final report

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Phosphorous efficiency in pastures

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Executive Summary

The aim of this project was to improve phosphorous (P) use efficiency through increased understanding of soil benchmarks and critical soil values and identifying alternative legumes that have lower phosphorous requirements.

In 2014 a group of Southern Dirt producers came together to develop a project around this aim. They wanted to identify if they could grow an alternative legume crop with lower phosphorous rates that would produce more feed with the same or less amounts of P than sub clover. They also wanted to explore if liquid P is a more effective treatment than equal unit of granular P. The group wanted to find out the response from each variety with a sub optimal dose of P. These questions led to the final project objectives:

1. To compare alternative legume species with potentially lower critical P values with the standard sub-clover currently grown in the Kojonup area.
2. To evaluate the plant health and biomass of alternative legume species and sub-clover when P is applied in either a liquid or granular form.
3. To investigate if a lower level of P rather than the recommended rate can still produce as much biomass from pastures.

The treatments used were a combination of low to high rates of P (0, 5, 10, 20, 40, 60kg/ha) which were replicated throughout the trial. The sown species were Yellow Santorini Serradella, Margurita French Serradella, and sub clover (2014 a pasture mix and 2015-16 Dalkeith clover).

The results were not straightforward as nutrients, seasonal stressors, and weed control caused the assessments and data collection to give very few results. In all pasture species the 0 – 10kg/ha showed little difference, where in the 20 – 60kg/ha the species showed an increase in biomass, with the exception of Yellow Santorini Serradella in 2015 and the sub –clover in 2016. This is an expected result as the higher P application; the more biomass is produced, as it is not a limiting factor. The soil results however show an unexpected result. The amount of applied P in the higher application treatments (20kg/ha – 60kg/ha) should show and increase in the colwell P values. Despite P inputs of 170, 365, and 620 kg/ha Double Phos over the two growing seasons and minimal uptake by plants in the 20, 40 and 60 treatments respectively, the final Colwell P soil test values were (on average) 9, 28 and 42 mg/kg for the three highest treatments. This means that in treatment 20 there were 30 units of P applied for an increase of less than 5mg/kg Colwell P. In treatment 40 we applied 64 units of P for an increase of 22 mg/kg and in treatment 60 we applied 110 units of P to increase it by almost 37 mg/kg.

For the two highest treatments this equated to 3 units of P into the system for an increase in Colwell P of 1 mg/kg. For the 20 treatment this figure was 6 units of P.

Based on current research being performed by CSIRO, NSW DPI and UWA the expected Colwell values are approximately 30 and 22-24 for subclover and serradella respectively in a soil with PBI above 50. However, due to the unfavourable climatic conditions in the final two years of the project, differences in yield from the fertiliser treatments were unable to be examined.

The project has identified that producers need to select a pasture based on soil type, limiting nutrient, and rainfall. Serradella species achieve best results when sown on sandy more acidic soils, whereas the sub clovers out compete serradella species on clay and moderately acidic to neutral soils.

It was identified that producers should treat their pastures like they would their crops to achieve the best outcomes for their pasture. There a few key tools producers can use to determine what pasture will produce the best results. One of these is soil testing. By collecting soil samples producers can determine their nutrient inputs for the pasture, this is good for the environment as producers can reduce fertiliser and other macronutrients inputs if there are sufficient nutrients found in the soils. Another way to ensure a productive pasture is by selecting a pasture that suits a producer's soil type. Serradella produces more biomass on sandy acidic soil whereas the sub clover would out compete serradellas on clay more neutral soils.

There is not one pasture variety which performs better than others over different soil types. Therefore, producers are better equipped by selecting a suitable pasture for their area and soil type, rather than looking only at a low phosphorous variety

There were a number of limitations other than P which has impacted the results from 2014, 2015, and 2016. Although these were addressed in each subsequent year of the trial it impacted heavily on the results. This highlights restrictions on the application of laboratory based research for farmers and the importance of field trials to test hypotheses in real situations.

Other issues that impacted the trial were not all seasonal stressors or limiting factors, each of the years the project was run it was managed by a different project officer or consultant. This impacted the project when it came to analysing the data, as it was collected similarly however, not that same over the three years. Continuity of staff or a protocol handbook would be helpful in the future to collect each measurement correctly and the same each time.

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1 Background

Southern dirt

Southern Dirt is one of Western Australia's leading grower groups, encompassing some of WA's most productive land and representing some of the states' most innovative farmers. Our region extends from Boddington to Frankland and everywhere in between from the coast to the Wheatbelt. The area encompasses over 2600 mixed farming enterprises with flock sizes ranging from 200 to 10,000 sheep. The property sizes range from 500 ha up to 8,000ha. Southern Dirt has a membership base of more than 200 farming businesses.

The core producer group who were apart of the initial meeting were a group of 10 producers, 3 industry professionals and 9 project contacts/advisors. The group's motivation to participate in the Participatory Research program was to address some issues that were facing many of the producers in the area and to expand their knowledge on growing a pasture and understand soil results. The questions the producers faced were which pasture species suited the region, how much phosphorous (P) was required the interactions with pastures on low pH soils and issues types of applied P would give the best outcomes, liquid or granular. Some other problems were how to access the locked up P in the soils, how pastures work with cropping P in systems and rotational vs permanent pasture, and what strategies could be used with the best economic return.

Producers wanted to research these issues to help them understand what would be the most productive and profitable for their farming enterprises. They always wanted to be educated on soil health and the interactions that P had on the soils.

The topics that were of most interest to the group were the pasture varieties and comparing current varieties to potentially lower critical P varieties and perennials. They were also interested in the forms of P available and wanted to compare liquid and granular to see which gave the better response and most economical. The final topic of interest was how much P should be applied, they wanted to know what were the critical levels and the least amount of P that could be applied to get a response. These topics of interest formed the basis of this project and were initiated in 2014.

2 Projective objectives

2014

1. To compare alternative legume species with potentially lower critical P values with the standard sub-clover currently grown in the Kojonup area.
2. To evaluate the plant health and biomass of alternative legume species and sub-clover when P is applied in either a liquid or granular form.
3. To investigate if a lower level of P rather than the recommended rate can still produce as much biomass from pastures.

2015 - 2016

To compare alternative legume species with potentially lower critical P values with the standard sub-clover currently grown in the Kojonup area.

To investigate if a lower level of P rather than the recommended rate can still produce as much biomass from pastures.

3 Methodology

2014

Three treatments were sown next to each other in strips, repeated three times. These treatments were Dalkeith sub-clover, Margurita French serradella and a Self-Regeneration mix (SafeGuard annual ryegrass, Border clover, Hykon Rose clover and Dalkeith sub-clover). All seeds were treated with the appropriate inoculant at seeding. Spray strips were applied across the seeding strips at two rates of P – recommended rate and half recommended rate, and in two formulations – liquid and granular. A control of no P treatment was kept as a baseline. Initial soil tests were taken to ensure no other nutrients were limiting. If limitations were found, all plots were treated to remove the limiting factor.

2015 - 2016

It was decided in a meeting that was held in early 2015 between the growers and researcher that were involved in the trial in 2014 that the trial needed to be simplified. The amount of multiple repetitions was reduced while increasing the repetitions for the remaining treatments. This meant omitting the liquid phosphorous (P) plots and using only granular P.

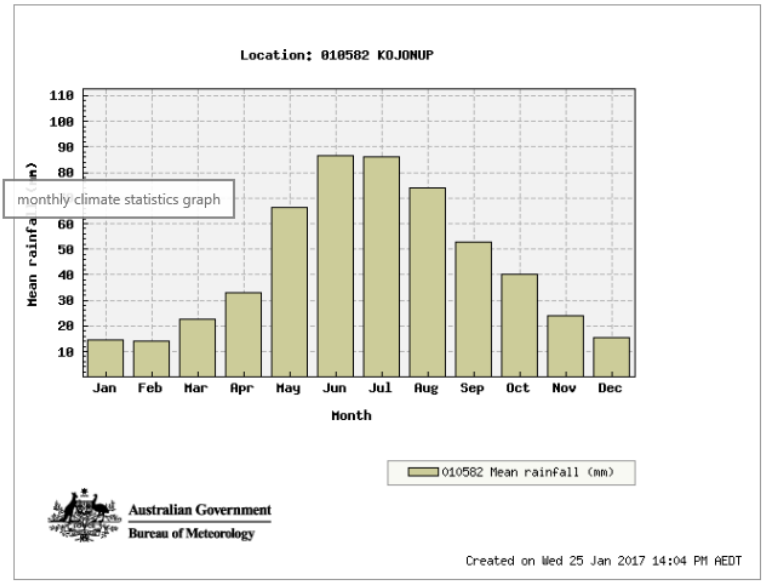
Six granular P treatments (0, 5, 10, 20, 40, 60kg's per ha), applied at sowing, over three pasture varieties (Santorini yellow Serradella, Margurita French Serradella, and Dalkeith sub-clover). Each of the P treatments were replicated twice within the trial. All seed were treated with the appropriate inoculant at seeding. Initial soil tests were taken to ensure no other nutrients were limiting. If limitations were found, all plots were treated to remove the limiting factor and to control weeds within the trial. Data that was collected through the growing seasons were biomass samples and they were collected and weighed in August. September nodule scoring was completed and analysis of P uptake in the plant tissue in October.

3.1 Research sites

Trial site Host – John Tuckett (project host) and Rob Johnson (land owner)
Trial site location: Yonka Farm – Cranbrook (Boundary Paddock)
Trial Site and Plot Sizes: There was a single trial site with 36 x 13m x 11m plots
Latitude and Longitude of the site: -34.180844, 117.434206

Average rainfall:

Table 1 shows the mean monthly rainfall data for the trial site



Predominant soil type(s) at the site: Sandy duplex gravel, low pH, and low colwell p (mg/kg – 7mg/kg)
Site description and topography: Boundary Paddock has a slight slope running east to west.
Site history: Pasture

3.2 Treatments

2014

Table 1 shows the pasture varieties and treatments used at the site in 2014.

