MEAT & LIVESTOCK AUSTRALIA

final report

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Grasslands Society of Southern Australia - Central Ranges branch - Phosphorus use efficiency

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Executive summary

A three-year research program was established, with producers in the Central Ranges region of Victoria, to investigate options to improve phosphorus fertiliser use efficiency. Fertiliser is a major enterprise cost for livestock producers. Data from the three regions involved in the Victorian Monitor Farm project indicates the average cost of fertiliser is $3-4/DSE per year. Maintenance phosphorus (P) applications are a requirement for productive sub clover based pastures in the Central Ranges region. It is estimated 40% of farms in the region may also require capital applications of P fertiliser. The Central Ranges producer group are a branch of the Grasslands Society of Southern Australia. They were concerned about the sustainability of P supplies and increasing cost that has been the trend over the past 7-8 years.

One aim of the research was to identify whether serradella, which was thought to be a more phosphorus efficient legumes than sub clover, would grow and persist in the different soil types of the Victorian central ranges. The forage production of serradella was to be compared with sub clover under moderate (≤ Olsen P 10 mg/kg) and high soil phosphorus conditions (Olsen P 15 mg/kg). The use of more P efficient legumes is a possible strategy for reducing the amount of capital P inputs required on low P paddocks and could potentially save producers hundreds of dollars per hectare.

The second aim of the research was to identify whether soil factors (nitrogen, trace elements, acidity, poor nodulation, soil borne diseases) were constraining pasture and sub clover production on paddocks where P, K and S were adequate. Identification of other soil constraints is a strategy to grow more kg dry matter per unit of P applied.

Yellow serradella and French (pink) serradella were found to be more difficult to establish and regenerate than several cultivars of sub clover. Two sites were sown in June 2014 and re-sown 2015, at Glenhope and Pastoria, for the alternative legume trials. Very little serradella regenerated at the two sites in 2016.

During this research project, more results from the CSIRO legume experiments became available which confirmed that the critical P level for serradella was lower than for sub clover. There was a change in direction suggested to the group for the alternative legume work to sowing larger areas in paddocks to test out the serradellas and trialling some different cultivars that might be better suited to the environment. In May 2016, a group member sowed a large-scale serradella trial at Baynton. This is being monitored as part of a new national project called *Phosphorus for Pastures*.

The challenge for producers in this region is that sub clover is well adapted and is already present in most paddocks, even those with low-moderate P levels. Establishing and regenerating serradella will be difficult if there is some seed-bank of sub clover to compete with. Selecting paddocks that have been cropped for a few years may improve serradellas ability to establish and regenerate. Also, there has been a lot less work done on breeding and selection of improved cultivars of serradella compared with sub clover. It is still not clear which cultivars of serradella are best suited for this environment.

Several soil factors were identified to be constraining pasture and sub clover production on paddocks where soil P, K and S were adequate. Two subtractive fertiliser trials were established in 2014 at Glenhope and Baynton to investigate this.

The pathogens *Pythium* and *Rhizoctonia* were found to be present in a number of paddock in the region. *Phytophthora* was less common. Sub clover plants from these sites were found to have moderate levels of root disease and low-moderate nodulation which was contributing to low soil N levels and constrained pasture production. Sub clovers at Glenhope were the more disease susceptible cultivars, Mt Barker and Enfield. A large response to Metalaxyl fungicide occurred at the Glenhope site in the very dry year of 2015. No fungicide response occurred at Baynton most likely due to the presence of Trikkala. Producers were very interested in making use of the Predicta B-DNA test to identify what soil pathogens were in their paddock. A better understanding of soil pathogens in the area and the potential lost production, made producers more aware of the importance of selecting more disease resistant cultivar for future sowings.

Addition of trace elements improved the clover content at Glenhope. Molybdenum is the main trace element deficiency that occurs in this region. Clover leaf analysis and fertiliser test strips were promoted to producers as tools to help them identify molybdenum deficiency.

Liming to increase soil pH/reduce aluminium did not improve clover content or pasture dry matter production even though trial sites had a pH of less than 4.5 (Cacl2). This is an important finding as producers often prioritise expensive lime applications over fertiliser applications in the short term, thinking they will get better results from the fertiliser and make nutrients more available. In the long term, lime is required to prevent further acidification of the soil profile, but in the short-term, producers with low soil P levels can get better return on capital from investing in capital P inputs.

The subtractive fertiliser trials confirmed that where P was adequate based on a soil test, there was no response to P. After 3 years of omitting P fertiliser, soil P levels were still satisfactory. This gives the producers confidence that if they have high soil P levels they can omit P application for several years without losing production or feed quality, saving money and improving P use efficiency. Many paddocks in the project area did have P levels above the critical level for sub clover.

For paddocks with good species and good P,K,S levels, there is an opportunity to grow more winter feed, at low cost, with the tactical use of urea or gibberellic acid. Responses to nitrogen were obtained each winter at both sites, the degree to which depended on the seasonal conditions. Good N responses in the clover dominant pasture at Glenhope indicated the nodulation and N fixation by the clover was being constrained. Responses to Gibberellic acid (GA) were also obtained each winter at both sites, but were generally lower than that obtained from using nitrogen. The combination of N and GA gave variable results. The use of GA or N were shown to be cost-effective options for filling winter feed gaps compared with feeding supplements to stock. The sites were very useful for farm walks/ field days to demonstrate to local producers the extra feed that could be grown.

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1 Background

1.1 Grasslands Society of Southern Australia - Central Ranges branch

The Grasslands Society of Southern Australia has a membership base of 500. The Central Ranges branch was established in 2009. There is a local committee of 5 producers and around 40 producers on the mailing list. The branch takes in the area between Seymour, Kyneton and Bendigo.

Producers in the Central Ranges area mainly run livestock enterprises such as beef, prime lamb and wool. Soils in the area are of granitic, sedimentary and volcanic origin. Pastures range from native grasses on the steeper and rocky areas, annual grasses/sub clover, phalaris/cocksfoot/sub clover and perennial ryegrass/sub clover in the higher rainfall areas.

1.2 Issues faced by the group

Regular phosphorus (P) applications are a requirement for productive pastures in this region. Fertiliser (mainly phosphorus and sulphur based – single superphosphate) is a major enterprise cost for livestock producers. Based on data from the three regions involved in the Victorian Monitor Farm project, the average cost of fertiliser is $3-4/DSE per year.

The group is concerned about the sustainability of P supplies and increasing cost that has been the trend over the past 7-8 years.

1.3 Producer management practices

Historically, many of the group have applied capital rates of P fertiliser to improved pastures, on their better country, to lift Olsen P to target levels for sub clover (12-15 mg/kg) and had great success in lifting carrying capacity. Many are now in a maintenance phase in terms of P applications and wish to explore opportunities to refine their maintenance rates of P fertiliser and potentially reduce P inputs and costs while maintaining/improving pasture productivity. Other producers in the area are starting from a much lower base, with very low Olsen P levels, and are faced with large capital expenditure to lift to target levels for sub clover. For these producers, the establishment of more P efficient legumes such as serradella, that may only require target Olsen P levels of 8-10 mg/kg, may be an option.

1.4 Motivation of the group

The group were keen to explore the following ideas and areas of research to determine if they could help improve phosphorus use efficiency:

I. Soil testing and interpretation in relation to the specific soil types in the area. More rigorous testing regimes on select areas will:
   - identify paddocks that are above critical Olsen P that can immediately have P inputs reduced
   - help to refine maintenance P inputs for different soils/systems

- identify other nutrient/soil limitations reducing efficiency of applied P (along with tissue testing for micro nutrients)

II. Trialling use of satellite imagery (NDVI biomass maps) or GPS/grid soil sampling to identify high/low production zones in paddocks/soil types and reasons for the variation. This could lead to variable rate fertiliser application across paddocks.

III. Identification of other factors limiting efficiency of applied P such as low N (low legume content; problems with rhizobia/nodulation; clover root diseases), pH, trace elements or uneven distribution/nutrient transfer due to grazing system/paddock size and aspect.

IV. Novel products or methods to enhance the availability of P.

V. Trialling of any P efficient sub-clovers, or other legume species, that might be suited to the region.

2 Projective objectives

This project forms part of MLAs Producer Research Site program that is part of the southern Feedbase Investment Plan. In particular, this project supports the MLA-funded project B.FDP.0047: CR GSSA — Phosphorus use efficiency.

The group formed links with Dr Richard Simpson (CSIRO) and the scope of the producer research sites was designed to complement/add value to the research being undertaken by his team. The PRS project objectives were to:

1. Identify whether or not alternative legumes (serradella) grow and persist in the different soil types of the Victorian central ranges
2. Compare the forage production (quality and quantity) of alternative legumes to sub clover grown under moderate and high soil phosphorus conditions for three years
3. Identify whether soil factors (nitrogen, trace elements, acidity, soil borne diseases) are constraining pasture and legume production on paddocks where P, K and S appear to be adequate.

3 Methodology

3.1 Phosphorus efficient legume trials (Sites 1 and 2)

3.1.1 Experimental design and treatments:

Trial sites 1 and 2 were a randomised block design replicated three times testing up to seven legume species suited to the soil type and conditions under two phosphorous levels: moderate (Olsen P 10) and high available phosphorous conditions (Olsen P >15). The sites were located on moderate P soils with an Olsen P of around 10 mg/kg (Table1). The species and cultivars sown at each site are summarised in Table 2.

3.1.2 Site establishment and management

Soil samples (0-10 cm) were taken from six paddocks on four properties during April/May 2014 to identify two appropriate trial sites with moderate levels of soil phosphorus (≤10 mg/kg). Soil samples were sent to the Farmright Laboratory in Kyabram for analysis. Two sites were selected and pegged for the alternative legume trials. The soil test results for the selected sites are summarised in Table 1.

Site 1 Glenhope: Average annual rainfall of 600 mm. Loam soil in sedimentary hill country. The paddock had probably not had fertiliser for 20 years. The paddock was sown down to phalaris and sub clover in the 1960's. In autumn 2014, the pasture composition was mainly native grasses (Austro-danthonia) with some sub clover.

Site 2 Pastoria: Average annual rainfall of 750 mm. Loam soil in granite hill country. The paddock was sown to Tetila annual ryegrass in 2013 and grazed off. In autumn 2014, the pasture composition was mainly annual ryegrass, some sorrel and capeweed.

Table 1. Soil test results for sites selected for legume trials, May 2014.

Soil test parameter	Site 1. Glenhope	Site 2. Pastoria
Olsen P (mg/kg)	11.0	10.5
Colwell K (mg/kg)	217.0	150.0
KCl40 S (mg/kg)	6.8	6.3
pH (water)	5.1	5.5
pH ($CaCl_2$)	4.2	4.7
Sum of cations (meq/100g)	4.04	7.10
Aluminium (%)	26.0	2.0

Capital P fertiliser (200kg/ha) was applied prior to sowing to raise Olsen P for plots to be the High P treatments. Producers sprayed sites with glyphosate and alpha-cypermethrin insecticide and fenced the sites. Sites were sown on the 17 June 2014, using a cone seeder with the assistance of the Southern Farming Systems. Plot sizes were 1.3 m wide by 5 m long with a gap of 0.7 m between plots to allow for any spread of legumes, and a 2 m pathway between replicates. Seed was sown with 100 kg/ha MAP. The species and cultivars sown at each site are summarised in Table 2. There was no lotus seed available in Australia in 2014 so it could not be sown. Molybdenum (sodium molybdate) was sprayed onto the plots.

Seed was donated by Stephens Pasture Seeds, AusWest Seeds, SeedForce and NSW Agriculture, Wagga. Legume seed was freshly inoculated with the appropriate rhizobia.

Table 2. Legume species/cultivars sown at sites in 2014 and 2015

Site 1. Glenhope	Site 2. Pastoria	Sowing rate Kg/ha
Riverina sub clover	Riverina sub clover	15
Narrikup sub clover	Rosabrook sub clover	15
-	Leura sub clover	15
Margurita Pink Serradella	Margurita Pink Serradella	12
Santorini Yellow Serradella	Santorini Yellow Serradella	12
Prima Gland clover	-	8
-	Casbah Biserulla	12
Arrowtas Arrowleaf clover*	Arrowtas Arrowleaf clover*	8

**Sown in 2015*

After sowing in 2014, a follow up grass selective herbicide (clethodim) was applied for annual ryegrass control at the Glenhope site. Both sites were grazed off by stock after pastures dried off in spring.

In May 2015, Capital fertiliser (200 kg/ha superphosphate) was applied to High P plots and maintenance fertiliser applied to Low P plots.

The two alternative legume trial sites were re-sown on 12 June 2015. It was planned to re-sow one legume trial (Glenhope) due to poor establishment in 2014 resulting from a combination of factors (soil disturbance from seed drill and poor spring). However, in autumn 2015 at the second site (Pastoria), there appeared to be very little regeneration of the serradellas and biserrula, so it was decided to re-sow both sites. Site 1 was sprayed out in November to control the sorrel and sprayed again after the autumn break in 2015. Site 2 was sprayed prior to sowing. Plots were sown using a cone seeder with the assistance of the PGG Wrightsons. The cone seeder was narrower than the one used in 2014, so only the central section of each plot was re-sown. Plot sizes were now 0.96 m wide by 5 m with gap of 1.0 m between plots. Arrowtas Arrowleaf clover was included instead of the Lotus after consultation with Richard Simpson and the group.

3.1.3 Measurements

Establishment counts - Seedling density of legumes (seedling/m^2) was to be assessed 6-8 weeks after sowing using a quadrat placed at random (5 places) in each plot.

