Final report

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Establishing persistent and productive new legumes

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Executive Summary

This producer participatory R&D project aimed to identify the value of alternative legumes (based on their establishment success, persistence and production) compared with the traditional legumes that are used in the Monaro region of NSW and the effectiveness of sowing these new legumes into existing pasture swards to increase pasture and animal production. It also evaluated the role of sowing time on legume performance and persistence.

In addition this project aimed to document nodulation status and occupancy of subterranean clovers in the Monaro region to understand the current level of rhizobium performance and associated factors that may be limiting this performance.

MFS has identified pasture legumes and soil nitrogen as a major driver of production for producers on the Monaro. Low legume content pastures is estimated to affect >50% of Monaro farms. The widespread lack of legume nitrogen constrains pasture and animal productivity and restricts responses to phosphorus fertiliser applications as well as inhibits plant water use efficiencies.

Due to weed invasions and existing pasture dominance at two of the sowing sites, many of the sowing treatments could not be statistically analysed. However these trial sites served to re-inforce several key messages around legume establishment in permanent pastures which has applicability and benefits to all Monaro graziers.

These included the paramount importance of paddock preparation, weed control and managing competition to give legumes continual space, light, adequate soil moisture and seed soil contact to establish successfully and persist. Chemical treatments such as glyphosate and gramoxone used to “set-back” existing pasture to allow legumes to establish proved ineffective and sowing legumes directly into an existing perennial pasture proved unsuccessful and resulted in no long term legume establishment.

Significant weeds inhibiting the successful establishment of permanent pasture on the Monaro include bent grass, vulpia, and sorrel and a minimum of three years absolute weed control is required when considering sowing a new pasture.

At the Gaerloch site serradella and white clover proved the most successful species in terms of establishment and regeneration but both were not able to persist long term. Balansa and biserrula also did have some establishment success at this site.

For the statistically analysed data at the Kyleston site, the following results were obtained:

In terms of germination, there was a significant effect of species ($p<0.001$), sowing time ($p<0.001$) and species by sowing time ($p=0.02$) on germination. Overall, balansa clover sown in autumn had significantly higher germination than all other species (357 plants/m^2). Summer sowing generally resulted in less than 10 plants/m^2 germinating. Within species, sowing time did not have a significant effect on germination except for biserrula where germination was significantly higher in spring than in autumn.

In terms of herbage production, there was a significant effect of species ($p<0.001$) and species by sowing time ($p=0.02$) but not of sowing time alone ($p=0.11$). Arrowleaf clover and French serradella (summer and autumn sown), balansa clover and subterranean clover (autumn sown) were the best performing species, all producing more than 1500 kg DM/ha.

The autumn sown sub clover showed the strongest regeneration compared to all the other species (124 plants/m^2) adding evidence to the common belief that this legume remains the best adapted legume on the Monaro in terms of persistence. The spring sown arrowleaf was the second best performer in terms of regeneration with 31 plants/m^2.

Overall the results suggest that arrowleaf clover, balansa clover and French serradella may have a role in pasture systems on the Monaro with comparable results to sub clover.

However, producers should be aware of the high cost of dehulled seed of serradella required for autumn sowing and alternatively, the high sowing rates (20-30 kg pod/ha) needed for summer sowing using the much cheaper "pod" establishment option. The on-going trial work at two more Monaro sites (as part of the MLA led Rural R&D for Profit project on P Efficient Pastures) comparing the performance of the serradellas with sub clovers in a grass pasture mix will continue to add data to support the case for this species.

No spring sown treatment exceeded 800 kg DM/ha and for bladder clover, gland clover and biserrula, this was less than 160 kg DM/ha and as such, spring sowing of legumes of Mediterranean origin should not be attempted in the Monaro region.

Caution should be exercised when drawing too many conclusions from a trial with only one years' sowing time data due to the highly variable effects of season on results. Ideally further replicated trials with a full three to five year data set would add much needed validation to back up these preliminary findings.

The nodulation survey highlighted the sub-optimal levels of legume nodulation and N-fixation present across the Monaro with the survey establishing a benchmark of 2.6 average paddock nodule score (from 54 sites) out of a possible score of 8.
The most current strains of legume rhizobia were found in just over 80% of the legumes plants tested and older strains of rhizobia were found in the remaining 19% of samples.

There are many different characteristics influencing the nodulation and N-fixation capacity of the legume plants studied. These characteristics vary within paddocks and include available soil nutrients such and phosphorus and sulphur, soil pH, waterlogging and previous herbicide use.

Further research and evaluation work is needed into the areas of re-inoculation of old pasture paddocks with more efficient and productive rhizobia, correction of key soil constraints and residual herbicide impacts to evaluate the most effective strategies to manipulate nodulation and N-fixation which underpin and drive increases in pasture productivity.

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1 Background

1.1 Monaro Farming Systems

1.1.1 Addressing the problem with pasture legumes

The Monaro Farming Systems (MFS) group was established in 2007 by a progressive group of local innovative producers with Industry support with an aim to build capacity and continuous improvement in the Monaro grazing Industry. Over the previous eight years, MFS has grown from strength to strength and now consists of 63 farm businesses which equates to over 200 individuals.

The MFS group collectively manages 123,988 hectares on the Monaro and is responsible for approximately 40% of total production. Members run approximately 375,500 sheep and 25,000 head of cattle, produce on average 1,875,845kg of wool per year and turn off over 2,500,000 kg of sheep meat and 4,207,000 kg of beef annually.

Low legume content pastures is estimated to affect >50% of Monaro farms with the largest issue on black/basalt-derived soils which comprise about 25% of the Monaro. Newly established sub clover may only persist at high density for 3 or so years on these soils. The widespread lack of legume N is likely to limit productivity, to restrict responses to fertiliser applications, result in poor water-use efficiency and require higher inputs of N fertiliser in dual-purpose crop enterprises.

The MFS group were keen to trial the performance of alternative legumes versus traditional legumes in terms of establishment, production, feed quality and persistence thereby potentally identifying legumes that may be better adapted to the Monaro climate.

2 Projective Objectives

2.1 Project Objectives

1. Identified the value of alternative legumes (based on establishment, persistence and production) compared with traditional legumes used in the Monaro region of NSW.
2. Evaluated the role of sowing time on legume performance and persistence.
3. Investigated how alternative legumes can be sown into existing pasture swards to increase pasture and animal production, using alternative strategies.
4. Completed a survey to quantify nodulation status and occupancy of the Southern Monaro and identify a baseline for this region.
5. Evaluated the role of associative factors that affect nodulation such as soil pH, Soil P and S, root pathogens, chemical applications, pasture age etc to inform further trial work on methods to manipulate legume nodulation in existing pastures to drive increased pasture production.

3 Methodology

3.1 Research Sites

The pasture trial component of this project was initially conducted at two sites on the Monaro tablelands in the Bombala (Site 1, Sth Bukalong) and Cooma districts (Site 2, Gaerloch).

Due to challenges experienced at both these sites, a project variation was approved half-way through the project term to sow an alternative site in the Bombala district (Site 3, Kyleston) as well as re direct resources from Site 2 to conduct a legume nodulation survey (Site 4) on 54 sites along a North / South transect of the Monaro (**see meta data storage template**).

Pasture sites were initially selected, characterised and sown with their respective treatments. Soil nutrient testing was undertaken prior to sowing.

A grazing record sheet and weed control guide was developed by Luke Pope (SE LLS Agronomist) and given to site co-operators. **See Appendix 1.**

Grazing is to be a "crash" grazing strategy, with the gate shut and a large number of animals for short periods to prevent selective grazing and to reduce pasture height to an agreed level. A window of at least 6 weeks post grazing will be needed before measurements are taken to allow pasture to recover.

After each assessment was performed, Doug Alcock calculated a Feed Budget to advise hosts on future grazing capacities.

The following measurements were taken where applicabale for each of the sites;

- Pasture biomass (dry matter production) assessments (botanal approach)
- Pasture composition (using botanal)
- Ground cover will be estimated for each quadrat using the botanal process
- Grazing days, time of grazing and number / type of stock recorded

The timing of the measurements allowed for the assessment of feed accumulation before winter, the peak production potentials and the duration of the summer growth periods.

