final report

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Potential for phosphorus efficient legumes

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Executive summary

Research was conducted by the Tablelands Farming Systems Group (TFS) to establish if legume species with a critical phosphorus requirement lower than subclover, such as Serradella, would survive and be productive in the high altitudes of the Southern Tablelands of NSW. Two trials were conducted with the first trial comparing the performance a range of legume species at two levels of soil phosphorous and the second testing the adaptation of these legumes in different soil types and locations.

The cost of phosphorus fertilisers is high (SSP = $350 per tonne spread in 2016) and increasing scarcity could see an increase in the cost in the future (Simpson et al 2011). Given there is also mounting evidence that soil acidity also poses a limitation for traditional use of sub clover and their rhizobium, (Hackney et al 2017) the use of an acid tolerant legume that has a low P requirement such as Serradella could see an improvement in carrying capacity of the low pH soils typical of the region.

Farms in the Southern Tablelands predominantly graze beef cattle and sheep for meat and wool production. The findings of this trial will assist farmers in making decisions about plant selection and fertiliser use to improve the productivity of their properties.

The Phosphorus Buffer Index (PBI) of the soils represented in the trial were very low (30 to 100) and the results show that plant available soil P can change markedly with lower than expected rates of fertiliser. The responsivness of these soils to applied P meant in trial 1 the target Colwell P level in the high and low Phosphorous treatments were exceeded. On the low treatment, Colwell P exceed the critical P level for sub clover growth (35 mg /kg) rather than reaching the expected level of 20 mg/kg. Unfortunately this meant there was no difference observed in the growth of legumes between plots with high and low fertiliser applications.

At most sites in both 2015 and 2016 Pink Serradella (*Ornithopus sativus* cv Margarita) produced comparable biomass to Leura Sub clover and the naturalised clovers although due to the higher than expected soil P response in trial 1 it cannot be determined whether this level of production would have been maintained at lower P levels. Caucasian Clover (*Trifolium ambiguum)* cv Aberlast survived at high elevations in the trial area but was slow to establish so its potential productivity was probably not realised within the short time frame of the research.

Crimson clover (*Trifolium incarnatum)* cv Blaza and pink serradella had the highest production of the novel legumes tested.

Trial results show that comparable performance can be expected from the naturalised clover base with improved management of soil fertility, but in areas where application of fertiliser is limited by topography or if phosphorous price increases, pink serradella would appear the best of the alternative legumes tested.

This project did not evaluate conclusively the role of pink serradella in the region as more time will be needed to determine if it can successfully regenerate from seed in the long term.

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1 Background

1.1 Tablelands Farming Systems Group

1.1.1 The group

Tablelands Farming Systems (TFS) is a farmer initiated group formed in 2013 in the NSW Southern Tablelands.

The 55 members of the TFS farm an area of 60,000 hectares. The farmers in the group manage 240,000 sheep and 11,000 head of cattle.

The TFS have been involved in a wide range of training activities and workshops including a Soil Club, seasonal forecasting, business benchmarking, Farmer Forum field days, sheep and cattle production workshops, fertiliser efficiency and soil health information sessions, pasture management and utilisation and conservation and environment sustainability workshops.

The TFS works closely with research and advisory staff from NSW DPI, CSIRO and the South East LLS. They also have a close working relationship with the Monaro Farming Systems Group.

1.1.2 Participatory research program

The TFS was a newly formed group when MLA called for expressions of interest to be involved with the research. As the group was planning to run a soil club, the involvement with the phosphorus use efficiency program of the research was appealing.

The Southern Tablelands is predominatly a grazing district. The soils tend to be acidic with a low Phosphorus Buffer Index (PBI) and a low natural fertility. The native pastures are enhanced by the inclusion of legumes. The opportunity to investigate novel pasture legumes that will survive and be productive in the region was a strong driver for the TFS to be involved in the Producer Research Site program.

2 Projective objectives

To determine which of a novel range of legumes identified as having lower critical P requirements establish, persist and produce in pastures across different soil types in the NSW Southern Tablelands when grazed by sheep and cattle.

To assess the performance of these P efficient legumes relative to sub clover at two soil P levels approximating the critical levels for both sub clover and for the P efficient legumes.

3 Methodology

3.1 Research sites

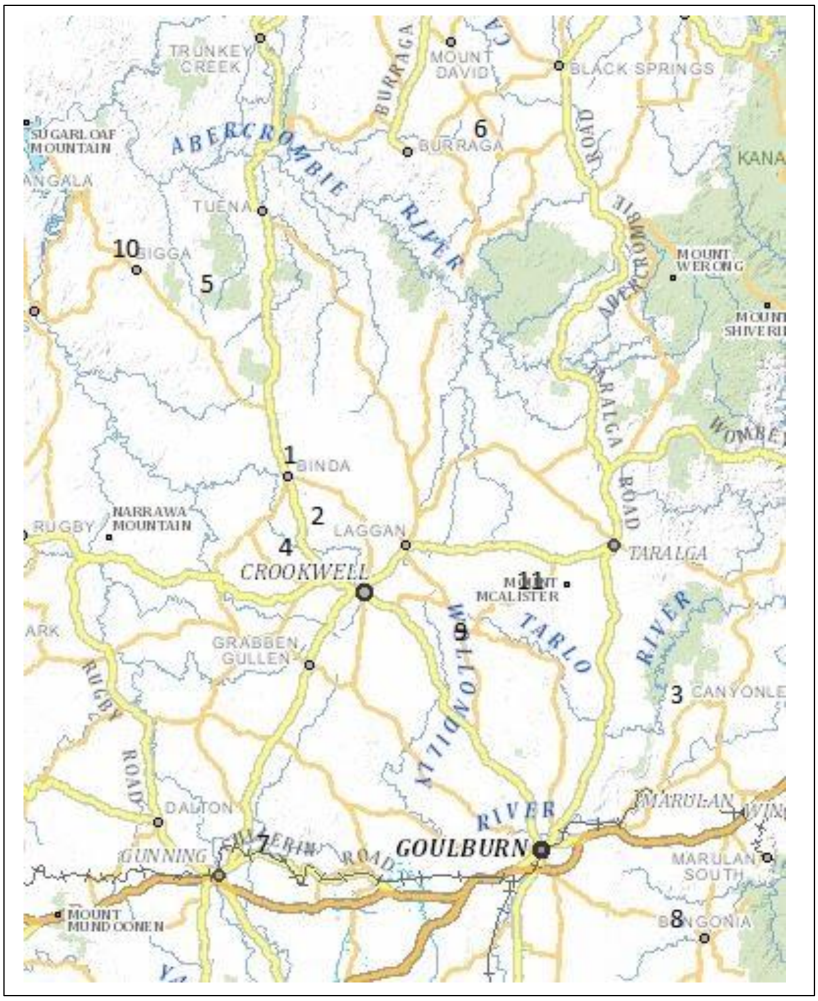
3.1.1 Site selection

An Expression of Interest (EOI) was sent to members of the TFS asking farmers if they wished to be involved with the project. See appendix 1

In June 2014 soil samples were taken at 0 – 10 cm across a transect line in the proposed trial sites.

Samples were submitted to Incitec's Nutrient Advantage Laboratory for analysis. All samples were tested for a range of soil nutrients including pH (CaCl), Phosphorus Buffer Index, Phosphorus (Colwell), Sulfur (KCl40), Potassium, Sodium and Aluminium.

Trial sites were selected ensure initial soil P levels were sub optimal for serradella and to ensure trials were sited on a range of soil types and locations in the the district.



Map of the area surveyed for the legume trial and location of the farms.

1. Funny Hill, Binda
2. Cadfor, Binda
3. Tullamore, Big Hill
4. Mt Henry, Binda
5. Burnahaffes, Bigga
6. Pomeroy , Isabella
7. Knights , Gunning
8. Spring Ponds, Bungonia
9 McAlister Heights, Laggan
10 Bigga Station, Bigga
11 Redbank, Laggan

3.1.2 Sites

Trial 1

Mt Henry Cultivation (MtHC), Binda

The site is located on a property that had little to no fertiliser applied over the past 50 years. The research plots however were located in an area of a paddock which had been previously cultivated and some fertiliser had been applied at that time. Despite this the available Phosphorous remained low and below the critical P level for both sub clovers (*Trifolium subterraneum)* and Serradellas (*Ornithopus spp.)* The soil is a yellow podzolic granite based acid soil type (pH 4.3 and PBI 50). This is supported by the NSW SCS Goulburn soil landscape series (Sheet SI 55-12) it is included in the Garland soil landscape group. The trial site is at 820 metres elevation with a northerly aspect.

Pasture on the site is predominantly *Vulpia stipoides* and broadleaf weeds sorrel *(Acetosella vulgaris)* and chickweed *(Stellaria media)* and no naturalised sub clover was observed at the site. The Colwell phosphorus soil test value was 12 mg/kg in October 2014.

Trial 2

Mt Henry Trial (MtHT), Binda

This site is located close to a creek to the east of the site described above. There had been no fertiliser applied to this part of the property for many decades. Soil test value for Colwell phosphorus in October 2014 was 5 mg/kg.

The soil is an acidic yellow podzolic of granite origin. This is supported by the NSW SCS Goulburn soil landscape series (Sheet SI 55-12) it is included in the Garland soil landscape group. (pH 4.6 and PBI 50). The site has an easterly aspect. Elevation 800 metres.

The pasture is mainly native grass species *Microlaena stipoides* and *Themeda triandra* and the annual grass weed Sweet Vernal *(Anthoxanthum oderatum)*. Very little naturalised sub clover was present.

McAlister Heights (McAH), Laggan

This site is located on top of the Great Dividing Range at an elevation of 1000 metres. The soil is basalt derived (pH 4.9 and PBI 96). According to the NSW SCS Goulburn soil landscape series (Sheet SI 55-12) it is included in the Macalister soil landscape group. It is described as a remnant basalt with exposed underlying metasediments and granites. Colwell P levels in October 2014 was 14 mg/kg.

There was a large amount of sub clover *(Trifolium subterraneum)* present on the site prior to herbicide application.

The properties Mt Henry and McAlister Heights are located in the Lachlan Catchment and are on or to the west of the Great Dividing Range.

Spring Ponds (SP), Bungonia

Elevation 500 metres, northerly aspect. The soil is acidic and of granite origin (pH 4.4 PBI 50). According to the NSW SCS Goulburn soil landscape series (Sheet SI 55-12) it is included in the Marulan soil landscape group. It is described as a yellow podzolic. The October 2014 Colwell P level was 19 mg/kg. *Microlaena stipoides* was the dominant pasture species with no sub clover observed.

This property lies within the Hawkesbury Nepean Catchment on the eastern side of the Great Dividing Range.

3.2 Treatments

3.2.1 Legume species

Legume species selected for the trials were Crimson clover (CrC) (*Trifolium incarnatum)* cv Blaza, Biserrula (B) (*Biserrula pelecinus)* cv Casbah, Caucasian clover (CauC) (*Trifolium ambiguum)* cv Aberlast, Pink serradella (PS) (*Ornithopus sativus)* cv Margarita, Sub clover (SC) (*Trifolium subterranean)* cv Leura, Yellow serradella (YS) (*Ornithopus compressus)* cv Santorini. Control plots were included to identify naturalised clover (N).

3.2.2 Site preparation

A one hectare site was fenced at each of the properties selected . In October 2014 soil samples were taken to determine the quantity of fertiliser required for the plots.

In January 2015 the sites at MtHC and McAH were sprayed with glyphosate herbicide at a rate of 3 L/ha.

Trial 1 Mt Henry Cultivation (MtHC)

Three blocks of 14 plots measuring 1.5 x 16 metres were identified and allocated to treatments of species and high (35 P) and low (20 P) fertiliser treatment.

In May 2015 the blocks were sprayed with a mixture of glyphosate herbicide and the insecticide Alpha-Cypermethrin 100 Duo at a rate of 100 ml/ha and in February 2016 were sprayed with glyphosate only at a rate of 3 L/ha.

Trial 2 Mt Henry Trial (MtHT), McAlister Heights (McAH) and Spring Ponds (SP)

Three blocks of seven plots measuring 2 x 10 metres were identified and allocated to species.

In May 2015 the blocks at McAH were sprayed with a mixture of glyphosate and insecticide at the same rate as MtHC. The blocks at MtHT and SP were grazed, mown and treated with insecticide only at 100 ml/ha.