Plant frequency - Frequency was to be measured each autumn/winter following the establishment year as an indication of the annual legumes ability to regenerate/persist and expand to fill spaces.

Botanical composition - This was to be assessed before each dry matter yield harvest by the dry matter ranking technique (Mannetje and Haydock /Botanal method).

Dry matter production (kg DM/ha) - This was to be assessed when the highest yielding species had no more than 2.0 t DM/ha (green) available. Cutting was to be avoided when the legumes were flowering. One strip (0.5 m × 5.0 m) was to be cut per plot using a lawn mower to 3 cm above ground level (estimated grazing height) and placed in bags, labelled and weighed. A sub sample was to be taken, labelled and oven dried at 60°C for 72 hours to obtain dried weight to allow calculation of kg DM/ha.

Not all of these measurements were taken according to the planned timing and method due to poor growth and limited dry matter. Details of measurements are described in the results section (4.1).

3.2 Constraints to phosphorous response Trials (sites 3 and 4)

3.2.1 Experimental design and treatments:

The paddocks selected were those where soil testing indicated adequate levels of P, K and S but were thought to be under-performing paddocks. The subtractive trials aimed to assess if pasture growth and P responses were being constrained, by how much and by what factor/s. Additional soil factors chosen to investigate if they could improve growth were nitrogen, trace elements, lime, fungicide and rhizobia inoculation. Urea and Gibberellic acid (GA) were investigated to evaluate their impact on winter pasture growth. Urea and GA were not used by many producers in the project area to tactically fill feed gaps and the trials could demonstrate the cost/benefit of using these products.

A subtractive fertiliser trial was established at Site 3 in July 2014 (M. Shea's - existing sub clover/native and annual grass pasture) and Site 4 in October 2014 (G. Ryans – sown to Landmaster phalaris in 2007). Site 3 was located next to Site 1 legume trial. The site had adequate P, K, S levels but the pH was below the target range and the paddock had not received molybdenum for many years. Site 3 was selected to see if soil acidity or lack of molybdenum or rhizobia or root disease was constraining clover/pasture growth. Site 4 was located on granite soil, had good P, K & S levels in the soil but had very little sub clover present and was showing obvious N deficiency symptoms in spring.

The replicated trial sites 3 and 4 were a randomised block design (split plot) replicated three times. Each plot was 2m wide by 10m long. The following treatments were applied in 2014:

- Nil
- All macro (PKS) and trace nutrients (Molybdenum, Copper, Zinc and Boron)
- All macro (PKS) and trace nutrients plus lime
- All macro minus trace nutrients
- All nutrients minus P
- All nutrients minus K
- All nutrients minus S
- All nutrients plus Gibberellic acid
- All macro (PKS) and trace nutrients plus Fungicide
- All macro (PKS) and trace nutrients plus Rhizobia

The above treatments were applied with and without nitrogen (urea). This was achieved by spreading urea to half of each plot (area of 2 m x 5 m).

Capital rates of lime, P, K and S and trace elements were applied at Site 3 in July 2014 and capital rates of lime, P, K and S and trace elements (except moly) were applied at Site 4 in October 2014. Molybdenum was applied at site 4 in late May 2015. Molybdenum (Sodium molybdate) was sprayed on the plots while the other trace elements were applied as granules. At both sites, only maintenance rates of P, K and S were applied to the appropriate plots before the autumn break in 2015, 2016 and 2017.

Each year, Urea (N) and gibberellic acid (GA) were applied to plots in late May/early June and June/July, respectively. The fungicide treatment was applied after the autumn break in 2015, 2016 and 2017. The Rhizobia treatment (Alosca granules) was applied before the autumn break in 2015, 2016 and 2017. Riverina sub clover seed (20 kg/ha of inoculated & Poncho plus treated seed) was also broadcast before the autumn break in 2017 to Rhizobia plots at site 4 (Baynton) as clover content was still low.

Fertiliser was donated by Incitec Pivot, Metalaxyl fungicide was donated by NuFarm and Rhizobia granules donated by Alosca.

3.2.2 Site establishment and management

The soil test results for the selected sites are summarised in Table 3.

Site 3 Glenhope: same details as Site 1. Sub clover was keyed out and identified as Mt Barker and Enfield and photos and descriptions were sent to Kevin Foster (UWA) for confirmation.

Site 4 Baynton: Average annual rainfall of 750 mm. Loam soil at foot of granite hill country. Paddock had been cropped for a couple of years and then sown to Landmaster phalaris in 2009. The phalaris was sown in spring 2009, so no new clover seed was sown. The sub clover was keyed out and identified as Trikkala and Mt Barker.

Table 3. Soil test results for paddocks selected for the subtractive fertiliser trials

Soil test parameter	Site 3. Glenhope (same as in Table 1)	Site 4. Baynton
Olsen P (mg/kg)	12.0	21.0
Colwell K (mg/kg)	217.0	185.0
KCl40 S (mg/kg)	6.8	17.1
pH (water)	5.1	5.2
pH ($CaCl_2$)	4.2	4.4
Sum of cations (meq/100g)	4.04	5.62
Aluminium (%)	26.0	10.5

The sites were fenced off by the producers. Plots were locked up for at least 6 weeks after the nitrogen treatments were applied to allow a winter dry matter harvest. The plots were then crashed grazed (or mown off when not convenient to graze) and then locked up again for at least 4 weeks to allow a mid-late spring dry matter harvest. Plots were crashed grazed by stock after the spring harvest and before the autumn break.

3.2.3 Measurements

Botanical composition- This was assessed in spring before the dry matter yield harvest, using the dry matter ranking technique (Mannetje and Haydock /Botanal method) in the 2016 at both sites, and in 2017 at Baynton, after additional clover was broadcast in the Rhizobia treatments.

Dry matter production (kg DM/ha) – this was assessed around 6 weeks after the urea had been applied in late May/early winter (and plots locked up) to determine any N responses. After crash grazing to even up plots, plots were locked up again for a spring dry matter assessment. One strip (0.5 m × 5.0 m) was cut per plot using a lawn mower to 3 cm above ground level (estimated grazing height) and placed in bags, labelled and weighed. A sub sample was taken, labelled and oven dried at 60°C for 72 hours to obtain dried weight to allow calculation of kg DM/ha.

Soil tests – soil tests (0-10cm) were taken from each site at the start of the experiment. In October 2016, soil tests were taken from the “Nil”, “PKS+Trace”, “PKS+Trace+Lime” and “PKS+Trace +N” treatments. (Note budget constraints meant every plot was not sampled).

Leaf analysis - clover leaf samples were taken, in October 2017, from the “PKS” and “PKS + trace” treatments, to look at the effect of the trace elements applications and lime on nutrient concentrations.

Sub clover root disease investigations - Sub clover plant samples and soil from Site 3 (Glenhope) and from the paddock adjoining Site 4 paddock (Baynton) were sent to the University of Western Australia, in September 2014, with kits supplied by Kevin Foster and Martin Barbetti. This was to assess the level of nodulation and presence of root disease to see if it was a factor constraining pasture production. The samples were analysed as part of the AWI root rot disease survey. Preliminary results from Kevin Foster, indicated that at site 3 the clover (Mt Barker and Enfield) had moderate levels of root disease (*Pythium* and *Rhizoctonia*), which could affect growth and nitrogen production. The sub clover at this site had only moderate levels of nodulation. The clover (Dinninup and Trikkala) from the paddock adjoining site 4, had moderate levels of root disease (*Pythium* and *Rhizoctonia*) and low nodulation score. (Note the clover samples from Baynton had been sent to UWA, independently by the producer, before Site 4 was selected).

Due to the confirmed presence of disease, a fungicide treatment was applied to the plots in autumn 2015, 2016 and 2017 when the clover was in the cotyledon stage (2 leaf stage). Provision was made for a fungicide treatment in the original plot design. Metalaxyl (Apron) was chosen for the 2015 treatment based on the species of root diseases present and in consultation with Martin Barbetti.

Prior to application of fungicide in 2016, soil samples (0-10 cm) were taken from the Control/nil plots at each site and sent to South Australian Research and Development Institute (SARDI) to undertake the PreDicta B test.

The PreDicta B service (and test panel) is a commercial service that has been developed to identify the major soil borne disease in broadacre cereals and reports risk categories for growers based on potential yield loss in wheat.

The Pasture Legume service offered by SARDI is for research purposes only and risk categories haven't been developed. This test was undertaken to identify the potential pathogens and determine the appropriate fungicide to use. The same species of soil pathogens were identified by the PreDicta B test in 2016 as by the UWA tests in 2014 and a small amount of phytophthora was found at Site 3, Glenhope. Metalaxyl was used again in 2016 and 2017. Samples from 4 other farms were also sent in for testing as other group members were interested in learning more about soil borne diseases in their paddocks.

Rhizobium identification - The Maldi Id test was used to identify the strains of rhizobia in plots to determine if the new strain in the Alosca granules had successfully colonised the sub clover roots and improved nodulation. On 31st July 2017, five sub clover plants in each replicate of the "PKS + trace +Rhizobia" and "PKS + trace" treatments were dug up carefully to prevent damaging the roots. Soil was washed off the plants. Shoots were cut off and roots were dried off on paper towel. Roots were placed in zip lock plastic bags and sent to Sofie de Meyer at Murdoch University, WA.

3.3 Statistical analysis

Dry matter yields were analysed using a two-way Analysis of Variance (ANOVA). The P-value or Probability indicates if the treatment means are significantly different from one another. Results are significantly different if the P value is less than 5% P< 0.05). This is known as the 95% confidence interval. Standard errors of the means were also calculated for each treatment. Standard errors have been included on the dry matter yield graphs.

3.4 Extension and communication

The Central Ranges PRS group had their first project meeting in February 2014 to discuss the project topic and seek agreement with Dr Richard Simpson on participatory R&D activities, what research questions were to be investigated, and plan how the project might proceed.

Annual review meetings with the researchers and producers, focussing on the progress of the project, were completed in 2015 and in 2016 following the MLA Pasture Update which Richard Simpson and Lisa Warn spoke at about P use efficiency results and trial updates.

A series of field days and MLA/GSSA Pasture Updates were held in the area to keep producers up to date with the research findings and other related research.

3.5 Other work and collaboration in the project area

3.5.1 National clover root disease study

Links were made with Martin Barbetti and Kevin Foster from UWA to investigate if sub clover root diseases were an issue in the district. In 2014, UWA provided clover and soil sampling kits, and samples were sent to them to determine if root disease was present and the level of nodulation. UWA continued to provide advice and expertise to the group on these issues. In May 2015, the UWA team established a site on Gerard Ryan's (in paddock next to subtractive fertiliser trial) to investigate root rot control options in more detail as part of a national project funded by AWI and MLA.

3.5.2 Soil testing and interpretation

To encourage local producers to undertake more soil testing, in order to make better fertiliser decision and improve P use efficiency, the group organised a 10% discount on soil tests from Farmright laboratory. Around 50 soil tests were submitted to Farmright laboratory from 15 producers. A soil test interpretation workshop was conducted by Lisa Warn at Baynton in January 2015. Producers who took soil tests attended. Twenty fertiliser test strip kits (including urea and a vial of gibberellic acid) were made up and distributed to local producers to determine if paddocks were responsive to macro/trace elements and if they could boost winter pasture growth.

3.5.3 Variable fertiliser rate project

The producers were interested in looking at how variable P levels were across paddocks to determine if they could use variable fertiliser rate application technology to improve efficiency of P use. Some preliminary work was conducted by Lisa Warn in April 2015 on 2 paddocks. This was followed up with involvement of Precison Ag in September 2017, who donated their time and soil lab costs to study the same 2 paddocks but using their commercial service methodology.

4 Results

4.1 Phosphorus efficient legume trials (Sites 1 and 2)

4.1.1 Establishment

Establishment in 2014 was slow due to later than optimal sowing time and cold conditions. By late August 2014 at both sites, sub clover plots had an even germination but plants were only at the 3-leaf stage. Serradella plots showed patchy germination and plants were only at the 1-2 leaf stage. The points on the seed drill used caused too much soil disturbance, especially in the more clay loam soil at Glenhope, resulting in a second wave of annual grass germination and competition. Post emergent weed control was undertaken for annual ryegrass in September at Glenhope, but a later germination of silver grass (*Vulpia spp*.) was an issue. Some sorrel had also germinated at the Pastoria site. A broadleaf spray for sorrel was not used due to concern about potentially damaging the serradellas. In addition, the poor spring rainfall meant there was very little growth at both sites and hence a spring harvest was not undertaken. Plants were allowed to set-seed and hay off and plots were grazed after that. Figure 1 shows images from Site 1 at Glenhope.

Figure 1. The legume site at Glenhope during 2014. Plots were sprayed with Glyphosate and Dicamba on 5 June 2014, with excellent brown-out achieved. Plots were sown on the 17 June. A successful post-emergent spray was applied for annual ryegrass on 22 September. *Vulpia spp* (silver grass) became an issue around the time the plants were flowering in October and spring was cutting out.

The 2015 seasonal conditions in the project area were characterised by a late autumn break and a dry spring and it turned out to be one of the lowest rainfall years on record.

Plots were re-sown at both sites on 12 June 2015. Legumes started to germinate in early August 2015. By early September at Site 1, germination of sub clover and gland cover was good and while the serradella plots looked better than in 2014, there still wasn't enough herbage to do a harvest. At Site 2, germination was much poorer than at Site 1. The Pastoria site failed to establish despite good weed control and correct sowing depth, hence no data was collected for this site in 2015. The cause of failure at Site 2 was unclear as there were no signs of pests which may have caused establishment failures.