Pasture Walk – Dec 2014, Sth Bukalong

Luke Pope, SE LLS sowing legumes with cone seeder into the glyphosate sprayed plots – Sept 2014

Site 1 (Sth Bukalong) characterisation

Paddock history - CURTIN Paddock (5.5 ha)

- originally Native (Poa tussock & Stipa majority)
- 1978 was disced then cropped to sunflowers and under sown at 2 pd/acre with each of the following species: Hunter River Lucerne, Woogenallup sub clover, Australian Phalaris & Currie Cocksfoot in with a bag of double super to the acre.

Fertliser history

80kg/ha single super every third year since sowing (1978)
- 1999 single super 100kg/ha, then same again in 2000.
- June 2004 applied TNN FCMP @100kg/ Ha,
- Aug 2007 applied TNN FCMP @ 61kg/ Ha,
- May 2014applied TNN FCMP @ 124kg/Ha

[TNN FCMP consists of P 11.2% , 10% Mag, 24% Ca, 12% silicon, & 0.25% sulphur with trace elements 800ppm Boron, 4000ppm manganese, 40ppm zinc, 250ppm nickel, 60ppm cobalt, 5ppm copper & 10ppm molybdenum.]

General

-Nearly 50% saffron thistle and rest cocksfoot at the end of the 2008 drought.
-Now 100% groundcover, 25%+ basal cocksfoot plants, rest clover, litter or dung
-Split into 5.5ha in 2009 from 17 Ha (Winston paddock)

-Been holistic grazing for last 10 years now, sheep all gone in 2010, now just cattle

- Soil test - collected 30th July 2014 (**see meta data storage template**)
- Soil type (classification) – granite derived
- Pasture species / composition - Heavily dominated cocksfoot, black thistle (minor), poor legume
- Ground cover - 95%
- Aspect - North East
- Slope - 10%
- GPS - 55° 691 753 E / 59° 199 39 N
- Photos – See **Appendix 2**

Site 2 (Gaerloch) characterisation

- Soil test - collected 21st July 2014 (**see meta data storage template**)
- Soil type (classification) – Granite / podosol
- Pasture species / composition - Chemically fallowed prior to sowing trial, 20% weed cover
- Ground cover – bare with 20% weed
- Aspect - West
- Slope - 5%
- Photos – see **Appendix 3**

Site 3 (Kyleston) characterisation

- Soil Test – collected 15th January 2016 (**see meta data storage template**)
- Soil type (classification) – Granite / podosol
- Pasture species / composition - Chemically fallowed for 18 mths prior to sowing trial
- A native paddock with a history of high weed infestations.
- Ground cover – bare with small amount dead trash
- Aspect – North West
- Slope - 10%
- Photos – see **Appendix 4**

Site 4 – Survey of 54 sites across the Monaro (**see meta data storage template**)

3.2 Treatments

Site 1 – South Bukalong

Trial Site 1 was prepared (August 2014) and sown on the 2nd of September 2014. Paddock preparation included; 1L/ha Glyphosate 450 applied on the 1st of August 2014 and 1L/ha Gramoxone 250 applied on the 31st of August (see site map – **meta data storage template**).

The treatments were direct drilled using a cone seeder into 1500kg DM/ha cocksfoot and sub clover on the 2nd September 2014 along with 125kg DAP.

Good soil moisture was present at sowing and approximately 5mm of rain fell on the day of sowing.

The following treatments were applied in a randomised plot design (11 treatments, 3 replications, 3 spray preparation treatments, 99 plots). The spray preparation treatments included gramoxone, glyphosate and no spray.

Treatment 1
12kg Atom Prairie Grass, 7kg Margurita French Serradella, 3kg Prima Gland Clover
Treatment 2
12kg Atom Prairie Grass, 7 kg Casbah Biserrula
Treatment 3
2kg Holdfast GT Phalaris, 7kg Margurita French Serradella, 3kg Prima Gland Clover
Treatment 4
2kg Holdfast GT Phalaris, 7 kg Casbah Biserrula
Treatment 5
10 kg Casbah Biserrula
Treatment 6
7kg Margurita French Serradella, 3kg Prima Gland Clover
Treatment 7
12kg Atom Prairie Grass, 5kg Aurora Lucerne
Treatment 8
2kg Holdfast GT Phalaris, 5kg Aurora Lucerne
Treatment 9
7kg Aurora Lucerne
Treatment 10
7kg Stamina Lucerne
Treatment 11
Nil
+ Alosca inoculant (S, BS, C)

Grazing

- 1st grazing - 154 heifers (350kg) for 8 hrs on the 2nd March 2015.

Botanal assessments were conducted on the following dates;

- A germination/establishment assessment was done on the 5th of Nov 2014
- A botanal assessment was done on the 16th December 2014
- A botanal assessment was done on the 10th June 2015

Doug Alcock – GrazProphet – establishment assessment

Trial Site 1 – ADDITIONAL SITE

A SECOND trial site was prepared to give additional data for some of the legumes trialled in Trial site 1 and to reallocate the resources from the "assessment budget" due to the failure of legumes to establish in the "gramoxone" and "nil spray" prepared plots.

This second trial site was slashed in Dec 2014.

Preparation - 1L/Ha Glyphosate 450 Applied Jan 15th and 28th Feb 2015

The 1st sowing took place on the 6th March 2015 and the second sowing on the 30th April (6-8 weeks later).

The treatments were direct drilled using a commercial seeder along with 125kg DAP.
Good soil moisture was present at both sowing dates however little rain was received in the 5 weeks following the sowing on the 6th March but then significant rainfall was received (approx.100mm) 2 weeks prior to the sowing on the 30th of April.

See site map – **meta data storage template**

Treatment 1
10kg/ha Margurita French Serradella
Treatment 2
10kg/ha Casbah Biserrula
Treatment 3
10kg/ha Gland clover
Treatment 4
10kg/ha Bladder clover
Treatment 5
10 kg/ha GT Stamina lucerne
Treatment 6
10kg/ha sub clover
+ Alosca inoculant (S, BS, C)
+ Fertiliser – 125kg DAP

Unfortunately due to slug damage, lack of soil moisture or site preparation issues (sowed into large amount of trash), establishment was very poor for both these sowings so no assessments were warranted.

Following a phone hook-up on the 13th August 2015 with Oli Cay and Nancy Spoljaric (MFS), Doug Alcock (State Coordinator), Irene Sobotta (MLA) and with prior approval from researcher Belinda Hackney, the decision was made to disband this Trial Site 1 and re sow at a neighbouring site "Kyleston" (same soil type).

Site 3 – Kyleston

Paddock preparation included two years of spray / fallow.

Compare seven (7) legume varieties at 3 sowing dates;

- ❖ spring (scarified seed)
    - sown 16th September 2015
    - sowing rate 10kg/ha + DAP @ 100kg/ha + alosca (10kg/ha)
    - plots sprayed out with powermax (glyphosate) day before sowing
- ❖ summer (in-pod/un scarified)
    - sown 3rd February 2016
    - sowing rate 15-30 kg/ha + DAP @ 100kg/ha + alsoca @ 10kg/ha
    - plots sprayed out with powermax (glyphosate) 3rd Dec 2015 and 31st Jan 2016
- ❖ mid autumn sow (scarified seed)
    - sown May 4th 2016
    - sowing rate 15kg/ha + DAP @ 100kg/ha + alosca (10kg/ha)
    - plots sprayed out with powermax (glyphosate) a week prior

- ➢ Species in the "spring" sowing included A*rrowleaf clover, Santorini Yellow Serradella, Casbah Biserrula, Prima Gland* and *Bartolo Bladder clover.*
- ➢ Species in the "summer" sowing included A*rrowleaf clover, Avila Yellow Serradella, Casbah Biserrula, Prima Gland* and *Bartolo Bladder clover and Margarita french serradella*
- ➢ Species in the "autumn sowing included A*rrowleaf clover, Santorini Yellow Serradella, Casbah Biserrula, Seaton Park Sub, Margarita french serradella* and *Bartolo Bladder clover and Balansa Bolta*

All sowings were prepared as follows;

- ➢ The site was sprayed out with powermax (glyphosate) @ 1L / ha the day prior to sowing.
- ➢ The site was prepared using a rotary hoe.
- ➢ The seed was weighed, bagged and pre-mixed with the relevant group alosca rhizobium innoculant prior to spreading by hand.
- ➢ Fertiliser was also weighed and bagged per plot and spread by hand.
- ➢ The sown plots were then lightly raked.

