Final report

Growing red meat productivity through the selection and establishment of perennial legumes

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Abstract

This project sought to address the low proportion of perennial legumes in rainfed red meat grazing systems in Tasmania. The focus in the sheep producing low-medium rainfall Midlands region (450-650 mm AAR) was on establishing and re-establishing perennial legumes in mixed pasture swards for lamb production using a range of sowing techniques and adapted species. Pasture renovation and over-sowing experiments in the Midlands regions have provided key insights into how difficult it is to establish long-lived perennial plants in a seasonally moisture stressed environment. Oversowing phalaris dominant pastures with perennial legumes provided only short-lived composition changes. In the beef producing high rainfall North-west (750-1100 mm AAR) the focus was on improving the quality of winter wet pastures for beef production using waterlogging tolerant species. Strawberry clover remains the best available waterlogging tolerant option for high rainfall mixed pastures.

The establishment of involve and partner activities on commercial farms has proven a successful method of engaging producers and getting them to trial novel sowing techniques and pasture mixes with legume content. Attendance at field days has been strong where they were held on commercial farms alongside sowing/pasture demonstrations, while attending existing producer group events and presenting research updates was an efficient way to engage red meat producers.

Executive summary

Background

Mixed pastures provide the backbone of the grass-fed feedbase in South-eastern Australia. While there are many combinations of different species chosen for different soils, climates, and purposes, they all generally contain at least one species of grass, and one species of legume. The role of legumes in providing high quality feed as well as fixing atmospheric nitrogen that can be utilised by the grass component is well established. However, pastures are often grass dominant, either through design at sowing or through degradation processes over time. Legumes are at a competitive disadvantage to grasses during emergence and establishment; they are generally slower to establish being less competitive for moisture, nutrients, and light. This project sought to research methods of maximising legume establishment in mixed pastures through sowing techniques and species selection. If the proportion of legumes can be optimised at establishment, then there is greater likelihood that there would be persistence as a significant component of a mixed pasture.

Objectives

The aim of the project was to evaluate methods for improved legume establishment in mixed pastures through novel sowing methods that advantage legumes in new and existing pastures. Another aim was to evaluate the waterlogging tolerance of perennial legumes with a particular focus on strawberry clover and Lotus species. In addition, establish a series of involve and partner demonstration sites that are informed by project learnings and assist in extending knowledge to producers in the North-west and Midlands regions. All of these objectives have largely been achieved. An objective around enhancing modelling capabilities is yet to be fully realised, though input was provided to the NEXUS project (project code: P.PSH.1219) where requested. This project has provided an outlet for the extension of other Livestock Productivity Partnership (LPP) Project findings through visits and presentations from collaborating partner researchers. The objective of building capacity with student projects has proven unsuccessful.

Methodology

Sowing methods including direct drilling, broadcast roller, matrix sowing and alternate row were evaluated for pasture renovation in research and commercial farms. Furthermore, direct drill, broadcast, and strip till methods with and without pre-sowing herbicide were evaluated as a means of oversowing legumes into grass dominant pastures. Pot and field studies evaluated the waterlogging tolerance of strawberry clover and Lotus sp. On farm demonstrations involved producers with decision making on the selection of species, method of establishment and provided seed as a way of reducing some of the risk for producers trying something outside of their business-as-usual pasture practices.

Results/key findings

A range of methods are likely to be successful for establishing legumes in mixed swards, each with their own set of advantages and limitations. Much of the success of pasture establishment relates to seasonal conditions (soil moisture), though preparation remains the most controllable and often short-cutted phase of the pasture renovation. None of the sowing methods used appeared to have an advantage over mixed row sowing in terms of increasing the proportion of legume content. Broadcast rolling appeared susceptible to surface soil moisture deficit and as such should be used where soil moisture is good or where irrigation can be applied. Matrix sowing appears a good method, though adoption from producers may be restricted due to the need for two passes with the drill. Alternate row sowing showed no real benefit over mixed row in the method implemented. At Cressy, red clover and lucerne contributed the highest amount of dry matter compared with white clover, Talish clover and Caucasian clover. However, these quantities were still below 25% of the overall mix and is the hypothesised reason why only a marginal benefit in crude protein was seen in lucerne plots and little difference in nutritional quality across all plots.

Over-sowing perennial legumes into existing swards is very challenging. Competition from the existing pasture is high. Greater success is likely to be found with annuals, which have greater seedling vigour. Long-term persistence will be more related to seed set rather than surviving in competition with existing pasture species through moisture deficits. Of the perennial legumes, red clover, being more vigorous as a seedling appears best adapted though it lacked persistence at the low rainfall site.

Strawberry clover remains the best available waterlogging tolerant option for high rainfall mixed pastures. Feed quality analysis suggested that strawberry clover had consistently better dry matter digestibility and metabolisable energy than Lotus pedunculatus. Our research suggests there is sufficient variability in strawberry clover germplasm to develop more productive cultivars without the risk of losing waterlogging tolerance.

Involve and Partner sowings showed the benefits of; using crops for control of weeds before re-sowing; the difficulty of oversowing perennial legumes into grass dominant swards; the need to keep grass sowing rates low when combining with perennial legumes such as lucerne; the adaptability of strawberry clover in a range of mixes; the timing of autumn and spring sowing; and feed testing in order to prioritise feeding of livestock.

Benefits to industry

This project increased the focus on the importance of legumes in mixed sward pastures and motivations of producers to establish and manage pastures for legume production and persistence. The project increased awareness of appropriate sowing techniques for low-med rainfall environments, directly exposed 40 producers and service providers in each region by the presentation of project findings and other LPP projects and directly engaged 13 producers in 18 on-farm sowing activities. Presentations were given of experimental results and on farm demonstrations at Red Meat Updates (largest red meat producer conference in Tasmania) to over 350 producers and advisors in 2022 and 2025.

On a technical note, project results offer an insight into the relative success of a number of sowing methods in establishing perennial pasture legumes. The trend towards a reduction in chemical use and cultivation provides limitations on existing methods for pasture renovation. Strip till offers a method of renovating pasture with minimal soil disturbance and no chemical use, though large changes in botanical composition with perennial plants is unlikely. Pasture renovations with multi-year clean up phase where weeds are controlled with the use of cereal and/or brassica crop phases are likely to assist legume establishment by reducing competition from broadleaf weeds that are difficult to control in pasture with selective herbicides.

Future research and recommendations

Dramatically changing species composition in existing pastures by oversowing without herbicide is very challenging. Further investigation to improve the placement of the seed in strip till machines may yield better results. Further exploration of strawberry clover germplasm, including within existing populations of cv. Palestine may yield more productive cultivars without losing waterlogging tolerance. Producers were most interested in building resilient pasture mixes and engaged well one on one with research teams and through the support of the involve and partner model with regular visits on farm and regular monitoring of newly sown pastures.

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1. Background

1.1 South-eastern Australian pastures

Mixed pastures provide the backbone of the grass-fed feedbase in South-eastern Australia. While there are many combinations of different species chosen for different soils, climates, and purposes, they all generally contain at least 1 species of grass and legume. For instance, the dairy enterprises in the high rainfall zone utilise pastures that are dominated by perennial species such as perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.). In medium rainfall areas where beef and lamb grazing is common, a wider range of species are often utilised including cocksfoot (*Dactylis glomerata* L.), tall fescue (*Festuca arundinacea* L.; syn *Lolium arundinaceum* (Schreb.) *Darbysh*), red clover (*Trifolium pratense* L.), and lucerne (*Medicago sativa* L.). In the low rainfall regions commonly dominated by wool and cropping enterprises, species like phalaris (*Phalaris aquatica* L.) and subterranean clover (*Trifolium subterraneum* L.) are common. Herbs including chicory (*Cichorium intybus* L.) and plantain (*Plantago lanceolata* L.) are also used in pasture mixes along with a range of other alternative grasses and legumes. There is clearly considerable overlap of species between regions, farming systems, enterprise, grazing management practices, and farmer preference.

1.2 Importance of legumes in mixed pastures

The three most important attributes legumes contribute in mixed pastures are nutritional quality, nitrogen fixation, and yield. Legumes are known to be high in crude protein (>20%) and metabolisable energy (>10 mj/kg) when vegetative (Norman et al. 2021; Vercoe 2015) particularly important nutritional factors for growth and reproduction in livestock. Legumes can fix atmospheric nitrogen through the symbiosis with rhizobia, which helps legume growth and contributes to the nitrogen pool that can be utilised by the grass component. This is particularly important in extensive grazing systems where large synthetic nitrogen applications are not cost effective. Legumes also contribute to overall dry matter when complimentary to the grass component. They can utilise different spatial and temporal gaps in the sward not utilised by other species. Numerous other benefits that legumes can provide include diverse rooting structures that utilise moisture and nutrients, have different mineral profiles than grasses which assist in animal health, provide ground cover that reduces erosion, and provide pollen and nectar sources for honey production.

1.3 Lack of legumes in pasture composition

Pastures are often grass dominant, either through design at sowing or through degradation processes over time. Legumes are at a competitive disadvantage to grasses during emergence and establishment; they are generally slower to establish being less competitive for moisture, nutrients, and light. High sowing rates of grasses heighten competition for light and often results in early canopy closure. Furthermore, long-lived persistent species tend to allocate resources to the development of the root resulting in smaller and slower growing organs for light capture. Once established, grazing management tends to favour the grass as the dominant component. Grazing strategies such as the three-leaf stage in perennial ryegrass focus on the needs of the individual grass species, sometimes to the detriment of other components.

A study in 2011 found a lack of legumes in Tasmanian pastures (Smith et al. 2023). Average percentage composition (cover) of annual and perennial legumes combined accounted for only 12%

of total composition, with the main species being white clover and subterranean clover. A follow up survey in 2022 using the same method reported little change in legume content, with a small increase to 13% (Smith et al. 2023). These observations are not uncommon across much of the South-eastern Australian feedbase, with numerous reports of pasture decline (Hutchinson and King 1999; Reeve et al. 2000; Vere et al. 2001). Identifying the reasons for legume failure and elucidating some solutions is paramount given that they have the potential to improve overall pasture yields, fill feed gaps and improve feed quality and animal performance.