The Glenhope site had adequate plant numbers established to allow an assessment of dry matter yield in October 2015. The dry conditions meant that the growth was minimal for all cultivars sown (Figure 2), and harvesting with a mower was impractical, so a visual estimate of available dry matter was made. There was not enough dry matter to allow a FeedTest sample to be taken on each cultivar as originally planned. There was no difference in the number of plants/m drill row establishing for all the species/cultivars except for the Margurita Pink Serradella which had significantly lower plant numbers in both Low and High P treatments (Figure 3).

Figure 2. Glenhope legume trial - pasture pictures on 1 October 2015.

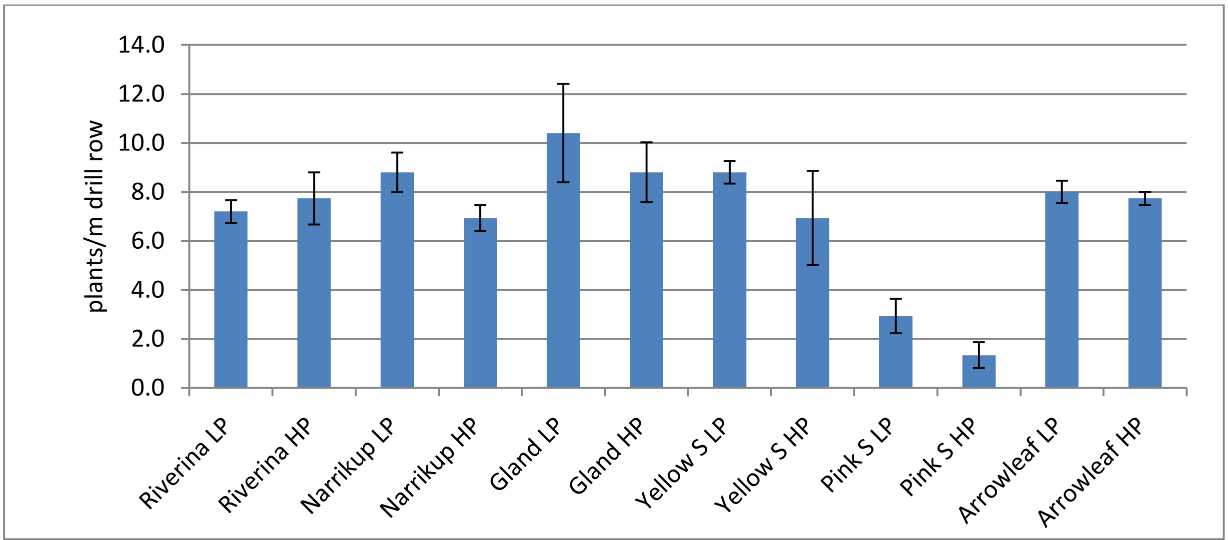

Figure 3. Establishment plant counts per meter of drill row for legumes at Glenhope, 1 October 2015. LP = low phosphorus and HP = high phosphorus. Bars indicate the standard errors.

4.1.2 Dry matter yields

At Glenhope in 2015, there was trend for higher pasture mass at High P than Low P for the sub clover, Gland clover and Arrowleaf clover (Figure 4), but this was not significant (P>0.05). At Low P, yellow serradella had a similar yield to the sub clover cultivars. There was minimal pasture mass on the pink serradella plots but this was associated with low seedling density (Figures 3 and 4).

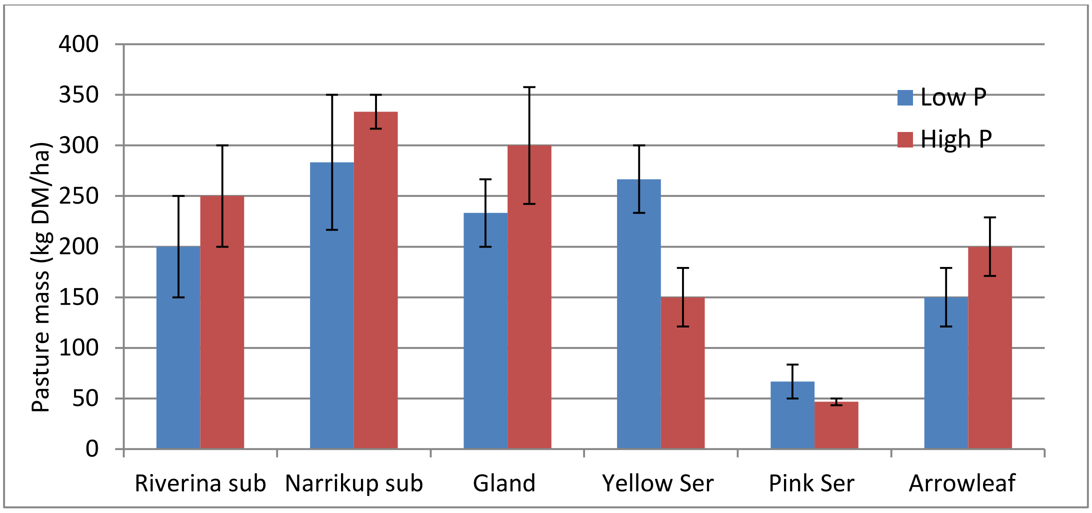

Figure 4. Pasture mass, for legumes sown at Glenhope, representing total growth from 15 June (sowing) until 1 October 2015. Bars indicate the standard errors.

In 2016, there was very little regeneration of serradellas at the Pastoria site after the autumn break. After discussions with Richard Simpson (CSIRO), it was decided not to re-sow this site. At Glenhope, regeneration was patchy. It was decided to watch this site through the year to see if the serradella plots improved. Serradella plants were not really obvious until the spring. Seedling counts were not taken as it was too difficult at that time of year due to the amount of grass weeds. Silver grass (*Vulpia spp.)* was a problem so plots were sprayed with Simazine in early August 2016. Pasture compositions and dry matter yields were assessed in spring 2016 at Glenhope. Total yields in LP and HP plots averaged 3,500 kg DM/ha with annual grasses, sub clover and broadleaf weeds making up most of the yield. The serradellas did not contribute very much to the yield due to low plant numbers (Table 4).

Table 4. Legume composition at Glenhope on 31/10/16.

Fertiliser Treatment	Species	Legume content (% dry matter)	Standard error of mean
Low P	Sub clover (Riverina)	33	14.5
	Sub clover (Narrikup)	25	10.4
	French Serradella (Margurita)	2	1.7
	Yellow Serradella (Santorini)	13	8.8
	Gland clover (Prima)	2	1.7
High P	Sub clover (Riverina)	47	13.3
	Sub clover (Narrikup)	40	17.3
	French Serradella (Margurita)	7	3.3
	Yellow Serradella (Santorini)	12	4.4
	Gland clover (Prima)	17	6.7

4.2 Constraints to phosphorous response trials (sites 3 and 4)

4.2.1 Soil fertility changes

At Site 3 (Glenhope) by 2016, the average Olsen P for the Nil fertiliser treatment was 10.6 mg/kg, just below the target range of 12-15 mg/kg, compared with 22-24 mg/kg for plots receiving P fertiliser for 3 years (Table 5). The Colwell K was above the critical level (160 mg/kg) for the four treatments and ranged from 205-237 mg/kg. The KCL40 S was higher in the fertilised treatments compared with the Nil Control but still below the target range of 8-12 mg/kg. The addition of 2 t/ha of lime raised the pH slightly and brought it into the target range of 4.5 – 5.2 ($CaCl_2$), and reduced the exchangeable aluminium, compared with non-limed treatments.

Table 5. Soil test results for selected treatments at Site 3, October 2016.

Soil test parameter	Nil	PKS +Trace	PKS +Trace +N	PKS +Trace +Lime
Olsen P (mg/kg)	10.6	24.4	22.2	23.7
Colwell K (mg/kg)	205	237	206	226
KCl40 S (mg/kg)	3.1	5.0	4.3	5.1
pH (water)	5.3	5.3	5.1	5.5
pH ($CaCl_2$)	4.2	4.2	4.1	4.5
Sum of cations (meq/100g)	3.2	3.5	3.5	4.0
Aluminium (%)	37	33	36	18

At Site 4 (Baynton) by 2016, the average Olsen P for the Nil fertiliser treatment was 21.2 mg/kg, still well above the target range, compared with 23.5- 31.7 mg/kg for plots receiving P fertiliser for 3 years (Table 6). The Colwell K was above the critical level for the four treatments and ranged from 178- 218 mg/kg. The KCL40 S was slightly higher in the fertilised treatments compared with the Nil control but still below the target range of 8-12 mg/kg. The addition of 2 t/ha of lime raised the pH slightly and brought it into the target pH range, and reduced the exchangeable aluminium, compared with non-limed treatments.

Table 6. Soil test results for selected treatments at Site 4, November 2016.

Soil test parameter	Nil	PKS +Trace	PKS +Trace +N	PKS +Trace +Lime
Olsen P (mg/kg)	21.2	31.7	27.0	23.5
Colwell K (mg/kg)	218	210	178	201
KCl40 S (mg/kg)	5.2	5.5	6.7	5.8
pH (water)	5.3	5.3	5.3	5.7
pH ($CaCl_2$)	4.2	4.4	4.2	4.6
Sum of cations (meq/100g)	5.4	5.5	5.3	6.4
Aluminium (%)	16	16	18	5

4.2.2 Leaf analysis

At Site 3 (Glenhope), clover from plots that received PKS + trace elements had a higher molybdenum concentration in the tissue than plots that only received PKS. Molybdenum content was below the desirable range in clover from the PKS treatment. Zinc and Boron were slightly higher in PKS + trace element plots but there was no difference in any other nutrient levels between the two treatments (Table 7).

At Site 4 (Baynton), clover from plots that received PKS + trace elements had a higher molybdenum concentration in the tissue than plots that only received PKS. Molybdenum content was below the desirable range in clover from the PKS treatment. There was no difference in any other nutrient levels between the two treatments.

Table 7. Leaf analysis results for selected treatments at Sites 3 and 4, October 2017.

Nutrient	Site (Glenhope)		Site 4 (Baynton)		Desired level for sub clover
	PKS	PKS +Trace	PKS	PKS +Trace	
Total Nitrogen %	3.40	3.10	3.90	4.20	3.3 - 5.5
Phosphorus %	0.24	0.23	0.31	0.30	0.25 - 0.50
Potassium %	2.80	3.20	2.60	2.10	1.50 - 3.00
Sulphur %	0.23	0.21	0.26	0.29	0.25 - 0.40
Calcium %	0.84	0.63	0.89	0.91	0.80 - 2.50
Magnesium %	0.34	0.34	0.30	0.31	0.15 - 0.50
Sodium %	0.26	0.29	0.67	0.78	< 0.70
Copper mg/kg	8.3	9.4	11.0	11.0	5 - 30
Zinc mg/kg	26.0	39.0	42.0	48.0	15 - 50
Manganese mg/kg	170.0	180.0	130.0	160.0	25 - 300
Iron mg/kg	71.0	65.0	91.0	100.0	50 - 400
Boron mg/kg	14.0	18.0	17.0	17.0	20 - 100
Molybdenum mg/kg	0.11	1.40	0.23	0.86	> 0.40

4.2.3 Dry matter yields

Site 3 Glenhope.

In 2014, nitrogen and gibberellic acid responses were evident 3 weeks after their application on 28 July. A dry matter harvest was taken on 24 September 2014, around 8 weeks after all products were applied. Significant ($P<0.05$) responses to nitrogen occurred, with 25-40 % yield response evident in some treatments. There appeared to be a small phosphorus response but this was not significant ($P>0.05$). A summary of results is shown in Figure 5.

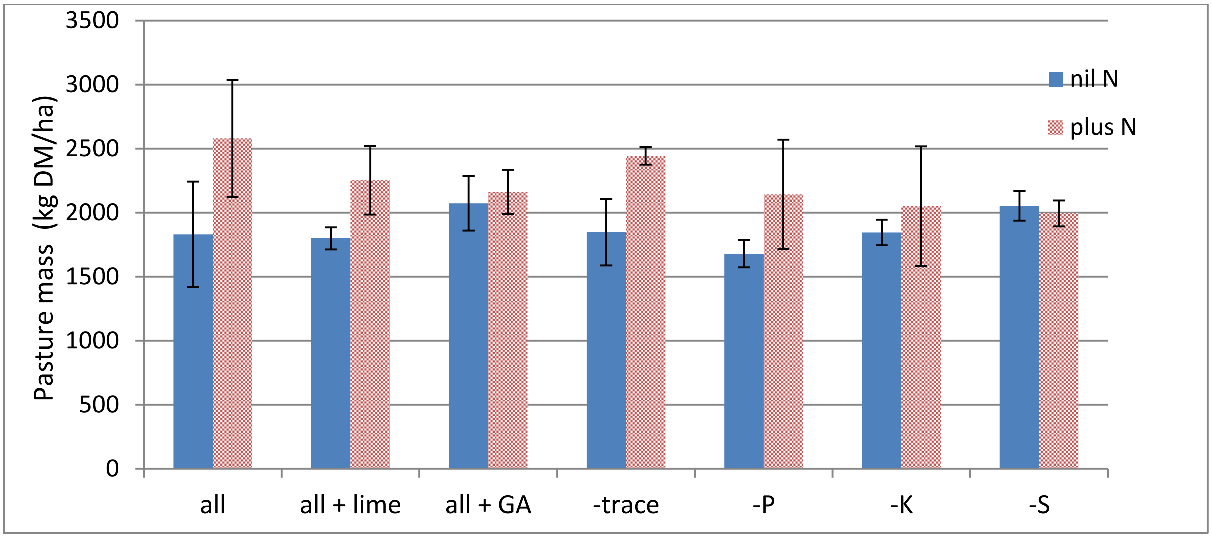

Figure 5. Dry matter yields from the September 2014 harvest at Site 3, Glenhope.