3.2.3 Sowing

In May 2015 the plots at all sites were sown with lime treated legume seed at a rate of 20 kg/ha. Phalaris seed (*Phalaris aquatica cv Holdfast)* was included at 5 kg/ha at McAH only.

In March 2016 the plots at MtHC and MtHT were resown with the legume species under investigation using a cone seeder at 40 kg/ha.

The plots at McAH and SP were resown by hand in May 2016 following rain at a rate of 40 kg/ha.

Prior to sowing in 2016, a germination test was performed on the legume seed on hand and all of the varieties were found to be viable. The weight of the seed coat was also investigated and found to be approximately 40% of the weight of the coated seed. At resowing the rate of seed sown was increased from 20 to 40 kg/ha at all sites

3.2.4 Fertiliser

Trial 1 Mt Henry Cultivation

Superphosphate fertiliser was applied to raise the Colwell phosphorus concentrations to 35 mg/kg (MtHCH) which is the critical P concentration for sub clover growth or 20 mg/kg (MtHCL), the critical P concentration for serradella .

The quantity of phosphorus fertiliser required was calculated using the equation described by Simpson et al (2009) from results of the soil tests performed in October 2014. Additional gypsum was applied to the L plots to balance the quanity of sulfur applied from superphosphate in the H treatments. A mixture of superphospahate with and without Mo was applied to the H treatment plots to ensure the same quantity of that trace mineral was applied to each of the plots. Potasium fertiliser was applied to all of the plots and the quantity applied was calculated by the method as described by Havilah et al (2006).

Actual quantities of fertiliser applied at each site is shown in Table 1.

Trial 2 Mt Henry Trial, Spring Ponds and McAlister Heights

Superphosphate was applied to all plots to raise the Colwell phosphorus level to 20 mg/kg calculated from soil tests taken in October 2014 as described by Simpson et al (2009). A Colwell P of 20 was taken to be the target critical level for the low P requirement legumes (Richard Simpson pers Comm).

Potassium fertiliser was applied to plots at MtHT and SP. Quantities of potassium fertiliser were calculated by the method as described by Havilah et al (2006). No potassium fertiliser was required at McAH.

Molybdenum was applied as MoSuperphosphate to the plots at MtHT and McAH but was not required at SP as it had been applied to the site by the farmer in March 2014.

Table 1: Quantity of seed and fertiliser applied to Mt Henry Cultivation (MtHC) high (H) and low (L) phosphorus treatments Mt Henry Trial (MtHT) McAlister Heights (McAH) and Spring Ponds (SP) in May 2015 and seed in March or May 2016.

Site	Super g/plot 2015	MoSuper g/plot 2015	Gypsum g/plot 2015	Potash g/plot 2015	Legume g/plot 2015	Phalaris g/plot 2015	Legume g/plot 2016
MtHC H	648	432		144	48		96
MtHC L		432	500	144	48		96
MtHT		622		120	40		80
McAH		300			40	10	80
SP	120			120	40		80

3.3 Monitoring

3.3.1 Rainfall

Daily rainfall data has been collected from Bureau of Meteorology sites at Crookwell and Bungonia and Cadfor, Binda weather station data. See appendix 2

3.3.1 Germination counts

In August 2015 a 25 cm x 25 cm quadrat square was placed on a diagonal transect at 2 metre intervals in each plot and the number of legume plants was recorded. Seven measurements were made in each plot at MtHC, four measurements per plot were made at MtHT, McAH and SP.

Sites were inspected for regeneration in February 2016, February 2017 and May 2017.

3.3.2 Soil samples

0-10 cm soil samples were taken from each plot in October 2015, March 2016 and March 2017. The samples were analysed for phosphorus, sulfur and potassium at the Nutrient Advantage Laboratory at Werribee. In November 2016, soil samples from all sites were tested for pH, aluminium %, phosphorus, phosphorus buffer index, potassium and sulfur.

3.3.3 Pasture and legume biomass

In October 2015 and 2016, four samples per plot were cut to ground level within a 25 cm x 25 cm quadrat square. Samples for each plot were bulked and weighed. A subsample was dried in a microwave to determine dry matter content. The remaining sample was sorted, dried and weighed to calculate the proportion of legume in each sample.

3.4 Statistical analysis

For trial 1 the MtHC H and L, data have been analysed using a split plot analysis of variance in Genstat. Data for 2015 and 2016 were analysed separately.

For trial 2 data has been analysed using analysis of variance in Genstat. Data for 2015 and 2016 were analysed separately.

3.5 Economic analysis

No economic analysis has been performed for the trials.

3.6 Extension and communication

Updates of the trial were presented at TFS meetings throughout the operation of the trial. Trial plans and initial observations were presented at a roving field day in November 2015. A field day planned for October 2016 to observe regeneration in the second year was cancelled due to very wet weather preventing access to the Mt. Henry trial site. Persistently wet conditions meant this field day could not be rescheduled at a meaningful time that year. A field day involving farmers and LLS staff was held after the official end of the project in October 2017 instead.

4 Results

4.1 Measured trial results

4.1.1 Pre trial site survey

The soil tests performed in June 2014 from 18 paddocks across 11 properties in the Southern Tablelands show a range of phosphorus fertility. The majority of paddocks were below critical Colwell P for sub clover growth and half the paddocks were more than 10 units below critical values. Sulfur levels were also below the optimum level of 8 mg/kg in KCl40 in 13 of the sites measured. Soils were acidic with a very low to low phosphorus buffer index (PBI).

Table 2: pH, Phosphorus Buffer Index (PBI), Colwell Phosphorus, Sulfur, Potassium and Aluminium on 11 properties in the Southern Tablelands of NSW in June 2014.

Site location		pH (CaCl)	PBI	Critical Colwell P	Actual Colwell P	Sulfur (KCl40)	Potassium Meq/100	Al %
Funny Hill, Binda	1	4.4	54	29	73	4.3	0.15	9.5
	2	5.1	120	35	78	9.9	0.26	1.8
Cadfor, Binda	1	4.4	89	33	33	7.2	0.55	11
	2	4.2	70	31	29	3.8	0.33	17
Tullamore, Big Hill		5.6	95	34	26	3.4	0.27	3.4
Mt Henry, Binda	1	4.6	49	29	13	2.9	0.17	4.8
	2	4.4	46	29	19	3.4	0.12	13
Bernahaffes, Bigga		5.0	57	30	24	3.2	0.15	2.2
Pomeroy, Isabella	1	4.2	150	37	46	8.5	0.61	15
	2	4.2	110	34	21	4.5	0.19	32
	3	4.4	130	36	22	4.0	0.22	18
Knights, Gunning	1	4.5	38	28	19	16	0.27	9.2
	2	4.1	44	28	13	3.1	0.31	39
Spring Ponds, Bungonia		4.4	51	29	33	17	0.24	15
McAllister Heights, Laggan		4.8	96	34	22	7.9	0.53	7
Bigga Station, Bigga		4.5	56	30	11	3.3	0.19	8.4
Redbank, Laggan	1	4.5	82	32	17	6.5	0.15	8.5
	2	5.1	54	29	20	5.6	0.71	1.8

The sites selected for the trial were Mt Henry 1 and 2, Spring Ponds and McAlister Heights.

4.1.1 Climate

The trial operations were severely affected by the weather conditions in 2015 and 2016. The rainfall in early Autumn was well below average at all sites which delayed preparation and sowing of the plots. Above average rainfall occurred in the winter of 2015 and winter and spring of 2016 including heavy snow falls at Binda and Laggan in 2015. Rainfall in spring 2015 was well below average. Severe water logging and flooding conditions were experienced at all sites in 2016. See graphs in the appendix of this report.

4.1.2 Germination

In 2015 all of the legumes germinated at all of the sites following broadcasting in May 2015. Lime coated seed was used at a rate of 20 kg/ha. The lime coating makes up about 40% of the weight of the seed used which resulted in the legumes being sown at a much lower rate than that proposed. Germination was achieved following the broadcasting of seed onto bare ground at MtHC and McAH and into native pasture at SP and MtHT.

Table 3: Germination counts of seedlings of Crimon Clover (CrC), Biserula (B), Caucasian Clover (CauC), Naturalised (N), Pink Serradella (PS), Sub Clover (SC) and Yellow Serradella (YS) at sites at Mt Henry Cultivation (MtHC) high (H) and low (L), Mt Henry Trial (MtHT), McAllister Heights (McAH) and Spring Ponds (SP) in July 2015.

Site	CrC	B	CauC	N	PS	SC	YS
	Seedlings / square metre						
MtHC H	37	32	194	8	43	24	24
MtHC L	44	18	290	10	49	21	22
MtHT	49	24	67	4	109	27	56
McAH	35	4	193	16	33	32	20
SP	77	9	73	3	183	56	93

The legumes were sown at the same rate but the seed size between the species were very different. A greater number of seeds were sown in the Caucasian Clover plots compared to Sub clover which led to a range in the number of seedlings germinating in each plot.

All the sites were inspected for regeneration in February 2016 but no legumes were evident. Due to the apparent lack of regeneration the MtHC and MtHT sites were resown in March 2016 and at SP and McAH in May 2016 but germination counts were not able to be performed due to the extremely wet weather throughout winter preventing access to the sites.

By February 2017 no legumes had regenerated at any of the sites but by May 2017 Pink Serradella, Crimson Clover and Sub Clover were evident in the plots at Spring Ponds and Pink Serradella and Naturalised clovers were present in the plots at Mt Henry Trial however no quantitative measurements were made.

4.1.3 Soil test results

Trial 1

In October 2015 and May 2016 the Colwell phosphorus results exceeded the target level of 35 and 20 mg/kg in the high and low treatments respectively. A very low PBI on these soils and low removal of P due to low pasture growth may explain why the result is higher than expected.

By November 2016, tests performed on the soil samples demonstrated Colwell phosphorus levels had dropped closer to the desired level in both treatments.

Sulfur levels were adequate in the 2015 samples. In 2016 they had dropped to levels well below the desired level of 8 mg/kg. Waterlogging and extreme cold weather in winter and spring is likely to have increased the loss of sulfur by leaching and slower organic matter recycling.

Potassium levels remained below the accepted critical level of 139 mg/kg for the sandy loam soils despite the addition of the nutrient at the start of the trial.

Table 4: Soil test results for the trial sites in October 2015 and November 2016 at Mt Henry Cultivation (MtHC) high (H) and low (L) phosphorus treatments

P rate	Test	Date	Block 1	Block 2	Block 3
High	P (Colwell)	October 15	51	39	53
	mg/kg	May 16	50	40	43
		November 16	44	34	32
Low		October 15	34	33	32
		May 16	38	30	31
		November 16	32	21	22
High	Sulfur (KCl40)	October 15	13	9	15
	mg/kg	November 16	3.7	2.3	2.1
Low		October 15	12	8	10
		November 16	2.3	1.8	1.9
High	Potassium (Colwell)	October 15	100	63	100
	mg/kg	November 16	76	47	86
Low		October 15	120	68	99
		November 16	76	42	86
High	pH ($CaCl_2$)	November 16	4.2	4.2	4.3
Low		November 16	4.1	4.3	4.2

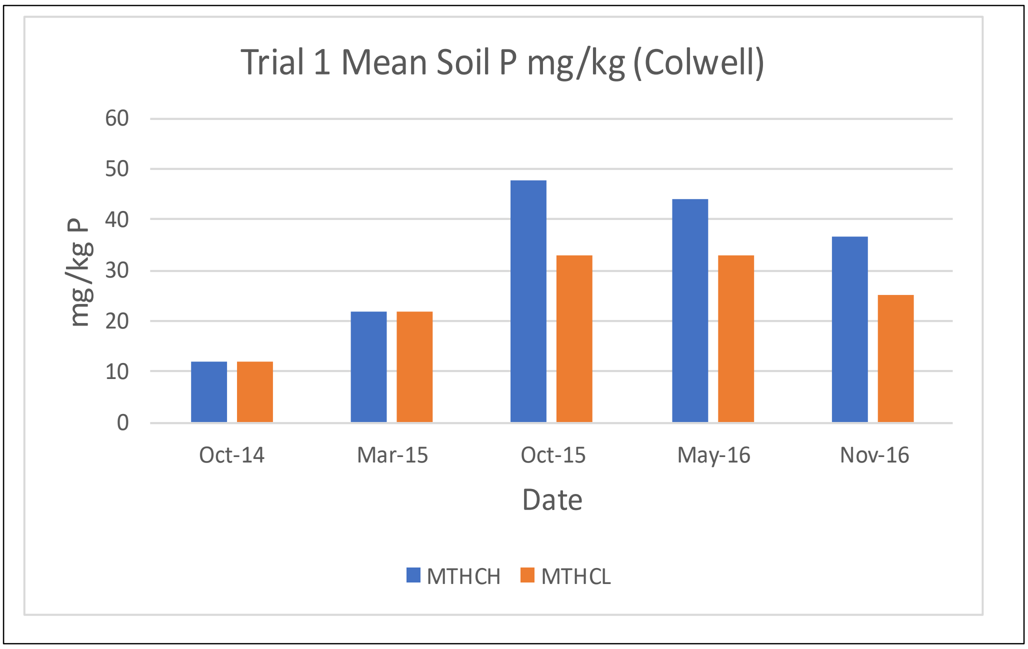


Fig 1: Changes in soil phosphorus levels (Colwell) In MtHC over the trial period from October 2014 to November 2016. Superphosphate was applied in May 2015.