Pasture Variety	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5
Pasture mix	Nil	Liquid P 10 kg/ha	Granular P 10 kg/ha	Liquid P 25 kg/ha	Granular P 25 kg/ha
Serradella Margurita	Nil	Liquid P 10 kg/ha	Granular P 10 kg/ha	Liquid P 25 kg/ha	Granular P 25 kg/ha
Subclover	Nil	Liquid P 10 kg/ha	Granular P 10 kg/ha	Liquid P 25 kg/ha	Granular P 25 kg/ha

2015 – 2016

Table 2 shows the pasture varieties and treatments used in both 2015 and 2016.

Pasture Variety	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5	Treatment 6
Yellow Serradella	Nil	5 kg/ha	10 kg/ha	20 kg/ha	40kg/ha	60 kg/ha
Margurita Serradella	Nil	5 kg/ha	10 kg/ha	20 kg/ha	40kg/ha	60 kg/ha
Dalkeith Subclover	Nil	5 kg/ha	10 kg/ha	20 kg/ha	40kg/ha	60 kg/ha

3.3 Monitoring

Over the duration of the project a number of in field assessments were conducted and analysed for results.

Soil samples were collected from each of the plots to investigate whether the P levels in the soil were increasing or decreasing. The tests were taken to also identify if there was a difference between the plots of the different pasture varieties.

Pasture cuts were collected to identify if there was a difference in production levels between varieties. Pasture cuts were collected at two different stages throughout the growing season for assessment.

Composition assessments were conducted to identify which varieties were performing at a higher level of production. These assessments were taken twice during the season at the time of the pasture cuts.

Plant tissue testing was carried out with samples collected from each plot, which were dried, weighed and a representative sample send to UWA to be analysed for phosphorous in the plant tissues and a bulked sample from each phosphorous treatment were sent for ICP analysis.

Nodule scores were conducted to identify if the plant species were successfully producing nodules. This assessment was carried out once in each growing season.

Normalized Difference Vegetation Index (NDVI) assessments were collected in the first year of the trial, to identify if there was a difference in the overall health and vigour between the different varieties in response to the P treatments.

3.4 Statistical analysis

The statistics for the projects were run using Sigma Plot and Microsoft Excel.

3.5 Extension and communication

The results and outcomes of the project were extended to Southern Dirt members through quarterly newsletters, social media, email updates, annual trials booklet and in field day booklets. Summaries of the project were sent out in the newsletters, whereas the trial results and reports were published in the Annual trials booklet. Field walks were also held at the site in 2014 at the Southern Dirt spring field day and at a field walk in 2015.

4 Results

4.1 2014 Trial results

The composition data shows a poor performance of the treatment species; this is likely a reflection of either poor establishment or reduced growth due to competition and lack of P Fig.1.

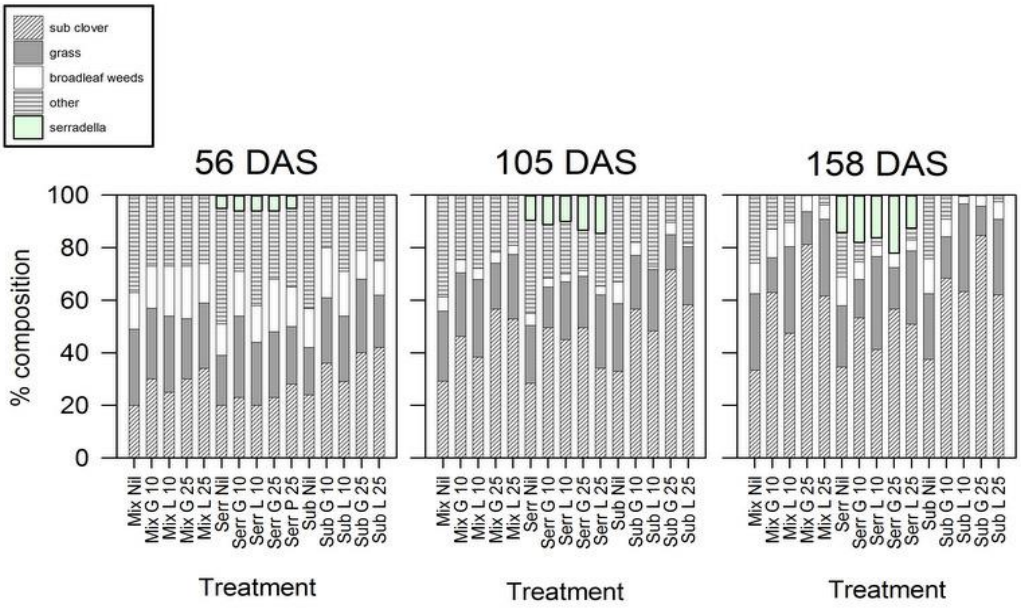


Figure 1 Percentage composition of sown and volunteer species at 56, 105 and 158 days after sowing (DAS). Serradella composition is highlighted. Treatment abbreviations describe: species (pasture mix (Mix), serradella (Serr), subclover (Sub)); P application type (granular (G), Liquid (L)); and, application rate (Nil (Nil), 10 kg/ha (10), 25 kg/ha (25)).

The amount of early feed in the season was low and at 56 days after seeding (DAS) was at about 400kg/ha. The spring peak production can be seen in the final experimental assessment 158 DAS Fig.2.

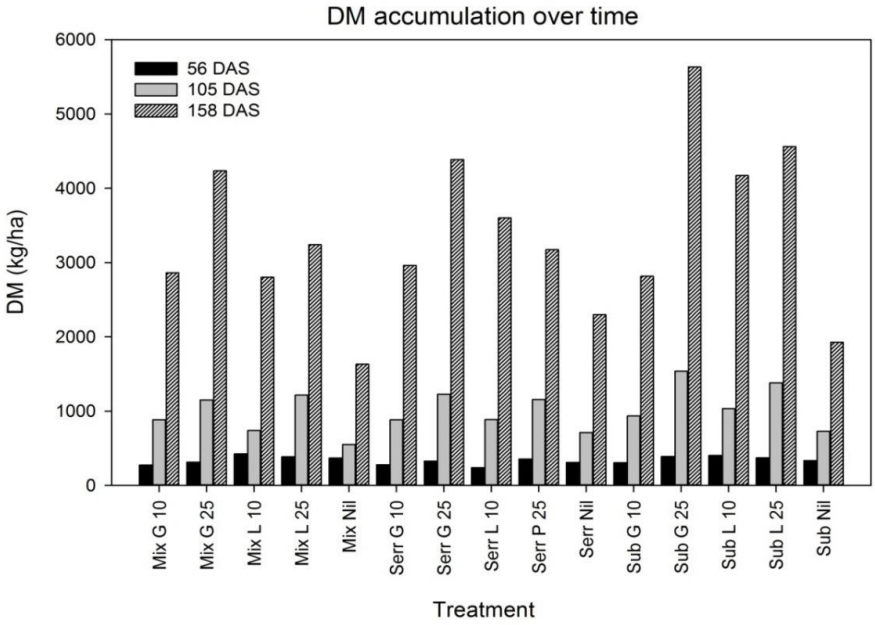


Figure 2 Variation in dry matter (DM) production. Treatment abbreviations describe: species (pasture mix (Mix), serradella (Serr), subclover (Sub)); P application type (granular (G), Liquid (L)); and, application rate (Nil (Nil), 10 kg/ha (10), 25 kg/ha (25)).

Dry matter estimates from the first assessment at 56 DAS show little significant variation among variety treatments. Fig. 3 shows that at 56 DAS, some treatments had less production than the plots with no applied P. At 105 DAS, all treatments had more dry matter than the nil plots, with the high rates (25 kg/ha) displaying the highest dry matter. At the final sampling time 158 DAS, the subclover treatments generally had the highest dry matter, followed by the pasture mix and the serradella. We should reiterate that these figures do not necessarily mean that serradella had the poorest growth as it only represented approximately 20% of the biomass.

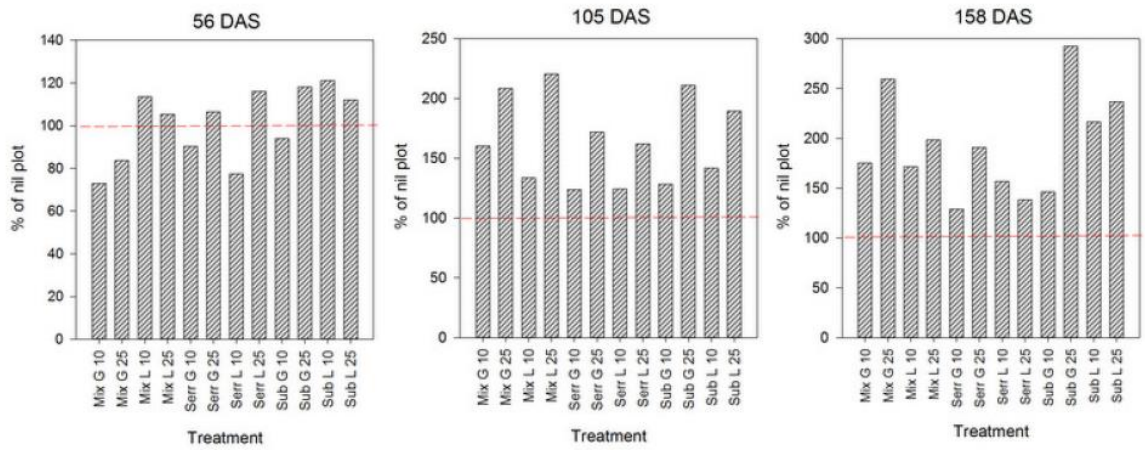


Figure 3 Dry matter production of each treatment at the three sample times represented as a percentage of the nil plot. The nil plots are represented by the dotted red line. Treatment abbreviations describe: species (pasture mix (Mix), serradella (Serr), subclover (Sub)); P application type (granular (G), Liquid (L)); and, application rate (Nil (Nil), 10 kg/ha (10), 25 kg/ha (25)).

At low rates of applied P (10 kg/ha) all varieties achieved similar levels of dry matter production. Subclover plots tended to have the best production at the higher rate (25 kg/ha) and while this might suggest that an alternative legume cannot compete production wise, the limitations due to establishment and species composition cannot be overlooked.