Treatment 1
10kg/ha Margurita French Serradella (summer, autumn)
Treatment 2
10kg/ha Casbah Biserrula (spring, summer, autumn)
Treatment 3
10kg/ha Bartolo bladder clover (spring, summer, autumn)
Treatment 4
10kg/ha Prima Gland clover (spring)
Treatment 5
10 kg/ha Santorini Yellow Serradella (spring, summer, autumn)
Treatment 6
10kg/ha Arrowleaf (spring, summer, autumn)
Treatment 7
10kg/ha Sub clover (autumn)
+ Alosca inoculant (S, BS, C) + Fertiliser – 125kg DAP
For Site Map – see see meta data storage template

Botanal assessments were conducted on the following dates;

- Establishment data – November 2015
- Seeding data – January 2016 (for spring sown legumes)
- Re-establishment assessment - 19th July 2016
- Establishment data – August 2016 (for summer and autumn sown legumes)
- Re-establishment assessment - 19th September 2016
- Spring biomass – 7th November 2016
- Re-establishment data – April 2017

Feed Quality Tests - see meta data storage template
-November 2016

Arrowleaf – summer sown, photo taken 4th May 2016

Trial Site 2 – Gaerloch

Trial site was sprayed out on the 7th of April 2014 and pegged and sown with treatments (7 pasture mixes, 3 replicates) on the 10th of April with the assistance of a NSW DPI cone seeder and operator.

Paddock preparation included;

- cultivation and summer fallowed;
- Sprayed with 3L Glyphosate 450 and 100mL Fastac Duo on 7 April 2014.

The trial was sown into excellent soil moisture with 21 mm of rain falling during the week following sowing. Soil Temperature at 10mm below surface was 17.5 C.

The following treatments were applied in a randomised plot design (7 treatments, 3 replications, 21 plots). – **Site Map - see meta data storage template**

Treatment 1
0.5kg Phalaris, 0.5kg Fescue, 3kg Perennial Ryegrass, 6kg Sub Clover, 0.5kg White Clover
Treatment 2
2kg Phalaris, 4kg Fescue, 9kg Sub Clover, 1kg White Clover
Treatment 3
2kg Phalaris, 4kg Fescue, 5kg Lucerne
Treatment 4
2kg Phalaris, 4kg Fescue, 6kg Sub Clover, 0.5kg white Clover, 3kg French Serradella, 1kg Gland Clover, 1kg Biserrula, 0.5kg Balansa, 1kg Lucerne
Treatment 5
2kg Phalaris, 4kg Fescue, 7kg French Serradella, 3kg Gland Clover
Treatment 6
2kg Phalaris, 4kg Fescue, 7kg Biserrula
Treatment 7
2kg Phalaris, 4kg Fescue, 3kg Gland Clover, 3kg Balansa

+ Alosca inoculant (S, BS, C)

- Trial area fenced June 2014.
- Feed quality tests were taken and analysed in November 2015
- Grazing was conducted on the following dates;
    - ✓ 16th of Sept 2014 - 160 lambs (2 hrs)
    - ✓ 5th Feb 2015 - 377 ewes (36 hrs)
    - ✓ 22nd Feb - 95 wethers for 1 ½ weeks (until 4th March 2015)

Botanal assessments were conducted on the following dates;
- Establishment data Nov. 2014
- Botanal 15th Jan 2015 - inc. qualitative data on seed set
- Botanal 9th June 2015
- Botanal 9th November 2015

Variation in schedule

A decision was made in consultation with MLA, Researchers and Coordinators (phone teleconference 29th January 2016) to also discontinue any further measurement at Trial Site 2 (Gaerloch) and reallocate resources to conducting a legume nodulation survey on the Monaro in Spring 2016.

Trial Site 4 - Monaro Legume Survey

Design and sampling protocol - see meta data storage template

Sampled 54 sites;

- 29th April 2016 – survey was designed and emailed to MFS membership and Monaro producers to select suitable sites (**see Appendix 5)**

- Sites were sampled in Spring 2016 (Sept / October). Site methodology included;

    - A 20m X 20m grid was established on a representative area within the selected site (paddock).
    - A GPS reading was taken at centre of the grid.
    - Soil samples (0-10cm) collected and bulked together for a site sample.
    - Pasture composition was assessed.
    - “Chunks” of pasture & soil collected and taken away to equate to the removal of approximately 15 legume plants.
    - A site history was recorded and photos were taken at fixed points.

- The plants were then washed to expose roots and each of the 15 plants per site assessed for nodulation score using standard guidelines (Jo Powells did scoring for all sites to ensure consistency of approach).

- Samples were then sent to Monash University laboratory (Dr Sofie DeMeyer) for analysis of nodule occupancy.

- December 1st 2016 – preliminary results were presented at a MFS Field Day to 50 participants.

- March 20th 2017 – Final Field Day and results distribution.

3.3 Monitoring

Site 1 – South Bukalong, Bombala

Monitoring was performed by the following activities;

-soil tests, pasture cuts, quadrant sampling (calibration regressions), botanal assessments, pasture compostion assessments, feed quality tests, photographs

Site 2 – Gaerloch, Counteginny

As above

Site 3 – Kyleston, Bombala

As above

Site 4 – Monaro district

Not applicable

3.4 Statistical analysis

Results from the initial hardseeded annual legume sowing trials were not statistically analysed owing to failure of many of the sowing treatments. Statistical analysis was only performed for Site 3 (Kyleston) and is included in the Results section.

3.5 Extension and Communication

The extension and communication activities conducted throughout the project are listed below.

Progress / Annual Review meetings

- 15th of July 2014 (progress meeting)
- 28th of October 2014 (annual review teleconference)
- 16th of December 2015 (annual review meeting)
- 29th of January 2016 (teleconference between MLA and MFS to discuss variation in schedule to approve legume nodulation survey)
- 22nd of April 2016 in Cooma (planning meeting to discuss legume nodulation survey)
- 29th November 2016 (annual review teleconference)

Pasture Walks / Site Visits / Field Days

- Belinda Hackney 9th Dec 2014 – site visit – Sth Bukalong site
- Belinda Hackney and Jo Powells 18th Dec 2014 – site visit and pasture walk – Sth Bukalong site
- Doug Alcock gave a presentation of the MFS Legume Trial at the MLA Pasture Update field day on the 7th of May 2015 in Nimmitabel. – estimated 60 attendees – **see Appendix 11**

- Luke Pope (SE LLS) 4th July 2015 – Field Day for approximately 25 participants. Topics discussed included legume agronomics, characteristics of the trial legumes, trial results and weed and ground cover management – Gaerloch site
- Field Day on the 1st December 2016 for 50 participants to present preliminary results for the nodulation survey. The average nodulation score for the region was presented as well as a summary and commentary on the scoring results and factors that may be affecting nodulation ie. pasture age, renovation practices, inoculant delivery systems, pH, soil fertility and chemical interactions etc (**see Appendix 6**).
- Final field day was held on the 20th March 2017 to present the full set of results as well as presentations by key speakers such as Dr Sofie DeMeyer (Murdoch University), Belinda Hackney (Local Land Services) and Susan Orgill (NSW DPI). Topics included maximising nitrogen fixation, paddock priorities and other factors affecting nitrogen fixation and soil constraints to nitrogen fixation. (**see Appendix 7,8,9,10** for copy of presentations)

Jo Powells (SE LLS) digs a “chunk” of soil out with approx.. 15 legume plants for washing and nodule scoring

MFS Newsletter Articles

- June 2014 and Dec 2014
- March 2015, June 2015 and December 2015
- June and November 2016

Radio interview between Belinda Hackney and Michael Cavanagh (SE NSW ABC Rural Reporter) aired on the 17th Dec 2014.