Trial 2

In 2015 the desired soil P level of 20 mg/kg was achieved or slightly exceeded at all sites. However in November 2016, the P level at MtHT fell to 10-13 mg/kg Colwell P in the plots. The sites at McAH and SP remained close to 20 mg/kg.

Table 5: Soil test results for the trial sites in October 2015 and November 2016 at Mt Henry Trial (MtHT), McAllister Heights (McAH) and Spring Ponds (SP).

Site	Test	Date	Block 1	Block 2	Block 3
MtHT	P (Colwell)	October 15	18	24	21
	mg/kg	November 16	12	13	10
McAH		October 15	26	24	34
		November 16	23	20	18
SP		October 15	23	24	28
		November 16	22	26	26
MtHT	Sulfur (KCl40)	October 15	8	8	11
	mg/kg	November 16	3	3	3
McAH		October 15	9	10	10
		November 16	8	5	4
SP		October 15	8	9	12
		November 16	5	5	4
MtHT	Potassium (Colwell)	October 15	76	66	66
	mg/kg	November 16	85	75	69
McAH		October 15	200	210	220
		November 16	180	170	160
SP		October 15	92	180	150
		November 16	100	130	72
MtHT	pH($CaCl_2$)	November 16	4.6	4.6	4.7
McAH		November 16	5	4.8	4.4
SP		November 16	4.4	4.4	4.4

Sulfur levels were adequate in October 2015 but were well below the adequate test level of 8 mg/kg (KCl40) by November 2016 again, presumably due to waterlogging and cold weather.

Potassium levels remained below the critical level of 139 mg/kg for sandy loam soils at MtHT and SP despite the addition of the nutrient at the start of the trial. The potassium in the clay soils at McAH met or exceeded the critical level of 161 mg/kg K in samples taken in October 2015 and November 2016.

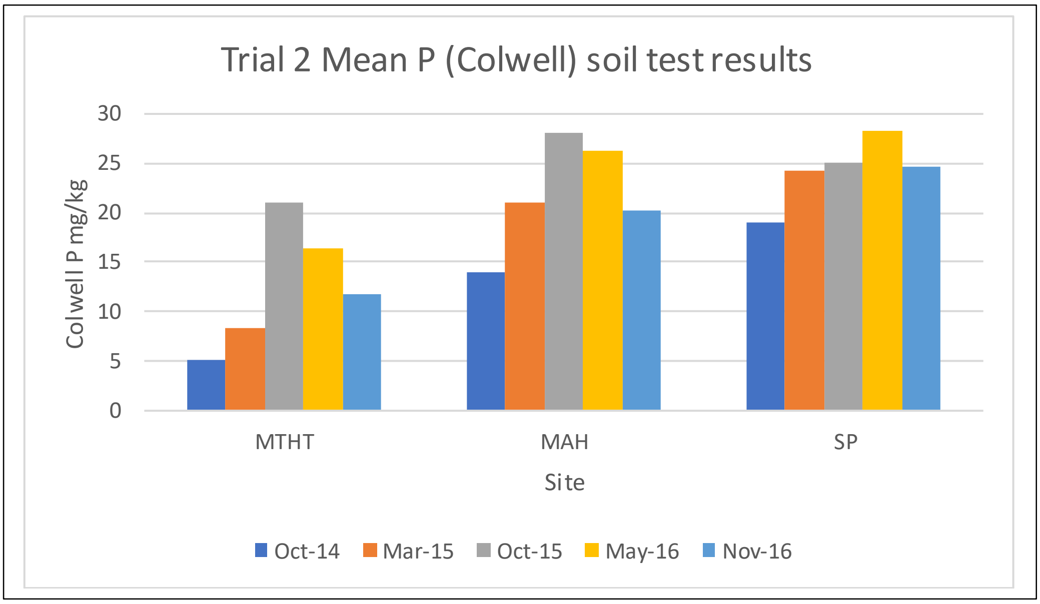


Fig 2: Changes in soil phosphorus levels (Colwell) In MtHT, McAH and SP over the trial period from October 2014 to November 2016. Superphosphate was applied only in May 2015 to target a Colwell P of 20mg/kg

Response to fertiliser application

Colwell phosphorus levels increased linearly with added P as superphosphate. In the soils on the trial about 15 kg P was required to raise the Colwell P test by 10 mg/kg.

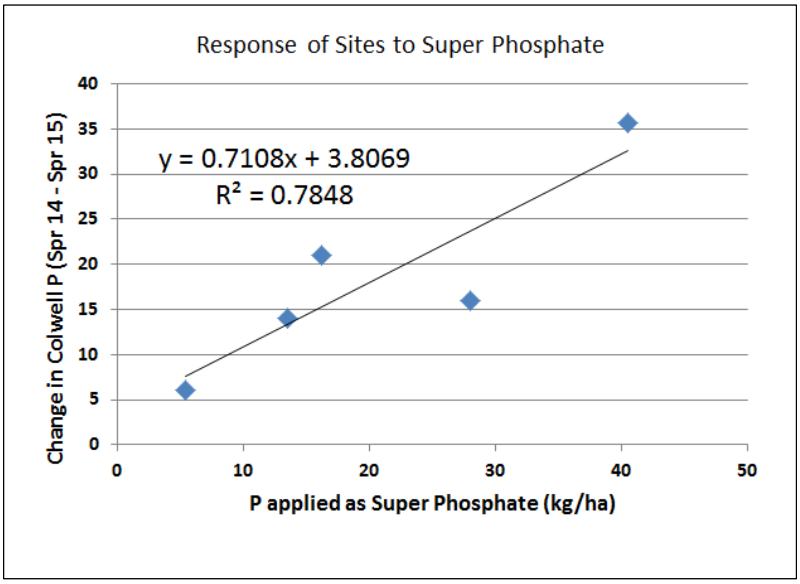


Fig 3: The change of Colwell P soil test levels in response to phosphorus applied as superphosphate in May 2015. The change in Colwell P is the difference in average soil test between sampling in October 2014 and October 2015.

4.1.4 Pasture and legume biomass

Trial 1

In 2015 the non-legume biomass in the plots at MtHC largely consisted of the annual grass weed, Silver grass *(Vulpia spp)* and the broadleaf weed Sorrel (*Rumex acetose*). There was more overall biomass in the biserrula, pink serradella and sub clover plots.

In 2015 and 2016 there were no apparent interaction between the legumes and the P treatments. The soil tests taken in October 2015 and May 2016 indicated that an excess of P fertiliser had been applied in May 2015, and the Colwell phosphorus in the low treatment was around the critical P level for sub clover growth, not that for serradella. As Colwell P was in fact not limiting for either the low or high P requirements legumes, the data for the high and low treatments have been combined for pasture and legume biomass analyses.

Table 6: Total pasture (and legume) biomass kg/ha for the trial sites in spring 2015 at Mt Henry Cultivation (MtHC) high (H) and low (L) phosphorus treatments

Site	CrC	B	CauC	N	PS	SC	YS
	Kg Dry Matter / ha						
MtHC H	958 (133)	1685 (863)	1043 (84)	1096 (110)	1831 (750)	1514 (397)	1371 (295)
MtHC L	748 (131)	1213 (430)	965 (132)	961 (0)	1529 (520)	1935 (250)	1013 (330)

The Pink Serradella, Sub Clover and Biserrula plots produced the most biomass with Crimson Clover, Caucasian Clover and the naturalised clover plot producing significantly lower quantity of pasture.

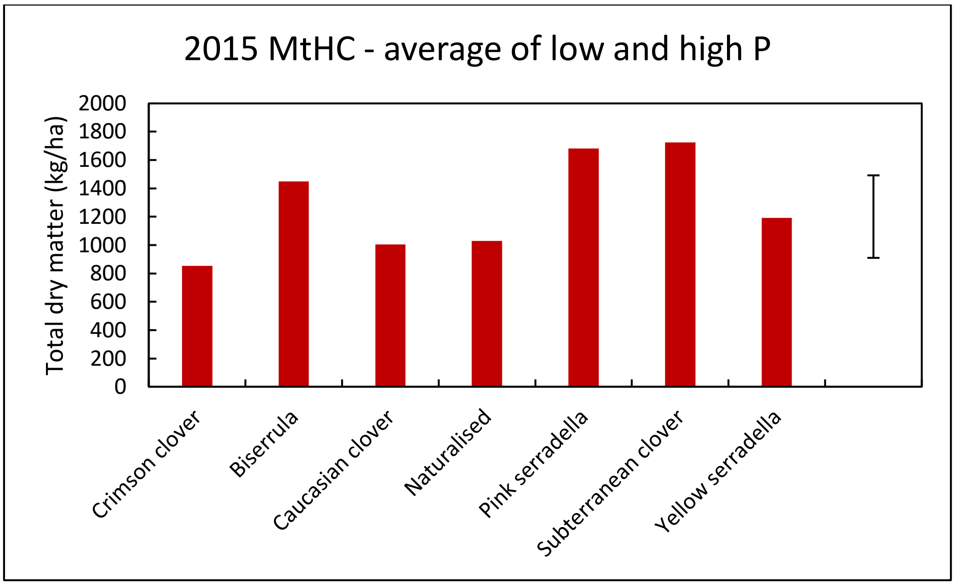


Fig 4: Total Dry Matter for plots at Mt Henry Cultivation in November 2015. The LSD bar on the right hand side of the graph shows that when the difference in yield between two treatments exceeds the LSD then those treatments differ significantly (P<0.05).

Figure 5 shows the Biserrula and Pink Serradella plots produced twice the legume biomass of Sub Clover and Yellow Serradella and in excess of five times more than the Crimson, Caucasian and naturalised clovers.

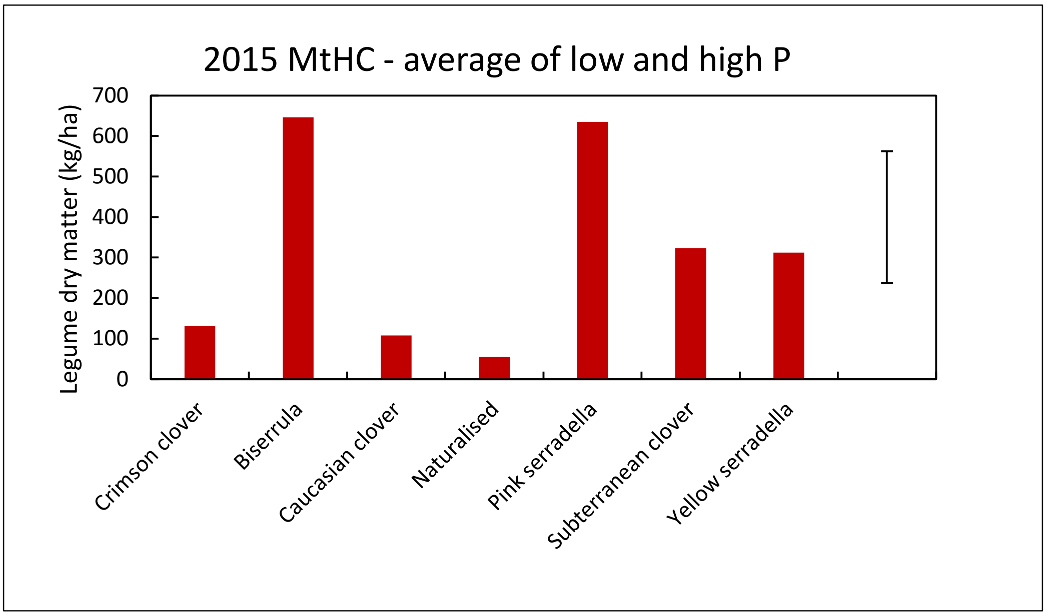


Fig 5: Legume Dry Matter for plots at Mt Henry Cultivation in November 2015. The LSD bar on the right hand side of the graph shows that when the difference in yield between two treatments exceeds the LSD then those treatments differ significantly ($P<0.05$).