In 2015, plots were closed off (not grazed or cut) from May until October, as there was very little growth due to the dry conditions. A dry matter assessment was made on 1 October 2015, using a calibrated falling plate meter (not a mower) due to the low pasture mass. There were no significant responses to macro or trace nutrients, rhizobia or gibberellic acid (Figure 6). In comparison to the "all" treatment, the "GA" treatment grew an extra 350 kg DM/ha but this wasn't significant at the 5% probability level.

Unlike in 2014, there were no significant N responses across the treatments due to the dry conditions. Responses were small or inconsistent across treatments. On average, only an extra 150 kg DM/ha was grown with N in 2015 compared with an extra 360 kg DM/ha in 2014. The largest response to N in 2015 was on the plots that did not receive trace elements in 2014 (Figure 6).

Compared with the "all" treatment, there was a large response to application of the fungicide and some response to lime (Figure 6). The dramatic effect of the fungicide on the sub clover shoot and root growth in such a dry year is shown in Figure 7.

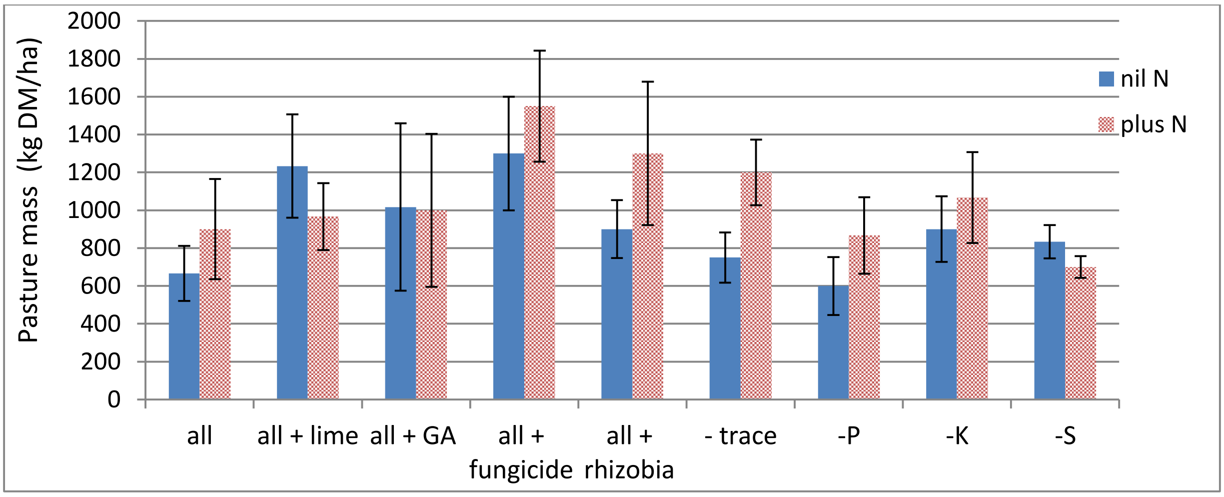

Figure 6. Dry matter yields on 28 September 2015 at Site 3, Glenhope. Bars indicate the standard errors of the means.

Figure 7. Ste 3, Glenhope, 28 September 2015. Centre photo: The plot on the left received all macro/trace nutrients and the fungicide (Metalaxyl), which had a dramatic effect on the sub clover shoot and root growth. The plot on the right received all macro/trace nutrients.

Note: these plots were locked up between May and October and there was little growth throughout the year due to the dry conditions.

In 2016, dry matter yield assessments were made on 20 July and 26 October. At the July harvest, there appeared to be small responses to lime, gibberellic acid, fungicide and rhizobia relative to the "All" treatment (Figure 8). Most treatments responded to nitrogen with an extra 250 kg DM/ha produced on the "All +N" compared with "All" treatment. K and S may have limited N responses in plots where these nutrients where omitted.

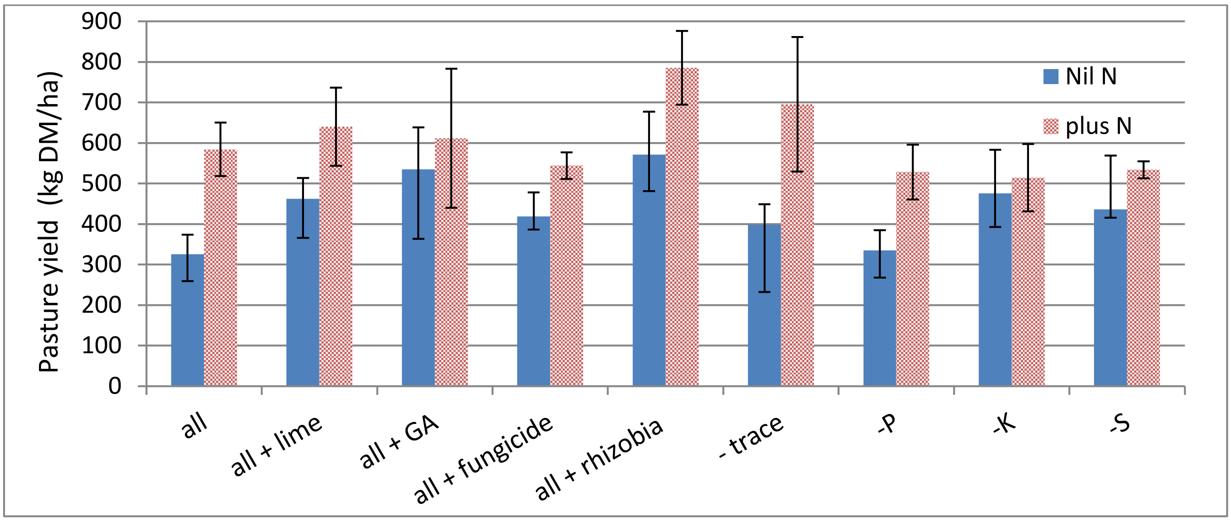

Figure 8. Dry matter yields on 20th July 2016, Site 3, Glenhope. Bars indicate standard errors of the means.

At the October harvest, there was no treatment effect across the nil N plots (Figure 9). The was generally no residual effect of the N applied in winter except for the Fungicide and Rhizobia treatments, which had a greater dry matter yield on the +N plots. This may indicate that the clover benefited from a combination of the N applied in winter and the fungicide or rhizobia and was able to fix more N, resulting in an ongoing supply of N in the spring.

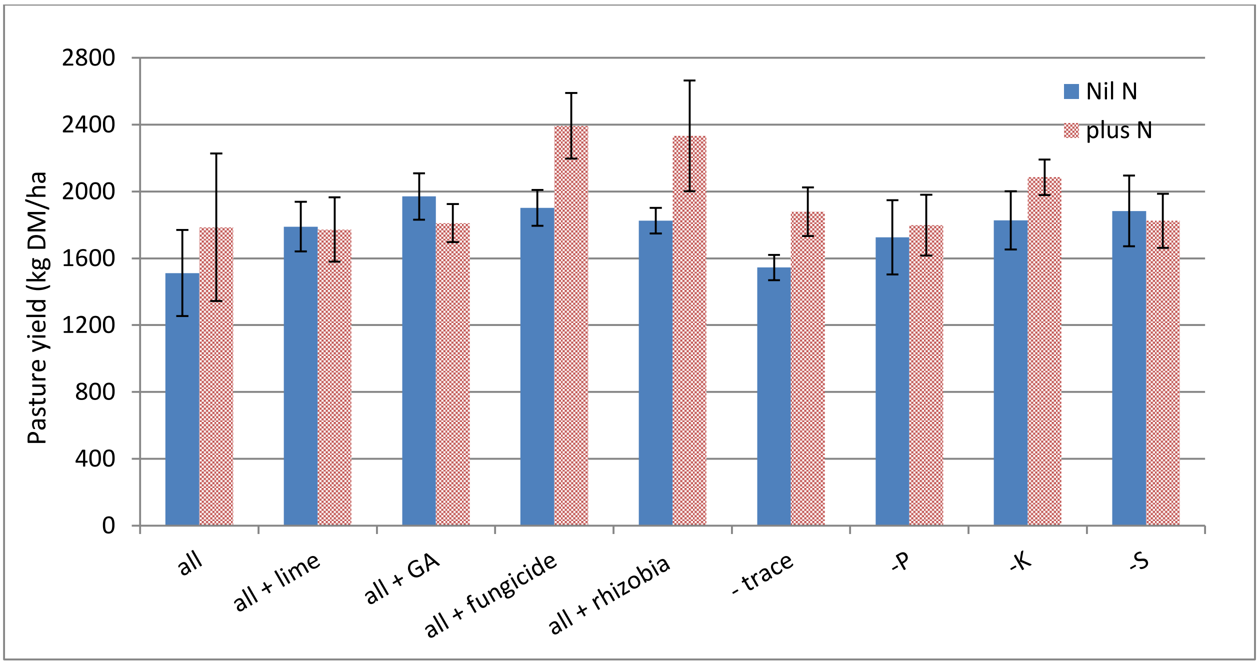

Figure 9. Dry matter yields on 26 October 2016, Site 3, Glenhope. Bars indicate standard errors of the means.

Site 4 Baynton.

In 2015, significant (*P < 0.0001*) responses to nitrogen occurred, between June and August, with an additional 420 kg DM/ha grown (range 320-770 kg DM/ha), on average across all the treatments (Figures 10 and 11). Nitrogen yield responses ranged from 42-135%.

In the absence of N, there was no signficant yield differences between fertiliser treatments (Figure 10). The Gibberellic acid treatment had the highest yield, which amounted to an extra 300 kg DM/ha compared with the "all" treatment, but this was not significant at the 5% probability level.

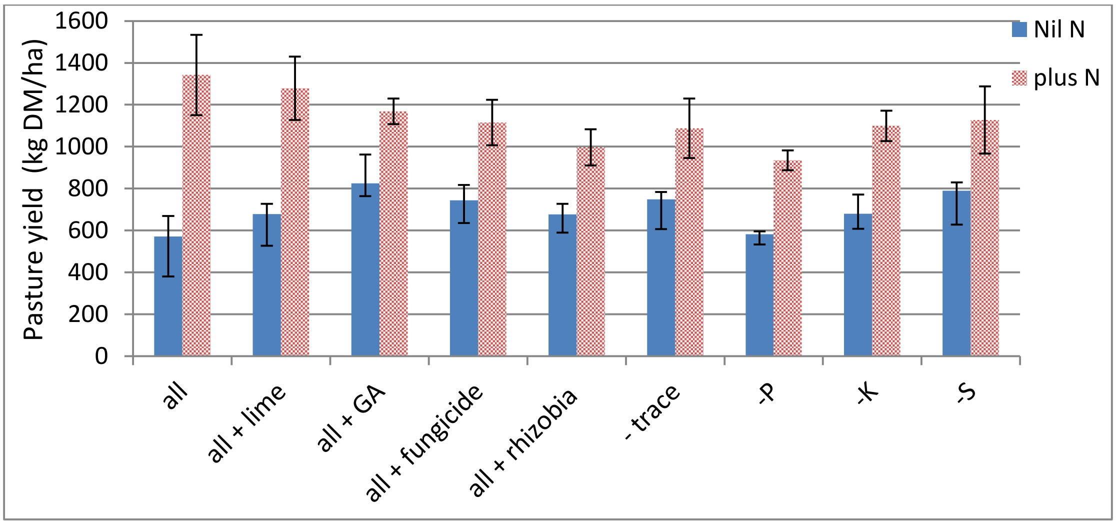

Figure 10. Dry matter yields on 28 August 2015 at Site 4, Baynton. Bars indicate the standard errors of the means.

Growing more winter feed at the lowest cost is usually a high priority on most farms. The use of gibberellic acid in winter is becoming a popular option with producers and they are often unsure whether to apply it on its own or with N or use N alone. The cost of the additional winter feed grown at the Baynton site, from applying these three options is summarised in Table 8. At this site in 2015, the nitrogen alone option produced more feed at a lower cost than the GA or GA plus N. The assumption was that urea cost $650/t spread (at 100 kg urea/ha) and GA cost $25/ha (at 10g/ha).

Table 8. Additional winter feed produced by application of gibberellic acid (GA) or urea (N) or both, compared with "all nutrients" treatment at Baynton, 2015.

