Peck et al. 2017). Furthermore, trials conducted on *S. hamata* and *S. scabra* species achieved up to 300% increases in dry matter yield with P application (Gilbert & Shaw 1987; Probert & Williams 1985; Hall 1993). This suggests the results from this trial may be an underestimation of the potential gains that can be achieved from P application. This may be due to several reasons including the long fallow resulting in increased available P, drought or the artificial nature of the trial which included no grass competition.

It is evident that the application of P fertiliser to obtain a soil Colwell P of 12-14 mg/kg during tropical legume establishment can increase legume yield and resultantly, improved pasture productivity. However, further study is required to verify these results and the corresponding dry matter gains that can be achieved and impact on the whole farm economics of applying P fertiliser.

References

Gilbert MA and Shaw KA (1987). Fertility of a red earth soil of Mid-Cape York Peninsula. Australian Journal of Experimental Agriculture **27**(6): 863-868.

Hall TJ (1993). Response of *Stylosanthes hamata* cv. Verano and native pastures to fertilisers on two light-textured soils in north-west Queensland. Tropical Grasslands **27**(2): 75-86.

Moody PW (2007). Interpretation of a single-point P buffering index for adjusting critical levels of the Colwell soil P test. Australian Journal of Soil Research **45**(1): 55-62.

Peck GA, et al. (2011). Review of productivity decline in sown grass pastures. Sydney: Meat and Livestock Australia.

Peck GA, et al. (2015). Use of phosphorus fertiliser for increased productivity of legume-based sown pastures in the Brigalow Belt region - a review. Sydney, Australia: Meat & Livestock Australia Limited.

Peck GA, et al. (2017). Improving productivity of rundown sown grass pastures. Volume 3: Persistence and comparative productivity of legumes in sown grass pastures. Meat and Livestock Australia, Sydney, Australia.

Probert ME and Williams J (1985). The residual effectiveness of phosphorus for Stylosanthes pastures on red and yellow earths in the semi-arid tropics. Australian Journal of Soil Research **23**(2): 211-222.