The non legume biomass in 2016 consisted of annual grass and broadleaf weeds similar to those in the previous year. Table 7 shows that the Crimson Clover, Pink Serradella and Sub Clover plots produced the highest total biomass. By comparison to 2015 the Biserrula plots ranked lower (last) in terms of both total biomass and legume biomass which is most likely due to the inability of Biserrula to cope with the waterlogged conditions experienced in 2016

Table 7: Total pasture biomass for the trial sites in November 2016 at Mt Henry Cultivation (MtHC) high (H) and low (L) phosphorus treatments.

Site	CrC	B	CauC	N	PS	SC	YS
	Kg Dry Matter / ha						
MtHC H	4134 (1992)	1828 (147)	3535 (307)	2688 (819)	3887 (723)	3872 (1045)	3061 (333)
MtHC L	3724 (1848)	2437 (80)	2889 (333)	2371 (581)	3265 (853)	3516 (1483)	2586 (400)

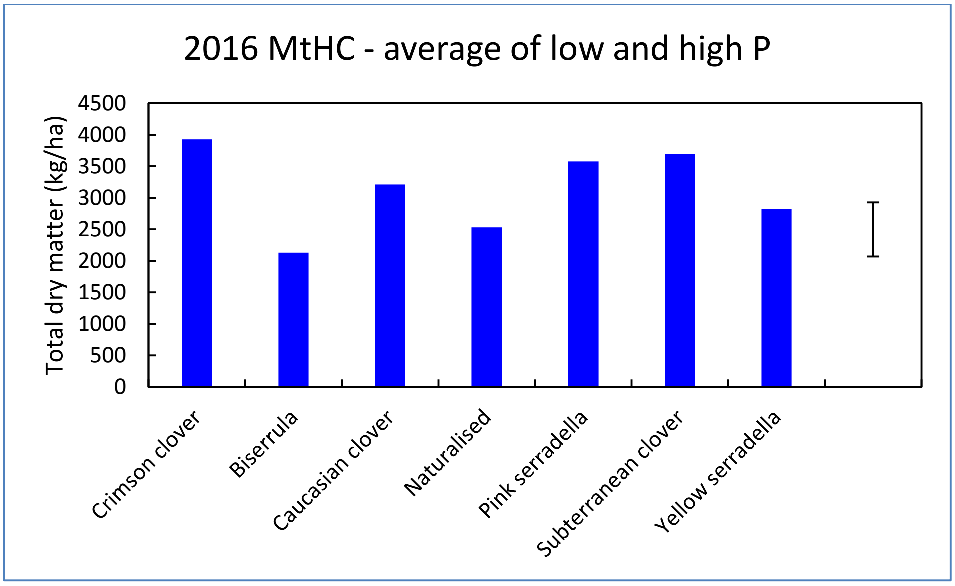


Fig 6: Total Dry Matter for plots at Mt Henry Cultivation in November 2016. The LSD bar on the right hand side of the graph shows that when the difference in yield between two treatments exceeds the LSD then those treatments differ significantly (P<0.05).

Figure 7 shows that in 2016 the legume biomass was highest in the Crimson Clover which produced almost twice that of Leura Sub Clover. Yellow Serradella and Caucasian Clover achieved only 30% of the production of Sub Clover and Biserrula only 10%

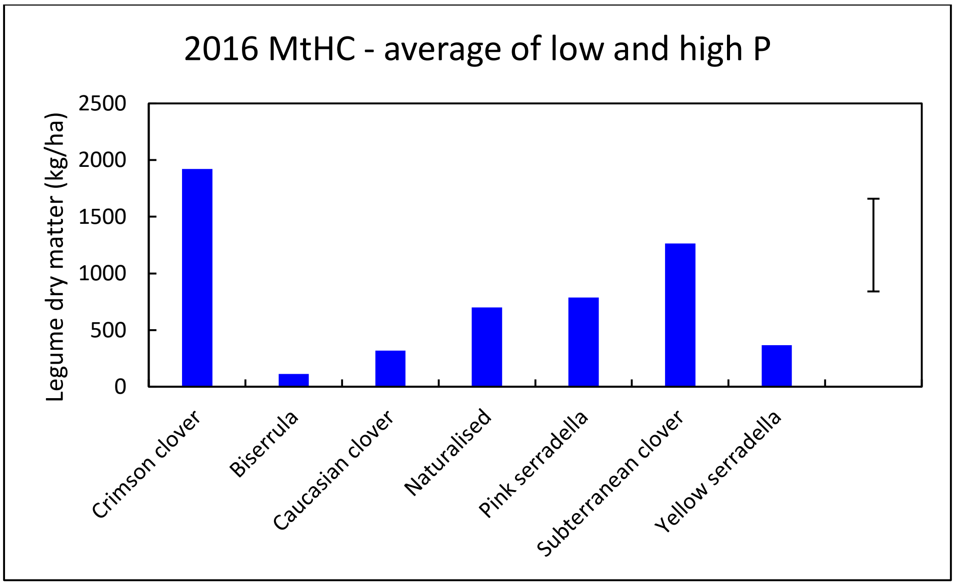


Fig 7: Total legume for plots at Mt Henry Cultivation in November 2016. The LSD bar on the right hand side of the graph shows that when the difference in yield between two treatments exceeds the LSD then those treatments differ significantly (P<0.05).

Trial 2

November 2015

In November 2015 pasture and legume biomass were measured in all of the plots at all three sites. All the legumes under investigation were evident at all of the sites, except Caucasian Clover was not present at MtHT and at very low levels at SP.

Table 8: Total pasture and (legume) biomass kg/ha for the trial sites in spring 2015 at Mount Henry Trial (MtHT), McAllister Heights (McAH) and Spring Ponds (SP)

Site	CrC	B	CauC	N	PS	SC	YS
	Kg Dry Matter / ha						
MtHT	2909 (504)	1847 (149)	1984 (0)	1734 (160)	2139 (426)	2139 (548)	1889 (93)
McAH	2977 (574)	1919 (394)	1506 (165)	1698 (214)	2375 (159)	1729 (97)	1941 (8)
SP	2545 (514)	2025 (214)	1793 (8)	1633 (111)	2847 (466)	3045 (107)	2262 (31)

At Mt Henry Trial the non legume biomass consisted of the native grasses Weeping Grass *(Microlaena stipoides)* and Kangaroo Grass *(Themeda triandra)* and the annual grass weed Sweet Vernal Grass *(Anthoxanthum odoratum)*. Crimson Clover, Pink Serradella and Sub Clover treatments where consistently high yielding across all sites although the sub clover treatment did not perform as well at McAH.

Figure 8 shows that at MtHT the Crimson Clover plots grew the highest biomass and the Pink Serradella and Sub Clover plots grew a similar quantity but significantly less than the Crimson Clover.

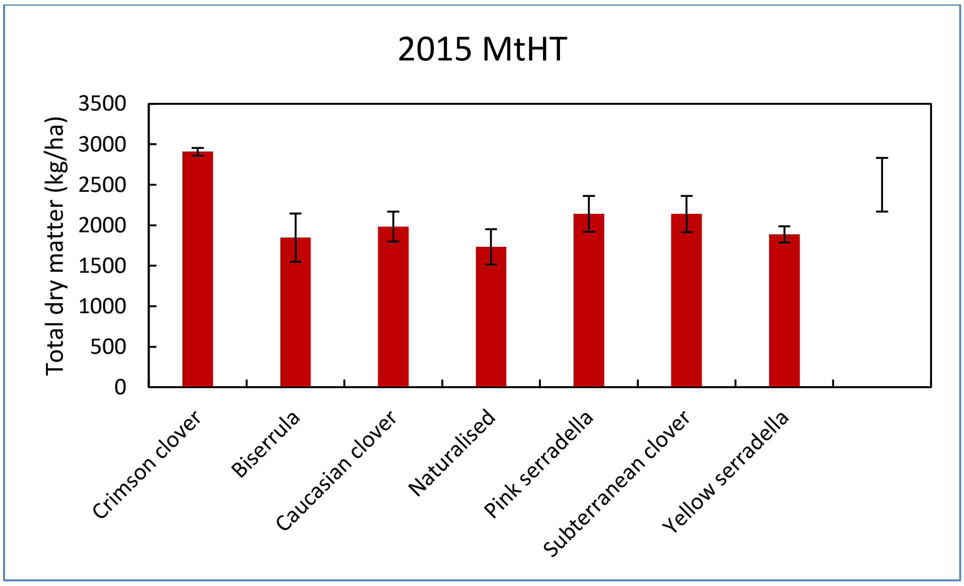


Fig 8: Total Dry Matter (kg/ha) for Mt Henry Trial in November 2015. The LSD bar on the right hand side of the graph shows that when the difference in yield between two treatments exceeds the LSD then those treatments differ significantly (P<0.05).

At Mt Henry Trial the Crimson Clover and Sub Clover grew a similar quantity of legume biomass while Pink Serradella production was only 80% of the Sub Clover. In the Biserrula, Yellow Serradella and Naturalised clover plots legume biomass was less than 20% of that growing in the sub clover treatment. Caucasian Clover failed to grow at the site.

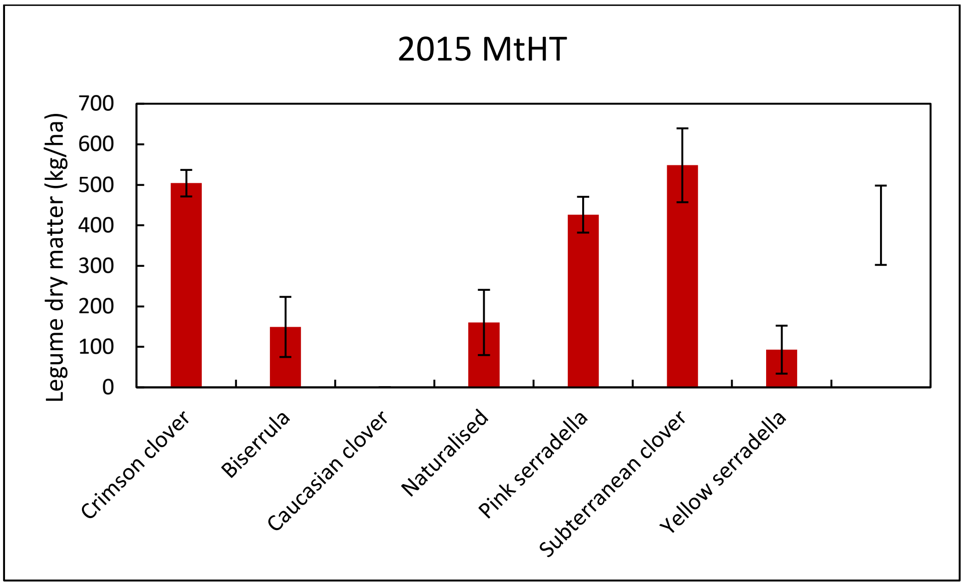


Fig 9: Legume Dry Matter (kg/ha) for Mt Henry Trial in November 2015. The LSD bar on the right hand side of the graph shows that when the difference in yield between two treatments exceeds the LSD then those treatments differ significantly (P<0.05).

At Mcallister Heights the non legume biomass consisted mainly of phalaris (Phalaris and ryegrass *(Lolium perenne)* pasture. The Caucasian Clover and Yellow Serradella plots produced the least total biomass at around 1500 kg DM/ha while all other treatments produced more than 2000 kg DM/ha (fig 10).