1.4 Increasing legumes in mixed pastures

Increasing the proportion of legume in mixed pastures can be achieved by removing some of the barriers that limit their growth (Figure 1). For instance, most legumes require a pH_{Ca} of >5.0 for good plant growth. However, the pH often needs to higher for successful nodulation. For instance, lucerne plant growth is optimal at a pH_{Ca} 5.0, but the likelihood of optimal nodulation with rhizobia of Group AL occurs in the 6.5-7.5 pH_{Ca} range. Furthermore, subterranean clover plant growth is optimal at a pH_{Ca} 5.0 but the likelihood of optimal nodulation with rhizobia of Group C occurs in the 6.0-7.5 pH_{Ca} range, indicating rhizobia strain specificity when it comes to soil pH (Burns, 2021). Liming, particularly the incorporation of lime during renovation phases can result in better growth and better persistence of pasture legumes (Dowling et al. 2025; Hayes et al. 2016). Nutrients such as phosphorus, potassium and molybdenum are key for healthy legume growth. Grazing management practices that are sympathetic to important legume growth phases (e.g. allowing aerial seeders to set seed) can assist in their persistence.

But perhaps the two most crucial factors relate to species selection and establishing good plant numbers. Species need to be chosen that are well adapted to the rainfall/soil moisture patterns of the region, that are well adapted to the soil conditions, that are complimentary to the major grass species, that can serve the purpose of the grazing enterprise and adapt to grazing management implemented. Good composition of legumes often relates back to preparation, sowing rates, and reducing competition with other species during establishment.

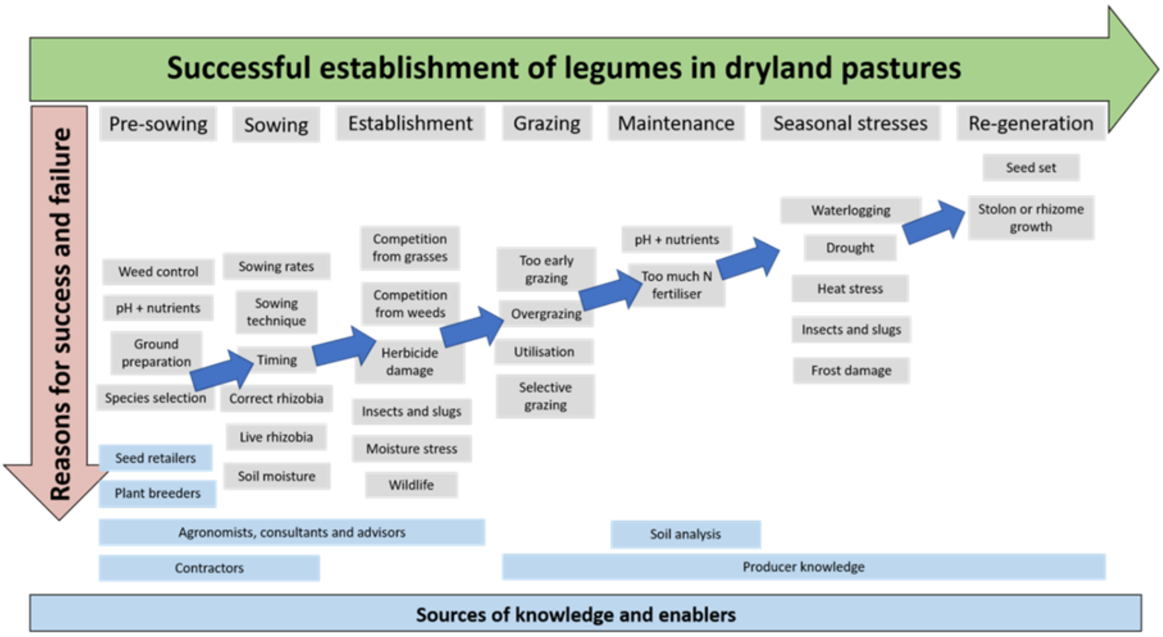

Figure 1 Key steps and reasons for success and failure in the establishment and maintenance of legumes in mixed sward pastures

1.5 The research concept

This project sought to research methods of maximising legume establishment in mixed pastures through sowing methods and species selection. The project focussed specifically on the pre-sowing, sowing, and establishment phases of pasture renovation in the low-medium rainfall region of the Tasmanian Midlands for sheep production. Here the centre of attention was on deep rooted perennial legume species that could extend growing seasons and investigate sowing techniques such as the separation of grass and legume components (spatially and temporally) and the use of advances in drilling technology including direct drills, broadcast/roller drills and cultivation vs direct drilling. If establishment of legumes could be optimised, then there is a greater opportunity for longer-term persistence as a significant component of a mixed pasture.

The focus in the high rainfall north-west was on filling winter feed gaps for beef production with waterlogging tolerant legumes to improve pasture productivity. There has been limited information on the establishment, agronomic, and grazing management of these species, and that is seen to be limiting their adoption. The adoption of waterlogging tolerant legumes will not only improve winter productivity and persistence of perennial pastures for longer.

Successful sowing methods and suitable species were demonstrated to producers in an involve and partner phase of the project.

2. Objectives

2.1 Research and involve and partner components

2.1.1 In the midlands low-medium rainfall zone sheep systems, extend the growing season of the rain-fed pasture through the successful establishment of perennial legumes.

a) Elucidate improved methods for legume establishment through novel sowing methods that spatially separate clover and grass in mixed swards.

Alternate row and matrix sowing spatially separate grass and legume components of mixed pasture seed blends and provide alternatives to direct drilling in mixed rows. However, they only provide a marginal benefit over direct drilling in mixed rows in terms of overall dry matter. They also had no effect on increasing the dry matter contribution of slow establishing perennial legumes such as Caucasian clover and Talish clover. Dry matter contribution of legumes was greatest in lucerne and red clover plots. Broadcast sowing methods are reliant on favourable surface soil moisture to aide germination. Broadcast methods will work best where the soil is cultivated or where there is sufficient bare ground for seed soil contact and will be advantaged by rolling or treading by livestock.

b) Explore enabling practices and new methods for enhancing the legume composition and persistence in established grass dominant swards.

Some form of competition reduction is required for successful germination and early establishment of perennial legumes in phalaris dominant pastures. Non-lethal pre-sowing herbicide application had the greatest effect, and the strip till sowing method was the best option when herbicide application wasn’t used.

2.1.2 In North-west high rainfall grassfed beef systems, improve autumn winter feed supply

a) Using controlled experimental conditions and field trials, evaluate genotype by environment interactions to identify waterlogging tolerant legume species

Strawberry clover germplasm appears quite consistent in its ability to tolerate waterlogging. Any further development work on strawberry clover should be focussed on increasing DM yield potential by selecting from within exiting cultivars or novel germplasm. Similarly, Lotus sp. appear tolerant of waterlogging, though feed nutritional characteristics from field were inferior.

b) Assess the capacity of legume component in pastures to alleviate mineral imbalances and enhanced feed intakes that could deliver improved animal performance and meat quality.

This has not been assessed in detail.

2.1.3 Enhance modelling capabilities

a) Enhance modelling capabilities and whole farm system analysis as part of the parallel NEXUS project to extend findings of other LPP projects into Southern Australia by providing a test bed for outputs.

This has been yet to be fully realised, though input was provided to the NEXUS project where requested. This project has provided an outlet for the extension of other LPP Project findings through visits and presentations from collaborating partner researchers.

2.1.4 Development of extension and adoption materials and opportunities aligned with LPP/MLA Feedbase Adoption Plan and existing red meat producer groups in each region.

This objective has been partially achieved but is on-going.

a) Integrate and develop the Involve and Partner Program activities of the Tasmanian component of the LPP ‘Nexus” project.

A number of activities were undertaken in conjunction with the Nexus project, mostly in project design and research updates to producers and the regional reference group.

b) In a staged approach, informed by the project learnings, establish 10 new Producer Lead Participatory sites (sites are in addition to those existing Project NEXUS sites) to trial alternative sowing techniques as part of the producer’s business plan and usual pasture renovation activity.

To date 13 producer lead participatory sites have been established as part of the Involve and Partner activities on farm. These producers have been encouraged and supported to trial high legume content pasture mixes and novel sowing methods. Red meat producers have shown good engagement by attending field days at involve and partner farms.

2.1.5 Capacity building and training of two student PhD theses; i) establishment of perennial legumes, and ii) waterlogging tolerance in perennial legumes.

This objective has not been achieved.

The objective of building capacity with student projects has proven unsuccessful. The project agreement was executed in July 2020 and rolling COVID border closures and travel restrictions prevented prospective overseas students from the obtaining visas to enter the country. Local recruitment of students was only partially successful with one student commencing in 2021 on project (i) and then withdrawing in mid-2022. In discussion with the MLA project manager, it was agreed the that the allocated budget in the project would be redirected towards additional technical support for data collection and maintenance of these field and pot experiments.

3. Methods

3.1 Designing the research

TIA has used a design-led thinking approach to determine the research themes. During the design phase, TIA engaged producers on where they thought the feedbase could be improved. There was a strong interest in improving their feed quality with the use of legumes and also reducing synthetic nitrogen inputs. Risk of renovation failure was identified as a major impediment in the Midlands region due to variable autumns. In the North-west, winter wet pastures see a reduction in growth and lack legume composition. These two areas were identified as focus regions and allowed a more targeted research and extension activities for producers with similar constraints, objectives, and values. Some of the findings are relevant to other regions of Tasmania and south-eastern Australia more generally.

This project sought to collaborate with researchers from aligned projects in demonstrating and delivering extension events to producer groups in these regions. Furthermore, the extension activities of this project provided opportunities to extend knowledge generated in legume focussed projects under the LPP program 'Improve year-round feed supply'. For instance, findings from 'P.PSH.1048 - Perennial pasture and forage combinations to extend summer feed in Southern NSW (CSIRO)' and 'P.PSH.1030 - Extending the boundaries of legume adaptation through better soil management (NSWDPI)' have direct relevance to producers in the North-west and the Midlands regions of Tasmania.

3.2 Experiment 1: Sowing new pastures for higher legume content using different sowing methods

3.2.1 Midlands

Two sites were established in the Midlands region in spring 2021, one on a commercial farm to the north of Campbell Town (41'50°51 S, 147'17'59 E; 30-8-2021) on and one at the Cressy Research and Demonstration Station, just south of Cressy (41'42°27 S, 147'06'05 E; 2-9-2021). The sites were prepared by heavy grazing and topping the existing pasture, followed by application of glyphosate onto the regrowth. The site was then direct drilled into the burnt off pasture.

The experiments were sown in a nested split plot design with four blocks (1 replicate per block) (Appendix 8.5; **Error! Reference source not found.**). Sowing technique was the main plot with the three techniques being; mixed row, alternate row and matrix sowing. Plots were sown with a Ojyard cone seeder with 10 rows, 150 mm between rows. The alternate row was sown by using a 5-tube manifold and splitting the grass 5 ways in alternate rows. The legume was then sown in between by going back over the plots, slightly offset. The matrix plots were sown first with the grass being sown perpendicularly across multiple plots and then the legume treatments being sown conventionally in individual plots. Sowing rates per hectare were maintained and consistent across plots.