Media Releases

- 26th Nov 2014 - released to three local print media (Bombala Times, Cooma Express, Monaro Post) as well as submitted to Bob Freebairn for inclusion in The Land newspaper

4 Results

Site 1 – Sth Bukalong

Results from the initial hardseeded annual legume sowing trials were not analysed owing to failure of many of the sowing treatments. It should be noted that failure was due primarily to invasion of the sites (due to the fact we were sowing into established existing grass swards) rather than by failure of the sown species per se. It is also worth noting that traditional species such as subterranean clover also performed poorly in these early trials, again as a consequence of weed invasion. The main key messages from Site 1 are as follows;

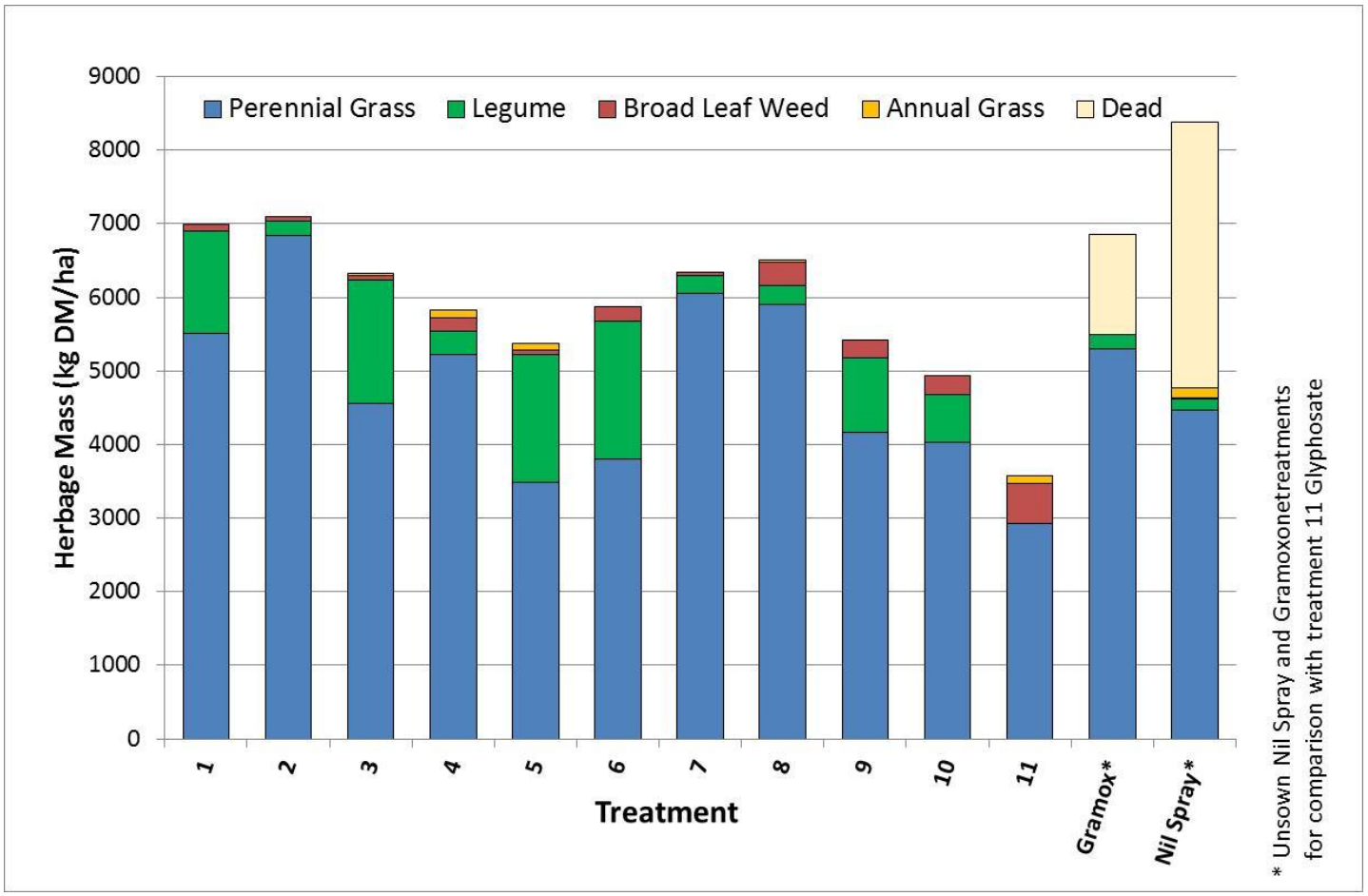
- The main enemies of pasture establishment continue to be;
  - paddock preparation, weeds, soil conditions – physical and chemical, species selection, rhizobia, sowing (Timing / Technique / Depth / Rate), post sowing management.
- The competition for moisture, light and nutrients prevented the legumes from successfully persisting at this site.
- Paddock preparation was not conducive at this site for legume persistence.
- Gramoxone and Glyphosate were not effective in this case when used to try and “set back” the existing pasture to allow the legumes to establish successfully.
- Sowing legumes directly into an established perennial pasture with nil spray was ineffective and resulted in no introduced legume establishment.
- Annual legumes need continual space, light and seed soil contact to establish successfully and persist
- Standing, high density, dry residue over summer and autumn in perennial, grass dominant pastures is not conducive to legume growth.
- This lack of light, space and/or seed-soil contact inhibits legumes trying to regenerate.
- Perennial grasses seasonal growth pattern coinciding with autumn rain removes critical soil moisture from the soil profile that germinating legumes cannot access due to an immature root system.
- All of these factors can result in very poor legume presence in pastures.

Additional sowings at trial site 1 also produced no measurable results. Germination from the March 2015 sowing was non-existent and from the April 2015 sowing was very little.
The reasons for this are unclear but could be due to any of the following;

- sowing was into thick, stubble, trash which may have affected germination;
- a large number of slugs were found in the drilled area;

- poor soil moisture for the March 2015 sowing;
- competition from weeds.

Contribution of functional groups to herbage mass – Site 1 assessment – 15th Dec 2014