Treatment	Additional winter feed (kg DM/ha)	Cost of extra feed (c/kg DM)
All nutrient plus GA	253	9.9
All nutrients + GA + N	597	15.1
All nutrients + N	770	8.4

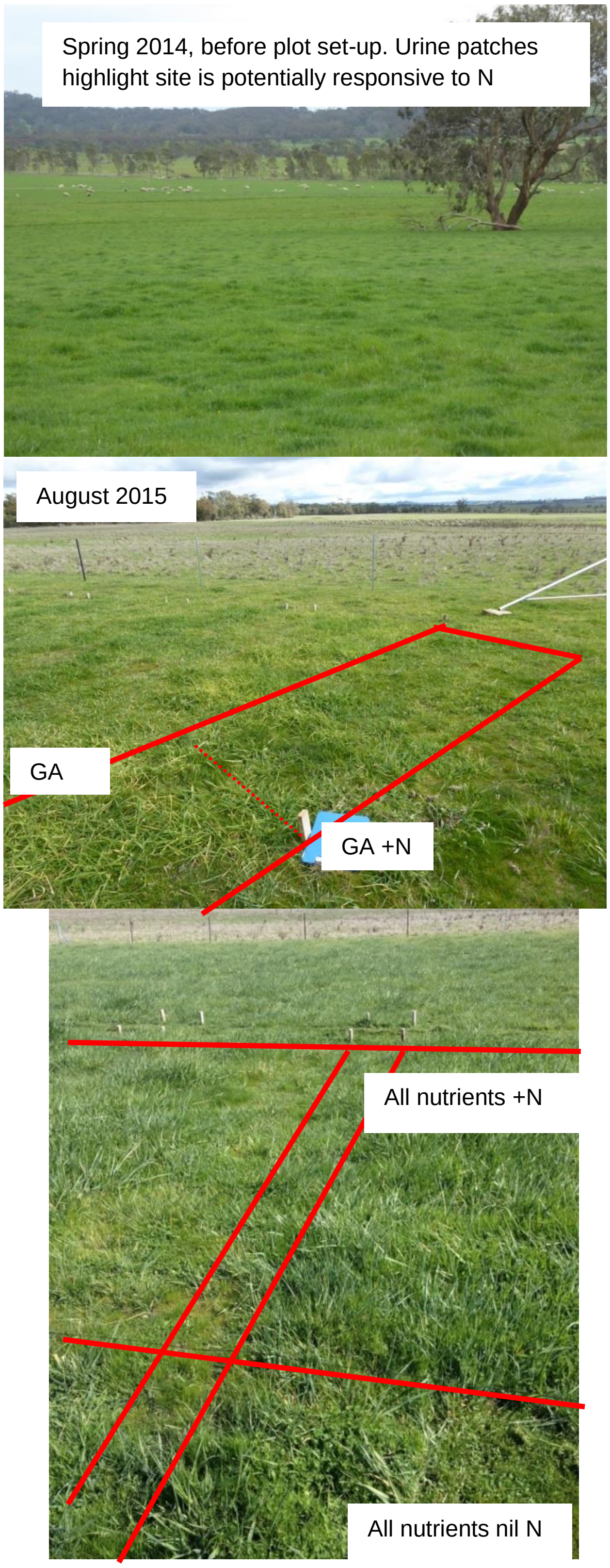

Figure 11. Site 4, Baynton in 2015. Centre photo: Small gibberellic acid responses occurred in winter 2015. The GA effect is evident by the paler green, elongated leaves on the phalaris. Bottom photo: The nitrogen response was the main treatment effect at site during winter 2015.

In 2016, the site was harvested on the 19 July and 26 September. At the July harvest, there were significant responses to gibberellic acid and nitrogen (Figures 12 and 13). There also appeared to be a small response to trace elements as indicated by slight reduction in growth where these nutrients were omitted, relative to the "All" treatment. There were no responses to fungicide or rhizobia and this could have been due to the low clover content of the pasture at this site and the more root rot resistant cultivar, Trikkala, compared with the Glenhope site. All treatments at Baynton responded to nitrogen with an extra 150 kg DM/ha produced on the "All +N" compared with "All" treatment. The extra pasture grown from application of N, gibberellic acid and N + GA at both sites is summarised in Table 9.

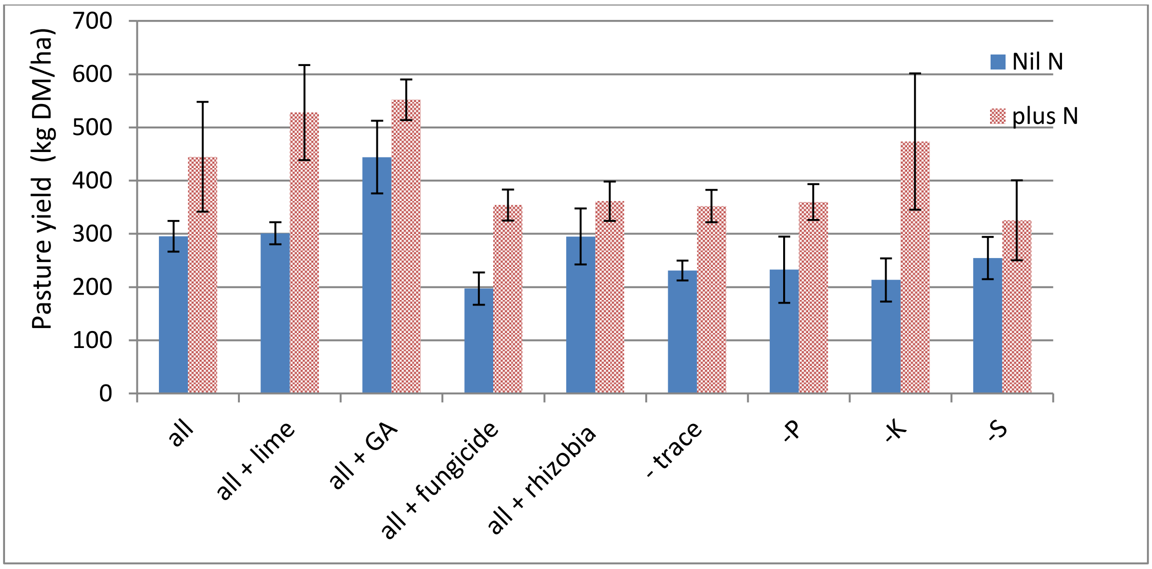

Figure 12. Dry matter yields at Baynton on 19 July 2016. (bars indicate standard errors of the means).

Figure 13. Gibberellic acid and nitrogen responses at Baynton, July 2016.

Table 9. Effect of nitrogen and gibberellic acid on dry matter yields (kg DM/ha) at Glenhope and Baynton in July 2016.

Treatment	Glenhope	Baynton
All	325	300
All + gibberellic acid	535	450
All + N	580	450
All + GA +N	610	550

At the September harvest, there were no significant differences between any of the treatments (Figure 14). There was significantly less dry matter on the "minus S + N" than the "minus S" treatment.

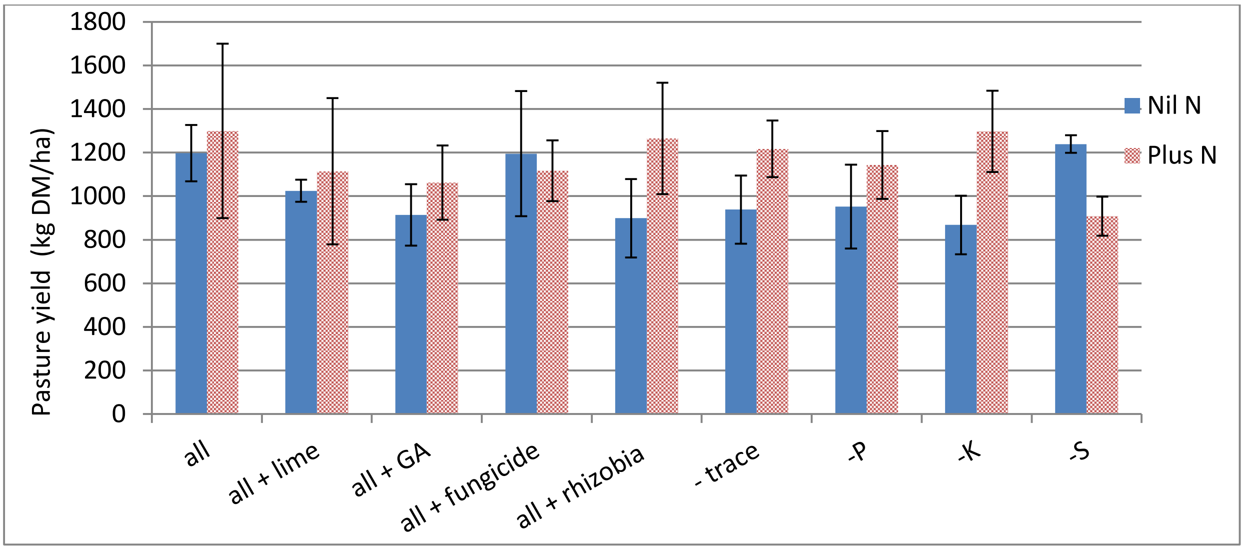

Figure 14. Dry matter yields at Baynton on September 2016. Bars indicate standard errors of the means.

4.2.4 Pasture composition

Glenhope

The pasture at Glenhope was mainly sub clover dominant with native grasses, annual grasses with a small amount of phalaris from when it was sown in the 1960's. There was no significant difference in clover content between most nil N treatments when composition was assessed on 26 October 2016 (Figure 15). The sub clover content was lower in the plots that did not receive trace elements. This was most likely due to a molybdenum deficiency rather than a copper, boron or zinc deficiency.

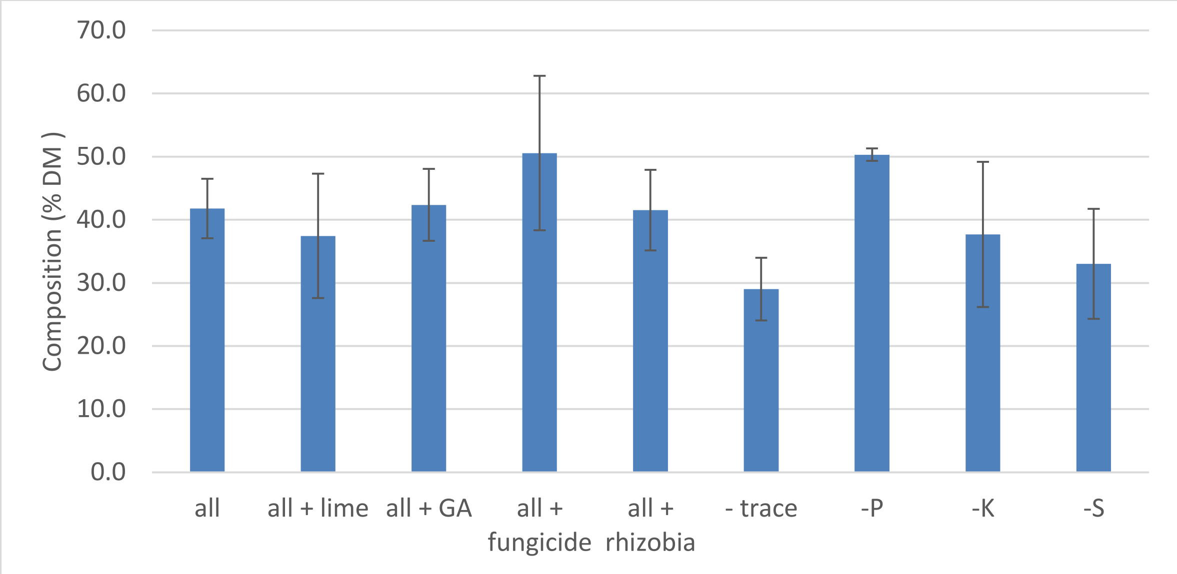

Figure 15. Sub clover content (dry matter basis) in nil N plots at Glenhope, October 2016. Bars indicate standard errors of the means.

Baynton

The pasture at Baynton was phalaris dominant with around 10% sub clover and 10% annual grasses and was similar each spring from 2014 to 2016. There was no difference in composition between treatments. Sub clover was broadcast onto the Rhizobia treatment before the autumn break in March 2017 to see if clover content could be improved. In 2017, the autumn break came early and all treatments had a large increase in sub clover content, making up to 40-50% of the composition. There was evidently a seed bank present but late breaks in previous years had not been favourable for dense sub clover regeneration at this site. There was no significant difference in clover content between all the nil N treatments when composition was assessed on 17 October 2017 (Figure 16).

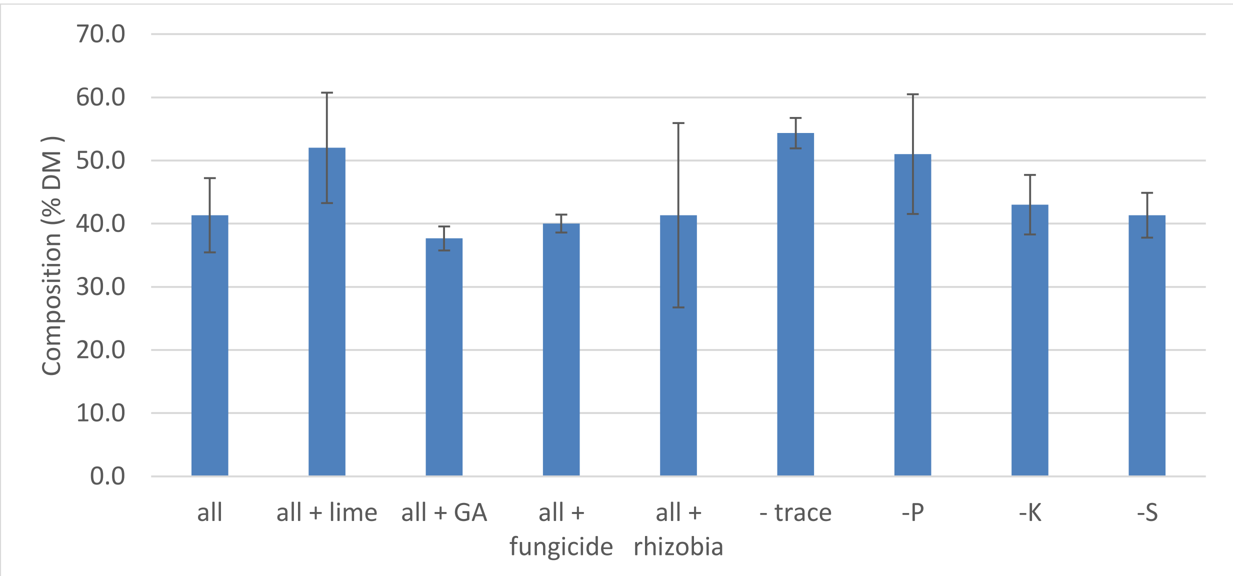

Figure 16. Sub clover content (dry matter basis) in nil N plots at Baynton, October 2017. Bars indicate standard errors of the means.