In 2014 project analysis was carried out to identify what form of P, liquid or granular, is a more effective treatment. The results showed that it was necessary to treat results relating to the type of P application with caution. Differences in the accompanying nutrients were likely to impact growth and to some degree these differences can be identified in the following graphs Fig.4

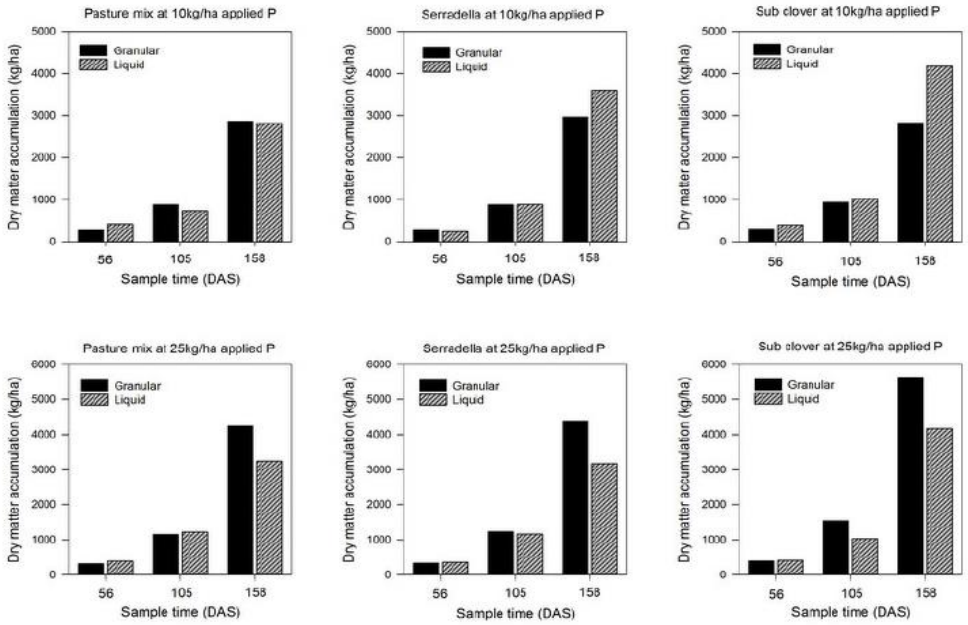


Figure 4: Dry matter accumulation in response to P application type across treatments.

At 56 to 105 DAS, there is little discernible difference between dry matter productions for the two methods of P application. At the low rate (10kg/ha liquid application resulted in higher DM in the serredella and most noticeably in the subclover plots. The differences however, do not relate to an increase or decrease of the sown species, rather the liquid P application resulted in an increase in grass dry matter production Fig. 5. This increase is likely to be related to the ammonium accompanying the liquid polyphosphate.

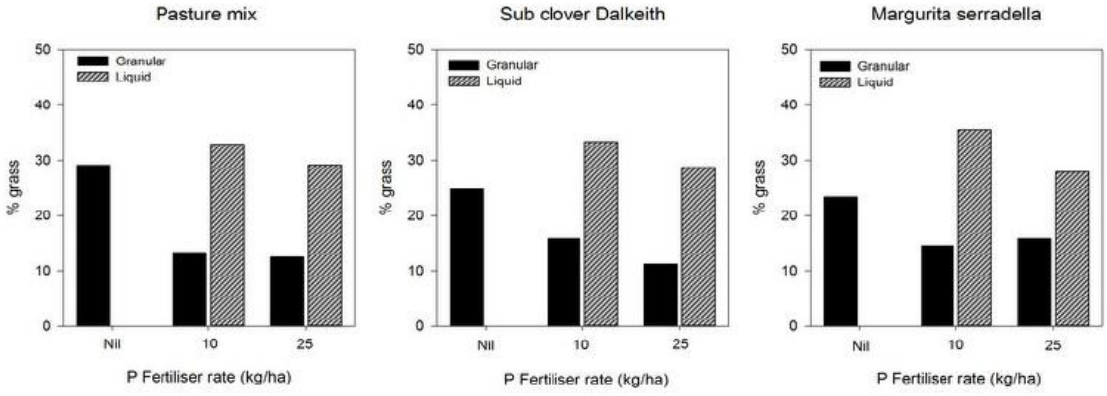


Figure 5 Percentage of grass in dry matter cuts related to P application type.

At the high rate of P (25 kg/ha), granular application resulted in higher DM production across all species treatments. In contrast to the low P rate, this corresponded to the highest percentage composition values for clover Fig. 6.

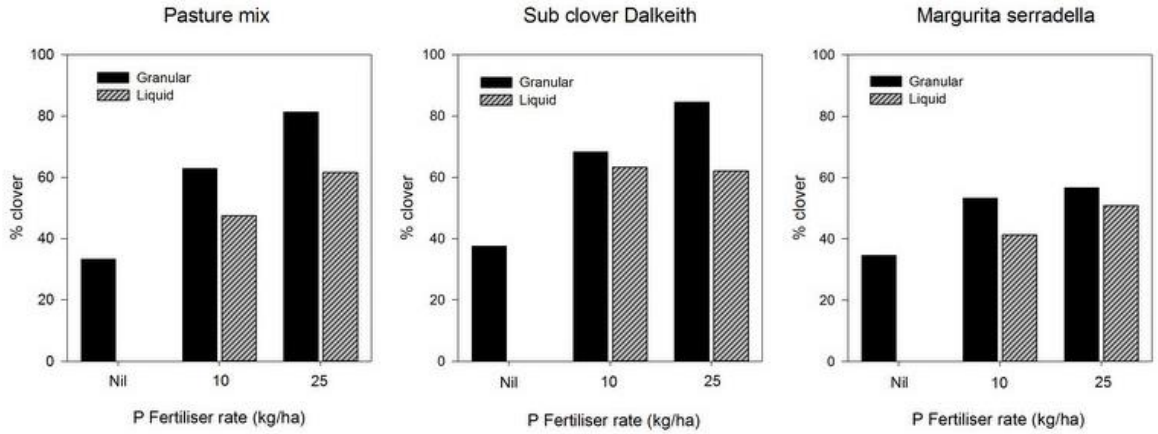


Figure 6 Percentage of clover (105 DAS) in dry matter cuts related to P application type.

Another of the projects aims was to identify what responses we would get from each variety with a sub-optimal dose of P. The results showed at the low rate of P application (10 kg/ha) there was no significant differences evident in dry matter production at any sampling time Fig. 7. The only differences occurred in the serradella and subclover liquid P plots which is likely a result of increased grass DM production rather than an effect on the sown species.

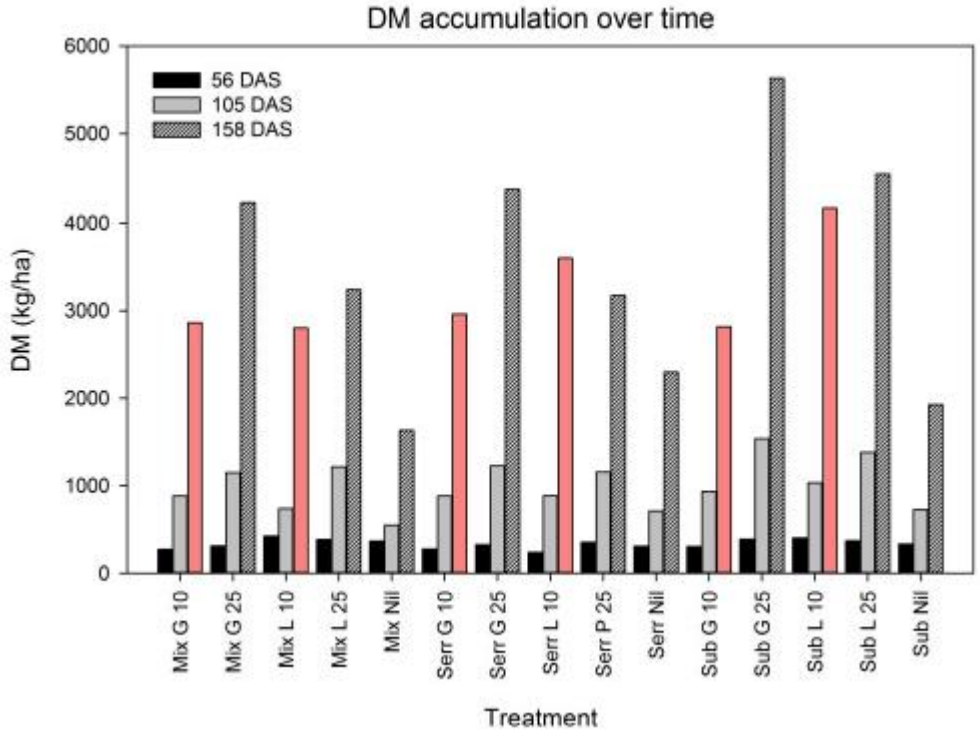


Figure 7: Dry matter (DM) accumulation over time - 10 kg/ha applied P treatments highlighted. Treatment abbreviations describe: species (pasture mix (Mix), serradella (Serr), subclover (Sub)); P application type (granular (G), Liquid (L)); and, application rate (Nil (Nil), 10 kg/ha (10), 25 kg/ha (25)).

Plant tissue analysis of sown species

Analysis of the plant tissues indicates that most plants were P deficient. Subclover is generally considered P deficient at tissue P concentrations below 0.2%; Fig. 8 shows that subclover was in this range.

As expected, calcium concentrations were higher in plants that received granular fertiliser, as this accompanied the P treatment along with sulphur. However, the granular application did not result in elevated levels of sulphur. The only other nutrient values that tend to stand out are the increased concentrations of zinc and boron, and the reduction in copper and manganese, in the serradella plots.

Based on values for subclover no other nutrients appear to be deficient.