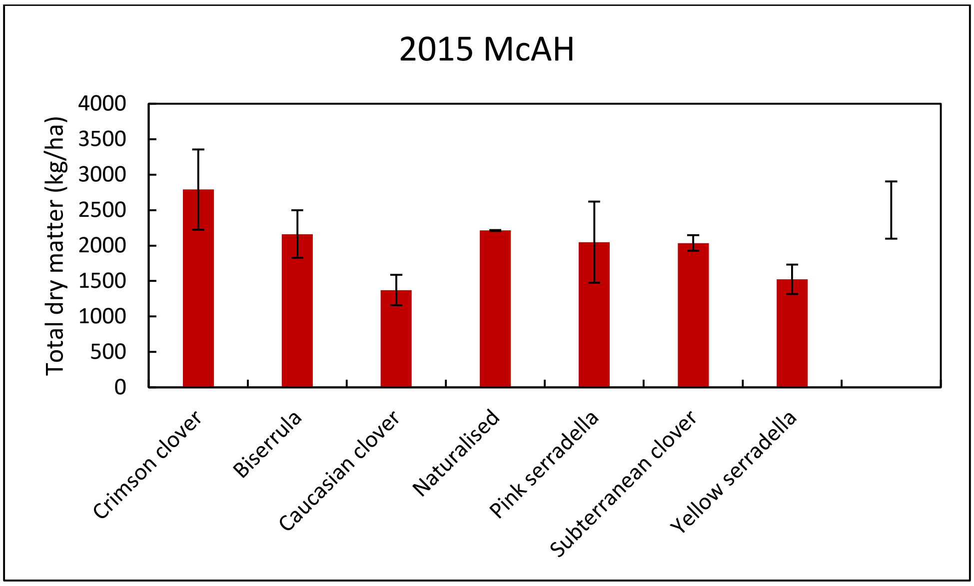


Fig 10: Total Dry Matter (kg/ha) for McAllister Heights in November 2015. The LSD bar on the right hand side of the graph shows that when the difference in yield between two treatments exceeds the LSD then those treatments differ significantly (P<0.05).

Figure 11 shows that on average Crimson clover produced the highest legume biomass although this was not significantly different to the other legumes. The sub clover treatment produced more legume biomass than Biserrula, both serradellas and the naturalised clover.

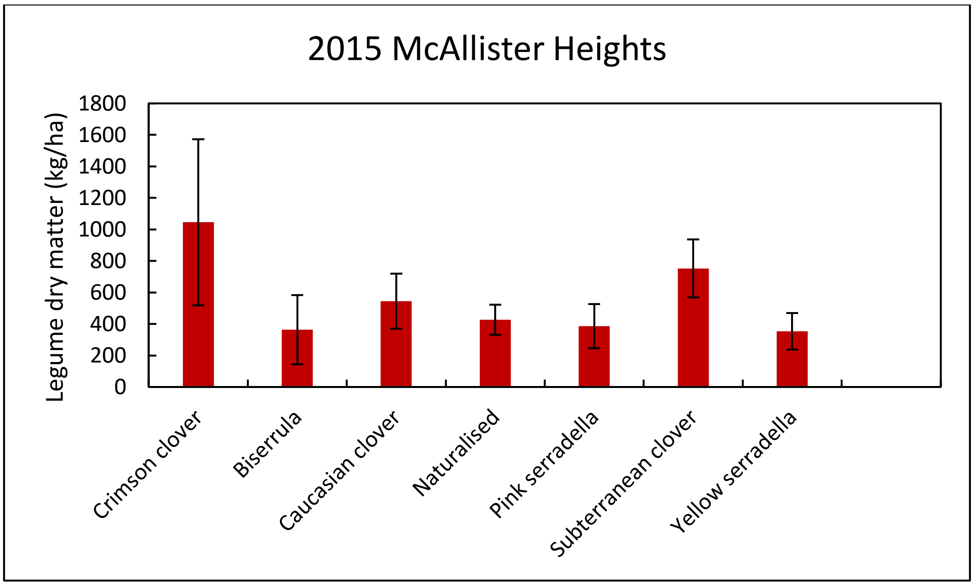


Fig 11: Legume Dry Matter (kg/ha) for McAllister Heights in November 2015. There were no significant difference in legume biomass between any treatments (P<0.05).

Total biomass at Spring Ponds was significantly higher for Pink Serradella, Sub Clover and Crimson Clover than for the other treatments (Fig 12). The non legume biomass was predominantly the native grass Weeping Grass *(Microlaena stipoides).*

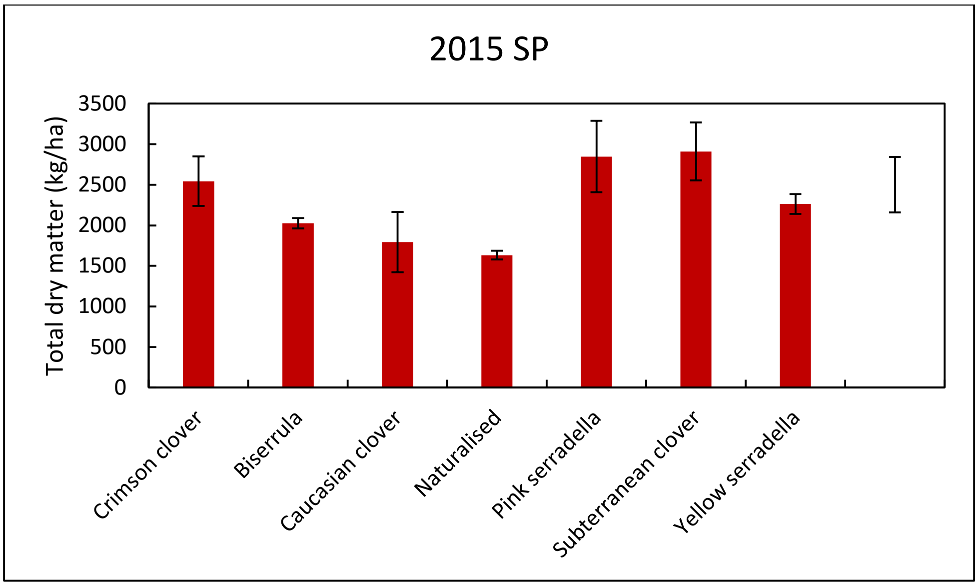


Fig 12: Total Dry Matter (kg/ha) for Spring Ponds in November 2015. The LSD bar on the right hand side of the graph shows that when the difference in yield between two treatments exceeds the LSD then those treatments differ significantly (P<0.05).

Figure 13 shows that the legume biomass was highest for Crimson Clover and Pink Serradella and approximately 5 times that of sub clover. Caucasian Clover and Yellow Serradella had the lowest legume biomass.

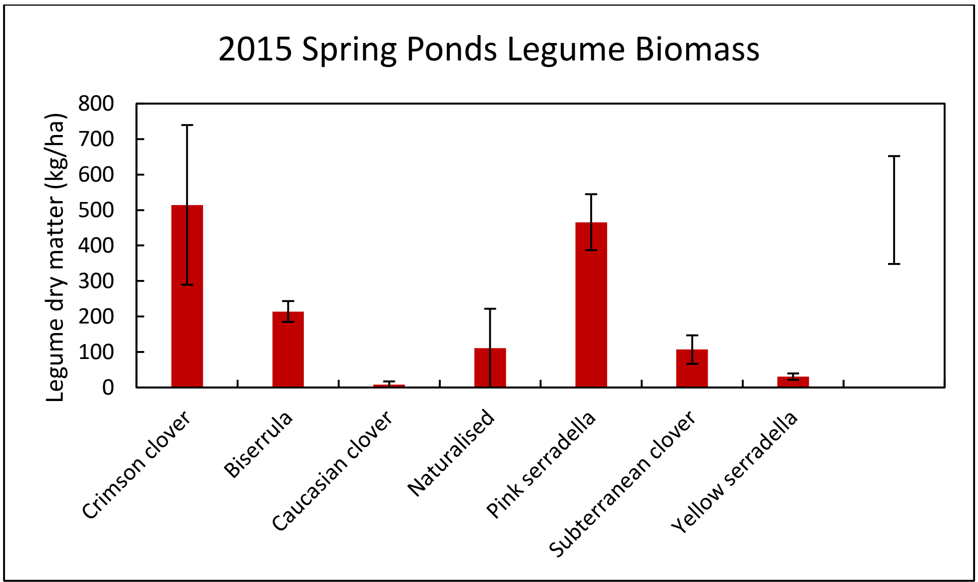


Fig 13: Legume Dry Matter (kg/ha) for Spring Ponds in November 2015. The LSD bar on the right hand side of the graph shows that when the difference in yield between two treatments exceeds the LSD then those treatments differ significantly (P<0.05).

November 2016

Between year comparisons and assessment of persistence cannot be made because the plots were resown at MtHT in March 2016 and at McAH and SP in May 2016. In November 2016 all plots were sampled for total pasture and legume biomass. Pasture species had not changed between sampling at each site.

Table 9: Total pasture and (legume) biomass kg/ha for the trial sites in spring 2016 at Mount Henry Trial (MtHT), McAllister Heights (McAH) and Spring Ponds (SP)

Site	CrC	B	CauC	N	PS	SC	YS
	Kg Dry Matter / ha						
MtHT	1453 (425)	780 (299)	1253 (174)	953 (597)	1640 (749)	1080 (213)	760 (272)
McAH	3569 (0)	2899 (0)	4232 (0)	4422 (1875)	4245 (0)	4112 (0)	3957 (0)
SP	2400 (1469)	1439 (347)	1027 (66)	800 (0)	2729 (1693)	1677 (835)	3305 (1339)

Figure 14 shows the Pink Serradella Caucasian clover and Crimson clover plots had similar total biomass at Mt Henry Trial in November 2016. The pink Serradella plots grew significantly more biomass than the Biserrula, Sub Clover, Yellow Serradella or Naturalised clover. While on average the pink serradella and naturalised clovers grew the greatest amount of legume biomass there was a large variation between replicates and the differences were not significant (Figure 15).

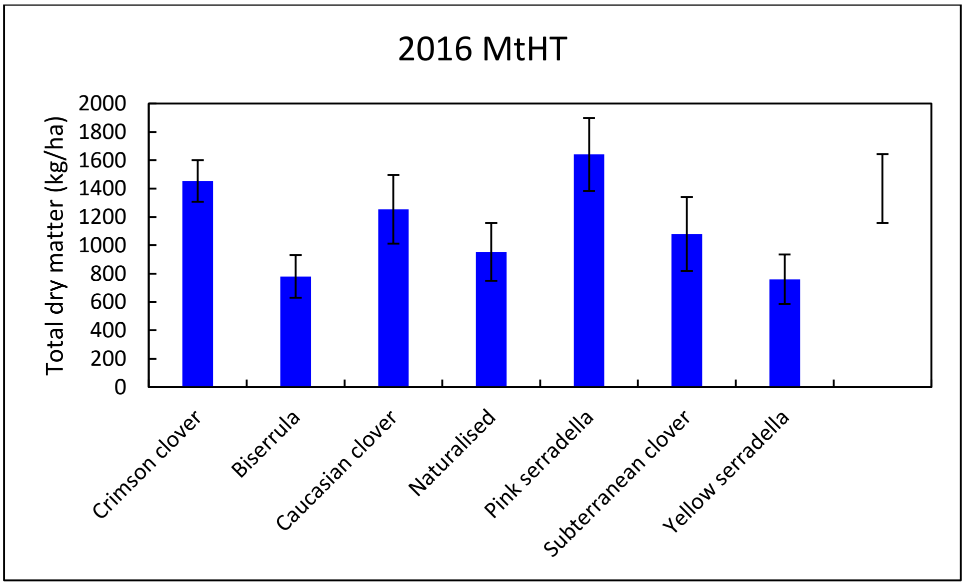


Fig 14: Total Dry Matter (kg/ha) for Mt Henry Trial in November 2016. The LSD bar on the right hand side of the graph shows that when the difference in yield between two treatments exceeds the LSD then those treatments differ significantly (P<0.05).