Grass species was the sub-plot treatment, with either cocksfoot (*Dactylis glomerata* L.; cv. Aurus) or phalaris (*Phalaris aquatica* L.; cv. Advanced AT). Legume species was the sub-sub plot treatment, with either red clover (*Trifolium pratense* L.; cv. Rubitas @ 5kg/ha), white clover (*Trifolium repens* L., cv. Quartz @ 3kg/ha), Caucasian clover (*Trifolium ambiguum* L.; cv. Kuratas @ 5kg/ha), Talish clover

(*Trifolium tumens* Steven ex M. Bieb.; cv. Permatas @ 3kg/ha), or lucerne (syn alfalfa, *Medicago sativa*; cv. Stamina GT 5 @ 5kg/ha).

Dry matter yield was evaluated by one of two methods at each harvest point. By either cutting one strip 1.37m (54 inch) x 5.5 m in length with an Iseki SXG 326 mower with a SCMA54 cutting desk and SBC600 collector to a height of 55 mm; or by cutting three 0.5 m x 0.5 m (0.25 m^2) quadrats, randomly positioned within the plot. Samples were weighed fresh in the paddock and a sub sample taken. Samples were oven dried at 60°C for 48 hours for DM % determination and converted to a kg DM/ha figure for each plot. These were undertaken on 1/11/2022, 23/1/2023, 18/5/2023, 21/9/2023, 22/11/2023.

Table 1 Monthly rainfall totals for Campbell Town, Northern Midlands Tasmania.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
2020	*35.2*	*34.6*	*100.2*	*100.6*	*23.8*	*30.2*	*25.0*	*79.8*	*19.6*	*89.0*	*14.8*	*67.8*	620.6
2021	*46.0*	*31.2*	*31.4*	*7.8*	*25.6*	*25.8*	*61.2*	*26.6*	*34.8*	*128.8*	*24.8*	*6.8*	450.8
2022	*45.2*	*1.8*	*20.2*	*23.4*	*27.4*	*26.4*	*10.0*	*78.6*	*61.8*	*116.2*	*101.0*	*48.0*	560
2023	*9.8*	*19.6*	*43.4*	*37.4*	*15.4*	*56.2*	*30.4*	*48.8*	*12.0*	*30.2*	*22.6*	-	325.8
Mean	32.5	30.3	39.8	37.7	37.9	35.0	34.7	35.4	44.2	50.5	45.3	41.6	440.4

Note: the mean represents the average rainfall for all years recorded between 2005 and 2023. Station: Fosterville #93059 Lat 41.93° S, Long 147.43° E. Elev 177m. Values in italics represent observations which have not been fully quality controlled.

Table 2 Monthly rainfall totals for Cressy, Northern Midlands Tasmania.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
2020	29.9	*65.0*	*110.0*	103.5	*35.2*	30.3	*31.2*	69.2	45.4	*103.6*	24.8	*63.7*	711.8
2021	*52.2*	77.2	*38.0*	*25.6*	*35.0*	47.8	*106.6*	77.0	*20.6*	*142.9*	*20.2*	*0.4*	643.5
2022	*80.2*	*14.0*	*36.2*	*45.7*	*40.8*	*67.7*	*27.5*	*156.8*	*55.6*	127.3	*61.2*	*39.8*	752.8
2023	*35.1*	*31.6*	*65.4*	*38.3*	*24.3*	*88.3*	*54.0*	*76.4*	*21.0*	*39.4*	*21.6*	-	530.5
Mean	40.0	39.2	37.5	50.7	55.0	54.8	70.6	69.3	56.9	54.1	49.3	48.8	621.7

Note: the mean represents the average rainfall for all years recorded between 1941 and 2023. Station: Cressy House #91021 Lat 41.66° S, Long 147.10° E. Elev 155m. Values in italics represent observations which have not been fully quality controlled by the Bureau of Meteorology.

3.2.2 Northeast

Large plot sowing method experiment

An opportunity arose in spring 2023 to evaluate the broadcast roller sowing method on a commercial farm in the Tamar Valley, north of Launceston (41'12°43 S, 146'55'12 E; 27-9-2023). While just outside of the northern midlands region, it did provide an opportunity to evaluate the broadcast roller sowing method in a dry spring season. The experimental plots were sown in a portion of a paddock being renovated by the farmer, with the previous turnip crop being heavily grazed and the stubble cultivated in. Fertiliser was truck spread prior to sowing with 250 kg/ha of 8-8-10-9 NPKS mix.

The experiment was sown in a randomised block design with four treatments (1 replicate per plot). Plots were 6m x 25m (Appendix 8.5; **Error! Reference source not found.**). The main plot sowing treatments were mixed row, alternate row, matrix, and broadcast roller drill. The broadcast roller drill was a Amazon Catross discs followed by an air seeder, which broadcast the seed in front of a finishing roller, 6m in sowing width, and was the same drill being used to sow the remainder of the paddock and was sown with one pass, while the three other treatments were sown with a PJ Green Double Disc Double Cone Seeder in four passes with 10 rows, 150 mm between rows. The alternate row was sown by using two x 5 tube manifolds and splitting the grass and the legume 5 ways in alternate rows. The matrix plots were sown first with the grass being sown perpendicular across the plot and then the legume being sown in the same orientation as with other plots. Mixed plots were sown conventionally with the grass and legume combined within the same row. Sowing rates per hectare were maintained and consistent across plots, with the perennial ryegrass (*Lolium perenne* L.; cv. Maxsyn @ 20kg/ha), red clover (*Trifolium pratense* L.; cv. Rubitas @ 3kg/ha), and white clover (*Trifolium repens* L., cv. NZ White @ 2kg/ha). This sowing mix was chosen by the producer and is a common sowing recommendation across the medium rainfall zone and was applied across the paddock.

Plant counts were undertaken 42 days after sowing (DAS) by using a 1m ruler, randomly thrown within the plot then positioned between drill rows. The number of perennial ryegrass, red and white clover plants on either side of the ruler was recorded, replicated 20 times. The broadcast roller plots did not have drill rows as such, rather press wheel lines. In this instance, the ruler was aligned to one of the press wheel lines and plants were counted within a 1m x 0.2m area, replicated 20 times. The matrix counts were conducted using the ruler technique both along the legume rows and the perpendicular grass rows. All sowing techniques were then converted to a plants/m^2 figure.

Dry matter yield was evaluated by cutting five 0.25 m2 quadrats, randomly positioned within the plot. Samples were weighed fresh in the paddock and a sub sample taken. Samples were oven dried at 60°C for 48 hours for DM % determination and converted to a kg DM/ha figure for each plot.

As all of the data violated either the assumption of normality, the assumption of homogeneity of variance or both, three Kruskal Wallis tests were performed, one for each of the species (ryegrass, white clover and red clover) with the sowing treatment as the independent variable. Confidence intervals were set at 95%. Dunn's Test with a Bonferroni correction of p-values was used using the FSA package (Ogle et al, 2023) to understand the differences between treatments, and the adjusted p-values were used.

Small plot sowing method x pasture species experiment

A small plot experiment was sown at the same site north of Launceston (41'12°43 S, 146'55'12 E; 27-9-2023). The aim of this experiment was to evaluate binary species combinations and sowing methods. The plots received the same preparation as the large plot sowing method experiment with fertiliser being truck spread prior to sowing with 250 kg/ha of 8-8-10-9 NPKS mix.

The experiment was sown in a nested split plot design with 4 blocks (1 replicate per block) (Appendix 8.5; **Error! Reference source not found.**). Plots were 6m x 1.5m with a PJ Green Double Disc Double Cone Seeder in one pass with 10 rows, 150 mm between rows. The main plot was sowing methods and were mixed row, alternate row, and broadcast roller. Mixed plots were sown conventionally with the grass and legume combined within the same row. The alternate row was sown by using two x 5 tube manifolds and splitting the grass and the legume 5 ways in alternate rows. The broadcast roller plots were sown by broadcasting the seed on the surface by hand and rolled with a small lawn roller. Sand was added to the seed and mixed thoroughly to bulk up the seed to facilitate hand spreading.

Grass species was the sub-plot treatment, with either cocksfoot (*Dactylis glomerata* L.; cv. Aurus @ 5kg/ha) or perennial ryegrass (*Lolium perenne* L.; cv. Maxsyn @ 15kg/ha). Legume species was the sub-sub plot treatment, with either red clover (*Trifolium pratense* L.; cv. Rubitas @ 4kg/ha), white clover (*Trifolium repens* L., cv. Quest @ 2kg/ha), Strawberry clover (*Trifolium fragiferum* L.; cv. Palestine @ 4kg/ha), or lucerne (syn alfalfa, *Medicago sativa*; cv. Stamina GT 6 @ 4kg/ha).

Plant counts were undertaken 42 DAS by using a 1m ruler, randomly thrown within the plot then positioned between drill rows. The number of perennial ryegrass, red and white clover plants on either side of the ruler was recorded, replicated 6 times. The broadcast roller plots did not have rows, thus a 500 mm x 500 mm (0.25 m^2) quadrat was randomly positioned within the plots, replicated 6 times. All sowing techniques were then converted to a plants/m^2 figure.

Dry matter yield was evaluated by cutting three 500 mm x 500 mm (0.25m^2) quadrats. The three samples were combined and weighed. Samples were oven dried at 60°C for 48 hours for DM % determination and converted to a kg DM/ha figure for each plot.

The data were natural logged to make the residuals normally distributed, and any zeros removed, as these cannot be logged. A two-way ANOVA for each legume species was performed with legume count as the dependent variable and sowing treatment and grass species and their interaction as the independent variables. A Tukey's HSD was then performed to understand significant differences between sowing treatments and grass species. Confidence intervals were set at 95%. All analyses were performed using R (R Core Team, 2023).

Table 3 Monthly rainfall totals for Greenhythe, Tamar Valley

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
2023	*60.8*	30.0	79.6	64.6	*36.8*	*123.0*	*76.7*	*78.2*	*30.6*	*42.4*	*21.8*	-	644.5
Mean	58.4	37.9	49.2	63.7	73.9	86.3	90.9	98.5	77.8	61.2	62.8	45.8	806.4

Note: the mean represents the average rainfall for all years recorded between 1988 and 2023. Station: Deviot Jetty #91255 Lat 41.23° S, Long 146.93° E. Elev 40m. Values in italics represent observations which have not been fully quality controlled by the Bureau of Meteorology.