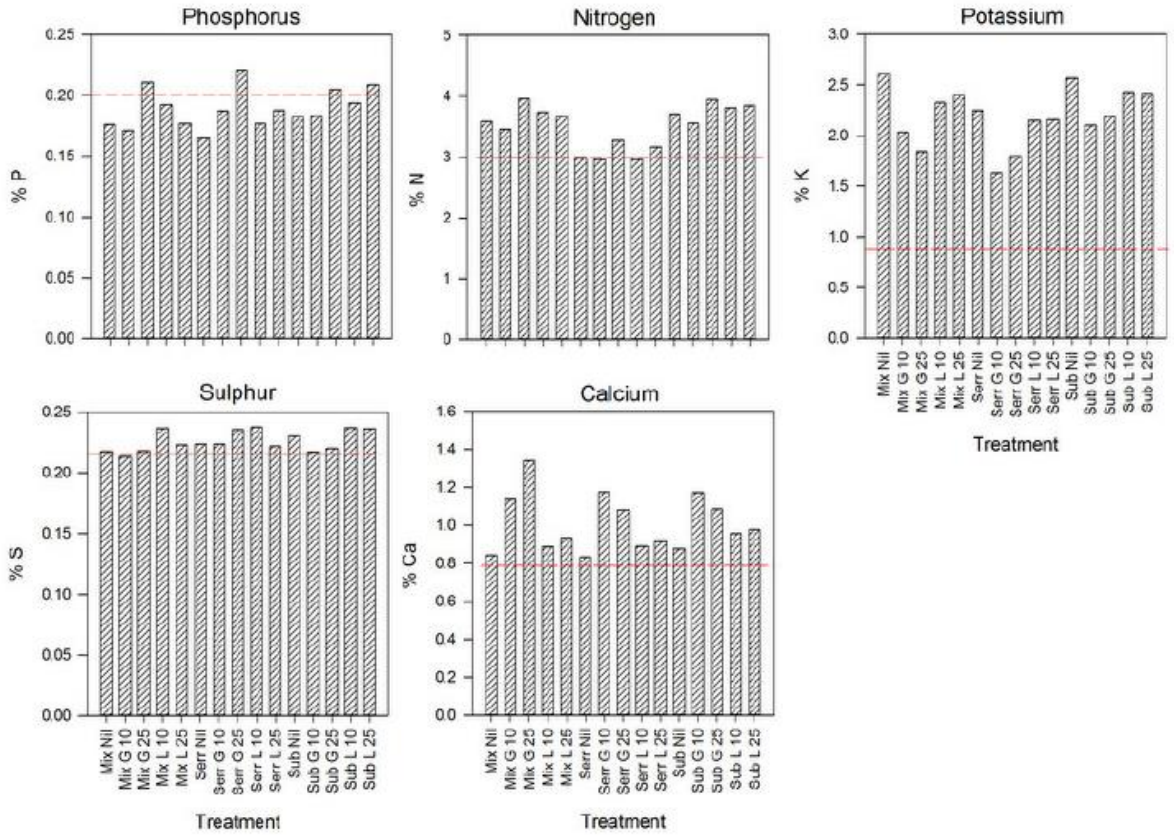


Figure 8 Tissue analyses of the macro elements including phosphorus. Values below the line indicate deficiency. Treatment abbreviations describe: species (pasture mix (Mix), serradella (Serr), subclover (Sub)); P application type (granular (G), Liquid (L)); and, application rate (Nil (Nil), 10 kg/ha (10), 25 kg/ha (25)).

Nodule Scoring and Analysis

Data for nodulation of subclover and serradella were provided by John Howieson at Murdoch University. Significant increases in nodulation occurred in the 25 kg/ha treatments Fig. 9.

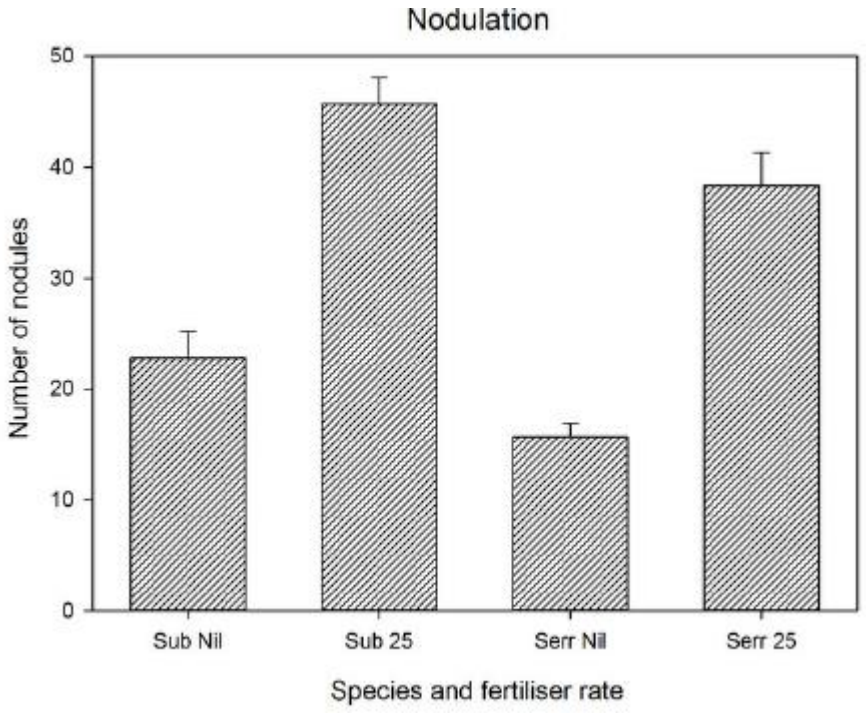


Figure 9 Nodulation assessments for subclover and serradella in 2014 trial

4.2 2015 Trial results

As mention some amendments were made to the trial in 2015. The treatments were simplified by removing the Liquid P treatment; therefore the objectives were slightly changed.

During the Field day in October, 2015 root nodules from plants at a range of P levels were examined and found to increase in proportion to dry matter of the plants. The serradella varieties nodules were still pink and healthy, whereas the Dalkeith sub clover nodules were whitish and anaemic.

The results show in all three varieties P had little or no effect up to 10kg/ha applied, then growth increased steadily with greater applications, with the exception of Margurita French Serradella, which showed a decline in growth after 40kg/ha. A visual inspection of the plots confirmed that the trend of the dry matter results looks correct, including the Margurita French Serradella at 60kg/ha P, although other, external, factors may have come into effect.

A small number of sheep got into the trial area and grazed some of the plots early in the growing season, before the first pasture cuts. A visual inspection concluded that the sheep had favoured the plots with the larger plants, which correlated with the higher P applications. Although the general trend of the results is accurate, we believe the differences would have been more extreme had the sheep not go in Fig. 10.

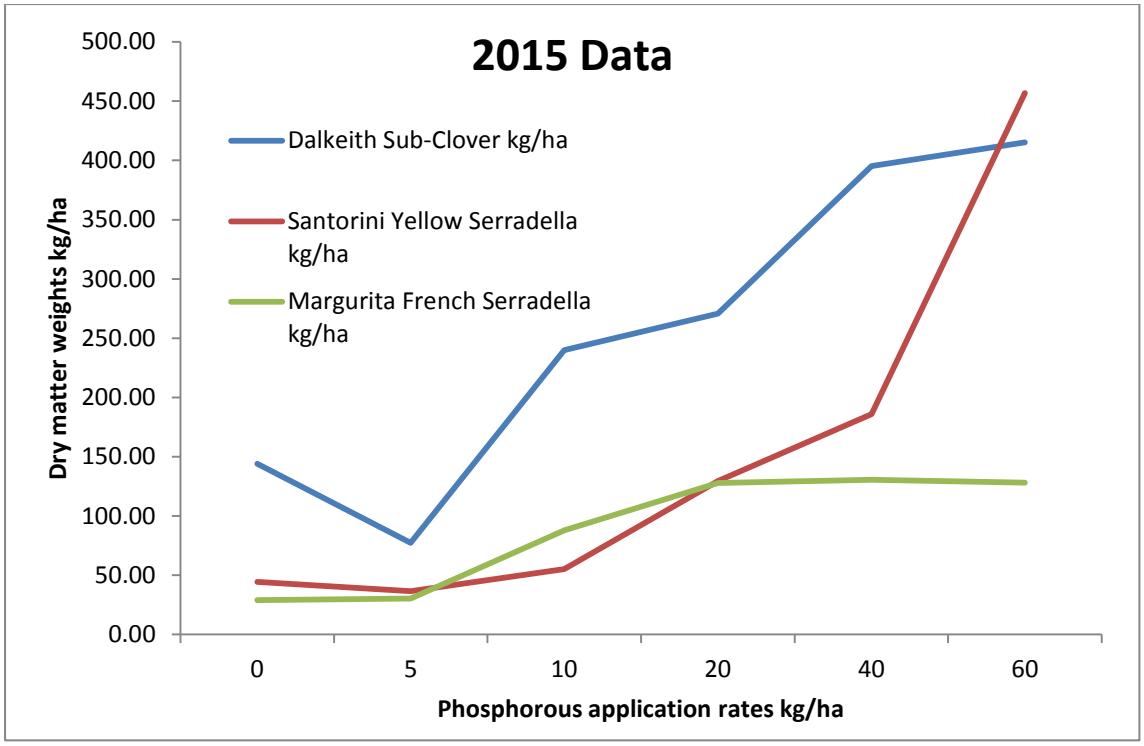


Figure 10 shows the results of the first pasture cuts. The trial was affected by a temporary sheep break-in, although a visual inspection backs up the trend of these results. The sheep favoured the larger plants with higher levels of P.