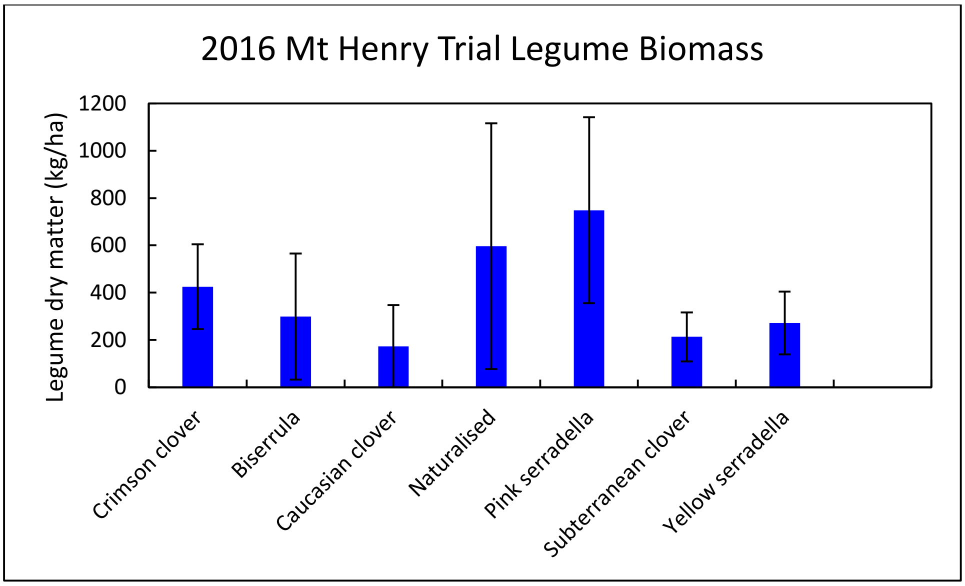


Fig 15: Legume Dry Matter (kg/ha) for Mt Henry Trial in November 2016. There were no significant difference in legume biomass between any treatments (P<0.05).

At McAH plots were dominated with phalaris and ryegrass *(Lolium perenne)* pasture and naturalised clover. None of the legumes under investigation had established on the plots either from the resowing in May 2016 or from seed set in 2015. There was no significant difference of the biomass present on the plots when sampled in November 2016.

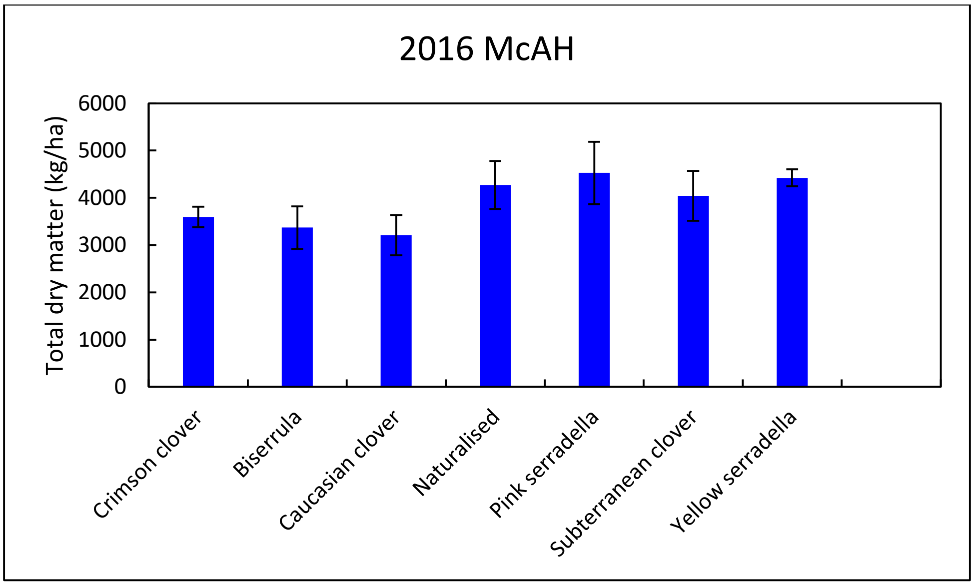


Fig 16: Total Dry Matter (kg/ha) for McAlister Heights in November 2016. There were no significant difference in legume biomass between any treatments (P<0.05).

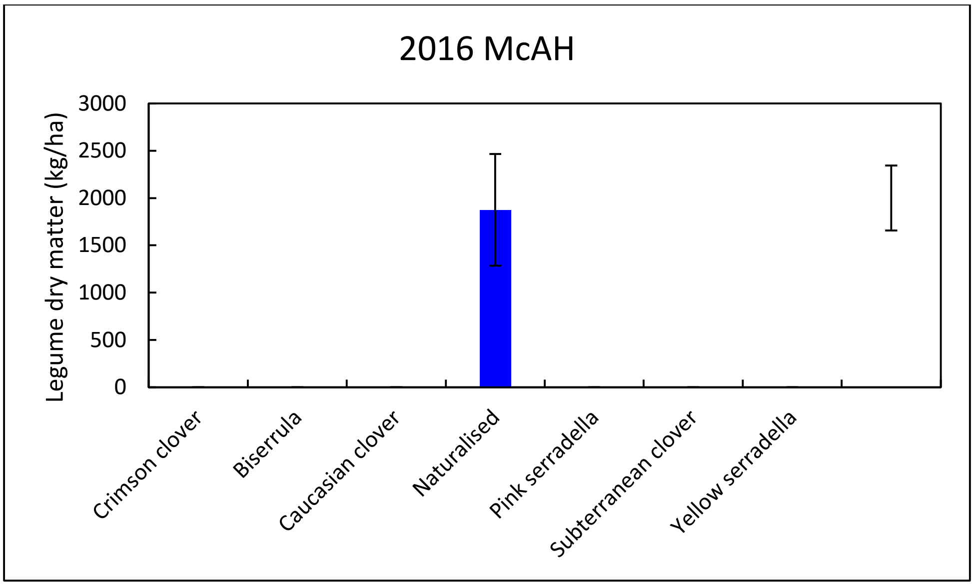


Fig 17: Legume Dry Matter (kg/ha) for McAlister Heights in November 2016.

Figure 18 shows that at Spring Ponds the Yellow Serradella, Pink Serradella and Crimson Clover treatments produced significantly more total biomass than the Biserrula, Caucasian clover, Sub. Clover or Naturalised clover treatments. Sub clover plots produced similar biomass to Biserrula but significantly higher biomass than Caucasian or naturalised clovers.

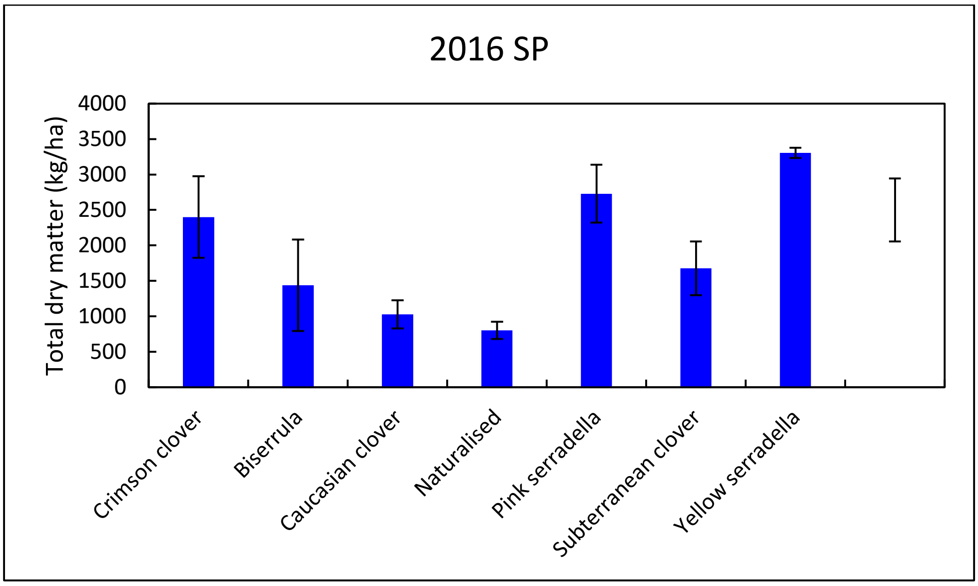


Fig 18: Total Dry Matter (kg/ha) for Spring Ponds in November 2016. The LSD bar on the right hand side of the graph shows that when the difference in yield between two treatments exceeds the LSD then those treatments differ significantly ($P<0.05$)

The pink serradella treatment produced the highest legume biomass which was significantly higher than the Sub clover, and Biserrula, Caucasian or Naturalised clover treatments There was no Naturalised Clover present at the site.

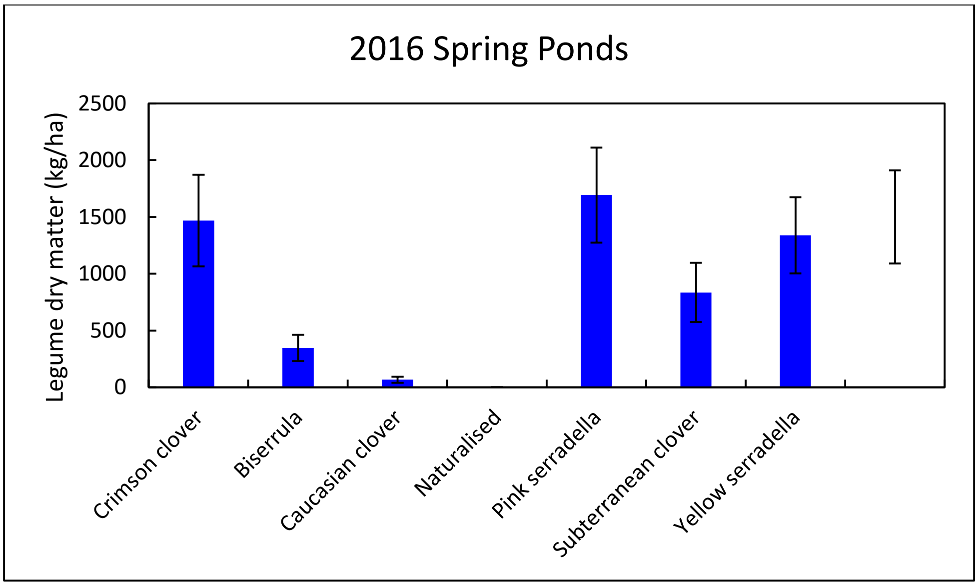


Fig 19: Legume Dry Matter (kg/ha) for Spring Ponds in November 2016. The LSD bar on the right hand side of the graph shows that when the difference in yield between two treatments exceeds the LSD then those treatments differ significantly ($P<0.05$).

Caucasian clover was the only perennial species sown in the plots. Despite hot and dry conditions it was still present in at the high elevation site at McAlister Heights in January 2017. On 12/1/17, legume biomass measurements were made on the Caucasian Clover with blocks 1, 2 and 3 having 240, 340 and 312 kg/ha of legume respectively. There was no evidence of Causcasian clover at the sites at the lower elevations.

Mt Henry Trial and McAllister Heights had pH levels of 4.6 and 4.8. The naturalised clover increased in the plots through the trial despite there being no clover present at sowing in 2015. There was no naturalised clover present at Spring Ponds with a pH of 4.4.

4.2 Extension and communication

Date	Activity	Number of people
February 2014	Crookwell show presentation of research topics	50
June 2015	Crookwell Gazette article raising awareness of the trial	1000
November 2015	Field Day presentation	35
October 2016	TFS Seasonal updating presentation	28
February 2017	Soil Club discussion	30
February 2017	LLS field day presentation	54
October 2017	Field day at McAllister heights involving producers from the Central West LLS	15

4.3 Participant reactions

Producers have shown considerable interest in the results from this trial.

Despite the low production of the Caucasian Clover in the trial plots, several farmers in the high elevation areas of the district are considering using or have sown Caucasian clover in pasture improvement programs as a result of its performance where it has been sown on some properties in the region.

Farmers have used the data from the phosphorus fertiliser application response curve to calculate the quantity of P fertilisers required on light soils.

Producers are considering using a legume forage instead of oats or brassica crops as part of the clean up phase in pasture improvement programs.

Further data will be needed relating to persistence before farmers will be convinced to sow Pink Serradella as a replacement for sub clover in mixed pastures. Due to the plots requiring resowing in 2016 after poor seed set in Spring 2015, and also uncertainty regarding the ability of Pink Serradella to set seed under grazing pressure, producers are understandably cautious regarding the propects of pink serradella becoming a regular addition to new pasture mixes. The TFS group has ongoing involvement in hosting sites for the new P4Pastures project which should give the opportunity to collect further data and experience regarding the persistence of both Pink and Yellow serradella in the tablelands environment.