3.3 Experiment 2: Reintroducing legumes into grass dominant pastures

3.3.1 Midlands

Two sites were established in the Midlands region in spring 2020. One on a commercial farm to the west of Campbell Town (41'57°41 S, 147'26'25 E; 24-9-20) on and one at the Cressy Research and Demonstration Station, just south of Cressy (41'42°27 S, 147'06'05 E; 28-9-20). A second Cressy site was sown on 28-9-21, though establishment was poor across all plots and the site was abandoned. The sites were dominated by phalaris (*Phalaris aquatica* L.) and grazed heavily through winter. See Table 1 and Table 2 for rainfall data.

The experiments were sown in a nested split-split plot design with 4 blocks (1 rep per block) (Appendix 8.5; **Error! Reference source not found.**). The main plots were three sowing methods including: mixed row, strip till, and broadcast. These treatments had to be nested in order for the machinery to work efficiently. The mixed row plots were sown with an Ojyard cone seeder, the strip till plots with a Soilkee Renovator and the broadcast plots were sown by hand. Plots were 7m x 3m.

The sub-plot was herbicide treatments to half of the plots. This was an application of glyphosate 360 @ 1L/ha was applied prior to sowing to reduce the vigour of the phalaris plants and offer a reduction in competition to the establishing legume. The sub-sub plot treatments were perennial legumes including: white clover (*Trifolium repens* L.; cv. Hilltop @ 3 kg/ha), red clover (*Trifolium pratense* L.; cv. Rubitas @ 5 kg/ha), Talish clover (*Trifolium tumen*s Steven ex M.Bieb.; cv. Permatas @ 3 kg/ha), Caucasian clover (*Trifolium ambiguum* L.; cv. Kuratas @ 5 kg/ha), and lucerne (syn. alfalfa; *Medicago sativa* L.; cv. Stamina GT5 @ 5 kg/ha).

Dry matter yield was evaluated by cutting one strips 1.37m (54 inch) x 5.5 m in length with an Iseki SXG 326 mower with a SCMA54 cutting desk and SBC600 collector to a height of 55 mm. Samples were weighed fresh in the paddock and a sub sample taken. Samples were oven dried at 60°C for 48 hours for DM % determination and converted to a kg DM/ha figure for each plot.

Plant counts were conducted as a measure of initial establishment, At Fosterville, plant counts were conducted on 6-11-20 and 11-5-21. For direct drill and strip till plots, a 1m ruler was thrown randomly within the plot and then aligned with a sowing row. The number of plants per 1m of row was recorded, replicated four times and converted to a plant count per m^2. For broadcast plots, a 0.5 m x 0.5 m quadrat was thrown randomly and the number of plants within recorded, replicated twice and converted to a plant count per m^2.

Frequency scoring using the 'EverGraze' frequency of occurrence method was undertaken as a measure of persistence on 22-6-23 at Fosterville. A 1m2 quadrat with 10 x 10 cm grid (100 squares) was used to identify the presence of absence of the target species within each of the squares.

The proportion of legume in the plots was assessed by hand separating the individual species components from a sub-sample in the laboratory prior to drying.

3.3.2 Northwest

A site was established in the north-west region in autumn 2022 (25-3-2022) on 'Freer Farm', a TAFE (Technical and Further Education) farm near Burnie (41'04°26 S, 145'52'11 E). A summary of the rainfall during the experimental period is provided in Table 4. The site was dominated by perennial ryegrass (*Lolium perenne* L.) and grazed through early autumn and mowed to remove standing residual. The experiment was sown in a nested split-split plot design with 4 blocks (1 rep per block). The main plots were three sowing methods including: mixed row, strip till, and broadcast. These treatments had to be nested in order for the machinery to work efficiently. The mixed row plots were sown with an Ojyard cone seeder, the strip till plots with a Soilkee Renovator and the broadcast plots were sown by hand. Plots were 7m x 3m.

The sub-plot was herbicide treatments to half of the plots. This was an application of glyphosate 360 @ 0.5L/ha was applied prior to sowing to reduce the vigour of the perennial ryegrass plants and offer a reduction in competition to the establishing legume. The sub-sub plot treatments were perennial legumes including: white clover (*Trifolium repens* L.; cv. Hilltop @ 3 kg/ha), red clover (*Trifolium pratense* L.; cv. Rubitas @ 5 kg/ha), strawberry clover (*Trifolium fragiferum* L.; cv. Palestine @ 5 kg/ha), lucerne (syn. alfalfa; *Medicago sativa* L.; cv. Stamina GT6 @ 5 kg/ha), and a combination of chicory (*Cichorium intybus* L.; cv. Commander @ 5 kg/ha) and narrow leaf plantain (*Plantago lanceolata* L.; cv. Tonic @ 3 kg/ha).

Dry matter yield was evaluated by cutting one strips 1.37m (54 inch) x 5.5 m in length with an Iseki SXG 326 mower with a SCMA54 cutting desk and SBC600 collector to a height of 55 mm. Samples were weighed fresh in the paddock and a sub sample taken. Samples were oven dried at 60°C for 48 hours for DM % determination and converted to a kg DM/ha figure for each plot.

Table 4 Monthly rainfall totals for Burnie, Northwest Tasmania

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
2020	53.6	*63.6*	94.6	129.6	61.6	80.4	25.6	88.2	*67.2*	128.6	48.2	67.0	908.2
2021	60.4	107.0	72.6	27.6	43.4	*151.0*	151.2	*130.6*	74.2	135.8	*54.6*	16.0	1024.4
2022	*102.6*	15.0	99.0	59.6	102.2	*137.6*	47.0	*134.2*	74.6	*195.4*	105.4	17.6	1090.2
2023	35.8	30.4	75.8	44.4	*43.8*	*169.4*	*108.4*	*76.6*	*40.2*	*35.4*	*38.4*	-	698.6
Mean	54.4	45.0	77.0	58.5	84.0	107.1	119.4	117.0	84.9	81.0	65.2	57.0	970.7

Note: the mean represents the average rainfall for all years recorded between 2009 and 2023. Station: Burnie (Park Grove) #91355 Lat 41.05° S, Long 145.88° E. Elev 99m. Values in italics represent observations which have not been fully quality controlled by the Bureau of Meteorology.

3.4 Experiment 3: Improving pasture productivity on winter wet pastures with waterlogging tolerant legumes

3.4.1 Pot study screening of trefoils

This experiment was undertaken at the Tasmanian Institute of Agriculture's Mt Pleasant Laboratories site, Launceston, Tasmania, Australia (41°28'S, 147°8'E; elevation, 144 m). Under glasshouse conditions, two seedlings of big trefoil (*Lotus pedunculatus* Cav.; cv. Sunrise), bird's-foot trefoil (*Lotus corniculatus* L.; cv Goldie, TIA_LC1), narrowleaf trefoil (*Lotus tenuis* Waldst. & Kit. Ex Willd; TIA_LT1, TIA_LT2 & TIA_LT3) were established in 0.64-L polyvinyl chloride pots containing potting media.

Plants were grown in glasshouse conditions for 35 days, before hardening off for 7 days prior to the implementation of treatments. The experiment was arranged in a split plot design with waterlogging treatment as the main plot, four waterlogging tanks were split in two, with the waterlogging treatment and the control randomly allocated (4 blocks) (*Figure 2*). The waterlogging period was imposed for 28 days. The six trefoil lines were the sub-plot treatments. Four pots of each trefoil line were assigned to each of the main plot treatment (except where 2 pots of TIA_LC1 and TIA_LT3 are allocated due to fewer plants establishing).

On day 0, two of the four pots were randomly selected. Plants were removed from their pots and their roots washed free of potting media and a subsample of root biomass removed and analysed for aerenchyma development. Remaining shoot and root biomass of each plant was then dried separately to constant weight at 60˚C in a forced-draught oven. This was repeated after day 28.

Figure 2 Four waterlogging tanks used to apply treatments. Each tank is separated in two with a waterlogged and control treatment bay.

Table 5 Monthly rainfall totals for Mt. Pleasant Laboratories, Launceston

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
2020	*47.3*	64.0	*97.0*	*159.6*	*42.7*	*40.1*	26.1	*102.1*	54.9	*108.5*	*41.4*	*98.2*	881.9
2021	*43.4*	47.6	*32.0*	*24.4*	49.7	*23.7*	*40.6*	*79.4*	*44.2*	*112.4*	*58.0*	12.2	567.6
2022	*30.9*	*16.1*	38.3	81.6	42.1	108.0	*27.8*	*88.9*	62.5	*120.4*	59.8	49.7	726.1
2023	*31.2*	24.8	*69.9*	57.6	*25.2*	*117.6*	*79.4*	*57.4*	*27.4*	*41.2*	*39.6*	-	571.3
Mean	42.1	39.0	39.0	56.2	62.6	66.1	80.7	82.0	62.5	60.2	49.0	49.8	689.2

Note: the mean represents the average rainfall for all years recorded between 1924 and 2023. Station: Kings Meadows #91072 Lat 41.47° S, Long 147.16° E. Elev 67m. Values in italics represent observations which have not been fully quality controlled by the Bureau of Meteorology.

3.4.2 Pot study screening of waterlogging tolerance in strawberry clover

Forty-two strawberry clover genotypes were evaluated, including twenty-nine wildtype (undeveloped) genotypes, seven breeding lines and six cultivars. With one exception, wildtype genotypes had been collected from the species' centre of origin, which includes EuroSiberia and the Mediterranean (*Figure 3*). Within these regions, wild-type genotypes were selected to encompass natural habitats with the widest range of altitudes (-15 to 2040 m), latitudes (-35.2 to 48.7), precipitation (annual, 202 to 1271 mm), mean daily ambient temperatures (winter, -19.0 to 14.6˚C; summer, 15.7 to 30.6˚C) and soil pH (5 to 10). All breeding lines originated from Australian research programs. Seed of the main commercial cv. Palestine harvested in 1957 and 2021 was included. Other cultivars included were Grasslands Upward (New Zealand), O'Connors (Australia), Princep Park (Australia) and Salina (USA).

This experiment was undertaken at the Tasmanian Institute of Agriculture's Mt Pleasant Laboratories, Launceston, Tasmania, Australia (41°28'S, 147°8'E; elevation, 144 m). Under glasshouse conditions, individual inoculated (group B) seedlings were established in 0.64-L polyvinyl chloride pots containing potting media. After 63-days, pots were moved outside and acclimated to ambient conditions for 34-days before the imposition of treatments. Between 12 July and 6 September 2022, treatments were imposed for 56 days. Treatments coincided with the winter months, when south-eastern Australian pastures are most likely to experience waterlogging stress.