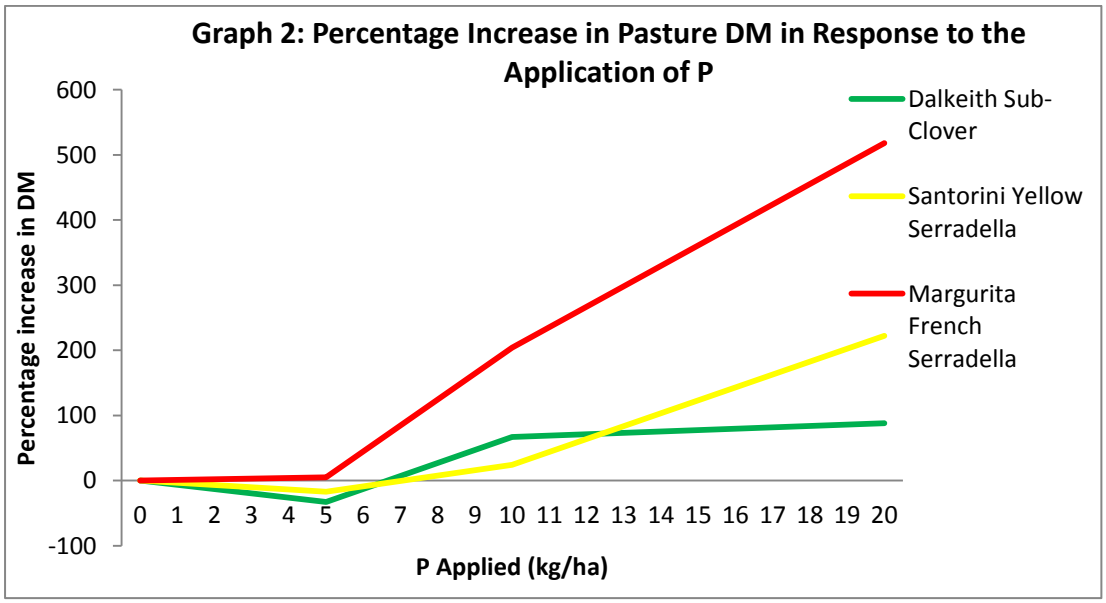


Figure 11 shows percentage increase in growth at lower levels of P applied. It appears that at least 10kg/ha of P is required to have any effect. Although Dalkeith Sub-clover showed the highest dry matter at all levels, it did not respond as much as Serradella, to the addition of P.

4.3 2016 Trial results

At the start of the 2016 season soil samples were collected from each plot and sent away for comprehensive analysis. The soil test results showed that the P applications for the 2015 season failed to increase the levels of P in the soil. pH, Potassium, copper, manganese was found to be deficient at the trial site while aluminium and sodium was found to be high. 2 tons of lime was

applied to the site by the farmer in April 2016 to ameliorate the aluminium toxicity and high sodium levels and to increase the soil pH.

The trial in 2016 grew very slowly due to the cold and wet weather during the growing season. In July/August the site was due to have pasture cuts collected however due to the size of the plants it was decided by Southern Dirt and Daniel Kidd from UWA to wait until the plant has grown. On assessment of weeds each of the plots had high weed competition even though it had a pre sowing knock down.

Pasture cuts were collected 152 days after seeding (DAS) the results showed that the Santorini Serredella and Margurita Serredella, increased biomass in the higher phosphorus applications. The Dalkeith subclover however, showed that it remained relatively the same throughout the trial Fig.12.

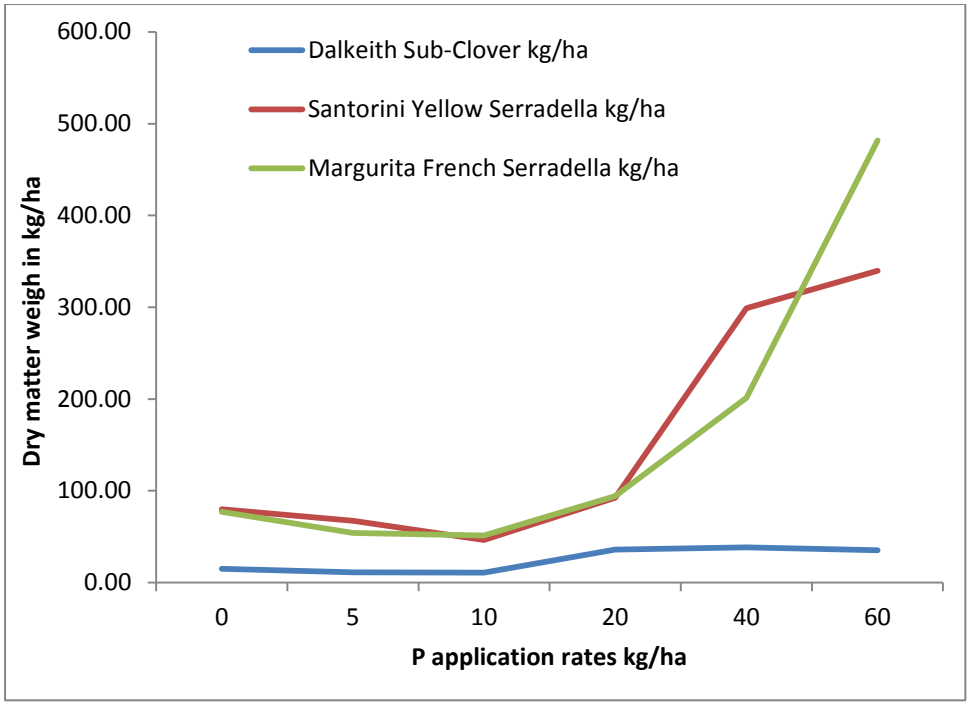


Figure 12 shows the dry matter production of each treatment of phosphorous.

A sample from each P treatment was sent to Daniel Kidd at UWA for plant tissue testing. The plant tissues were analysed for phosphorous. The results for the plant tissues test for phosphorous showed that the phosphorous levels were adequate for both of the Serradella varieties (2500 – 3000mg/kg). The Dalkeith sub-clover showed that there were inadequate levels of phosphorous where there should be 3000 – 4000mg/kg Fig. 13.

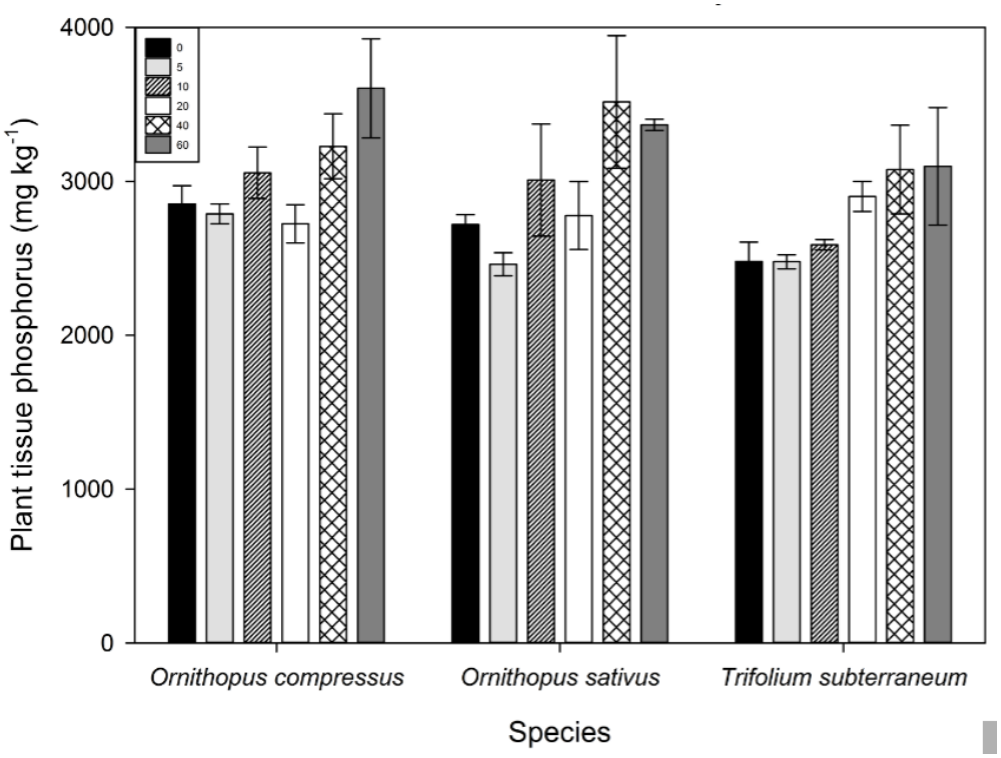


Figure 13 shows the plant tissue phosphorous (mg/kg) in each of the treatments and pasture species*. Ornithopus compressus* is the scientific name for Santorini Yellow Serredella, *Ornithopus sativus* is Margurita French Serredella, and *Trifolium subterraneum* is Dalkeith Sub-clover.

Root nodules assessments were collected from plants at a range of P levels. As in the 2015 trial the root nodules were found to increase in proportion to dry matter of the plants. The serradella varieties nodules were still pink and healthy looking, whereas the Dalkeith subclover nodules were starting to look whitish and anaemic. Please refer to the metadata spreadsheet for raw data from 2014 – 2016 from the trial.

Soil Test Results

The soil results show that the 2016 P applications had increased the Colwell P compared to the 2015 Colwell P results. The application of significant quantities of double phosphorous in 2015 failed to lift the colwell much past 10mg/kg Fig.14. In 2017 the amount of applied P in the higher application treatments (20kg/ha – 60kg/ha) have showed an increase in the Colwell P values. The Colwell P vales have be increased from deficient (<10mg/kg) to marginal/adequate (10 – 40mg/kg). The low P application treatments still showed P deficiencies in the soil Fig.14. The liming had an impact on the soil pH and aluminium, as both have increased to normal level after the first year of application.

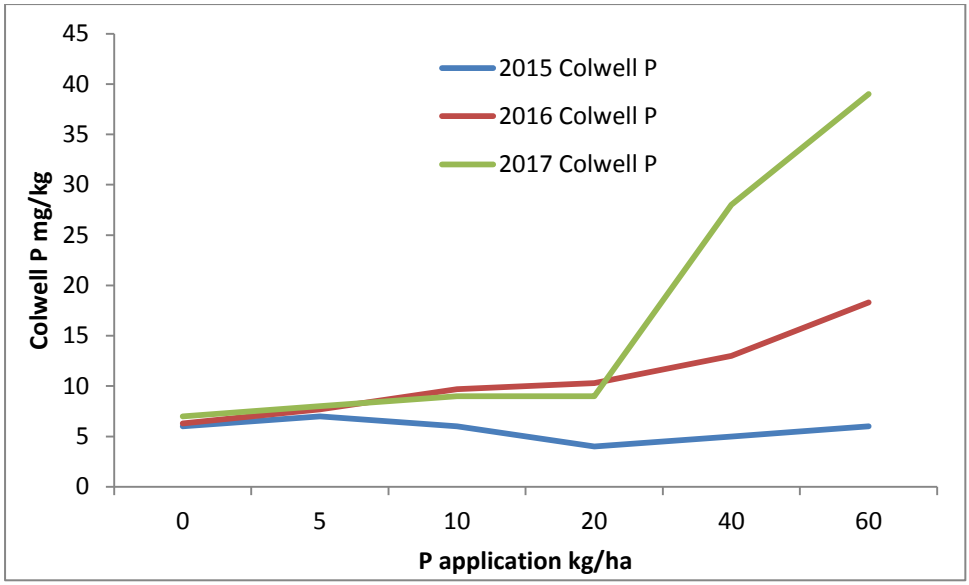


Figure 14 colwell p results comparing to the 2015, 2016, and 2017 colwell p results against the phosphorous applications in kg/ha

4.4 Extension and communication

The following list of extension and communication activities were completed as per our contract with MLA.