4.4 Producer research site program

Group members influenced the inclusion of fodder type legumes so these could be used in the clean up phase of pasture improvement programs. Crimson clover was added as a treatment as a result of this request.

The group initially applied to run a project to identify which phosphorus soil test (Colwell, Bray or Olsen) best predicted available phosphorus when fertilisers other than superphosphate were applied to the light acid soils in the district. This project proposal was not accepted by MLA on the basis that it was not well enough aligned with the core research in the FIP and the group had to progress an alternative project which was accepted. There is stll a strong desire of the membership to have this original question answered.

A problem, possibly unique to the operation of this project, was the difficulty in obtaining resources. Access to a cone seeder, drying ovens and laboratory space was offered by NSW DPI at the start of the trial but due to restructuring of the organisation, the offer was withdrawn. Research and biometrical advice was only obtained after constant requests for assistance. The nominated researcher did not have any contractual obligation to assist the group and naturally prioritised time toward projects where contractual obligations had to be met. This aspect of the program needs to be addressed in any future PRS work. There needs to be a clear agreement between MLA, the group and the researcher assisting the project.

5 Discussion

5.1 Outcomes in achieving objectives

The legume species under investigation germinated and produced biomass in all of the trial sites however they failed to set seed well in 2015 or regenerate in the subsequent season.

In trial 1 the best performing legumes averaged across both P treatments were Pink Serradella and Biserrula in 2015, but in 2016 Crimson clover and Sub clover produced significantly more legume biomass. While the first year indicated some promise for Biserrula and pink serradella, their poor performance in the very wet conditions of winter 2016 confirm that they do not tolerate waterlogging well. Despite producing significant biomass in spring of 2015, seed set was poor and there was no regeneration of these species observed in the trial plots in February 2016.

Caucasian clover did not produce high amounts of biomass at any of the sites. It performed best in trial 2 at McAllister Heights, suggesting a better adaptation to the basalt derived soil at this site. While Caucasian clover was still present in the trial plots in January 2017 the competition from a relatively large growth of other species made a meaningful measurement of Caucasion clover presence / persistence impossible in March 2017 . Local producer experience of the Caucasian clover persisting and spreading over time as well as it's ability to produce green herbage over summer unlike sub clover and serradella, means that it remains a species of interest for the Tableland Farming Systems group

Pink Serradella consistently matched or exceeded the legume biomass produced by the sown Leura or the Naturalised Sub Clover treatments in trial 2 at Mt Henry Trial and at Spring Ponds and also in the first year of Trial 1 at Mt Henry Cultivation. While the species appears adapted to grow in the Tableland environment there is insufficient data to give confidence that the species will persist past the year of sowing. While seasonal conditions in early autumn 2017 meant no persistence measurement was able to be done before the conclusion of these trials Pink Serradella was observed to have regenerated to some extent by May 2017 at the Mt Henry Trial and Spring Ponds sites where they had previously performed well in terms of biomass.

The naturalised clovers germinated and persisted at Mt Henry Trial and McAllister Heights. At McAllister heights the naturalised clover was the only legume to establish in the 2016 growth season. The soil pH was favourable for sub clover growth and the addition of a small amount of phosphorus proved sufficient to encourage better growth.

The trial also indicated that on these low PBI soils only 15 kg of phosphorus was required to obtain a 10 mg/kg rise in the Colwell P soil test. This soil P response is around double those reported by Havilah et al (2006) who found 33 kg of P was needed to raise the Colwell P by 10 units on low to medium PBI soils at Camden NSW. It is also disagrees with Simpson et al (2009), who's soil P model using data from Burkitt et al.2001) suggests 27 kg P would be required to increase Colwell P by 10 mg/kg on soils of a similar PBI to the current trial. This data suggest that the commonly used soil P responsiveness algorythms may need review but further work using a wide range of P rates on local soils should be conducted to confirm this apparent high soil test P response. Work currently being conducted by CSIRO should shed further light on this issue;(Simpson pers comm).

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

The objective of this research was to determine the adaptation of a range of more P efficient legumes to the Tableland environment. Data collected would be insufficient to perform any robust economic analysis. The biomass on the plots included many weedy species and overall biomass production was not well correlated with increased legume production which would confound the impact of the new legumes on animal production even if the trials had been grazed.

The relative cost of adopting the new legumes is comparable with the cost of optimally managing the existing legume base. To optimise soil fertility and pH for sub clover production would require considerable capital input of lime and superphosphate. At current prices of lime and superphosphate, to raise Colwell P from 5 to 35 and pH from 4 to 5 would cost in the order of $250/ha.

By comparison, to add sufficient fertiliser to raise the Colwell P from 5 to 20, the critical P level for Pink Serradella, would cost $50/ha with no need to correct pH. At a sowing rate of 10 kg/ha the cost of Pink Serradella seed would be around $200/ha. Farmers would need to be confident that plants would persist for many years under grazing pressure to get a return from the introduction of this alternative legume.

5.3 Promotion of research results and its effectiveness

There was a considerable amount of interest to the operation of the trial when presentations were made at farm meetings and updates. The three farmers that provided the sites were watching the plots very closely and could see value in the trial.

Unfortunately, wet weather precluded site access caused the cancellation of the field day in spring 2016 planned to highlight the alternate legumes that did perform in the region. However a field day was held in October 2017 in conjunction with the Central West Local Land Services and a delegation of farmers in October 2017.

The trial raised awareness of the production losses resulting from the low fertility and increased acidity of the farms in the area. The success of Pink Serradella, a legume that will be more productive than subclover in these conditions, made farmers consider their options to use an alternative legume or improve the fertility of the farm but a variety with improved persistence will need to be identified.

5.4 Effectiveness of the participatory research process

Producers were kept informed at regular TFS farmer updates and newsletter items. Results were presented to the group at the Annual General meeting.

The group were able to advise that Yellow Serradella and Biserula were not going to perform in the district. Further work will be required to demonstrate the success of Pink Serradella and Caucasian Clover under grazing on a paddock scale.

The farmers that provided the trial sites showed considerable interest in the trial, especially where Caucasian Clover was showing promise since pasture legumes for these higher altitude tabland environments would ideally be perennial.

The increased production on the plots, even with just a small addition of fertiliser demonstrated the value of adequate fertilisation on native pastures was also noted.

6 Conclusions/Key messages/Recommendations

Further work needs to be performed to identify a variety of Pink Serradella that would tolerate the water logged conditions that sometimes occur in the tablelands environment and which will seed and recruit reliably in a grazed pasture. A similarly productive but more reliably persistent cultivar would be a useful addition to the suite of species available for low P and low pH tableland soils.

Application of capital rates of fertiliser would improve conditions for growth of the naturalised sub clover present on many properties in the region.

It is apparent that soils in the project region may have a higher than expected response rate to applied superphosphate. If confirmed this would mean lower capital fertiliser requirement to lift soil P to critical levels. Lower rates of fertiliser P required to optimise production should lead to significantly higher P efficiency than if fertiliser was applied in accordance with standard recommendations. Further exploratory trials are being conducted by CSIRO to identify whether variations from the expected response curve is reliable and also prevalent in other areas.

7 Bibliography

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Simpson R., Oberson A., Culvenor R.A., Ryan M., Veneklaas E., Lambers H, Lynch J., Ryan P., Delhaize E., Smith A., Smith S.E, Harvey P. and Richardson A. (2011). Strategies and agronomic interventions to improve the phosphorus-use efficiency of farming systems, Plant Soil (2011) 349:89–120.

8 Appendix

8.1 Expression Of Interest

Potential for Phosphorus Efficient Legumes

The TFS has been awarded a Meat and Livestock Australia (MLA) funded project to investigate the potential for phosphorus (P) efficient legumes as an alternative to sub clover.

Expressions of interest are sought from TFS members to participate in the research project.

The Project

The aim of the trial is to identify which alternate phosphorus efficient legume species will establish, survive and produce best in the Southern Tablelands environment at different fertility levels and on different soils types.

The trial will run for three years. The plots will be sown in autumn 2015 but it is expected that site screening and preparation will start immediately.

The species under investigation include Caucasian clover, Yellow Serradella, French Serradella and Biserrula. To test the production and survival of the alternate species, subterranean clover cultivars known to persist in the district will be sown as part of the trial.

These species will be sown as a pure stand or as a component of a native or improved pasture in replicated 10 x 2 metre plots.

Field days will be held on the trial sites each year of the project.

Trial Sites

The selection of the site is an important factor in the success of the project. Suitable sites will need to have low to moderate P fertility, north or east aspect, flat to undulating slope and easy access for ongoing trial work and field days.

Research Team

The project leader for the project is Phil Graham from the Department of Primary Industries. Phil is well known for his role as a sheep extension officer and his interest in grazing systems in the Southern Tablelands.

Helena Warren from Binda has been appointed as the trial’s project officer. She will be responsible for the ongoing management and collection of data and samples. Helena was formerly employed by NSW DPI conducting research in nutrition, genetics and phosphorus fertiliser use. She was the officer in charge of the Feeds Evaluation Service.

Richard Simpson is from CSIRO Canberra. His research spans a broad area of pasture systems agronomy including issues of pasture management, botanical composition, feeding value forages for livestock, plant nutrition and fertiliser use.

Farmer Responsibility

The participating farmer will need to provide a fenced site of approximately one ha suitable for the research. Fencing materials will be provided.

Stock will need to be excluded but grazing for a short period is permitted once pasture measurements and samples have been taken following consultation with the project officer.

The farmer will need to work closely and communicate with the research team.

The farmer will not be expected to take measurements from the site, but is welcome to be part of the research process during the period of the trial.

An annual field day will be held on the site.

Site Screening

The success of the project relies on choosing a site with known soil fertility. Sites nominated for the trial will be characterised for physical and chemical characteristics.

Soil tests will be performed on suitable sites to determine if the site is included in the trial.

Further Information and Nomination

Please contact Helena Warren if you are interested in nominating your property for the project. She will discuss any questions you have about the farmer responsibility, soil testing and inclusion in the trial.