During the treatment period, 114 mm of rainfall occurred, with daily maximum and minimum ambient temperatures averaging 13.5˚C and 4.6˚C, respectively.

Treatments were imposed in a split-plot design, which had four blocks. Each block consisted of a fibreglass tank, which was split lengthwise by an impervious barrier into two main-plots of equal size (*Figure 4*). Waterlogging level was the main-plot treatment (non-waterlogged or waterlogged), with strawberry clover accessions the subplot treatments. In waterlogged main-plots, water was maintained 5-10 mm above the potting media surface. During the treatment period, rainfall met or exceeded the evapotranspiration demands of non-waterlogged plants. Within each main-plot, pots were arranged in a completely randomised design and surrounded by an outer borderer of buffer pots (cv. Palestine 2021) to minimise edge effects. A total of 2016 experimental units (pots) were included (four blocks by two waterlogging levels by forty-two accessions by six replicates).

At conclusion of the 56-day treatment period, plants were removed from their pots and their roots washed free of potting media and a subsample of root biomass removed and analysed for aerenchyma development. Remaining shoot and root biomass of each plant was then dried separately to constant weight at 60˚C in a forced-draught oven.

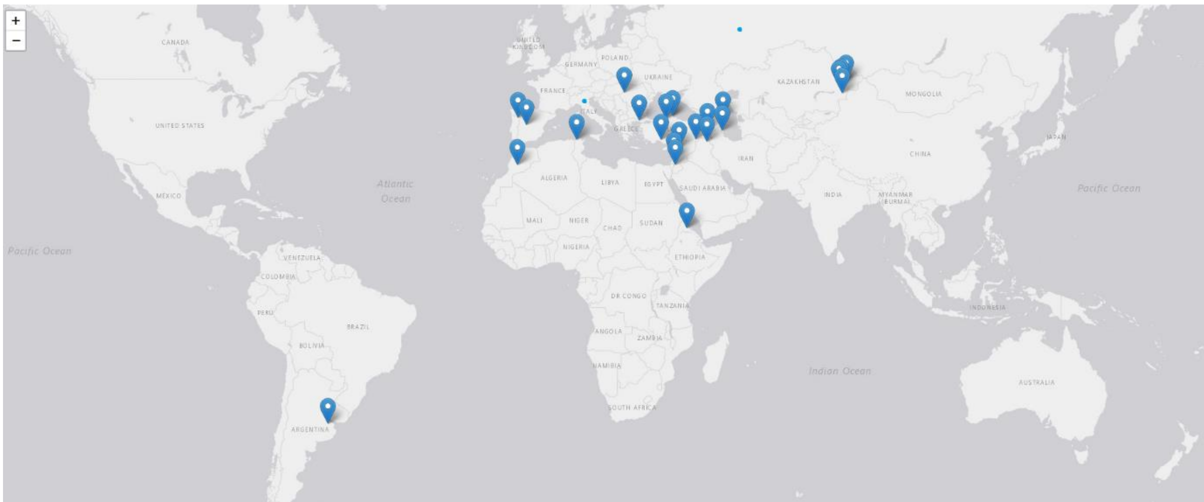

Figure 3 Map depicting wildtype genotype collection sites.

Figure 4 (a) shows the experimental layout, with fibreglass tanks divided lengthwise into main-plots; (b) shows plants immediately before harvesting.

3.5 Experiment 4: Field evaluation of waterlogging tolerant legumes

This experiment was established to evaluate the potential role of identified waterlogging tolerant species/cultivars on a commercial farm at Edith Creek in NW Tasmania (40°57'S, 145°05'E; elevation, 29 m). The experiment was sown in a low-lying paddock with poor drainage. Monthly rainfall totals are provided in Table 6.

The experiment was sown in 5/5/2021 and 19/5/2022 in a randomised complete block design with 4 blocks, 1 rep per block. Plots were 6 m x 1.5 m and were sown using an Ojyard cone seeder.

Legume species were sown in both monocultures and simple binary mixtures with and without perennial ryegrass cv Base AR37 @ 15 kg/ha. Monocultures were designed to demonstrate the ability of the individual species/cultivars to persist and produce in winter waterlogged environments, while binary mixtures were to show the potential value of tested legumes when incorporated into the existing perennial ryegrass feedbase. Legumes were strawberry clover cv. Palestine @ 3kg/ha, Lotus pedunculatus @ 3kg/ha, white clover @ 3kg/ha, and red clover cv. Rubitas @4 kg/ha. Grazing followed dry matter yield harvest events.

Dry matter yield was evaluated by three 0.5 m x 0.5 m ($0.25m^2$) quadrats per plot to a height of 55 mm. Samples were weighed fresh and a sub sample taken. Samples were oven dried at 60°C for 48 hours for DM % determination and converted to a kg DM/ha figure for each plot. The proportion of legume in the plots was assessed by hand separating the individual species components from a sub-sample in the laboratory prior to drying. Dry samples were ground through a 1 mm sieve and sent to the NSW DPI laboratory for NIR analysis.

Frequency scoring using the 'EverGraze' frequency of occurrence method was undertaken as a measure of persistence on 16/2/2023 and 25/5/2023. A 1m2 quadrat with 10 x 10 cm grid (100 squares) was used to identify the presence of absence of the target species within each of the squares.

Table 6 Monthly rainfall totals for Edith Creek, Northwest Tasmania

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
2020	63.2	48.4	82.0	166.6	116.8	*117.4*	*55.8*	*134.4*	*102.3*	100.8	52.2	95.2	1135.1
2021	76.4	47.3	85.6	85.9	90.2	110.2	*200.5*	138.8	130.6	*169.7*	55.6	19.4	1210.2
2022	23.2	19.2	42.4	38.2	*157.0*	*147.4*	75.4	*245.4*	*92.8*	179.2	103.2	33.0	1156.4
2023	19.4	42.4	*94.8*	*83.4*	*124.8*	*229.0*	*181.2*	*108.0*	*73.6*	*65.2*	*46.0*	-	1087.2
Mean	47.7	43.6	79.4	79.1	137.8	126.5	174.7	164.3	111.2	99.7	73.6	62.0	1211.9

Note: the mean represents the average rainfall for all years recorded between 2010 and 2023. Station: Edith Creek #91357 Lat 40.98° S, Long 145.09° E. Elev 50m. Values in italics represent observations which have not been fully quality controlled by the Bureau of Meteorology.

3.6 Extension and adoption

Extension and adoption activities were embedded throughout the project. Project guidance and feedback was provided by the regional reference group. Traditional out-projecting extension was undertaken through conferences and field days. The Involve and Partner activities formed the basis for Case Study learnings throughout the second half of the project.

3.6.1 Out projecting extension

In extending project updates and key messages, the project team used a range of different media including:

- stand-alone field days organised by the project team
- paddock walks organised by the project team with some involving researcher from other LPP projects
- conference presentations at red meat updates
- updates at producer group events facilitated by Pinion Advisory, Derwent Valley Catchment and Tamar NRM
- presentation evenings
- on-line webinars and recorded presentations
- project awareness and updates in print media, radio and social media
- newsletters

3.6.2 Involve and partner

Involve and partner activities were undertaken on 12 properties, 4 in the northwest of Tasmania and 5 in the midlands. A further 3 properties outside of the focus regions also participated. Some properties had more than one sowing due to establishment failures or improving on the first. Activity on each farm varied slightly due to enterprise and farming system, but most related to either sowing of a new pasture or oversowing a degraded one. In every instance there was an attempt to advantage the legume component of the sward, whether that be by high sowing rates of legume, reducing sowing rates of grass, spatially separating the grass and legume with broadcast roller sowing techniques, and in every case choosing appropriate species for the growing environment and enterprise.

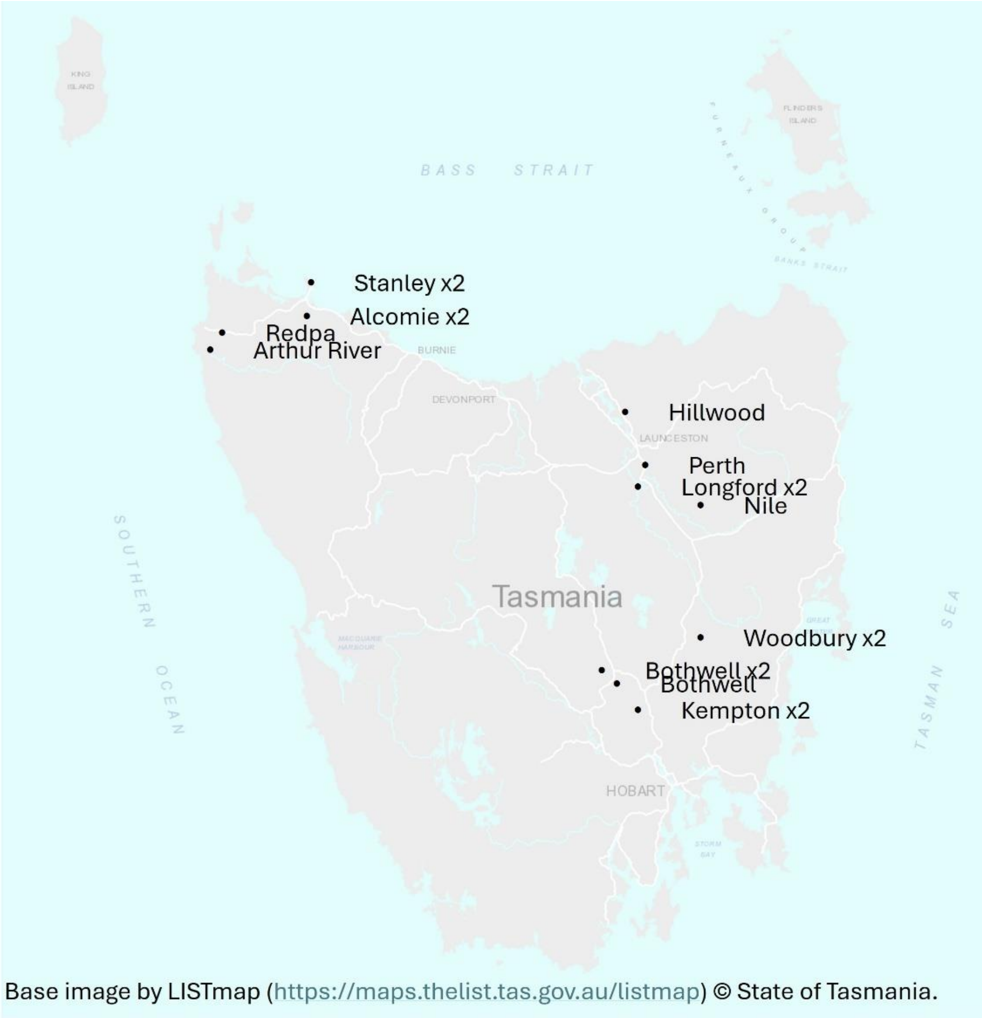

Figure 5 Map of involve and partner sites across Tasmania

4. Results

4.1 Experiment 1: Sowing new pastures for higher legume content using different sowing methods

4.1.1 Midlands

At the Cressy site, the sowing method appeared to have no significant effect on overall dry matter yield. Alternate row (10,489 kg DM/ha) recorded the highest overall yield, followed by matrix (10,477 kg DM/ha) and then mixed row (10,296 kg DM/ha) (Figure 6). Overall dry matter was highest in red clover plots, both in combination with cocksfoot (11,213 kg DM/ha) and phalaris (11,112 kg DM/ha) (Figure 7). Lucerne had the second highest overall dry matter both in combination with cocksfoot (10,711 kg DM/ha) and phalaris (10,740 kg DM/ha). Caucasian clover plots had the lowest overall dry matter (9,961 kg DM/ha).