4.2.5 Rhizobia identification

The MALDI ID test indicated that the current commercial Group C strain of rhizobia (WSM1325 released in 2006) in the Alosca granules had successfully been able to colonise the clover nodules at both sites (Table10). At Site 3, no clover/rhizobia had been sown since the 1960's. In the plots that did not receive the Alosca granules, the rhizobia strain recovered from clover plants was an old strain (possibly TA1 released in 1961). At Site 4, the rhizobia strain recovered from clover plants that did not receive the Alosca granules, was a mix of the old and new Group C strains.

Table 10. Strains of Rhizobia identified in clover nodules, July 2017.

Treatment	Site 3 Glenhope	Site 4 Baynton
PKS + trace	Old group C	Mix of old and new group C
PKS + trace +Rhizobia	Current group C	Current group C

4.3 Extension and communication

Annual review meetings with the researchers, producers, Lisa Warn and Lisa Miller focussing on the progress of the project, were held in 2015, 2016 and 2017.

A series of MLA/GSSA Pasture Updates were held in the area to keep producers up to date with the research findings and to feature the work on P efficiency and serradellas by Richard Simpson and Sub clover root disease implications and control options by Martin Barbetti. Articles on the PRS project appeared in the GSSA newsletter and the MLA Feedback magazine. A summary of all activities and communication is shown in Table 11.

Table 11. Extension activities conducted during the project

Date	Activity	Number of people
February 2014	Workshop with GSSA Central Ranges branch and Dr Richard Simpson. Initial planning.	15
August 2014	Article in MLA Feedback magazine. *(see Appendix/ PDF file)*	Circulation 5000
2014	Factsheet – Project Snapshot for MLA website.	-
September 2014	Article in the GSSA newsletter *(see Appendix/ PDF)*	Circulation 1000
September 2014	GSSA Central Ranges branch meeting Presentation of project progress.	15
February 2015	Annual review meeting with GSSA branch, Lisa Warn, Lisa Miller and Dr Richard Simpson (CSIRO) who presented an update on P cycling studies and his alternative legume experiments.	7
September 2015	Mackinnon Project annual seminar. Improving P use efficiency presentation by Lisa Warn	80
October 2015	MLA/GSSA Pasture Update at Baynton. Included Guest speakers Dr Martin Barbetti, Kevin Foster (UWA) and Lisa Warn. Inspected the National sub clover disease expt at Baynton.	60
February 2016	Workshop Annual review with Lisa Miller.	6
June 2016	MLA/GSSA Pasture Update at Sutton Grange. Included Guest speakers Richard Simpson and Lisa Warn. *(see Appendix/ PDF)*	42
June 2016	Article in the GSSA newsletter – Pasture Update report by G.Ryan.*(see Appendix/ PDF)*	Circulation 1000
June 2016	Articles from Sutton Grange Pasture Update in the Weekly Times newspaper.	Circulation ?
June 2016	Workshop. National MLA PRS at Attwood.	65
September 2016	Perennial Pasture Systems (PPS) group annual conference at Ararat – Presentation by Lisa Warn on P use efficiency project.	100
December 2016	Annual review and Extension extraction meeting with Lisa Miller	5
October 2017	MLA/GSSA Pasture Update at Baynton. Guest speaker Lisa Miller, Lisa Warn, Brendan Torpy Precision Ag.	40

A number of additional activities were held with the Central Ranges Grasslands Branch.

- Local producers sent over 50 soil samples to the Farmright laboratory in spring 2014. The group were able secure at 10% discount off the standard soil analysis price from Don Cook, Farmright Technical Services, for the bulk submission. Some producers had only previously had soil test information for a limited number of paddocks, some had not taken soil samples for many years and some had never taken any before.
- A workshop was held for the producers (with L.Warn), in January 2015 at the Baynton hall, on interpreting soil tests and making better fertiliser decisions. Around 15 producers attended the workshop. The soil tests that were taken in spring 2014 revealed that, one third of the paddocks had Olsen P levels well above the target range, one third were well below the target and the other third were in the target range. Hence, there was potential to reduce P use on 33% of the paddocks tested and thereby improve efficiency/ reduce costs.
- Twenty fertiliser tests strip kits (including a vial of gibberellic acid) were made up and distributed so that the local producers could set up their own fertiliser trials. The kits included an MLA pasture ruler to help them monitor any responses.

5 Discussion

5.1 Research objectives

5.1.1 Growth and persistence of alternative legumes to sub clover

Objective 1 was about identifying whether or not alternative legumes (serradella) grow and persist in the different soil types of the Victorian central ranges.

Yellow serradella and French (pink) serradella were found to be more difficult to establish than several cultivars of sub clover. The two legume trial sites sown in early June 2014, did not establish very well due to a combination of factors. The seed drill used created soil disturbance which was caused a second germination of weeds and this was more of an issue at the Glenhope site. The time of sowing was most likely too late for this environment and then the spring cut-out early in 2014. This meant the legumes did not produce much dry matter or set much seed. Although the Pastoria site established better than Glenhope, there was virtually no regeneration of the serradellas there after the autumn break. Both sites were re-sown in June 2015, later than desirable as the autumn break was late in 2015. The trial at Pastoria failed to establish in 2015, and uncertain as to why as weeds or insect did not appear to be the cause. The trial established at Glenhope in 2015 but the late autumn break and dry conditions meant dry matter yields were minimal for all cultivars. Very little serradella regenerated at the Pastoria and Glenhope sites in 2016.

It would have been preferable to crop the sites for several years prior to establishing the trials to reduce weeds and clover seed bank, but the time-lines for the project didn't allow this. Different establishment techniques for serradellas could be explored to get the legume seed sown as early as possible such as sowing seed dry (without using a knockdown herbicide) provided suitable selective post emergent herbicides can be used for weed control. At present, there are not many herbicides that have label registration for safe use in serradella compared with sub clover.

5.1.1 The forage production of alternative legumes to sub clover

Objective 2 was about comparing the forage production (quality and quantity) of alternative legumes to sub clover grown under moderate and high soil phosphorus conditions for three years

This objective could not satisfactorily be achieved due to the issues with establishment of the legumes, particularly the serradella. At Glenhope there was no significant difference in the establishment or yield at low P or high P for any species/cultivar except for the pink serradella which had very low plant numbers at both levels of soil P. At Low P, the two sub clover varieties yielded the same as the Yellow serradella.

During this research project, more results from the CSIRO legume experiments became available which confirmed that the critical P level for serradella was lower than for sub clover. There was a change in direction suggested to the group for the alternative legume work to consider sowing larger areas in paddocks to test out the serradellas and trialling some different cultivars that might be better suited to the environment. In May 2016, a group member sowed a large-scale serradella trial at Baynton. This is being monitored as part of a new national project called *Phosphorus for Pastures*.

The challenge for producers in this region is that sub clover is well adapted and is already present in most paddocks, even those with low-moderate P levels. Establishing and regenerating serradella will be difficult if there is some seed-bank of sub clover to compete with. Also, there has been a lot less work done on breeding and selection of improved cultivars of serradella compared with sub clover. The best cultivars of serradella suited for this environment remain unclear, with further research required.

5.1.2 Identification of soil constraint factors

Objective 3 was to identify whether soil factors (nitrogen, trace elements, acidity, soil borne diseases) are constraining pasture and legume production on paddocks where P, K and S appear to be adequate.

The subtractive fertiliser trials at Glenhope and Baynton confirmed that where P, K, and S were adequate based on a soil test, no responses to these nutrients were obtained. After 3 years of omitting these nutrients soil P and K levels were still satisfactory, but S was slightly below the target range. This gives the producers confidence that if they have high soil P levels they can omit P application for several years without losing production or feed quality, saving money and improving P use efficiency.

There was no lime response at either site. Both sites had a topsoil pH ($CaCl_2$) below the target range. The application of 2 t/ha of lime of lime raised the pH and reduced the exchangeable aluminium as you would expect, but it did not increase the dry matter production nor improve the clover content. This is also an important finding as producers often prioritise expensive lime applications over fertiliser applications in the short term, thinking they will get better results from the fertiliser and make nutrients more available. In the long term, lime is required to prevent further acidification of the soil profile, but in the short term, producers with low soil P levels may get better return on capital by investing in capital P inputs.

There was no trace element response as assessed by dry matter production at either site, but the addition of trace elements improved the clover content at the Glenhope site. Although a combination of molybdenum, copper, zinc and boron was used in the trace element treatments in this trial, it is mainly molybdenum deficiency that occurs in this region. Molybdenum had not been applied for more than 20 years at Glenhope and around 10 years at Baynton. The clover leaf analysis indicated that the molybdenum content was below the desirable level in plots that did not receive trace elements, and adequate in those that did.

Responses to nitrogen were obtained each winter at both sites, the degree to which depended on the seasonal conditions. The phalaris dominant pasture at Baynton had responded very well to applied nitrogen with up to an extra 600 kg DM/ha grown in winter. The sub clover dominant site at Glenhope also responded well to N with up to extra 800 kg DM/ha grown in late winter 2014. The N response indicated the nodulation and N fixation by the clover was being constrained.

Responses to Gibberellic acid (GA) were also obtained each winter at both sites, but were generally lower than that obtained from using nitrogen. The combination of N and GA gave variable results, sometimes it produced less dry matter than the N alone and sometimes slightly more. Producers frequently ask *will the use of GA in winter reduce the dry matter production in spring*, but the results from these sites show that spring dry matter production was not affected. The use of GA or N were shown to be more economic options for filling winter feed gaps compared with feeding supplements to stock. The sites were very useful for farm walks/ field days to demonstrate to local producers the extra feed that could be grown.

Strategies to increase clover content trialled at Baynton, such as adding lime, trace elements, new rhizobia, fungicide and more clover seed (in 2017), had no impact. The early autumn break in 2017 had the biggest impact and sub clover content made a dramatic improvement in all plots. The main clover present at Baynton was Trikkala, which has tolerance to some root diseases.

There was no dry matter response to Alosca Rhizobia granules broadcasted at either site. These granules are usually drilled in with seed not broadcast, so how effective they would be at introducing a new strain of rhizobia when broadcast on the soil surface was not known. The MALDI ID test indicated that the new commercial strain of rhizobia had successfully colonised the clover nodules where it was broadcast. This is an encouraging finding as it gives producers an option to use this technique, if they wish to introduce new strains, rather than have to drill the granules in or re-sow a paddock with inoculated clover seed.

Soil borne disease were identified as being a constraint to sub clover nodulation and nitrogen fixation in the district. Testing by UWA in 2014 indicated that the sub clover at Glenhope had moderate - high levels of root disease (*Pythium* and *Rhizoctonia*), which could affect growth and nitrogen production. The sub clover had only moderate levels of nodulation. In the very dry year of 2015 at Glenhope, a fungicide response was observed in plots treated with Metalaxyl fungicide. The fungicide had a dramatic effect on the sub clover shoot and root growth. The plants were clearly able to extract more soil moisture and remained green longer than non-treated plots.

The species of soil pathogens that cause root disease can vary from year to year at the same site. Hence, testing completed in 2014 may not reflect pathogen species present every year. Also, the type of testing done in 2014 at UWA, required pathogens to be plated out/cultured to identify them and consequently took a long time to get results back. In order to select the appropriate fungicide to use in trials each autumn, a diagnostic test with a more rapid turn-around time is required.

In 2016, the group used SARDI's Predicta B - DNA test. This test is calibrated for crop soils and is commercially available for croppers to use pre-sowing. The calibrations for pasture soils are still being developed. Producers in the group were excited about the potential role the Predicta B test could have in determining if, in the short-term, there was economic merit in applying fungicides to pastures in autumn, and in the long term, helping them make better decisions about which disease tolerant sub clover varieties to sow.

Three samples were sent to SARDI from trial paddocks and four samples from other producers keen to be involved in any future fungicide trials. The test identifies the species of soil pathogens present but cannot predict what impact the disease will have. Predicta B results indicated *Rhizoctonia (2 strains), Pythium, Didymella* and *Eradu* present in all samples and *Phytophthora* in 2 samples.

The long-term solution to preventing soil pathogens from constraining sub clover growth is to sow disease tolerant sub clover varieties. There is a need to continue the research on screening new cultivars for a range of diseases. At present, not all diseases are being screened for, so producers can't get the information they need to make better cultivar selections. Also, much of the sub clover extension material does not include the new cultivars and has gaps in the disease information.

5.2 The value of the research results (Benefits/Costs)

The use of more P efficient legumes that have a lower critical P level, such as serradella, can potentially save producers hundreds of dollars per hectare on capital P inputs. It is estimated that at least 40% of the paddocks in the region could have Olsen P levels well below the critical level for sub clover (Olsen P 12-15mg/kg).

Therefore, there is appeal in using serradella to reduce fertiliser costs. Producer's comments were:

- *"Fertiliser is our highest cost and I try to keep P levels around 15 to 20 on our good country and 10-15 on our rocky soils. So, if serradella can be productive and reduce fertiliser bills then I would use it."*
- *"Fertilisers in 10 years may be three times more expensive so you would have to consider using it."*
- *"Benefit is the cost saving in fertiliser, I have a range of Phosphorus levels across the farm (6 to 18) and I'm trying to lift P* levels."

For paddocks that are planned to be renovated, the capital cost of sowing the serradella should be the same as sowing sub clover. The main issue with introducing serradellas into suitable lower P paddocks, is will they be able to grow and persist and compete with sub clover as most paddocks in the region already have a sub clover seed bank.