Date	Activity	Number of people
April 2014	Write newsletter article & circulate	Project Officer Report including a brief Project Update written for the Southern DIRT Autumn Newsletter which was distributed to at least 100 people on the mailing list
May 2014	Write email update & circulate	Update on Project Progress and achievement of operational tasks, include invite to visit site during assessment
June 2014	Write email update & circulate	Update on Project Progress and achievement of operational tasks, include invite to visit site during assessment
August 2014	Write email update & circulate	Update on Project Progress and achievement of operational tasks, include invite to visit site during assessment
13/08/14	Collate initial data, prepare presentation and attend event	Up to 30 attendees including Project managers, host farmers, researchers and advisors
August 2014	Write newsletter article & circulate	Project Officer Report including a brief Project Update written for the Southern DIRT Winter Newsletter which will be

		distributed to at least 100 people on the mailing list
September 2014	Write email update & circulate	Update on Project Progress and achievement of operational tasks, include invite to visit site during assessment
September 2014	Write newsletter article for submission & circulate at the Spring Field Day event and through the Southern DIRT Office	Project Officer Report including a project overview of objectives, methods and current results and observations. To be distributed to at least 100 people including Southern DIRT members, affiliates, researchers and industry
October 2014	Write email update & circulate	Final update on Project Progress and achievement of operational tasks for the 2014 season
October 2014	Write newsletter article & circulate	Project Officer Report including a brief Project Update written for the Southern DIRT Spring Newsletter which will be distributed to at least 100 people on the mailing list
October 2014	Write website article & update	A brief project overview of objectives, methods and current results and observations which will be available to Southern DIRT members, affiliates and interested public.
June 2015	Write email update & circulate	Update on Project Progress and achievement of operational tasks, include invite to visit site during assessment
August 2015	Write email update & circulate	Update on Project Progress and achievement of operational tasks, include invite to visit site during assessment
13/08/15	Collate initial data, prepare presentation and attend event	
August 2015	Write newsletter article & circulate	Project Officer Report including a brief Project Update written for the Southern DIRT Autumn Newsletter which was distributed to at least 100 people on the mailing list
August/ September 2015	Field Day- Site visit and training session on evaluating nodulation	At least 8 people attended,. The results were presented and Brad Nutt from the Centre of Rhizobia Research, Murdoch University, demonstrated how to test for healthy nodules. Inoculants were

		also discussed with Neil Ballard and Floyd Sullivan from Alosca Technologies
September 2015	Write newsletter article for submission & circulate at the Spring Field Day event and through the Southern DIRT Office	Project Officer Report including a project overview of objectives, methods and current results and observations. To be distributed to at least 100 people including Southern DIRT members, affiliates, researchers and industry
October 2015	Write newsletter article & circulate	Project Officer Report including a brief Project Update written for the Southern DIRT Autumn Newsletter which was distributed to at least 100 people on the mailing list
October 2015	Write newsletter article & circulate	A brief project overview of objectives, methods and current results and observations which will be available to Southern DIRT members, affiliates and interested public.
December 2015	Write newsletter article & circulate	Project Officer Report including a brief Project Update written for the Southern DIRT Spring Newsletter which was distributed to at least 100 people on the mailing list
February 2016	Write newsletter article & circulate	Project Officer Report including a brief Project Update written for the Southern DIRT Summer Newsletter which was distributed to at least 100 people on the mailing list
May 2016	Write newsletter article & circulate	Project Officer Report including a brief Project Update written for the Southern DIRT Autumn Newsletter which was distributed to at least 100 people on the mailing list
May 2016	Write reports and publish in 2015 Annual Trials Booklet	Project Officer Report including a project overview of objectives, methods and current results and observations. To be distributed to at least 100 people including Southern DIRT members, affiliates, researchers and industry
August 2016	Write newsletter article &	Project Officer Report including a

	circulate	brief Project Update written for the Southern DIRT Winter Newsletter which was distributed to at least 100 people on the mailing list
August/ September 2016	Field Day- Site visit and training session on evaluating nodulation	Could not be completed due to conditions at the site. The rainfall made the path to the trial site inaccessible.
September 2016	Write newsletter article for submission & circulate at the Spring Field Day event and through the Southern DIRT Office	Project Officer Report including a project overview of objectives, methods and current results and observations. To be distributed to at least 100 people including Southern DIRT members, affiliates, researchers and industry
December 2016	Write newsletter article & circulate	Project Officer Report including a brief Project Update written for the Southern DIRT Winter Newsletter which was distributed to at least 100 people on the mailing list
April 2017	Write reports and publish in 2016 Annual Trials Booklet	Report completed, trials booklet to be published May 2017

4.5 Participant reactions

At the beginning of the project the producer group participants identified that they wanted to look at how they could improve phosphorous use efficiency through increased understanding of soil benchmarks and critical soil test values. They also wanted to identify alternative legumes that have lower phosphorous requirements.

There has been an increased understanding of soil benchmarks and soil test values. The initial search for a low P paddock proved very valuable to many farmers as they have come to the realisation that P was not limiting in their paddocks.

Due to seasonal stresses and weed competition the producer group participants have discovered and learnt that to grow an effective and efficient pasture the pastures need to be treated like a crop. Farmers need to make sure if weeds are a problem a double knockdown is necessary to avoid heavy weed burdens which create competition for the pasture species.

There has been more serradella pastures grown in the Kojonup region in the past three years. Often farmers plant serradella on sandy soils where crops are performing poorly.

Brad Nutt from the Centre of Rhizobia Research, Murdoch University demonstrated how to test for healthy nodules to a group of producers at a field day. They were able to take this information away and to use this method on their own pastures to check for nodulation.

Producers also learnt about inoculants and why they are used at the field day with Neil Ballard and Floyd Sullivan from Alosca Technologies. They explained the symbiotic relationship between legumes and bacteria, where the plant gains N from the bacteria and feeds the bacteria carbohydrates in return.
'Useful bacteria,' as cultivated for inoculants, breeds with less favourable bacteria already present in the soil, reducing the efficiency of fixation over time, making inoculation every 4-5 years worthwhile, particularly as it can often negate the requirement to re-seed. They also drew attention to the fact that many herbicides strip root hairs on legumes, preventing them from wrapping around microbes and fixing N and some fungicides and insecticides kill bacteria in the soil, making re-inoculation necessary.

4.6 Producer research site program

Initially the producer group wanted to evaluate the plant health and biomass of alternative legume species and sub-clover when phosphorous was applied in either liquid or granular form. At the end of 2014 it was discussed that the evaluation of P application type (granular and liquid) added a complicating factor to the experiment. The comparisons between the two applications were made difficult by the differences in accompanying nutrients. The researchers recommended discontinuing with the objective and evaluation unless there was sufficient interest and support to do so.

In 2015 it was decided by the group after discussion with MLA, to remove that objective from the project to simplify it. It was necessary then to move the trial site on to pasture alongside the 2014 trial. The treatments were changed to having six granular P treatments (0, 5, 10, 20, 40, 60kg's per ha), applied at sowing, over three pasture varieties (Santorini yellow Serradella, Margurita French Serradella, and Dalkeith sub-clover). Each of the P treatments were replicated twice within the trial.

In the 2016 annual meeting, the soil test results were discussed. The results showed that aluminium levels were high and that aluminium toxicity was likely to be an issue. The group decided two ton of lime would be applied by the host grower John Tuckett to help alleviate complications that could occur from aluminium toxicity during the growing season.

5 Discussion

To compare alternative legume species with potentially lower critical P values with the standard sub-clover currently grown in the Kojonup area.

The result for the 2014 trial showed that due to poor establishment it was difficult to establish whether an alternative crop to sub-clover that produces more feed with the same or less amounts of P, is viable.

There were some problems identifying and sorting the sown pastures mix with clovers that had germinated and persisted at the site. This is likely to be why the results show a higher percentage of sub clovers compared to the other species within the plots.

At low rates of applied P (10kg/ha) all species treatments achieved similar levels of dry matter production. Sub-clover plots tended to have the best production at the higher rate (25kg/ha) and while this may suggest that an alternative legume cannot compete production wise, the limitations due to establishment and species composition cannot be overlooked. A pure sward of each sown species would need to be successfully established to achieve a result for this objective. This could be achieved with tighter weed control.

In 2015 initially the serradella varieties and sub clovers grew well, with very little weed competition. The results however have been affected by other influences, which included an early finish and low soil pH. Daniel Kidd from UWA stated that low pH causes Aluminium toxicity. Toxic levels of aluminium in the soil solution affect root cell division and the ability of the root to elongate. The root tips are deformed and brittle and root growth and branching is reduced. Poor crop and pasture growth, crop yield reduction and smaller grain size occur as a result of inadequate water and nutrition. The effects of aluminium toxicity are most noticeable in seasons with a dry finish which occurred in 2015. Roots are unable to effectively grow through acidic subsurface soil, which forms a barrier and restricts access to stored subsoil water for grain filling. Liming soil to increase the soil pH is effective in reducing the availability of aluminium to non-toxic levels which we applied 2 t/ha in 2016 to alleviate this issue.

Brad Nutt from the Centre of Rhizobia Research, Murdoch University demonstrated how to test for healthy nodules. He explained that the nodules should be pink with leghaemoglobin, which is an oxygen and nitrogen carrier similar to haemoglobin in blood. The serradella has an indeterminate growing season, so the root nodules that we looked at were still pink and healthy, whereas sub-clover's growing season is limited to 110 days and was starting to die off, with white (anaemic) or green (shutting down) nodules. Serradella also has a more stable nodule system.