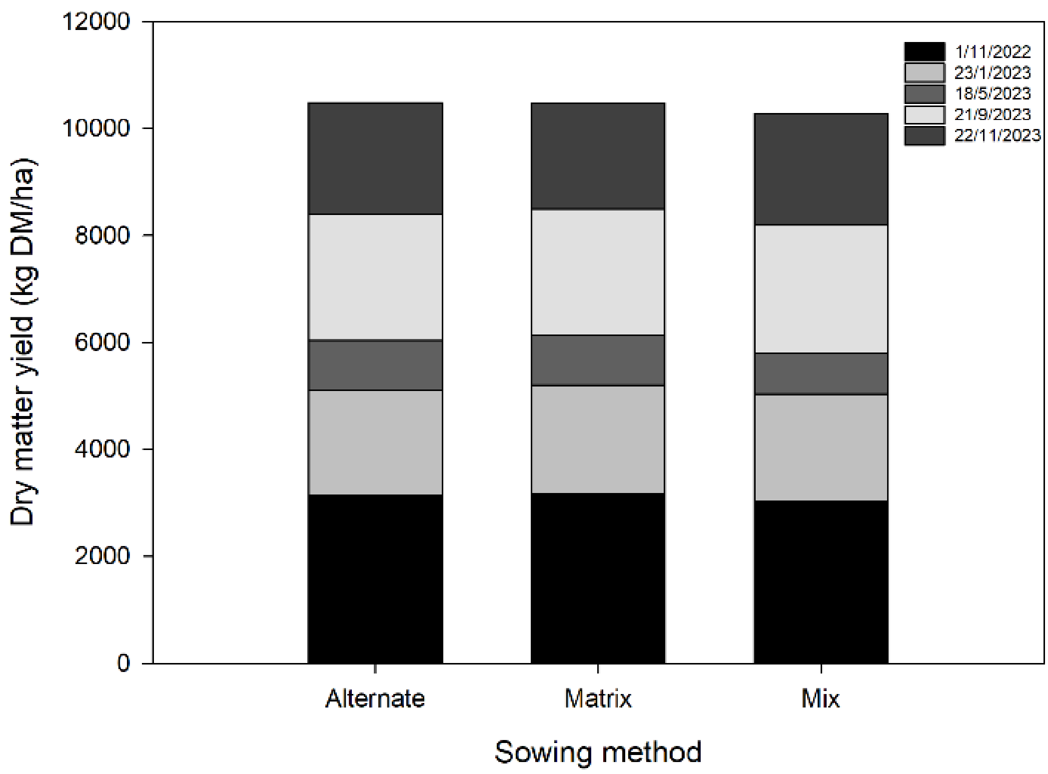

Figure 6 Cressy overall dry matter yield (kg DM/ha) of three sowing methods: Alternate row, matrix, and mixed row sowing.

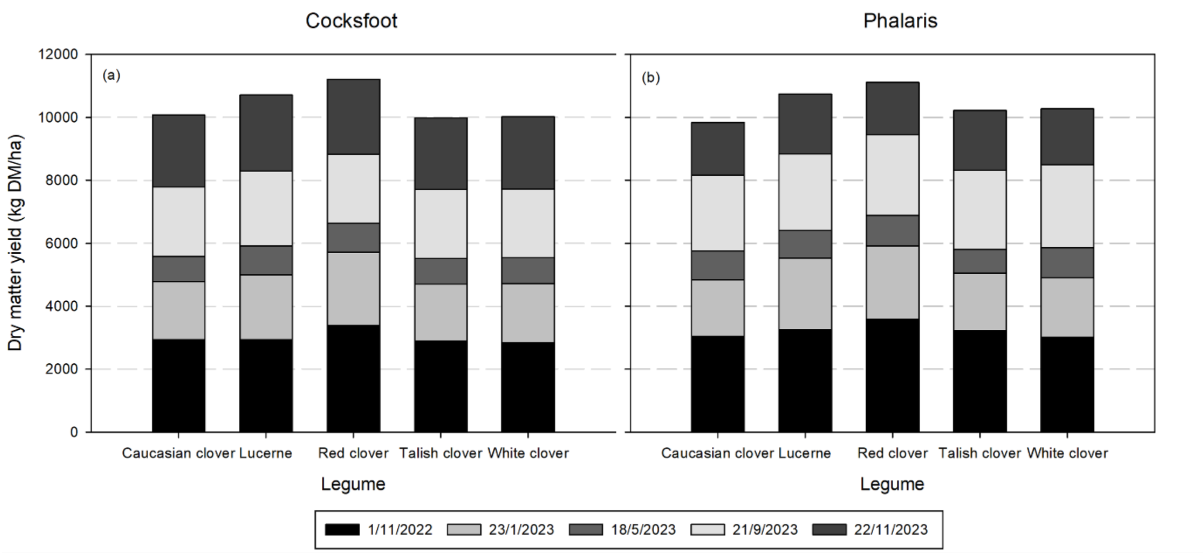

Figure 7 Cressy overall dry matter yield (kg DM/ha) of five legume species: Caucasian clover, lucerne, red clover, Talish clover, and white clover in combination with cocksfoot (a) and phalaris (b).

At the Cressy site, the contribution of sward components to dry matter was evaluated from the 22/11/2023 harvest (Figure 8). The sown grass component was highest in each of the alternate row and matrix sown legume treatments (Figure 8a,b). In mixed row, volunteer legume (Caucasian and Talish clovers), sown legume (lucerne) and sown grass (red and white clovers) split the highest contributors (Figure 8c). Of the sown legumes, lucerne contributed the highest amount of dry matter in each of the sowing method treatments. Red clover was next best, while white and Talish clovers contributed little, and Caucasian clover 0 kg DM/ha. The higher dry matter contributions of lucerne and red clover were possibly aided by their erect growth habit and herbage growth above the cutting height.

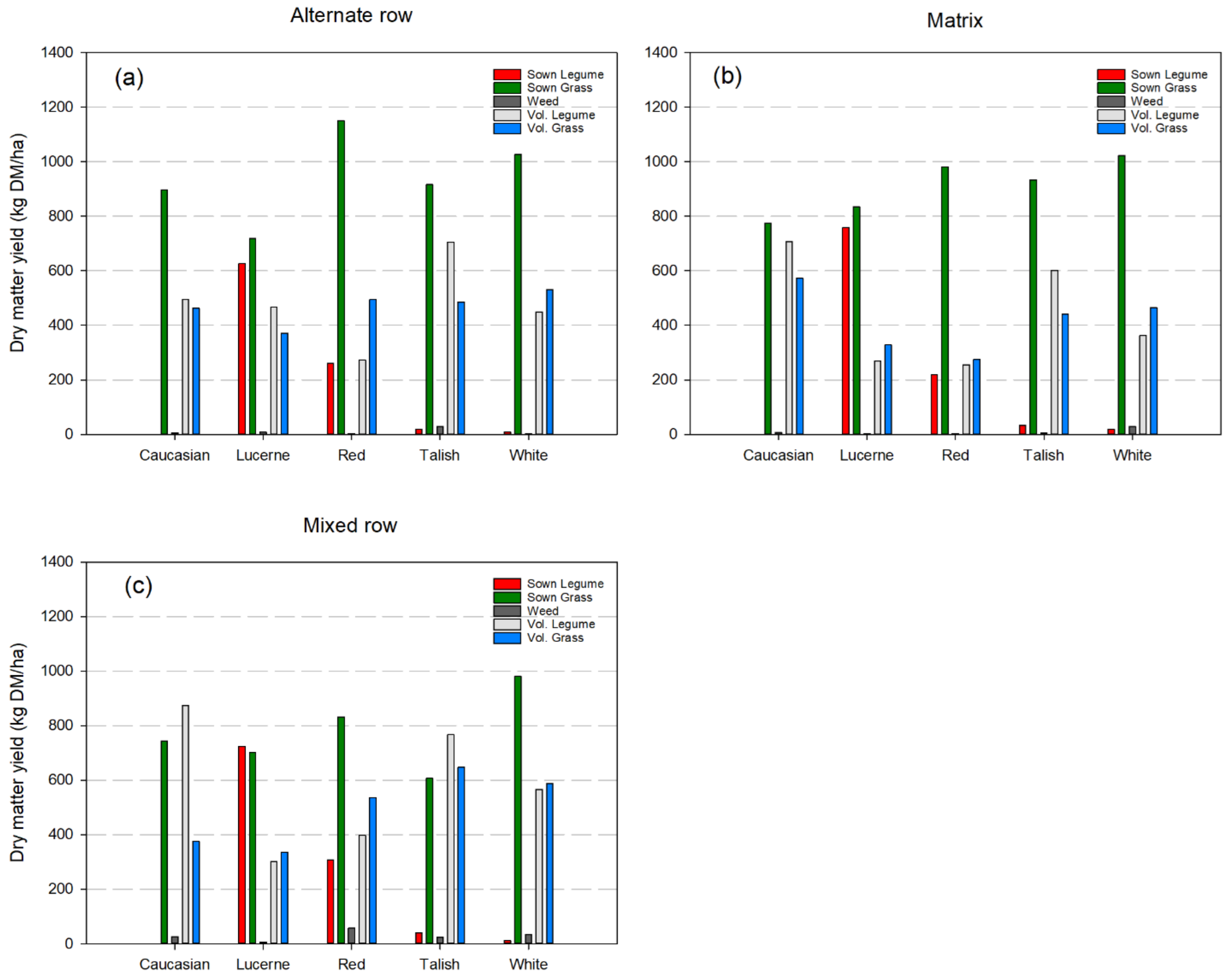

Figure 8 Cressy dry matter contribution (kg DM/ha) of sward components 'sown legume', 'sown grass', 'weed', 'volunteer legume', and 'volunteer grass' in five sown legume species treatments; Caucasian clover, lucerne, red clover, Talish clover and white clover from yield harvest (22/11/2023)

Feed nutritional analysis showed little difference between cocksfoot and phalaris in terms of neutral detergent fibre (NDF %), crude protein (CP %), dry matter digestibility (DMD %), calculated metabolisable energy (ME MJ/kg DM), and water soluble carbohydrates (%) (Table 7). There appeared to be a slightly higher CP level in plots sown with lucerne and Talish clover compared to the other legumes (Table 8). Higher CP in the lucerne plots makes sense given the proportion of legume in those plots is the highest of all the legumes (Figure 8). There was very little difference in feed quality between sowing method (Table 9).