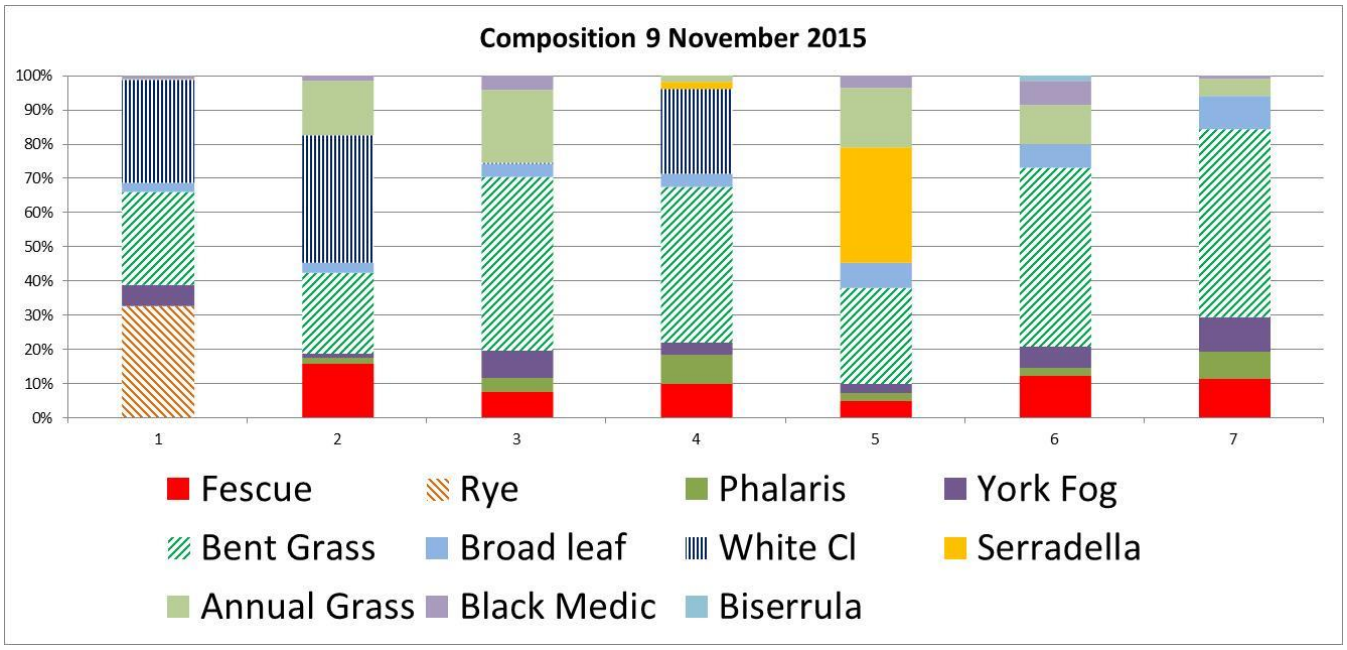


Serradella legume in cocksfoot pasture 10th Dec 2014

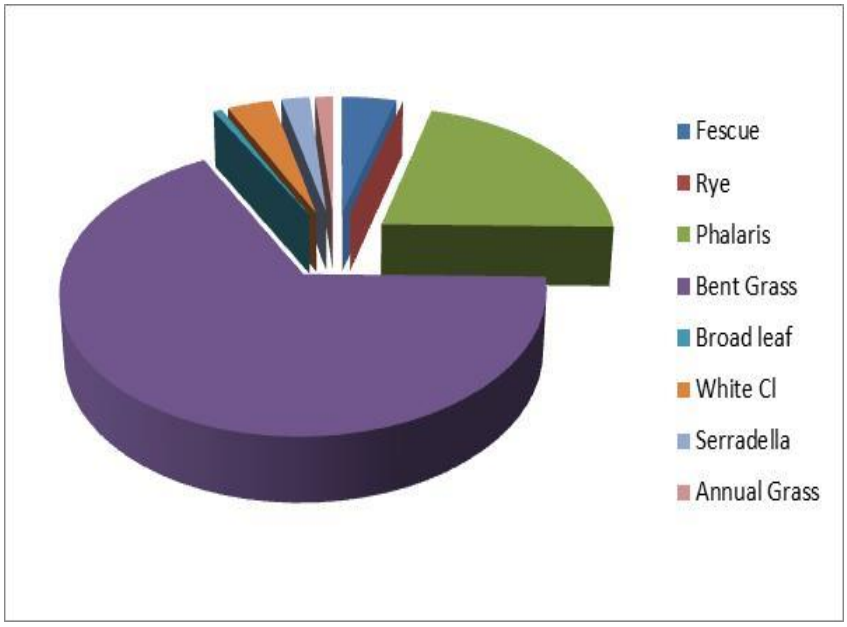
Site 2 - Gaerloch

While some treatments were complete failures and certainly re generation was not successful due to the bent grass competition, in the establishment period the white clover performed reasonably well. First year establishment was reasonable for some of the novel legumes at Gaerloch and bent grass really only caused problems for regeneration of the temperate annual legumes after wet summer conditions had allowed a return to bent grass dominance.
There was a significant germination of *French serradella* (June 2015) and it did manage to re-establish, the dry matter weight doesn't look much but the population actually looked good. The two legumes that persisted the longest as a significant green component in the pasture were white clover and *Serradella*.
The initial botanal in November 2014, showed balansa and biserrula made up 18% and 14% of the green biomass respectively so they did have some establishment success.

The Lucernes were a failure at the "Gaerloch" site as they were indeed almost non-existent at both sampling times, this is not surprising given the low pH and the level of spring competition. It is very apparent that weeds have had a major impact on establishment and performance. Really for species like vulpia, bent grass and sorrel, you need a minimum of two years preparation and preferably three to get to a stage where you would consider sowing a new pasture.



Example bent grass domination of plot results - Treatment 4



Fescue	4%
Rye	0%
Phalaris	21%
Bent Grass	67%
Broad leaf	1%
White Cl	4%
Serradella	2%
Annual Grass	1%

Site 3 - Kyleston

The effect of time of sowing on germination and herbage production of a range of annual legume species was evalulated at Kyleston where weeds had been controlled for the previous two seasons prior to sowing. Sowing times were spring (scarified seed), summer (unscarified seed or in the case of serradella, seed pod) and autumn sowing (scarified seed). The species evaluated were arrowleaf clover (cv. Cefalu), balansa clover (cv. Bolta, autumn only), bladder clover (cv. Bartolo), biserrula (cv. Casbah), French serradella (cv. Margurita, summer and autumn only), gland clover (cv. Prima, spring and summer sowing only), yellow serradella (cv. Santorini in spring sowing, cv. Avila at other times) and subterranean clover (cv. Seaton Park).

In the scarified seed state, annual legumes derived from Mediterranean germplasm are recommended to be sown in autumn. Due to highly variable autumn growing conditions on the Monaro, a number of annual legume species, those with deeper root systems (arrowleaf, serradella, biserrula, bladder clover) or earlier maturity time (gland clover) compared to subterranean clover were sown in spring to determine if this may be a feasible way to establish legume-based pastures.

Summer sowing of unscarified/in-pod seed has proved to be successful in Western Australia and in the mixed farming zone of NSW (Hackney et al. 2015), but it had not been evalulated on the Monaro. Species that have shown potential in Western Australia and/or the mixed farming zone of NSW were chosen to evaluate for summer sowing potential.

All species were also sown in autumn, the currently recommended time for sowing of scarified seed of these species.

The feed quality data was not analysed mainly because there appears to be some very abnormal results in terms of crude protein. Researcher Belinda Hackney explained normally she would expect to see crude proteins of greater than 15% (and more likely 20%) for the range of digestibility shown. She discussed the groups' results with John Piltz (ruminant nutritionist) at Wagga DPI and he agreed that they are highly unusual and he has not encountered results like this before for these legumes.

Kyleston Spring Biomass Assessment – 7th November 2016

	Spring Sown			
	R1	R2	R3	Average kgDM/ha
Santorini	1266	0	1121	**796**
Arrow Leaf	647	306	933	**628**
Casbah	0	261	206	**155**
Bartolo	0	0	0	**0**
Gland	0	0	0	**0**

	Summer Sown			
	R1	R2	R3	Average kgDM/ha
Arrowleaf	1918	3483	2988	**2796**
Margurita	3019	827	1394	**1747**
Avila	416	1353	1104	**958**
Casbah	174	0	225	**133**
Bartolo	0	0	0	**0**
Gland	0	0	0	**0**

	Autumn Sown			
	R1	R2	R3	Average kgDM/ha
Margurita	2446	2597	2497	**2513**
Balansa	3377	2143	1419	**2313**
Seaton Park	1973	1757	1397	**1709**
Arrowleaf	1420	132	1059	**870**
Bartolo	19	154	564	**246**
Casbah	0	158	102	**87**
Santorini	34	17	0	**17**

Re establishment Counts - Kyleston Trial Site, 3rd April 2017

	Average Plants/m2		
	Spring Sown (Sept 2015)	Summer Sown (Feb 2016)	Autumn Sown (May 2016)
Arrowleaf	31	2	3
Margurita (French serradella)		3	7
Avila (yellow serradella)		24	
Santorini (yellow serradella)	20		1
Casbah (biserrula)	20	0	1
Bartolo (bladder clover)	0	1	1
Prima gland	0	0	
Balansa			19
Seaton Park (sub clover)			124

Statistical Analysis Results – Kyleston (Site 3)

There was a significant effect of species ($p<0.001$), sowing time ($p<0.001$) and species by sowing time ($p=0.02$) on germination (Figure 1). Overall, balansa clover sown in autumn had significantly higher germination than all other species (357 plants/m^2). Summer sowing generally resulted in less than 10 plants/m^2 germinating. Within species, spring sowing did not produce a significantly different result in terms of germination compared to autumn sowing with the exception of biserrula where germination was significantly higher in spring than in autumn.