In 2016 the plant establishment was again poor due to the cold wet season. Relative growth rates for pastures are often slow early in the growing season due to cold, wet conditions and peak in spring when the conditions are warmer and moisture is still adequate. The 2016 growing season however, had below average temperatures and above average rainfall from April – October 2016 (see Appendix 1). All pasture varieties grew very slowly and did not appear to change in size for a number of months. This allowed the weeds to compete for space and nutrients. The weed competition was addressed after consulting with an agronomist who advised to spray 1l/ha of Ecopar, which should have killed the broadleaf weeds and have an effect on some grasses with minimal effects on the pastures. A contractor was employed to spray the entire trial area, however the application had minimal effects on the weeds.

Every pasture species have an optimal fit on different soil types, rainfall, and soil nutrients. Serradella varieties grow well on sandy, more acidic soils when sub clovers struggle to get established. Sub-clover outperforms serradella species on clay soils that are moderately acidic. Therefore it would be impossible to make any comparisons that an alternative legume, in this case Yellow and Margurita serradella, with the pasture species Dalkeith clover. Growers need to select a pasture type that will perform in their area, rather than looking for low P input variety.

To investigate if a lower level of P rather than the recommended rate can still produce as much biomass from pastures.

In 2014 there was no evidence to suggest there was a difference in dry matter and low rates of P (10mg/ha). The only differences were in both the serradella and sub clover plots which were likely the result of increased grass dry matter as a response to the ammonium accompanying the liquid P. To get a true reflection of varietal responses, all plots would have to be dominated by the sown species and unfortunately, serradella plots especially were instead dominated by background clovers, grasses and broadleaf weeds. Due to the complication and complexity of comparing the liquid P and granular P in was decided by the researcher and producer group to omit this from the trial in the following years as per the variation in the MLA contract.

The 2015 trial results showed that when there was no difference between the varieties in the low P applications up to 10kg/ha. The biomass then increased with each subsequent then growth increased steadily with greater applications, with the exception of Margurita French Serradella, which showed a decline in growth after 40kg/ha.

Researcher Daniel Kidd from the University of Western Australia explained at a field day, that under lab conditions, he would expect the growth of the sub-clovers to peak at 30 units/ha and the serradella to peak at 20 units/ha. The plants at the trial site were smaller than he expected and continued to increase dry matter gain beyond the expected levels of P. This suggested there were limiting factors stunted the plant growth possibly due to water stress. Chemical analysis confirmed the yellow serradella and sub-clover did not respond to the applied P until the 40mg and 60mg kg-1 treatments which equates to 225kg and 340kg ha-1 of Double P. The French Serradella responded at the earlier treatments but there wasn't a consistent increase. Further chemical analysis found that aluminium toxicity was a problem, although the serradella are known to have good aluminium tolerance. Calcium, sodium, and phosphorus were found to be deficient in all species and the sub-clover was all deficient in manganese, molybdenum, sulphur, and zinc.

The results from 2015 were influenced by other factors therefore it cannot be stated that lower levels of P can produce as much biomass from pastures. The host farmer John Tuckett also reported 230mm of rain on this farm during the 2015 growing season. This is compared to the average rainfall of 380mm, suggesting that water stress, in the spring period in particular, was likely in 2015.

In 2016 the results showed that there were adequate levels of P in both of the serradella species which is between 2500mg/kg – 3000mg/kg in all treatments. The sub clover levels were inadequate <3000mg/kg in the treatments 0 – 20kg/ha and the 40 – 60kg/ha were in the minimum range of 3000mg. The serradella varieties responded to the higher rates of applied P 20kg/ha – 60kg/ha but remained relatively the same in the lower P application treatments. The sub clover did not seem to respond in any of the applied P treatments.

Daniel Kidd from UWA explained that this is likely due to the serradella having longer root hairs compared to sub clover. This allows the serradella plants to explore phosphorous better over a deeper and wider area. He also explained that sub clovers do require high P inputs compared the serradella which requires 30% less p than sub clovers.

Limiting nutrient factors, weed control and seasonal stressors seemed to plague the trial over the three years. This has made it difficult to address the projects objectives fully and with any type of certainty.

To evaluate the plant health and biomass of alternative legume species and sub-clover when P is applied in either a liquid or granular form.

2014 was the only year these treatments were compared. The P levels were properly adjusted through the application rate to be similar for both fertiliser types, the liquid fertiliser also contained ammonium and the granular fertiliser also contained sulphur (S) and calcium (Ca). The readily available nitrogen in the liquid fertiliser would tend to favour the growth of grasses, and the S and Ca in the fertiliser would favour the legumes. A NKS blend was applied to the whole site, together with a muriate of potash, to address the other nutrient limitations and to ensure P was the only limiting factor to plant growth. However, the differences in the nutrient composition still needed to be taken into consideration when interpreting results.

Liquid P application tends to deliver P in a form that is more readily available to the plant. Based on this expectation the liquid p plots showed a slight increased initial growth response than the granular plots.

Other trial Outcomes

Soil Results

The site was sown to subterranean clover, yellow and French serradella in 2015. To test the response of each species to phosphorus (P) 6 fertiliser rates were applied, replicated three times. These rates were nil, 5, 10, 20, 40 and 60 kg/ha applied P. Phosphorus was applied as CSBP Double Phos at rates of 0, 30, 60, 110, 240 and 340 kg/ha in attempt to reach these desired Colwell P soil test values. Initial results revealed a Colwell P of 5.6 mg/kg (range 4-7) and pH sat just under 5. Phosphorus buffering index (PBI) ranged from 17-143 with an average of 89 across the trial area. Other nutrient limitations were addressed prior to sowing.

Soil sampling was again carried out over the summer period to track the effects of the fertiliser applications. The lower rates of application were OK in that we managed to achieve the soil test values we were looking for. However, the higher rates of application failed to deliver the desired results. With the afore mentioned application rates the following soil test Colwell P values were achieved (Note the desired value in brackets); 6.3 (Nil), 7.6 (5), 9.6 (10), 10.3 (20), 13 (40) and 18 (60). Pasture yield was poor so these levels were not impacted by plant uptake. The 2015 season was particularly dry (almost 200mm below average) with a very dry start (approximately 70mm for May and June) and an early finish due to the lack of October rainfall. Due to the low early rainfall any fertiliser loss due to runoff seemed unlikely.

The PBI at the site was generally low with a value less than 50 indicating a soil has an inability to retain nutrients and they may leach into the subsoil. Phosphorus is one of the most immobile nutrients but some leaching may have occurred. This low PBI also means P was unlikely to form significant bonds with other elements such as iron or aluminium (Al). Aluminium and pH were considered possible issues at the site, however, a pH of 5 is adequate for the growth of subclover and serradella and the aluminium (CaCl2) was generally below 1 which again is OK for the growth of these species. Despite this, the cation exchange capacity (CEC) for aluminium and sodium were well in excess of acceptable limits.

2016 was another difficult year climate wise. In contrast, it was an above average year for rainfall and almost 400mm fell in the growing season. The trial was sown late and the conditions were very cold and wet and not ideal for pasture establishment. Serradella especially, does not tolerate waterlogging and struggled with the conditions early on. Following the previous year's difficulties in achieving the desired high Colwell soil test values the P application rates were re-evaluated. The low treatments were left unamended while the higher treatments (20, 40 and 60) received 60, 140 and 280 kg/ha of Double Phos respectively. Although the Al ($CaCl_2$) was OK, as a proportion of the total cation exchange capacity (Al, Ca, K, Mg, Na) it was highly available and tissue tests indicated that this may be an issue, at least in the subclover which is less tolerant of Al. Therefore, lime was applied at 2 t/ha with a view to reducing the availability of Al and increasing the proportion of available calcium and potassium.

Overall, biomass was again very low such that plant uptake would have had very little effect on soil test values. The low P treatments remained relatively unchanged following the 2016 growing season however the required responses to the Colwell P soil test values in the higher treatments were again unsatisfactory. Despite further P inputs Colwell P remained unchanged in the 20 treatment, increased to 28 mg/kg in the 40 treatment and reached 42 mg/kg in the 60 treatment. pH increased from 5 to 5.5-6 which should have also increased P availability. Levels of available and total Al reduced significantly. Levels of available Ca, K and Mg increased as expected.

Despite P inputs of 170, 365, and 620 kg/ha Double Phos over the two growing seasons and minimal uptake by plants in the 20, 40 and 60 treatments respectively, the final Colwell P soil test values were (on average) 9, 28 and 42 mg/kg for the three highest treatments. This means that in treatment 20 there were 30 units of P applied for an increase of less than 5mg/kg Colwell P. In treatment 40 we applied 64 units of P for an increase of 22 mg/kg and in treatment 60 we applied 110 units of P to increase it by almost 37 mg/kg.

For the two highest treatments this equated to 3 units of P into the system for an increase in Colwell P of 1 mg/kg. For the 20 treatment this figure was 6 units of P.

Based on current research being performed by CSIRO, NSW DPI and UWA the expected Colwell values are approximately 30 and 22-24 for subclover and serradella respectively in a soil with PBI above 50. However, due to the unfavourable climatic conditions in the final two years of the project, differences in yield from the fertiliser treatments were unable to be examined. The soil results however, are certainly of interest, especially in the context of the new collaborative project. In an attempt to replicate fertiliser inputs in the new project these results will provide valuable insight into the P inputs required on Western Australian sandy soils. Soil sampling beyond the 10cm horizon may give some indication as to whether leaching occurs.

Other factors

Throughout the three years of the trial, it was managed by three different project officers or contractors. This is has had an impact on the analysis of data, while it is not significant it has caused some issue. Some if the ways it has impacted the data were the soil analysis, some of the years the soil samples were sent to be analysed by individual plots, while in other years the soil from each P treatment was bulk sampled and sent for analysis. It would have been ideal in the first year of the

project to have a protocol book which identifies collection methods, sample techniques and treatment of the samples collected to avoid any confusion.