Table 7 Nutritional analysis of herbage harvested in November 2023 by plots sown with cocksfoot and phalaris

Species	NDF %	CP %	DMD %	ME (MJ/kg DM)	WSC %
Cocksfoot	52.2	10.9	64.3	9.4	8.0
Phalaris	52.2	11.1	64.4	9.4	7.8

Note: NDF – Neutral detergent fibre (NIR), CP – Crude protein (NIR), DMD – Dry matter digestibility (NIR), ME – Metabolisable energy (by calculation from NIR), WSC – Water soluble carbohydrates (NIR). Results are an average of two plots.

Table 8 Nutritional analysis of herbage harvested in November 2023 by plots sown with legume species with grasses

Species	NDF %	CP %	DMD %	ME (MJ/kg DM)	WSC %
White clover	53.6	10.2	63.7	9.3	8.2
Red clover	52.7	10.5	64.5	9.4	8.3
Caucasian clover	53.1	10.5	64.2	9.3	7.9
Talish clover	51.0	11.8	64.1	9.4	7.4
Lucerne	50.5	12.1	65.4	9.6	7.6

Note: NDF – Neutral detergent fibre (NIR), CP – Crude protein (NIR), DMD – Dry matter digestibility (NIR), ME – Metabolisable energy (by calculation from NIR), WSC – Water soluble carbohydrates (NIR). Results are an average of two plots.

Table 9 Nutritional analysis of herbage harvested in November 2023 by sowing method

Species	NDF %	CP %	DMD %	ME (MJ/kg DM)	WSC %
Mixed row	52.4	10.9	64.3	9.4	7.9
Alternate row	52.4	10.9	64.4	9.4	8.1
Matrix	51.6	11.3	64.4	9.4	7.7

Note: NDF – Neutral detergent fibre (NIR), CP – Crude protein (NIR), DMD – Dry matter digestibility (NIR), ME – Metabolisable energy (by calculation from NIR), WSC – Water soluble carbohydrates (NIR). Results are an average of two plots.

4.1.2 North-east

Large plot sowing method experiment

There was a significant sowing method effect on plant counts 42 days after sowing (DAS). Plant counts per m^2 of ryegrass, white clover and red clover were significantly different between sowing treatments, with the broadcast having significantly lower plant counts than the other treatments (all were $P<0.0001$ for perennial ryegrass and white, and p-values ranged from $P=0.002$ [mixed and broadcast], $P=0.027$ [alternative and broadcast] and $P=0.05$ [matrix and broadcast]) (Figure 9). It was hypothesised that sowing depth is the major factor in this with the broadcast seed sitting on or close to the soil surface in a drying soil profile. Some seed will either have not germinated due to a lack of moisture or seeds have germinated and lacked vigour to reach moisture deeper in the profile before it dried out. This appears to be a limiting factor with the roller broadcast sowing technique; it will be more successful where there is good initial soil moisture or where irrigation can be applied.

For all species, the alternative row and matrix were not significantly different ($P=1.0$), nor were the alternative row sown and mixed sown ($P=0.238$, *0.900* and *1.0* for ryegrass, white clover and red clover, respectively). For ryegrass, the mixed sown plots had significantly greater plant counts than the matrix sown plots ($P=0.042$), but this was not found for white clover ($P=0.103$) or red clover ($P=1.0$). Feed quality was similar across sowing methods, though CP was slightly higher and WSC slightly lower in broadcast roller plots (Table 10).

Figure 9 Mean plant counts (per m^2) for perennial ryegrass, red clover and white clover sown by four sowing methods; mixed row (mixed), alternate row (Alt.), matrix and broadcast roller (Broad.). Error bars represent the standard error of the mean.

Table 10 Nutritional analysis of herbage harvested in December 2023 by sowing method

Sowing method	NDF %	CP %	DMD %	ME (MJ/kg DM)	WSC %
Mixed row	39.6	20.5	80.3	12.2	16.6
Alternate row	40.4	21.2	78.3	11.8	15.3
Broadcast roller	40.0	23.8	78.6	11.9	13.5
Matrix	39.1	21.3	78.1	11.8	15.0

Note: NDF – Neutral detergent fibre (NIR), CP – Crude protein (NIR), DMD – Dry matter digestibility (NIR), ME – Metabolisable energy (by calculation from NIR), WSC – Water soluble carbohydrates (NIR). Results are an average of 4 plots.

Small plot sowing method x pasture species experiment

There was a significant sowing method effect on legume plant counts 42 DAS. For all the legume species-companion grass combinations, the legume count per m2 was significantly lower when broadcast, in comparison to when they were sown in alternate rows (all *P* values were $P<0.02$) (Figure 10). For all legume species sown with ryegrass and for strawberry clover sown with cocksfoot, the legume count per m2 was not significantly different when direct drilled versus when sown in alternate rows (all *P* values >0.38) (Figure 10). For all legume species sown with ryegrass and for strawberry clover sown with cocksfoot, the legume count per m2 was significantly greater when direct drilled than when the plots were broadcast (all p-values <0.04).

Like in the larger plot experiment (4.1.1), it was hypothesised that sowing depth is the major factor in this with the broadcast seed sitting on or close to the soil surface in a drying soil profile. Some seed will either have not germinated due to a lack of moisture or seeds have germinated but lacked vigour to reach moisture deeper in the profile before it dried out. This appears to be a limiting factor with the roller broadcast sowing technique; it will be more successful where there is good initial soil moisture or where irrigation can be applied.

There was a significant sowing method effect on grass plant counts 42 days after sowing (DAS), with perennial ryegrass significantly higher than cocksfoot (Figure 11). This to be expected due to differences in sowing rates, but also might be an indication of the vigour of the grass. Perennial ryegrass is more vigorous than cocksfoot and as such would have an advantage over cocksfoot in the establishment phase in getting a root down to moisture in a drying profile. Once established, cocksfoot with its deeper rooting characteristic will have the advantage over ryegrass. There was no significant interaction between the sowing method and the count of companion grass species (*P=0.542*) (Figure 11).

Similar to the large plot experiment, CP appeared to be higher and WSC lower in broadcast plots relative to the other sowing treatments. This is perhaps being driven by the lower plant counts, but requires further investigation (Table 11). There is little difference in NDF and ME between sowing treatments. There were some differences between plots sown with cocksfoot and ryegrass, with cocksfoot plots having higher CP but lower DMD, ME and WSC (Table 12). There was little difference between plots sown with the different legume species (Table 13).

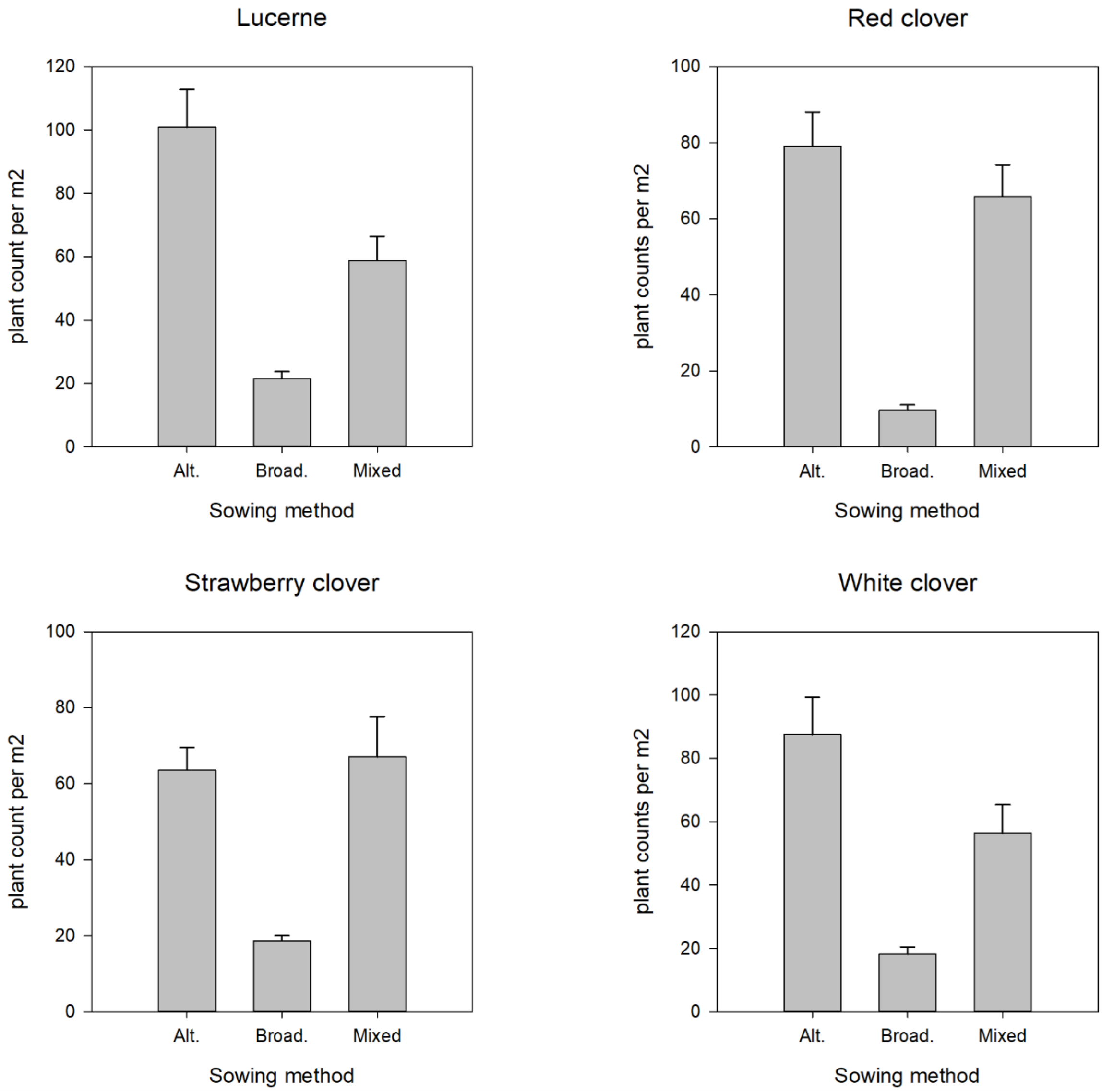

Figure 10 Mean plant counts (per m2) for legumes including lucerne, red clover, strawberry clover, and white clover sown by three sowing methods; mixed row, alternate row, and broadcast roller. Error bars represent the standard error of the mean.