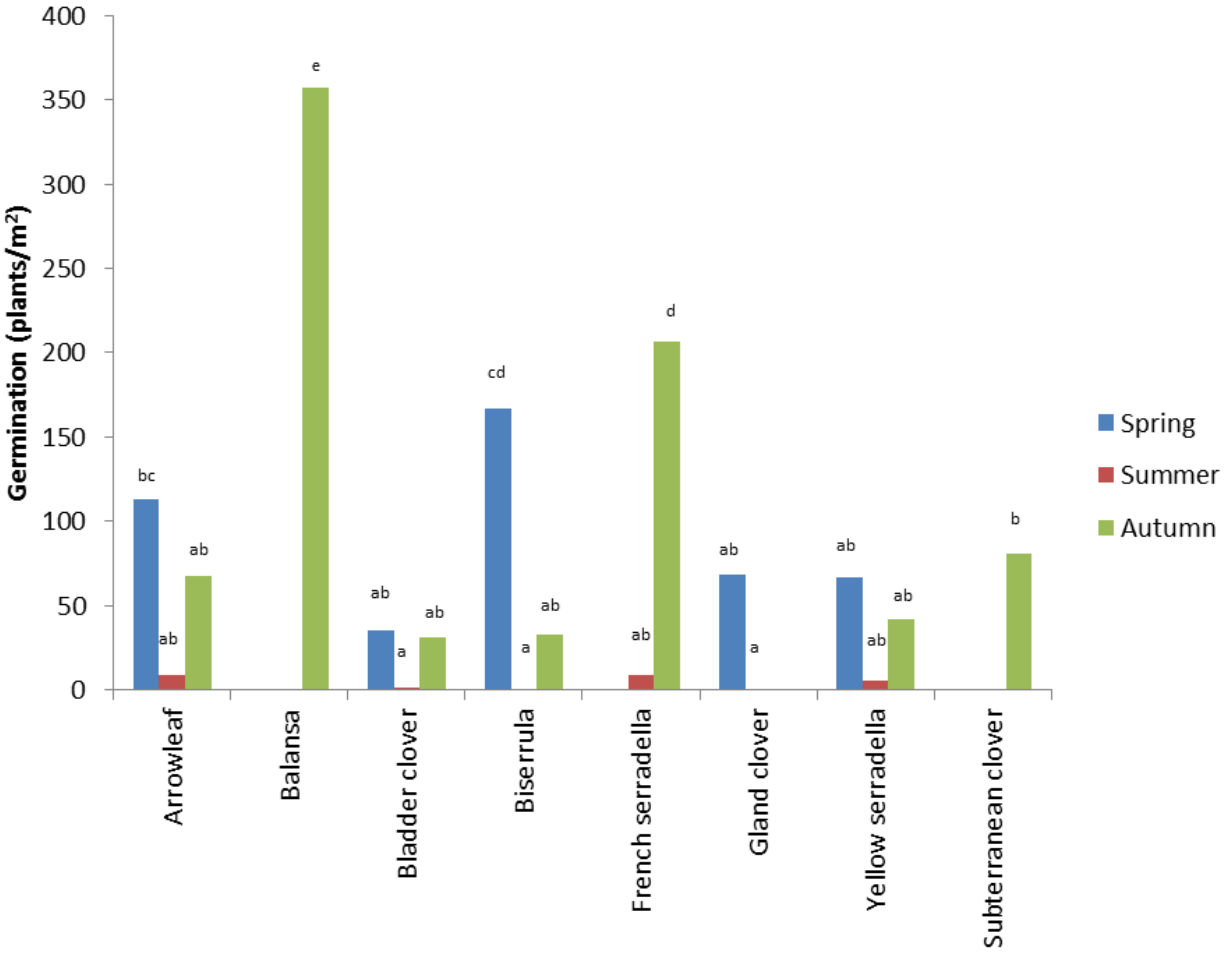


Figure 1. Germination (plants/m^2) for a range of annual legumes either sown as scarified seed in spring and autumn or as unscarified/in-pod seed in summer at Kyleston

In terms of herbage production, there was a significant effect of species ($p<0.001$) and species by sowing time ($p=0.02$) but not of sowing time alone ($p=0.11$). Arrowleaf clover and French serradella (summer and autumn sown), balansa clover and subterranean clover (autumn sown) were the best performing species, all producing more than 1500 kg DM/ha. Performance of bladder clover, biserrula and gland clover were very poor with less than 300 kg DM/ha produced.

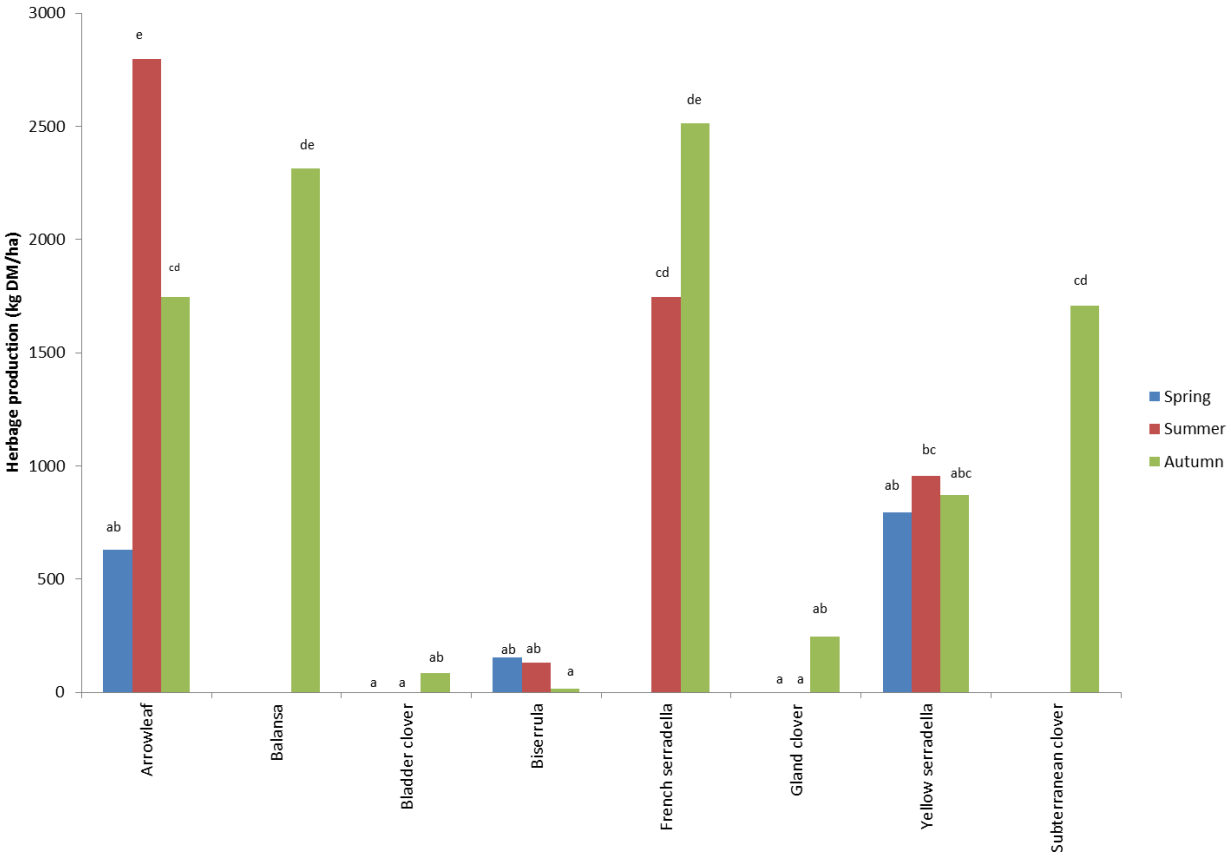


Figure 2. Herbage production (kg DM/ha) for a range of annual legumes sown as scarified seed (spring and autumn) or as unscarified /in-pod seed sown in summer at Kyleston.

In terms of the seed production data for the spring sown plots, the Santorini and Casbah showed the highest numbers of seeds/m^2 (487 and 1002 respectively) and kg seed / ha (105 and 70 respectively).

Regeneration plant counts from April 2017 showed the autumn sown Sub Clover achieved good regeneration compared to all the other species (124 plants/m^2) with relatively uniform results across the reps. Sub clover still appears to be the best adapted legume with regard to persistence based on the Kyleston data and it was a compelling factor behind re-directing resources to the legume nodulation survey. At the time of the regeneration counts in April 2017, of the summer sown trials, Avila showed the highest regeneration with 24 plants/m^2 and for the spring sown plots, the Arrowleaf had the highest regeneration counts of 31 plants/m^2 followed by Santorini and Casbah at 20 plants/m^2.