For paddocks in the region that have good Olsen P levels around or above the target range, the fertiliser trial results give producers confidence they can refine/reduce P inputs and save money without suffering losses in production. Some producers think more P is better but they may be above the point of diminishing returns and not getting an economic benefit. The importance of taking more soil tests more often was promoted during the project so that producers could make better decisions about fertiliser inputs and priorities.

The fertiliser trials demonstrated a range of possible factors that could be constraining pasture responses to P fertiliser on their properties. The project also showed them how to set up their own fertiliser test strips and highlighted some commercial tests and analysis they can use to help them identify possible constraints.

The cost benefit of using urea or gibberellic acid to boost winter pasture production was also demonstrated. The extra pasture grown can cost anything from 8-15 c/kg DM, but is usually cheaper than supplementary feed like grain or hay. Many producers in the region had not used urea or GA and were motivated to try these options after seeing the results.

Research into tactics, that helped lift winter production was highly relevant for the producers. Their comments were:

- *"Anything that makes pasture more productive during winter is critical."*
- *"Winter is a feed gap right up until spring and fungicides might help get healthier productive clover."*

5.3 Promotion of research results and its effectiveness

Although extension of results wasn't a main focus of this project, by having producers involved they increased their knowledge and skills and showed a willingness to adopt practices related to the FIP research topics.

Knowledge

There was an increase in producer knowledge about other potential constraints to pasture production than just P and understanding the reasons why pasture performance was not great even when P levels were optimal. Producer's comments were:

- *"We have gained some understanding of the effects of root disease in sub clovers so hope we can develop strategies to reduce their impacts."*
- *"Nutrient work opens up your eyes, that it's not just phosphorus but could be other nutrients, molybdenum, potash or nitrogen."*
- *"I got a much greater understanding on what is happening with the legume component and N fixation in our pasture system."*

Serradella was not used in the area, and although its persistence had not been proven, the project increased the knowledge that serradella could require lower levels of P to have the same production as sub clover and this excited the group. Producer comments were:

- *"Serradella use could result in large reductions in P fertiliser costs and also result in a more diverse legume population in our pastures that may be able to cope with the disease affects."*
- *"I carry a lot of stock and fertilise every year to keep P levels at 15-20, so it would make a difference, maybe 10% saving in fertiliser bill."*
- *"I have light and heavy country and serradella might be useful on the light soil."*

Before the project, there was a lack of awareness of soil borne diseases by producers but the research helped them recognise that it could be a constraint. Some of their comments were:

- *"There are large potential gains in winter production in sub clovers if we can reduce the effects of clover root disease, plus added benefit of greater N fixation, reducing the need and cost of applying N."*
- *"You could put a fungicide on with herbicide and it might cost $20/ha but return you $30/ha in extra winter growth and not counting the extra nitrogen that's there."*

Attitude

Producer's indicated that sub clover was their legume species of choice because it was well entrenched in the local area, so it would be difficult to convince producers that serradella was a viable option, even if it was proven to persist, produce and perform at lower P levels. Their comments suggested they would have to consider the use of serradella, not that they would not want to use it.

There many of the older producers were convinced about the benefits of P,but it was felt that younger farmers had missed out on the learning opportunities from Hamilton's long-term phosphate trial and Triple P program and remained unconvinced.

Skills

The before and after project producer survey responses picked up skill changes where they went from a 2 to a 4. (Scale 1 to 5 where 5 was highly skilled). These were likely to be increases in skills for identifying root diseases and understanding soil tests.

Extension activities within the group sought to increase the producer's skill at identifying root disease in sub clovers. Richard Simpson, CSIRO dug up plants and showed the groups what to look for, good healthy-looking white roots with lots of lateral branching.

Skill changes were also created through soil test interpretation workshops that were run by the group. Feedback from the group suggested that the area was made more complicated than required, as most of the producers just wanted to know how much fertiliser to put on.

Adoption

Producers indicated a willingness to adopt practices for more strategic use of fertilisers. Their comments about what changes they will make included:

- "*More soil testing, more targeted to different areas of the landscape and land classes."*
- *"In the future grid sampling and variable rate fertilizer application."*
- *"Ensure other nutrients are not limiting, particularly K, S, Mo."*
- *"More confidence using Gibberellic acid and N fertilizers to boost winter growth."*
- *"Fertiliser trials are showing how much production we lose if we don't maintain nutrient levels. At this stage, the results are just visual and we need some economics around it."*
- *"Gibberellic acid gave good results. I have only used it once but it wasn't that good, I may have applied it too late?"*

The project generated interest in the group to do further activities. They organised a co-ordinated an unfunded soil testing activity that resulted in farmers taking additional soil tests. This activity was highly effective activity, with 50 additional local soil samples collected, analysed and their results discussed at a workshop.

A co-ordinated collection of these results meant producers were motivated to meet the deadline to supply soil samples. The activity provided an opportunity for participants to action soil tests much earlier than planned and also helped engage producers that were very busy. Although a discount for these tests was offered, missing out on being part of the group testing was identified by participants as providing much more motivation.

The group also organised for 20 fertiliser tests strip kits (including a vial of gibberellic acid) to be distributed so that the local producers could set up their own fertiliser trials.

The improved awareness of soil borne diseases amongst participants ensured producers could "endeavour to choose disease tolerant sub clovers". This had been previously quite difficult for them as most extension material mentions *Phytophthora*, but not *Pythium* or *Rhizoctonia*, both of which had been found on the participants farms.

Barriers to change

Producer's comments indicated many potential concerns they had on the suitability of serradella to their environment, including:

- *"Cultivars of serradellas have not been bred to suit these environments."*
- *"Will it compete and survive like sub clover? Don't really understand how it grows, will it come back prolific like sub clover on bare-ground in autumn."*
- *"Needs to be able to withstand waterlogging and dry periods and aluminium in subsoils."*
- *"It may be good in dry years but not wet years, we don't really know. It may not hang around."*
- *"Serradella is unproven, the seasonal conditions have not been ideal to see what serradellas can do."*

There were also issues and questions around how to establish serradella and costs of establishment. There were also concerns expressed about trying to get it to establish where there is a background of hard sub clover seed. Producer's comments were:

- *"I would sow it when renovating new pastures and may use it in a mix but how would it go in a mix?"*
- *"Seed would need to be available when you want to sow and you need to be able to afford it, it could be too costly."*
- *"Not sure whether you could only establish it via a new pasture sowing or whether you could over-sow it into an existing pasture."*
- *"The challenge will be trying to introduce P-efficient clovers into existing pastures as we do not want to have to resow new paddocks."*

Producers had issues around understanding soil borne diseases and their management options. Their comments were:

- *"The results with soil borne diseases were really variable and it's not yet clear under what conditions it's an issue, (soil types and climatic conditions) and what options will work consistently."*
- *"There is a lot of soil borne diseases and I'm not big on spraying but I would spray to get a new pasture established but probably not after that."*
- *"We might know that (soil borne) diseases are holding back our clover growth and subsequent N production but control might be difficult (eg cultivation or annual application of fungicides). We might have to live with the damage or be applying nitrogen."*
- *"If we decide to replace susceptible cultivars then the background sub clover might be competitive (might not be if struggling with diseases) which could make establishment harder."*

Producers found information and recognition of species susceptibility to soil borne diseases difficult as the information is not readily available. Producers also reported difficulty in recognising what sub clover varieties were present on their farms due to the large range of species, with identification described as being "tricky". The Predicta B test costs for identifying the presence of soil borne disease is high ($90 per sample), but cannot currently predict what impact the disease will have, therefore whether the treatment necessary will pay off. It was also thought that the pathogens could rapidly change with season.

The barriers to adoption for treatment of soil borne diseases included a limited range within the current range of foliar fungicides, and producers required fungicides that had reasonable withholding periods and worked across a broader range of disease. Producers were also concerned about the impact, cost and time requirements of spraying fungicides. The problems identified were:

- Phosjet only works on *Phytophthora* and won't work on the other pathogens.
- The seed treatment Apron (Metaxyl) only works on *Pythiu*m and *Rhizoctonia*.
- Other fungicides eg Uniform has 6 week withholding period.
- Many other fungicides are only registered in crops.
- Which ones are broad spectrum or systemic as producers don't necessarily want to kill good fungi.
- Is it only cost effective in poor years or beneficial every year – the need for economics.

Enablers to change

The producers in the group identified a number of potential extension activities that could overcome barriers and enable change to occur.

Objective- For the producers to be:	Extension activity to enable change
Using appropriate levels of nutrients for their production system	• Organised soil testing and interpretation within groups. • Trained technicians that provide the same messages. (Merchandise stores offer this service but it's more expensive and producers worry about objectivity of advice).
Identifying sub clover cultivars and root disease symptoms so producers could determine what paddocks and in what seasons they are at risk	• Risk profile that can indicate where it is economic to treat. • Forecasts of disease presence based on seasonal conditions, district testing, lifecycle of disease. • Updating all extension material to include which varieties are susceptible. • Need PVNT to include a disease trait assessment.

5.4 Effectiveness of the participatory research process

The participatory research process

Producers in the group had an interest in increasing P fertiliser use efficiency but saw different solutions than what was offered in the FIP research. The group remain interested in potential improvements through variable fertiliser rate applications. Producers didn't necessarily have an interest in replacing existing sub clover pastures with serradellas, although were attracted to using less fertiliser. To add value to the FIP research, the group compromised and established trials on alternative legumes – and investigated other constraints that would also assist soil borne disease FIP research. In a true participatory research project, the group and researchers would have been engaged earlier and worked together to identify mutually beneficial areas of research, rather than adapting their individual productivity needs and areas of legume research.

The initial reservations from researchers was about getting producers involved without proven technology, which was demonstrated to an extent when groups had difficulty establishing or regenerating serradellas seedlings. However, this in itself provided a result, highlighting that existing varieties of serradella were not robust in the central Victorian ranges. The FIP research also moved quickly where it confirmed serradellas can operate in a lower P environment, and when producer trials identified differences in sub clover varieties requirements of P due to different rooting access abilities.

How the group added value to the research topic?

The group illustrated the risks of establishing clovers. There was limited success with direct drilling, and the timelines were too rushed. The legume trial sites were selected and established quickly and findings to date suggest the establishment of species may have been more successful with a year or two to prepare sites. The research also highlights the difficulty in introducing new legume species into established grass pastures they want to maintain. The research adds another location to the FIP research to both the P use efficiency project and the soil borne disease project.

The project has built good relationships between the researchers and the producers involved, which will allow further access for future trial work. The group were also able to discuss their reservations about replacing sub clover (which is well suited to the area) directly with CSIRO's FIP researcher, Richard Simpson. The producers appreciated the opportunity for local research. One producer commented:

"Research is occurring in our environment so is much more likely to be applicable."

The value proposition of this research method, from a producer's perspective, is it helped raise awareness of relevant topics and increased their knowledge. Being able to see local responses was of great value for learning. A producer commented "Even if serradella isn't suited to our environment it's still a result worth knowing. It will save me from sowing it."

Having group discussion regarding the results allowed the producers to work through issues and get a deeper learning. Producers without having someone to co-ordinate the group and take measurements would have unlikely found the time to commit. The group was also able to tap into expertise of:

- Richard Simpson, CSIRO
- Martin Barbetti, University of Western Australia
- Kevin Foster, University of Western Australia
- Sophie deMyer, MALD ID service, Murdoch University
- Predicta B services, SARDI

The group were very effective in seeking out and implementing an enormous amount of in-kind support from a range of people. Producers have applied herbicides, erected fencing for sites and grazed off plots when required. Stephens Pasture Seeds, AusWest Seeds, SeedForce, Incitec Pivot, NuFarm (fungicides) and Alosca (granular rhizobia) have kindly supplied products for trials. PGG Wrightsons supplied their cone seeder and labour to sow the legumes plots in 2015. Don Cook, Farmright Technical Services, has also supported producers in the branch by giving a 10% discount on their soil samples submitted in 2014.

Future areas of research identified

Producers felt the following areas could be worthwhile areas for future research:

- Qualifying where serradellas will persist and if they perform (establish, produce, regenerate) as well or better than sub clover in our current farming systems, which is currently occurring.
- New clovers brought onto the market need to be screened for disease tolerance, so farmers with disease issues can select them.
- Sub clover breeding to include more P efficiency would be highly desirable.
- Breeding of serradella species that establish and regenerate easily.

6 Conclusions/Key messages/Recommendations

6.1 Conclusions

Yellow and French (Pink) Serradellas have been shown to be more P-efficient than sub clover. They can optimise their growth at a lower soil Olsen P level than sub clover. On low P soils, if serradellas are to be sown instead of sub clover, there is the potential to save hundreds of dollars per hectare in capital P fertiliser inputs. More research is needed to determine the most suitable serradella cultivars for different environments in Victoria. Introducing serradellas into paddocks with a seed-bank of sub clover may be difficult and selecting paddocks that have been cropped for a few years may improve its ability to establish and regenerate.

Several ways were identified that could improve the efficiency of P fertiliser use in the project area. Many paddocks already have P levels above the critical level for sub clover and savings can be made by not applying P fertiliser in the short term.

There is also an opportunity to grow substantially more pasture in paddocks that already have adequate P, K and S levels. Nitrogen deficiency was shown to be a major constraint to pasture growth and the efficient use of P. Nitrogen fixation was below optimum for different reasons at different sites. Molybdenum deficiency and root disease were shown to be reducing clover content and N fixation. Liming to increase soil pH did not improve clover content or pasture dry matter production even though trial sites had a pH of less than 4.5 (Cacl2). There was no dry matter response to Alosca rhizobia granules, which were broadcast on the soil surface, but the new strain of rhizobia in the granules did successfully colonise the clover nodules.

