Response of white clover (*Trifolium repens*) varieties and ecotypes to phosphorus on the Northern Tablelands of New South Wales

Graeme Blair

Agronomy and Soil Science, School of Environmental and Rural Science, University of New England, Armidale, NSW 2350, gblair@une.edu.au

Abstract
White clover has been the primary legume used in improved pastures of the Northern Tablelands over the past 90 years, however data is lacking on the ability of white clover varieties and ecotypes to yield under low and high P conditions. An evaluation was undertaken that examined the yield performance of 5 white clovers when grown under P application rates of 0, 10, 20, 40 and 80 kg P/ha applied each year for just under 2 years. At the first harvest taken 7 months after sowing Ladino produced the highest yield at P_0 and Tablelands the lowest with responsiveness to P in the order New Zealand > Clarence > Algerian > Ladino > Tablelands. Yields at P_{80} ranged from 33 kg/ha for Tableland to 242 kg/ha for Clarence. Responsiveness to P over the 4 harvests taken over the experimental period was in the order New Zealand > Clarence =Algerian > Ladino = Tablelands. Yields at P_{80} ranged from 2013 kg/ha for Tableland to 5226 kg/ha for Ladino. Data like that reported here is becoming increasingly important as fertiliser prices rise. The lack of investment in public research to objectively evaluate new germplasm leaves producers without clear guidelines about replacement species. Significant value could be gained from developing well adapted and productive white clover cultivars that are significantly more P efficient.

Keywords
Clover, fertiliser, responsiveness, deficiency.

Introduction
White clover has provided the backbone of pasture improvement on the Northern Tablelands over the past 90 years. Research conducted in the 1920's on pastures containing white clover and trefoil found substantial increases in livewieght gain and carrying capacity from the application of single superphosphate (SSP), (Moodie 1934). Subsequently the optimal P fertility for a legume based pasture was developed (Olsen et al. 1954) for the top 10 cm of soil and is considered to be 15 mg P/kg (Moody 2007). This approximates a Colwell P of 30 mg P/kg where the soil phosphorus buffering index is less than 80 (Colwell 1963). Despite this knowledge and a long history of SSP application, Colwell P soil test results from throughout the New England Tablelands commonly remain below 20 mg/kg due to the relative low application rate and sporadic nature of the application, which is dependent on rainfall and disposable income.

Crush (1995) found that Al-tolerant genotypes of white clover collected in NZ had similar P response characteristics to the P-efficient genotypes indicating that in plant breeding it is possible to select white clover genotypes that are Al-tolerant without increasing the need for P fertiliser.

There have been many introductions of white clover varieties into the New England region, many which have been selected under high soil P conditions in New Zealand and other parts of the world, and the question arises as to how these perform under low P conditions and how they respond to applications of P, which is the aim of this study. This is becoming increasingly important as fertiliser prices rise. The lack of investment in public research to objectively evaluate new germplasm leaves producers without clear guidelines about replacement species.

Methods
The experiment was established on a podzolic soil with low P status (Colwell P = 6 mg/kg) at the University of New England, Armidale in March, 1971. Plots 0.9 x 2.7 m were laid out following cultivation in a split block design that included P rate as the whole plot and white clover (*Trifolium repens*) genotype as the sub-plot with 2 replicates. P was applied as single superphosphate at rates equivalent to 10, 20, 40 and 80 kg P/ha with a 0P control. S was balanced with gypsum. These applications were repeated at the start of year 2 of the experiment. A basal application of 200 kg/ha KCl, 5 kg/ha each of $CuSO_4.5H_2O$, $ZnSO_4.7\ H_2O$, $Na_2B_4O_7$ and $MgSO_4$ and 0.25 kg/ha $Na_2MoO_4.2\ H_2O$ was added to all treatments. Year 1 fertilisers were topdressed onto

the soil surface and raked in following seeding and year 2 topdressed. Plots were sown at 5.7 kg seed/ha in March 1971 with 5 genotypes of white clover (Table 1).Plots were harvested on 25/10/71, 26/4/72, 20/11/72 and 16/1/73 by cutting the plants approximately 3 cm above the soil surface. Harvested plant material was hand sorted to obtain a clean sample of white clover and dried at 80^0C for 48 hours before weighing.

Table 1. White clover type sown and source of seed used in the experiment.

Variety (v) or ecotype (e)	Source
Ladino (v)	Commercial cultivar
New Zealand (v)	Commercial cultivar
Algerian (v)	Commercial cultivar
Tablelands (e)	Ecotype, collected from unfertilised pasture near Armidale
Clarence (e)	Ecotype, collected from fertilised pasture near Grafton

Results

The dry period after sowing in 1971 (Table 2) resulted in poor early growth in the P limiting plots (Table 3) which did not recover well in spring. A dry autumn in 1972 similarly restricted growth (data not shown).