5.1 Outcomes in achieving objectives

Outcomes

Project objective	Outcome
1. To compare alternative legume species with potentially lower critical P values with the standard sub-clover currently grown in the Kojonup area.	The objective itself is difficult to answer. Pasture species suit different areas, it is important for grower to select a pasture species suited to their soil type and nutrient, and rainfall zones. They can expect better results from there pasture by doing this rather than looking for a only a lower p alternative legume.
2. To evaluate the plant health and biomass of alternative legume species and sub-clover when P is applied in either a liquid or granular form.	The project design in the first year was complex and difficult to assess. On assessment this objective was not able to be met due to the additionally micronutrient that are in the liquid P. It was decided by the researchers and producer group and by MLA to simplify the trial design and re-evaluate whether the project objective was achievable. This objective was omitted in the 2015 and 2016 trials and a variation in the contract between Southern Dirt and MLA was made.
3. To investigate if a lower level of P rather than the recommended rate can still produce as much biomass from pastures.	All pasture species showed in the trial the biomass was comparable in the lower p input applications 0 – kg/ha. As a general trend serradellas and the sub clover increase in biomass in the 20kg/ha – 60kg/ha, however the yellow French serradella in 2015 and the sub clover in 2015 were the exceptions. Due to seasonal stressor, weed control, and limiting nutrient factors the outcomes of this objective cannot be answered. The soil results are an unexpected result with the colwell P values increasing slightly even in the high P application plots.

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

The value producers will get from this trial result is on how important it is to know your soil type, test for soil nutrients and then select a pasture variety that is going to have good production and nutritional value for your soil, area and livestock.

Producers should treat their pastures like they would their crops to achieve the best outcomes for their pasture. There a few key details producers can use to determine what pasture will produce the best results:

1. Soil testing: By collecting soil samples you can determine your nutrient requirements for the pasture. This is good for the environment and cost effective as producers can reduce fertiliser and other macronutrient inputs if there are sufficient values found in the soils.
2. Selecting a pasture that suits a producer's soil type. Serradella produces more biomass on sandy acidic soil whereas the sub clover would out compete serradellas on clay and more neutral soils.

There is not one pasture variety which performs better than others over different soil types. Therefore, producers are better equipped by selecting a suitable pasture for their area and soil type, rather than looking only at a low phosphorous variety.

5.3 Promotion of research results and its effectiveness

Southern Dirt's annual trials booklet and spring field day booklets were one of the successful ways of extending the information on this trial as this was emailed and dispersed to each of the members of Southern Dirt and handed out to producers and industry professionals during field days . The annual trials booklet was distributed in 2015 to over 200 members and sponsors of Southern Dirt. In the booklet a report on the 2015 trial findings was published and the 2016 results and key findings will be published in 2017. In 2016 Southern Dirt membership grew to approx. 150 producers in which our region have expanded into Boyup Brook, and Darkan.

The spring field day booklet also has a project update and summary published in the 2014, 2015, and 2016. All producers and industry professionals were given a copy at the field day. This has allowed Southern Dirt to extend the project to reach producers outside of the producer group. 60 people attended the 2015 spring field day and in 2016 80 people were in attendance.

Field days were planned at the site and in 2015 Ed Riggall (consultant), Brad Nutt (Murdoch University), Daniel Kidd (UWA), and Neil Ballard (Ballard seeds) and Floyd Sullivan (Alosca Technologies) presented to at least 8 producers on inoculants, pasture varieties, and root nodulation. The 2016 field day however, was unable to be held. The trial site was located at the back of the property and due to the heavy rainfall the site was impossible to get through. Instead the fund was used to complete a soil analysis at the end of the trial to gain better understanding of the soil nutrients.

Project updates were published in each of the Southern Dirt's quarterly newsletters which are sent out to its members.

Social media was also used to update producers on the project results.

5.4 Effectiveness of the participatory research process

Producers were kept engaged consistently throughout the project through extension. Project summaries, results and reports were made available in all of Southern Dirt's newsletters and reporting booklets. Field days also kept the producers engaged and had excellent presentations were given on different aspects of pasture agronomy by experts in their given fields.

One of the producers stated that the benefits of having Producer Research Sites in the area are that the information is localised and trial data are relevant to the area. The benefits to his business are that he can correlate the trial data to his farming enterprise instead of using trial data that has been researched elsewhere across Australia which may not be as relevant and suited to his problem areas on his own farm.

Another Producer has stated that this PRS has increased his understanding on how a pasture needs to be treated, and he can use the information from the soil results and understanding of the pasture types to put into practice on his own farm.

A few research topics have come out of this project:

- How to successfully establish pasture legumes on marginal land
- Investigating P fertiliser applications on acid soils with low PBI – How to achieve desired levels for plant growth
- Liming and the successful establishment of pasture legumes.
- Understanding soil tests and pastures. What levels of fertiliser do I really need for my pastures?

The project was found to be useful to the producer group as it highlighted the need for better pasture agronomy to benefits from greater pasture production, and also the knowledge they gained from soil testing has helped them understand the importance of soil testing to see what is limiting and what is sufficient in the soil. They can benefit from the reduced input costs and improved nutrient management, while it is better on the environment.

6 Conclusions

There were many limitations other than P which has impacted the results from 2014, 2015, and 2016. Although these were addressed in each subsequent year of the trial it impacted heavily on the results. This highlights restrictions on the application of laboratory based research for farmers and the importance of field trials to test hypotheses in real situations.

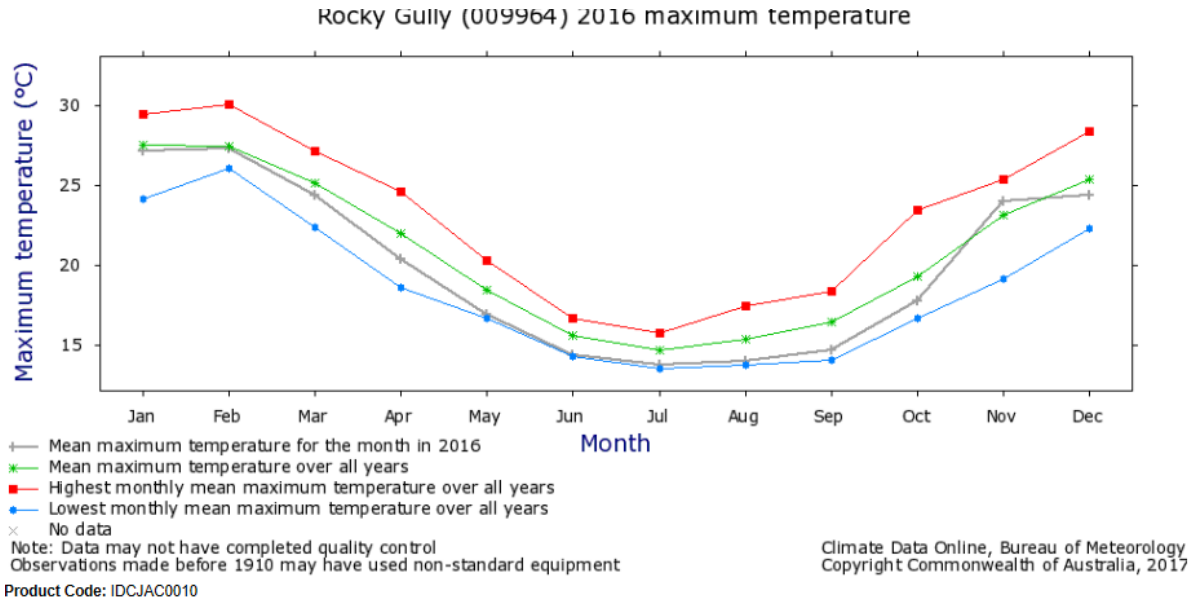
Other issues that impacted the trial were not all seasonal stressors or limiting factors, each of the years the project was run it was managed by a different project officer or consultant. This impacted the project when it came to analysing the data, as it was collected similarly however, not the same over the three years. Continuity of staff or a protocol handbook would be helpful in the future to collect each measurement correctly and the same each time.

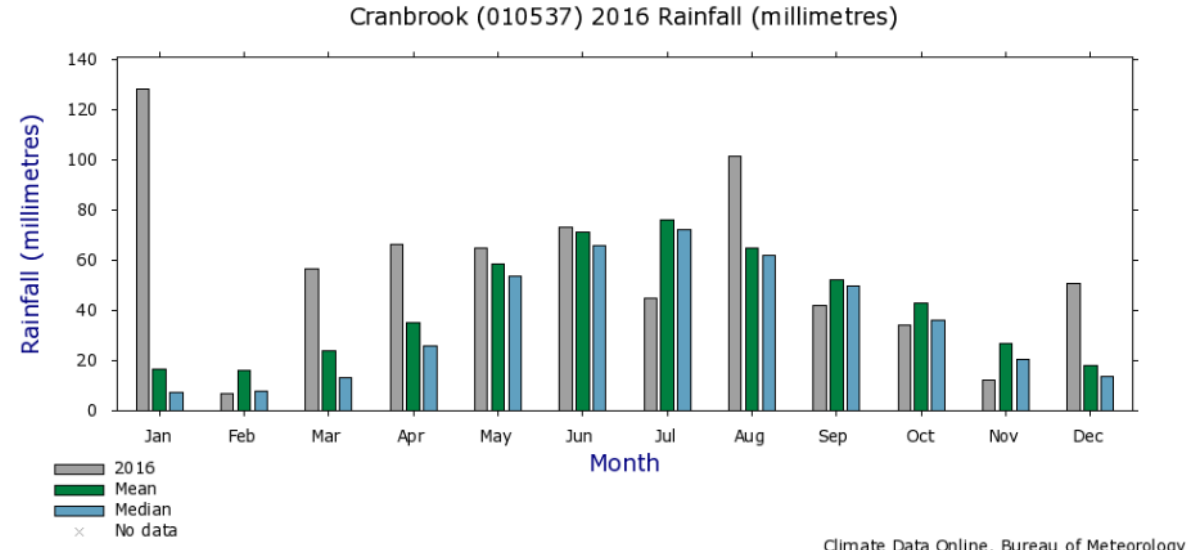
The project initially was complex including the comparison of liquid P and granular P. It would be wise in the future to keep the project simple which will hopefully achieve better and clearer results.

A key message of this project was the need for producers to understand how a pasture can be successfully grown when treated like a crop, through stringent weed control, carefully selected pasture varieties and knowing what nutrients are in the soils.

7 Appendix

7.1 Rainfall data





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