Results – Legume Nodulation Survey - See Appendix 12 and Appendix 14 (example of individual site report sent to each individual landholder)

4.1 Measured trial results

As above

4.2 Extension and communication

Date	Activity	Number of people
June 2014	*MFS Newsletter article providing results updates (summary tables) and trial activities*	*200 circulation MFS members*
Nov 2014	*Media Release*	*Bombala Times, Cooma Express, Monaro Post, Land newspaper readers*
Nov 2014	*Page posted on MFS website with trial details and updated throughout the project*	*Monaro producers, public access*
Dec 2014	*MFS Newsletter article providing results updates (summary tables) and trial activities*	*200 circulation MFS members*
Dec 2014	*Radio Interview – Belinda Hackney and Michael Cavanagh (NSW SE ABC Rural Reporter)*	
March 2015	*MFS Newsletter article providing results updates (summary tables) and trial activities*	*200 circulation MFS members*
May 2015	*Doug Alcock gave a presentation at the MLA Pasture Update - Nimmitabel*	*60 participants*
June 2015	*MFS Newsletter article providing results updates (summary tables) and trial activities*	*200 circulation MFS members*
December 2015	*MFS Newsletter article providing results updates (summary tables) and trial activities*	*200 circulation MFS members*
June 2016	*MFS Newsletter article providing results updates (summary tables) and trial activities*	*200 circulation MFS members*
November 2016	*MFS Newsletter article providing results updates (summary tables) and trial activities*	*200 circulation MFS members*
December 2016	Field day presentation of legume survey preliminary results – Jo Powells (SE LLS)	*50 participants*
March 2017	*Field day presentation of legume survey final results as well as factors driving pasture legume performance – Jo Powells (SE LLS), Belinda Hackney (LLS), Sofie DeMeyer (Murdoch University, WA) and Susan Orgill (NSW DPI)*	*45 participants*

4.3 Participant reactions

See Appendix 13 for a producer survey prior to the project commencement

The following **improvement in knowledge and skills** was achieved by this project in the following key areas;

- the paramount importance of effective weed control when preparing pastures
- the challenges involved in pasture renovation ie. managing competition specifically the dominance of established perennial grasses when trying to establish legumes
- the likely performance of alternative legumes in the Monaro environment and how they perform against challenges such as weed competition, lack of soil moisture and low soil fertility
- the impact of sowing time on performance of the trialed legumes
- ability to lift stocking rates from 2.5 DSE to 4-5 DSE as a result of establishing more legume content in pasture
- The baseline for the Monaro in terms of legume nodulation status and factors affecting nodulation and nitrogen fixation and associed pasture growth

Producer **practice changes** achieved by this project outcomes;

None documented due to limitations of data set and timeframe of project but feedback from the core producer group suggests some producers are considering the following changes;

- move from a spring sowing to an autumn sowing for some pasture legumes
- adopt a three year “preparation” program prior to establishing permanent pasture
- consider re-innoculation of current strain rhizobia into older aged pastures and correcting soil pH to help increase N fixation and overall legume health

4.4 Producer Research Site Program

The group did not influence the necessary variations made during the project, it was more a response to failures at trial sites and advice from researchers as to how to reallocate the resources.

5 Discussion

The effect of time of sowing on germination and herbage production of a range of annual legume species was evalulated at Kyleston where weeds had been controlled for the previous two seasons prior to sowing. Sowing times were spring (scarified seed), summer (unscarified seed or in the case of serradella, seed pod) and autumn sowing (scarified seed).

The results of this evaluation trial have shown that arrowleaf clover, balansa clover and French serradella may have a role in pasture systems on the Monaro with comparable, or in the case of summer sown arrowleaf clover, superior production compared to subterranean clover. The results show that no spring sown treatment exceeded 800 kg DM/ha and for bladder clover, gland clover and biserrula, this was less than 160 kg DM/ha. This indicates that spring sowing of legumes of Mediterranean origin should be carefully evaluated before being attempted and did not result in successful establishment in this trial. This conclusion can be also linked to the

results at the Sth Bukalong Site (Site 1) which showed poor performance of legumes at the spring sowing.

In regards to the Gaerloch trial site, our results have highlighted the need for adequate preparation of sites prior to sowing any evaluation trials (and also for the sowing of commercial pasture stands) to optimise the chance of success. A particular problem at this site was bent grass (Agrostis spp.). Bent grass is very problematic in the establishment of new pastures with a minimum of three years absolute weed control required to achieve adequate control. Bent grass is a summer growing perennial grass and as such it is capable of drying the soil profile significantly over the spring-autumn period which impedes the ability of newly sown pastures to establish quickly.

It should also be noted that bent grass is also most commonly found in situations of low fertility where it is generally very competitive against species requiring higher fertility for optimal performance. While fertiliser was applied at sowing in this evaluation, it is probable that moisture availability immediately around the seed was limited by the utilisation of this moisture by bent grass in the preceeding summer which limited the ability of sown species to access the applied nutrients.

The main conclusion to draw from “Gaerloch” is the fundamental principle of absolute weed control is paramount to establishment of new pastures (Belinda Hackney).

Recommendations

Compared to the mixed farming zone, the number of species with adaptation to soil and climatic conditions of the Monaro region is relatively small. Our trials suggest that there are additional species from the Trifolium genus (arrowleaf clover and balansa clover) that may compliment subterranean clover. Certainly arrowleaf clover with its deeper root system may have better tolerance to false breaks commonly encountered in autumn and also to unreliable rainfall in spring.

Certainly the performance of arrowleaf clover in the summer sown treatment gives some indication of its role as either a summer sown (unscarified seed) or earlier autumn (scarified seed) sowing role compared to subterranean clover which needs to be sown in autumn after the danger of a false break is past. Balansa clover is probably underutilised in Monaro farming systems. It is a widely adaptable species capable of growing in conditions similar to subterranean clover but with far superior tolerance to both periodic and prolonged waterlogging should those conditions arise.

The results also indicate that serradellas and particularly French serradella may have a role in Monaro farming systems. However, producers should be aware of the high cost of dehulled seed of this species relative to other species. Dehulled seed is required for autumn sowing. Results appear promising for this species as a summer sowing (pod) establishment option. While pod is approximately one-third the cost of dehulled seed, sowing rates of 20-30 kg pod/ha are required for summer sowing.

For the newer hardseeded annual legumes, there are relatively few varieties, and in the case of bladder clover and gland clover only one variety commercially available. It is therefore unrealistic

to expect that these few varieties can expand the full spectrum of mixed and tableland agricultural systems and be successful in all situations.

There have been many decades of investment and breeding of traditional species such as subterranean clover giving rise to more than 30 currently commercially available varieties. Our results indicate some of these species, even with their limited number of varieties, may have a fit in Monaro farming systems.

It appears imperative that there is support for further breeding and selection of these species to produce cultivars with greater regional specificity. Some of these species have been domesticated for less than 20 years and there has been little exploitation of their genetic resource base as yet.

It should also be noted here that the results for time of sowing represent only one year's performance. Establishment can be greatly affected by season and in the case of summer sowing, the rate of hard seed breakdown is affected by both moisture and temperature and therefore caution should be exercised when interpreting the results of a trial with only one sowing year data set and no replication.

5.1 Outcomes in achieving objectives

The main challenge with many pasture trials is the three year project term. Due to the myriad of factors influencing successful germination establishment and persistence of sown species (adequate soil moisture, rainfall amount and timing, pest pressures, preparation of sites, weed competition), trial sites are exposed to a high level of risk.

The major challenge MFS encountered in this project was the fact that we had to disband two trial sites half way through the project due to species persistence failures and therefore our data sets are limited. If we were able to achieve continuity of the trials over the full three years, we would have a much more robust data set which would form the basis for a stronger case for producer practice change and adoption.

Project objective	**Outcome**
1. Identified the value of alternative legumes (based on establishment, persistence and production) compared with traditional legumes used in the Monaro region of NSW.	Achieved however due to some species failure in establishment and regeneration, our data set was not as robust as hoped and therefore interpretation and conclusions are limited somewhat.
2. Evaluated the role of sowing time on legume performance and persistence.	Achieved but again due to site changes half-way through the project, the sowing time trial only has a data set for one sowing year (spring, summer and aurumn) and therefore interpretation and conclusions are restricted.