Table 2. Armidale rainfall received in the experimental period.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1971	195.5	125.0	24.1	13.6	11.7	23.8	64.4	105.5	97.9	34.2	75.7	94.2	847.3
1972	168.3	66.7	40.2	42.9	25.5	20.1	4.5	54.1	58.4	157.8	103.8	39.1	781.4
1973	187.5												
Mean 1857 to 1997	104.5	87.1	65.0	45.9	44.4	56.9	49.2	48.4	51.6	67.8	80.4	89.2	791.2

There was a marked response to P at each harvest (Table 3 and Figure 1). At the first harvest taken 7 months after sowing Ladino produced the highest yield at P_0 and Tablelands the lowest (Table 3) with responsiveness to P in the order New Zealand > Clarence > Algerian > Ladino > Tablelands. Yields at P_{80} ranged from 33 kg/ha for Tableland to 242 kg/ha for Clarence.

Table 3. Dry matter yield from regression analysis of white clover tops grown without applied P and yield response (kg DM/ kg P applied).

White clover	Harvest 1			Cumulative		
	Yield at P_0	kg DM/kg P	r^2	Yield at P_0	kg DM/kg P	r^2
Ladino	521	29.0	0.94	5226	58.2	0.95
New Zealand	184	45.6	0.99	3391	93.4	0.98
Algerian	123	34.0	0.99	2967	77.2	0.90
Tablelands	29	28.5	0.95	2468	54.0	0.90
Clarence	285	39.3	0.98	2013	77.6	0.99

Cumulative dry matter over the 4 harvests showed marked differences between genotypes in both their yield under P_0 conditions and at P_{80} (Table 3 and Figure 1). As was evident in the first harvest Ladino produced the highest yield at P_0 and the 2 ecotypes produced the lowest yield. Responsiveness to P was in the order New Zealand > Clarence =Algerian > Ladino = Tablelands. Yields at P_{80} ranged from 2013 kg/ha for Tableland to 5226 kg/ha for Ladino. Tableland, Clarence and Ladino had a curvilinear response curve and the other ecotypes a linear response over the 0-80 kg/ha application range.

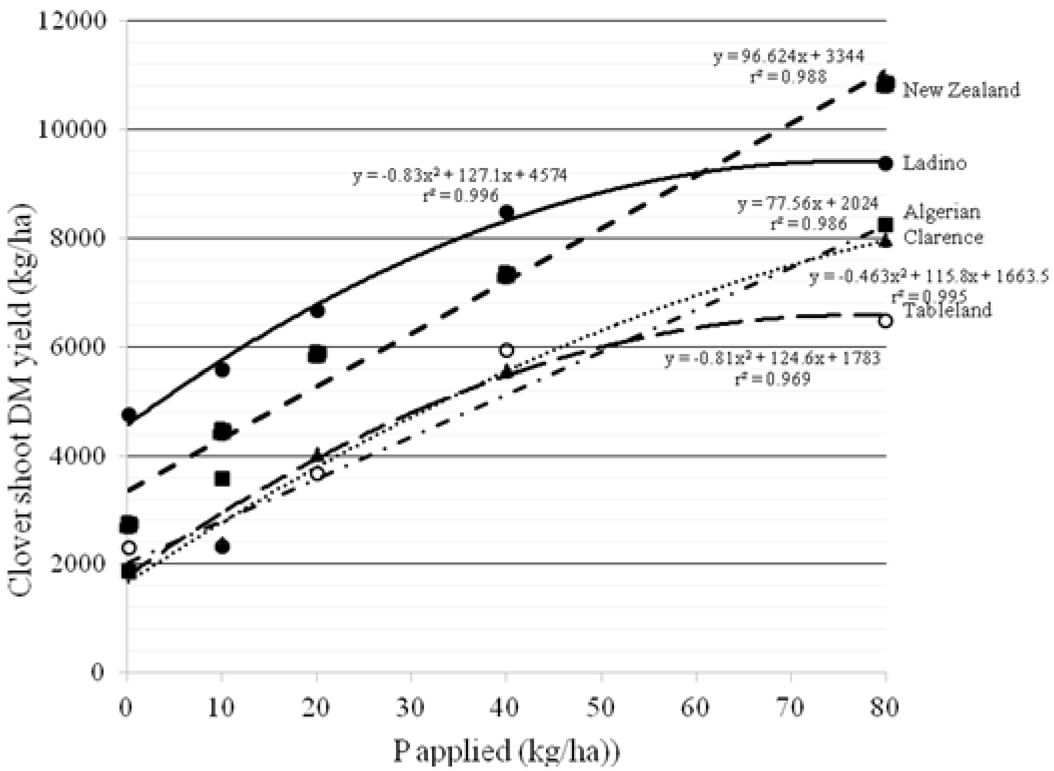

Figure 1. Cumulative shoot dry matter over 4 harvests of white clover at P application rates ranging from 0 to 80 kg P/ha/yr.