For paddocks with good species and good P, K, S levels, there is an opportunity to grow more winter feed, at low cost, with the tactical use of urea or gibberellic acid.

6.2 Key messages

Some key messages for producers are:

- Yellow and French (Pink) Serradellas have been shown to be more P-efficient than sub clover. They can optimise their growth at a lower soil Olsen P level than sub clover. On low P soils, if serradellas are to be sown instead of sub clover, there is the potential to save hundreds of dollars per hectare in capital P fertiliser inputs.
- More research is needed to determine the most suitable serradella cultivars for different environments in Victoria.
- Savings in P fertiliser (and other products) can be made and more pasture grown by being more targeted with applications. Take more soil tests more often to make better decisions about types of fertilisers and rates required in individual paddocks and land-classes. All nutrient deficiencies need to be corrected to optimise responses to P.
- Variable fertiliser technology is available which can allow you to be more targeted with P,K,S, fertiliser or lime inputs *within* a paddock.
- For paddocks with good species and good P,K,S levels, there is an opportunity to grow more winter feed, at low cost, with the tactical use of urea or gibberellic acid.

- Investigate if clover content and N fixation is adequate. Use clover leaf analysis or fertiliser test strips to check for trace element deficiencies. Check the root systems of clover plants in winter to check if root disease is affecting N fixation.
- When renovating paddocks, sow sub clover/legume cultivars that are known to have good disease tolerance to soil borne pathogens.

6.3 Recommendations

Research, and associated extension, should continue in the following areas:

- Qualifying where serradellas will persist and if they perform as well or better than sub clover. Identifying which serradella cultivars are best suited to different environments.
- Identification (selection/breeding) of sub clover cultivars that are more P-efficient.
- New clovers/legumes brought onto the market need to be screened for tolerance to the full range of common soil-borne pathogens (i.e. *Pythium, Rhizoctonia, Phytophthora*).
- Sub clover fact sheets (e.g. Agnotes) urgently need to be updated to include identification information/photos for all new cultivars, and disease tolerance information for all cultivars (old and new). This will allow producers and their advisers to identify clover cultivars present, the risk of production losses from root disease and which allow selection of the most appropriate cultivars to use in new sowings.
- If a PRS type process is run again, be more cautious and flexible about at what stage of the research process to involve the producer group. For some research topics, producer involvement early on may be important to influence the priorities, objectives and methodology. For other research topics, the initial R&D may need to conclude first and then the producers test out those findings or adapt the technology to their system.

7 Appendix - articles

7.1 MLA Feedback magazine article – August 2014

Soil management

Producers driving pasture research

Livestock producers are joining forces with researchers to put pasture R&D into the paddock, with over 20 Producer Research Sites launched this year.

With topics ranging from 'pasture persistence' to 'establishing legumes in temperate pastures' to 'strategic fertilising', these sites are part of MLA's investment in the southern feedbase, which targets an extra $25 million annually in on-farm value by 2020.

"The Producer Research Sites focus on hands-on producer involvement, supported by the technical capabilities of researchers involved in feedbase projects," Linda Hygate, MLA's Southern Feedbase Project Manager, said.

"By involving producers in designing and running trials, these projects engage end-users in research to test whether and how the research fits into their farming systems."

Feedback talked to leaders of two sites about their planned work program.

In the south

Victorian sheep producer Gerard Ryan chairs the Central Ranges Branch of the Grasslands Society of Southern Australia, which has joined forces with MLA, CSIRO and the Mackinnon Project to investigate ways to improve efficiency of phosphorus (P) fertiliser.

"Involving producers in a project like this ensures research can be applied on a practical basis in our local environment," Gerard said.

"Livestock producers want to increase input efficiency so this should give us information that is verified in our conditions to guide our fertiliser decisions."

The group will start several experiments this year to answer two questions:

- → Are there more P-efficient legumes (other than sub clover) that yield well in the different soil types of the central ranges under moderate P levels, to reduce fertiliser costs? The trial will compare yellow serradella, French (pink) serradella, biserrula, gland clover and lotus with several sub clover varieties including the new earth-mite tolerant varieties Narrikup and Rosabrook. Performance of species will be compared at moderate and high soil Olsen P.
- → What other factors could be impacting the response of pastures in high P soils? This experiment will assess if other nutrient or soil factors (nitrogen, trace elements, acidity, soil borne diseases, poor nodulation/rhizobia) are constraining pasture and legume production on poor performing paddocks and reducing efficiency of applied phosphorus.

Mackinnon Project researcher Lisa Warn from the University of Melbourne said typical fertiliser costs for Victorian livestock producers were around $3-4/DSE/year.

"So if P based fertilisers can be used more efficiently by applying less per hectare, or by applying them in a more targeted way across the farm, or by growing more pasture/kg/P applied, this will result in significant increases in gross margins," she said.

The MLA Producer Research Sites program in Victoria is supported by the state Department of Environment and Primary Industries.

In the west

Another Producer Research Site, run in conjunction with the Southern DIRT group on a property near Kojonup in Western Australia, is also looking at strategies to use P more efficiently.

This project compares legume species that potentially require less P than the standard sub-clover grown in the area. Different rates (recommended and half recommended) and formulations (liquid and granular) of P fertiliser will be applied.

The trials will be run on a farm with a low critical P value to determine the impact of P application and critical P values for alternative legume species. Measurements such as pasture cuts, plant tissue tests, annual soil tests and visual assessments will compare P uptake levels and biomass production from each pasture type in each treatment, and compare them to a control plot with no P application.

While University of Western Australia (UWA) researchers will provide technical advice to ensure the trial is scientifically valid, Southern DIRT producers are hands-on in designing the project and running the trial.

UWA Associate Professor Pasture Science, Megan Ryan, said the trial was developed with producer input to ensure the research addressed what they wanted to know.

"Producers wanted to know if they can grow different pastures with the same P input and achieve more production, or with lower P to maintain production, so the research team worked with them to develop a trial that would answer these questions," Megan said.

"It's exciting to have producers involved. It ensures research is relevant for industry and gives producers an insight into the constraints and considerations of research trials.

"The participatory model builds strong links between researchers and producers, so when we get to the point of disseminating practical outcomes from the broader feedbase project, the producers involved are an obvious choice for early adoption."

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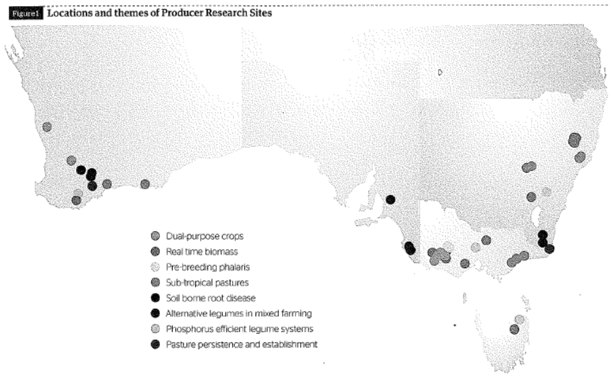
Figure 1 Locations and themes of Producer Research Sites



Investing in the feedbase

The three top priorities for MLA's feedbase R&D are:

1. Plant breeding and evaluation
- → Pre-breeding in phalaris and annual legumes
- → Pasture Variety Trial Network
- → Evaluation of new species

2. Productive and sustainable pastures
- → Getting more pasture with less P
- → Evaluation of new legumes in mixed farming
- → Pasture species for the sub-tropics
- → Root diseases in sub clover

3. Grazing systems management
- → Developing technology to measure pasture biomass in real time
- → EverGraze
- → Dual-purpose crops
- → Enrich

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7.2 Grasslands Society of Southern Australia newsletter -September 2014

Central Ranges branch report

Increasing phosphorus-use efficiency

Over the autumn of 2014, members of the Central Ranges branch worked closely with Lisa Warn from the Mackinnon Project to develop a research project to improve the efficiency of phosphorus use in local pastures.

Fertilisers, mostly phosphorus- and sulphur-based single superphosphate, are a major annual expense for producers, which for example cost Victorian livestock enterprises an average $3-4/DSE per year. Regionally, producers are concerned about the sustainability of phosphorus supplies and about the increasing cost trends of fertilisers over the past 7-8 years.

"*So if phosphorus-based fertilisers can be used more efficiently by applying less per hectare, or by applying them in a more targeted way across the farm, or by growing more pasture per kilogram of phosphorus applied, this will result in significant increases in livestock gross margins*." said Lisa Warn

Branch President Gerard Ryan commented that "*Inputs of phosphorus fertilisers are a major driver of productivity but also a major cost in maintaining productive sub clover based pastures in this area*."

"*Another issue is that, while we have established some very good perennial grass pastures, the performance of the legume content has been highly variable and in some ways neglected; we hope some findings of this research may go some way in redressing this*," he said.

A research proposal was submitted to MLA's Participatory R&D Pasture Research program to specifically address the 'Increasing phosphorus use efficiency' topic. The proposal was successful and the team gained three years of funding, which commenced in June 2014, to address the following two questions.

1. *Are there other pasture legumes that grow just as well as sub clover on the different soil types found across the Central Ranges that use soil phosphorus more efficiently than sub clover?*

In other words, are there any other pasture legumes as good as sub clover that don't need as much phosphorus fertiliser to grow? There is some evidence that serradella and lotus have a lower critical phosphorus requirement than sub clover, and so the hypothesis is that if they can grow as well as sub clover, perhaps soils could be maintained at Olsen P values of 8-10 mg/kg instead of the 12-15 mg/kg required for sub clover growth.

So the legume trials will establish if serradella and/or lotus can grow well in the district, and if they do yield similarly to sub clover, can they do so with less fertiliser phosphorus?

In this first study, the dry matter yields of the following legumes will be compared under moderate and high levels of available soil phosphorus.

- yellow serradella,
- French or pink serradella,
- biserrula,
- gland clover,
- lotus, and
- sub clover varieties Riverina, Leura, Narrikup and Rosabrook; the last two varieties have increased resistance to red-legged earth mites.

Two trial sites were sown on 17 June 2014; one is on a sedimentary soil at Glenhope (Matt Shea's property) and the second on a granitic soil at Pastoria East (Michael O'Sullivan's property). Both sites were treated with glyphosate, dicamba and an insecticide 10 days before they were sown.

Several demonstration strips were also sown at the Glenhope site to compare the following pasture mixes:

- Holdfast GT phalaris with Trikkala sub clover,
- Flecha winter-active tall fescue with Trikkala sub clover, and
- Holdfast GT phalaris with Stamina GT5 lucerne.

2. *Can phosphorus use efficiency be increased on under-performing paddocks where P, K and S levels are adequate?*

This subtractive experiment will assess if other nutrient or soil factors (nitrogen, trace elements, acidity, soil borne diseases, poor nodulation/ rhizobia) are constraining pasture and legume production on under-performing paddocks (which cannot be readily explained through soil tests or grazing management) and reducing efficiency of applied phosphorus.

This experiment also seeks to see if more pasture can be grown over the year with particular combinations of treatments.

In this design, all possible factors are applied together and then omitted one by one, and in combinations, to identify if one or more of these factors are holding back pasture growth.

Two sites will be established; one will be next to the legume trial at Glenhope as this soil has moderate levels of soil phosphorus, and a second site will be established on a soil with high phosphorus levels where the pasture is not performing well and sub clover content is low.

Urea (N) and gibberellic acid (GA) will also be applied as part of these subtractive experiments to look at how much extra winter feed can be grown, at what cost, and whether they increase phosphorus use efficiency of the pasture.

In addition to providing the field sites, local GSSA members and land holders have fenced the sites and applied the herbicides, and will continue to monitor and manage them. Additionally, they have committed to soil testing more regularly to better refine their maintenance phosphorus requirements.

The branch and the Mackinnon Project thank Incitec Pivot Fertilisers, Stephens Pasture Seeds, AusWest Seeds and SeedForce for their donation of the products used in the trials.

7.3 Weekly Times newspaper article, June 2016

THEWEEKLYTIMES.COM.AU WEDNESDAY JUNE 29 2016 LIVESTOC

ROOTS 'PRUNED'

Pathogens hurt pasture

By DALE WEBSTER

SUB-CLOVER pastures could be taking a 20 to 40 per cent hit in productivity over autumn-winter due to soil-borne pathogens stunting root systems.

And, according to research by the CSIRO, it is happening under the noses of farmers who are unaware of what is going on below the surface of their paddocks.

"I would guess that we could walk into any permanent pasture and find it,", CSIRO pasture research team leader Richard Simpson told a Grasslands Society field day near Bendigo recently.

"Fungus can be lethal if they knock the tap root off but normally they create bonsai plants by pruning the lateral roots.

"As you go into spring, the roots get going again."

Dr Simpson said because the plants generally recovered from the damage — caused in trials near Canberra by pathogens such as pythium, rhizoctonia and phytophthora cinnamomi — it often went unnoticed.

"You're already living with this, so don't panic," he said.

"But what is does is effectively put a cap on your ability to lift stocking rates.

"We estimate the potential range of constraint that we are regularly seeing from this sort of damage to the root systems is 20 to 40 per cent.

"A 20 per cent impact in autumn when you most need the feed is significant."

Dr Simpson said pruning of lateral roots could be so subtle researchers did not realise they were looking at actual damage until a year into the trial.

More severe cases can be identified visually by a blackened root system of a plant that has been pulled from the ground.

Treatments include fungicides but results could be starkly varied, he said.

"We have seen very dramatic effects of using metalaxyls," Dr Simpson said.

"At this stage modern cultivars are your best bet."