Helena Warren
Phone 4835 6220 Mobile 0414 860 502 Email helena@cadfor.com.au

8.2 Climate data

8.2.1 District rainfall 2015 and 2016

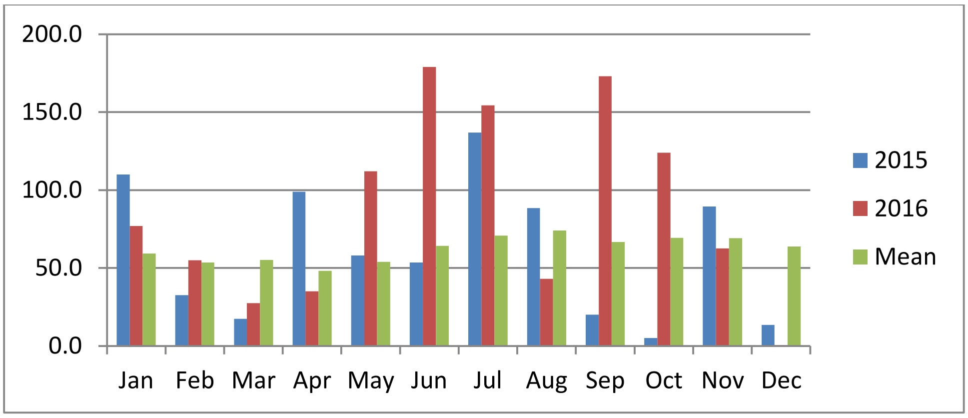


Fig 20: Rainfall for Mt Henry, Binda 2015, 2016 and mean

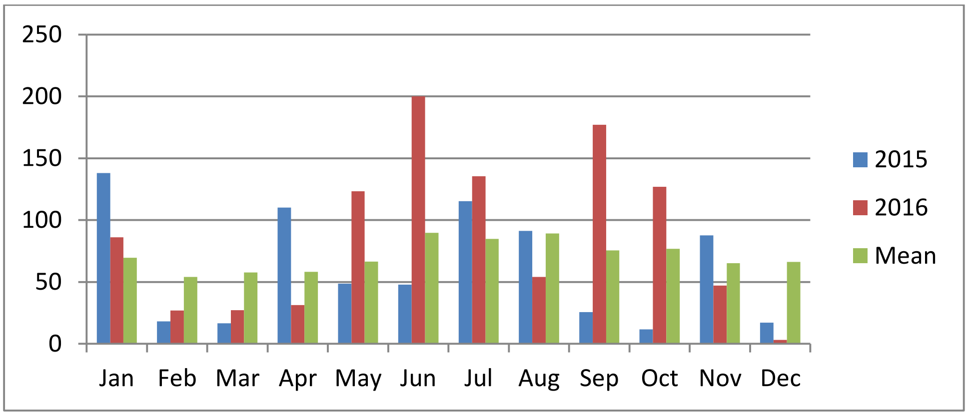


Fig 21: Rainfall for McAllister Heights, Laggan 2015, 2016 and mean

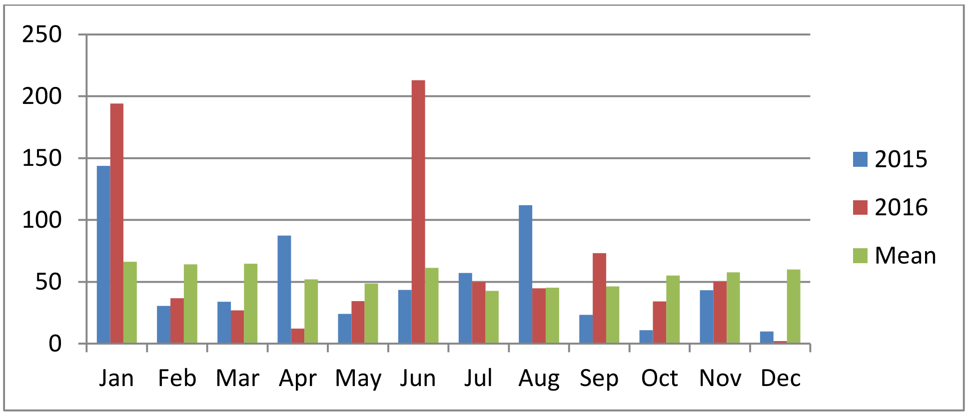
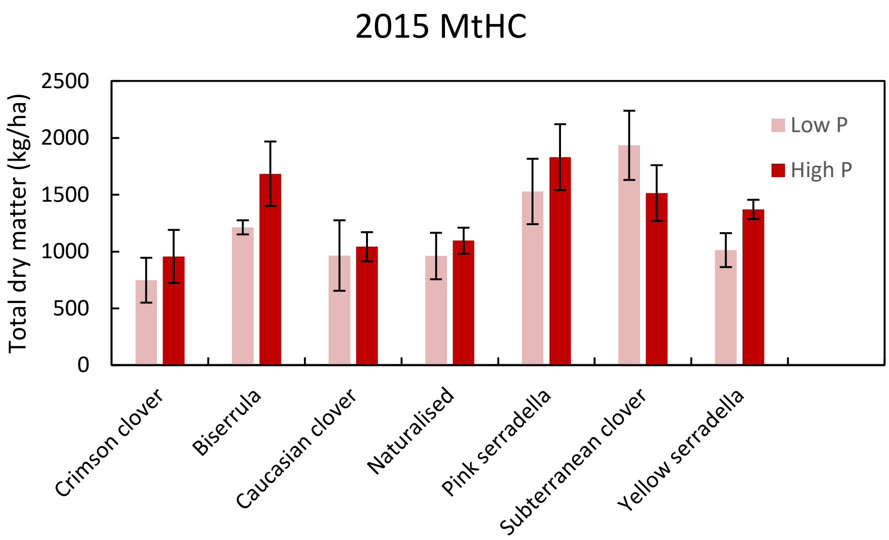
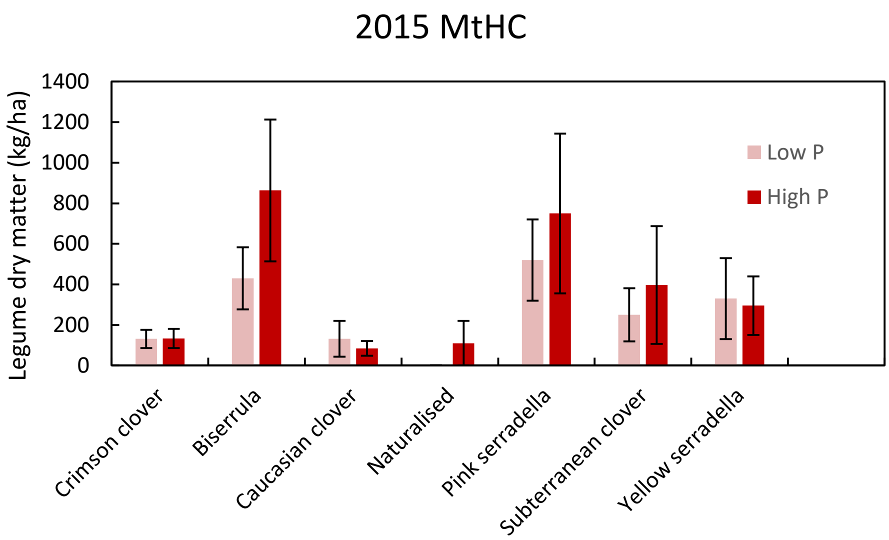
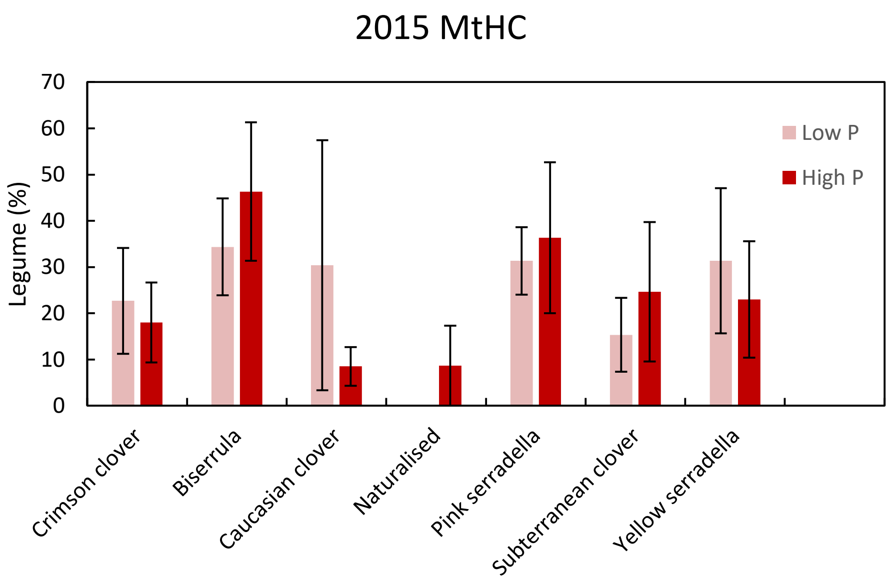


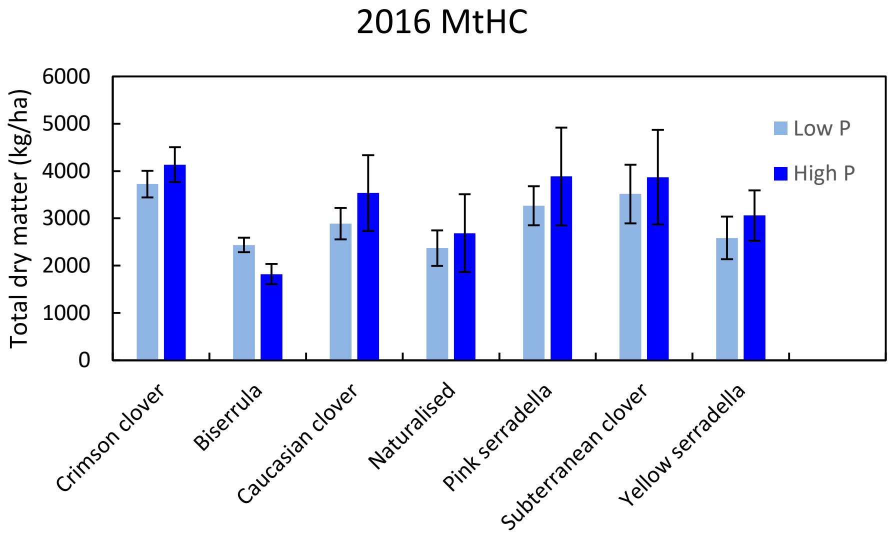
Fig 22: Rainfall for Spring Ponds, Bungonia 2015, 2016 and mean

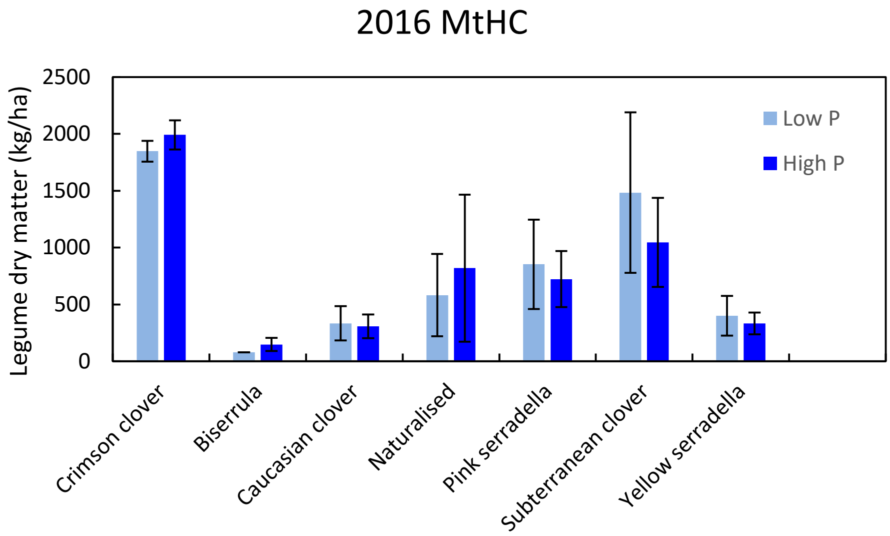
8.3 Statistical Analysis Graphs Trial 1 MtHC High and Low Fertiliser

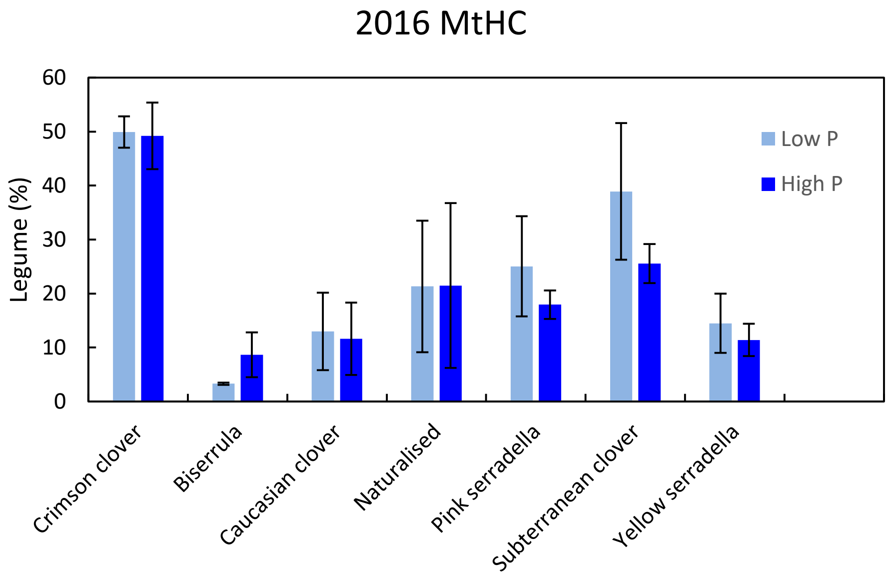







2016 MtHC
Total dry matter (kg/ha)
6000
5000
4000
3000
2000
1000
0
Low P
High P
Crimson clover
Biserrula
Caucasian clover
Naturalised
Pink serradella
Subterranean clover
Yellow serradella


2016 MtHC
Legume dry matter (kg/ha)
2500
2000
1500
1000
500
0
Low P
High P
Crimson clover
Biserrula
Caucasian clover
Naturalised
Pink serradella
Subterranean clover
Yellow serradella


2016 MtHC
Legume (%)
60
50
40
30
20
10
0
Low P
High P
Crimson clover
Biserrula
Caucasian clover
Naturalised
Pink serradella
Subterranean clover
Yellow serradella