The two applications of P resulted in changes in Colwell P being 8, 10, 19, 26 and 56 mg/kg for 0, 10, 20, 40 and 80 kg P/ha/year, respectively. These results indicate a large scope for selection of appropriate germplasm for the New England Tablelands as has occurred in New Zealand. For example Caradus (1983) grew eight white clover ecotype populations and two cultivars in culture solutions containing 10 ppm and 0.01 ppm phosphorus (P). Large differences in total P uptake were found between genotypes and most of this variation was accounted for by differences in root length.

In a range of other annual legume species Yang et al. (2015) showed similar effects to that of Caradus (1983) in a pot experiment using soil. Haling et al (2015) demonstrated that many of the legume species tested by Yang et al. (2015) had different soil P requirements to achieve 90% of maximum dry matter yield (critical soil P requirement) when tested in a pot experiment. Haling et al. (2015) concluded that selecting legumes that maximise nutrient foraging (e.g. long, thin roots with long root hairs) may reduce the critical P requirement of pasture legumes. Sandral et al. (2015) showed differences in the P application rates for 90% of maximum dry matter yield under field conditions which were consistent with Haling et al. (2015) results where the P efficiency differences where greatest (e.g. in serradella species).

Even under the cutting conditions imposed in this study it was observed that the growth habit and flowering time of the genotypes tested changed and similar or greater changes might be expected where hard grazing is imposed. The Tableland entry represents selection made under low P and hard grazing and is a small leaved, prostrate type with a wide flowering period. In this research it was shown to have a low potential yield; however adaptation, P efficiency and potential shoot biomass production all need to be considered when trying to maximise P efficiency, plant persistence and stocking rate. To this extent plant adaptation issues where highlighted in the P efficiency research undertaken by Sandral et al. (2015).

Conclusion

Considerable differences have been found between white clover genotypes in both their yield under P limiting and P adequate conditions as determined by dry matter response. Farmers are often choosing to run Colwell P levels below optimal levels and where this occurs significant dry matter increases might be possible by selecting more P efficient white clover genotypes that have adequate environmental adaptation.

This research and development approach to improving plant P efficiency is currently being undertaken in subterranean clover (*Trifolium subterraneum*), and white clover would benefit from a similar approach.

Acknowledgements

This research was funded by the Australian Meat Research Committee (AMRC) and the University of New England. The research was initiated during a sabbatical leave by Dr Warwick Harris, now of Landcare Research, Christchurch, NZ.

References

Caradus JR (1983). Genetic Differences in Phosphorus Absorption among White Clover Populations. Plant and Soil, 72, no. 2/3, 1983, pp. 379–383.

Colwell JD (1963). The estimation of the phosphorus fertiliser requirements of wheat in southern New South Wales by soil analysis. Australian Journal of Experimental Agriculture 3, 190-198.

Crush JR (1995). Phosphorus response of white clover (*Trifolium repens* L.) genotypes selected for tolerance of aluminium toxicity. New Zealand Journal of Agricultural Research. 38, 451-456.

Haling R, Yang Z, Shadwell N, Simpson R, Culvenor R, Stefanski A, Sandral G, Kidd D, Lambers H and Ryan M (2015). Phosphorus-efficient pastures: legume root traits for improved nutrient foraging. In: Proceedings 17th Australian Agronomy Conference, Hobart pp. 319-321.

Moodie AWS (1934). Top-dressing New England pastures. The Agricultural Gazette of New South Wales. 45, 301-306.

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, 55-62.

Olsen SR, Cole CV, Watanabe FS and Dean LA (1954). Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate. U. S. Department of Agriculture Circular No. 939. Banderis AD, D H Barter and K Anderson. Agricultural and Advisor. 9.5 QM-AD036-MP24 - Plant and soil sample preparation. ASL QMS.

Sandral G , Simpson R, Price A, Hildebrand S, Fuller C, Stefanski A, Yang Z, Culvenor R, Kidd D, Lambers H and Ryan M (2015). Phosphorus efficient pastures: response of alternative legumes to fertiliser application. In: Proceedings 17th Australian Agronomy Conference, Hobart. pp. 330-333.

Yang Z, Culvenor RA, Haling RE, Stefanski A, Ryan MH, Sandral GA, Kidd DR, Lambers H and Simpson RJ (2015). Variation in root traits associated with nutrient foraging among temperate pasture legumes and grasses. Grass Forage Science 72, 93–103. (doi:10.1111/gfs.1219).