3. Investigated how alternative legumes can be sown into existing pasture swards to increase pasture and animal production, using alternative strategies.	Achieved. The results were quite conclusive in that, in this trial location and conditions, no alternative legumes persisted and only established in one of the treatment plots when sown into existing grass swards both with chemical pre-spray and without.
4. Completed a survey to quantify nodulation status and occupancy of the Southern Monaro and identify a baseline for this region.	Achieved. Legume nodulation status was quantified for 54 sites across the Monaro and a baseline of **2.6** has been established for the region.
5. Evaluated the role of associative factors that affect nodulation such as soil pH, Soil P and S, root pathogens, chemical applications, pasture age etc to inform further trial work on methods to manipulate legume nodulation in existing pastures to drive increased pasture production.	Achieved. Presentations given by Dr Belinda Hackney, Dr Susan Orgill, Jo Powells and Dr Sofie DeMeyer, Field Day 20th March 2017.

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

The results will provide the following benefits for producers;

- Allow more informed choices and decisions around sowing pasture legumes;
  - Results indicate arrowleaf clover may have a role as a summer sown treatment (2796 av kg DM/ha) or earlier autumn (scarified seed) sowing role compared to subterranean clover which really only has an autumn sowing window
  - Balansa clover
  - Serradellas and particularly French serradella may have a role in Monaro farming systems
- There are economic benefits in not attempting to sow legumes into existing perennial grass swards even with chemical “set back” sprays
- Investment in paddock preparation for pastures will increase the probability of a successful establishment due to more efficient management of weeds
- Correcting factors affecting nodulation ie. re-innoculation, addressing pH limitations and soil fertility constraints, better choice of herbicide use etc.
- Not attempting the Spring sowing of legumes of Mediterranean origin
- Provide evidence to explore additional species from the Triloium genus (arrowleaf clover and balansa clover) that may compliment subterranean clover

5.3 Promotion of research results and its effectiveness

The extension methods were successful due to the fact MFS has strong established networks throughout the Monaro grazing community. We also employed a variety of extension methods which included pasture walks, producer forums, field days, media articles, radio interviews, newsletter articles and websites linkages. Overall the project directly engaged 58 farm businesses on the Monaro (core group) and reached a further 100 farm businesses through extension methods and the membership group.

Grower groups are very effective at building up the general capacity for an “adoption” process to happen on-farm and play a key role early in the adoption phase of a new "system" or technology where extension effects can be measured and quantified. They often “lead by example” and encourage flow-on effects and adoption rates by the broader rural community. MFS members include the most innovative and progressive farmers in their respective districts and therefore will be the key drivers in adoption when practice change benefits can be demonstrated and validated at a local level which is the main aim of these producer participatory projects.

The results from the pasture trials will certainly re-inforce some key messages around weed management, paddock preparation, species selection and sowing time however will not initiate change on its own. Producers tend to gradually change over time and use information from a variety of sources to inform their decision making. Another barrier to rapid adoption in the area of pasture improvement is the significant cost and investment involved in these decisions. Although the trial results provide one information source, other sources include other research trials from the private sector, seed companies, local agronomic advice and peer advice and practice.

In the Monaro the use of some of these legumes is slowly being integrated into the more traditional sowing mixes however once again, the evidence of their reliability and performance as compared to sub clover still needs to be stronger. With on-going investment in this area, practice change will be encouraged. For example the current Phosphorus Efficient trial being run by CSIRO (Richard Simpson) and NSW DPI (MLA led Rural R&D for Profit project ‘P Efficient Pastures’) has two local trial sites on the Monaro and are comparing the performance of the serradellas against subclover in a perennial grass mix. These results will add valuable data for the case for use of these alternative legumes and the role they can play in production systems.

The results from the legume nodulation survey have encouraged much more rapid practice change as the data set is much more definitive and provides accurate and targeted results for individual properties. Although it is too early to document, based on their results, producers can make tangible, measurable changes to increase the health and nitrogen fixation ability of their legumes. These steps were presented to producers at the final field day and involve, re-innoculation with current effective rhizobia strains, correcting soil chemistry (pH and fertility), changing species and selective herbicide use.

5.4 Effectiveness of the participatory research process

The producers were kept engaged via the regular extension activities. The participation of the site hosts also helps to create ownership and maintain interest in the project. Generally the model of participatory research does work well ie. trying to get producers involved in the project as much as possible.

However when sowing demonstration trials, the close supervision and input from technical professionals and an employed “coordinator” is crucial and integral to the success of the project. Site selection is absolutely paramount to the success of the project as well as on-going monitoring of the sites from technical experts.

Due to the site challenges experienced with this project, in some situations, species evaluation trials may be better off conducted in more controlled and regulated environments such as research stations where environmental variation can be minimised and site preparation can be optimised.

Future areas of research identified by the MFS group stem from the nodulation survey and these would include further evaluation of the management intervention strategies to address low rhizobia population issue. For example;

- Rhizobia top-up strategies – granule and other options
- Fertiliser addition relevant to the paddock needs including trace elements where required (specifically molybdenum and sulphur)
- Lime amendment where soil pH has been defined as limiting
- MALDI rhizobia testing to identify occupancy strains and inform re-innoculation strategies

6 Conclusions/ Key Messages /Recommendations

6.1 Conclusions

For the "**Kyleston" site**, there was a significant effect of species, sowing time and species by sowing time on **germination**. The Balansa legume showed the highest germination rate compared to all other species when sown in autumn. Summer sowing generally showed very poor results in terms of germination and persistence for all species.
Within species, there was no significant difference in germination between the spring, summer and autumn sowing with the exception being biserrula (significantly higher germination in spring compared to autumn).
In terms of **herbage production**, there was a significant effect of species by sowing time but not of sowing time alone. The best performing species with >1500 kg DM/ha were;

- Arrowleaf clover
- French serradella
- Balansa clover
- Subterranean clover

Sub clover demonstrated the best regeneration performance compared to all other species. Based on the Kyleston data, sub clover still appears to be the best adapted legume, in terms of persistence, for the Monaro environment.

The main enemies of pasture establishment continue to be;

- Inadequate paddock preparation ie; not enough strategic sprays and precursory annual sowings (fodder crops) to reduce weed seed beds;
- Weeds (Bent grass requires a minimum of three years absolute weed control to achieve adequate control);
- Sub-optimal soil conditions – Physical and Chemical;
- Species Selection;
- Rhizobia;
- Sowing / Timing / Technique / Depth / Rate;
- Post sowing management.

Gramoxone and Glyphosate were not effective in this case when used to try and "set back" the existing pasture to allow the legumes to establish successfully. Sowing legumes directly into an established perennial pasture with nil spray was ineffective and resulted in no introduced legume establishment.

Nodulation Survey – see **Appendix 12**

The 2016 Monaro survey highlighted several potential limiting factors affecting legume production and N-fixation. The average paddock nodule score across all legume plants sampled was 2.6 (out of a possible score of 8) indicating sub-adequate levels of legume nodulation.
The most current strains of legume rhizobia were found in just over 80% of the legume plants tested using MALDI ID. Older strains of rhizobia were found co-existing with new strains in 7% of samples and exclusively old strains in 12% of samples.

Unfortunately there was not one sole soil factor found to be influencing the nodulation status of all paddocks tested in the 2016 Monaro survey due to the large variability in paddocks tested. The results highlighted that many different characteristics were influencing the nodulation and N-fixation of the legume plants studied. These characteristics varied with each paddock and included available soil nutrients such and phosphorus and sulphur, soil pH, waterlogging and previous herbicide use.

Further investigation is warranted into several aspects highlighted in the 2016 survey in relation to this question including the re-inoculation of old pasture paddocks with more efficient and productive rhizobia, correction of key soil constraints and further investigation of residual herbicide impacts. Studies in other regions suggest that nodulation and N-fixation levels can be manipulated however the specific method adopted will need to consider the relevant soil factors in each paddock and the economic value of such actions evaluated.

7 Appendix

For copies of appendices referenced in this Report please contact MLA on reports@mla.com.au and quote Project Code

Appendix 12 – MLA Legume Survey – Final Results and Project Summary