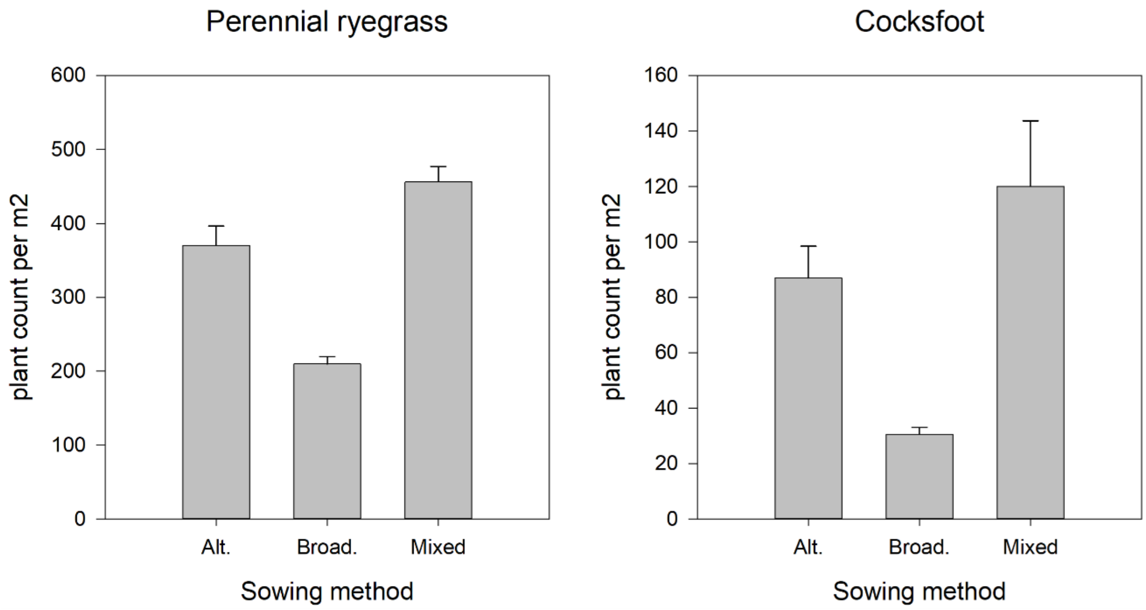

Figure 11 Mean plant counts (per m2) for grasses including perennial ryegrass and cocksfoot sown by three sowing methods: mixed row, alternate row, and broadcast roller. Error bars represent the standard error of the mean.

Table 11 Nutritional analysis of herbage harvested in December 2023 by sowing method

Sowing method	NDF %	CP %	DMD %	ME (MJ/kg DM)	WSC %
Mixed row	38.7	18.7	79.1	11.9	18.0
Alternate row	37.6	20.4	77.2	11.7	14.5
Broadcast roller	38.1	22.9	73.8	11.9	12.8

Note: NDF – Neutral detergent fibre (NIR), CP – Crude protein (NIR), DMD – Dry matter digestibility (NIR), ME – Metabolisable energy (by calculation from NIR), WSC – Water soluble carbohydrates (NIR). These results are an average of 2 plots.

Table 12 Nutritional analysis of herbage harvested in December 2023 by grass species sown

Sowing method	NDF %	CP %	DMD %	ME (MJ/kg DM)	WSC %
Cocksfoot	38.3	22.8	73.3	11.1	11.9
Ryegrass	37.9	19.6	78.7	11.8	16.8

Note: NDF – Neutral detergent fibre (NIR), CP – Crude protein (NIR), DMD – Dry matter digestibility (NIR), ME – Metabolisable energy (by calculation from NIR), WSC – Water soluble carbohydrates (NIR). These results are an average of 2 plots.

Table 13 Nutritional analysis of herbage harvested in December 2023 by legume species sown

Sowing method	NDF %	CP %	DMD %	ME (MJ/kg DM)	WSC %
Lucerne	38.3	19.8	75.3	11.4	13.5
Red clover	37.7	21.3	75.3	11.3	14.4
Strawberry clover	39.1	21.6	76.8	11.6	14.7
White clover	37.1	21.0	78.1	11.7	16.2

Note: NDF – Neutral detergent fibre (NIR), CP – Crude protein (NIR), DMD – Dry matter digestibility (NIR), ME – Metabolisable energy (by calculation from NIR), WSC – Water soluble carbohydrates (NIR). These results are an average of 2 plots.

4.2 Experiment 2: Re-establishment of legumes in grass dominant swards

4.2.1 Midlands

Legume establishment

The establishment of legumes at Campbell Town was tracked by undertaking plant counts 43 (Nov 2020) and 229 (May 2021) days after sowing (DAS) (Figure 12 a-f). Plant counts were significantly higher in direct drill plots than broadcast plots 43 DAS. They were also significantly higher in plots that received pre-sowing herbicide than their nil controls. There was a large reduction in plant counts across all treatments between 43 and 229 DAS. The number of red clover plants was higher than all other legumes at both assessment times and across all sowing methods.

Frequency counts conducted 22-6-2023 (1001 DAS) of legumes were overall quite low (Figure 12g-i). There was a positive effect of herbicide application on frequency counts of legumes across all sowing methods. In plots that received the herbicide application, frequency counts were higher in direct drilled plots than strip till and broadcast plots. In plots that were not sprayed with herbicide prior to sowing, frequency counts were higher in strip till plots, followed by direct drill and broadcast. Talish (7.2), red (6.3), and white (5.6) clovers had the highest frequency counts in plots that received the herbicide application, while red (3.3) and white (1.8) were the highest in unsprayed plots. Interestingly, frequency counts of Talish clover and lucerne unsprayed plots were just ~5% of their sprayed treatments respectively. In contrast, frequency counts of sprayed red clover plots were 52% and white clover 32% of the equivalent sprayed plots. Frequency counts of grasses were higher in broadcast and unsown plots that received herbicide, but lower in direct drill and strip till plots relative to the nil herbicide treatment. Regardless of treatment, grass frequency remained high at between 96 and 100.

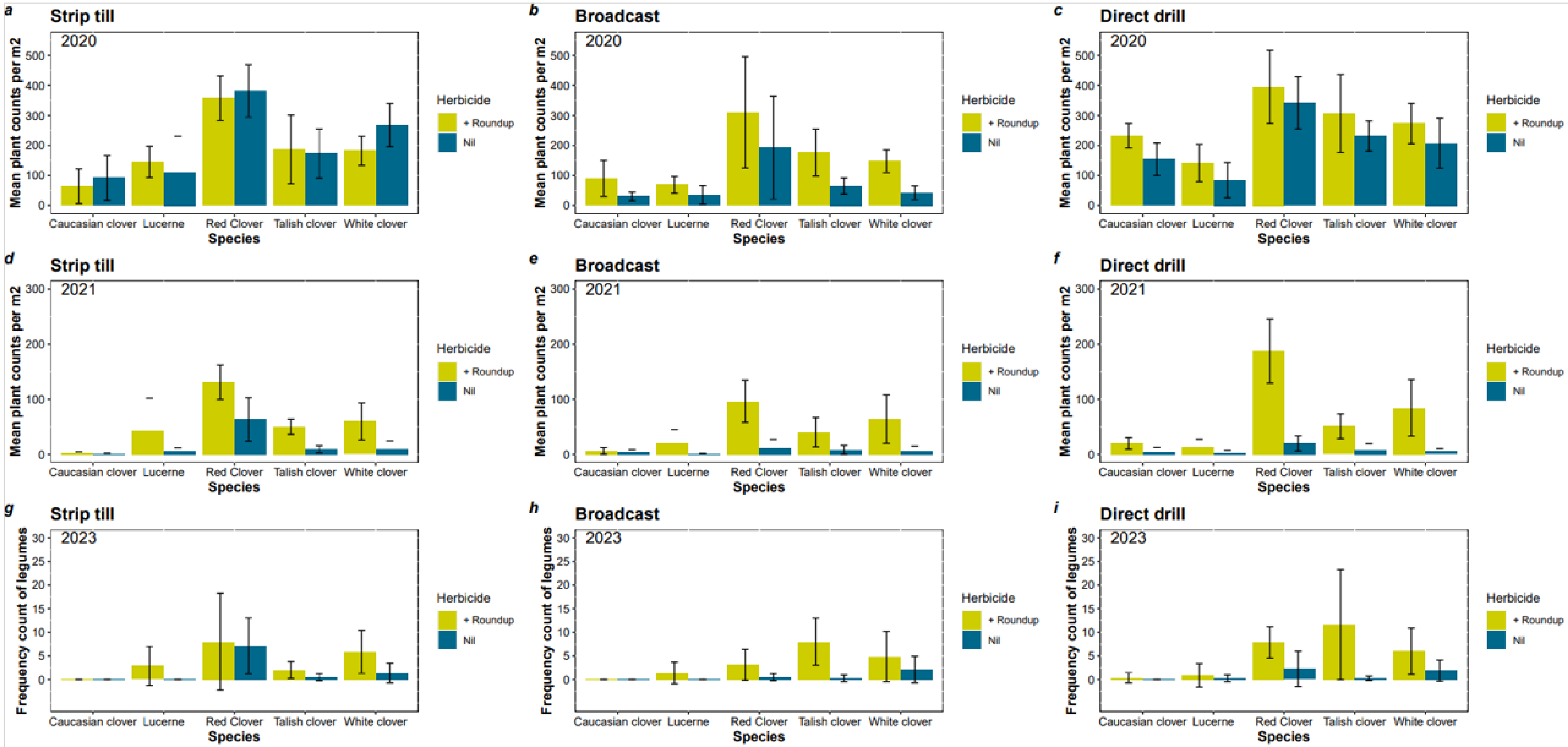

Figure 12 Mean plant counts (plants per m²) in 2021 (a, b, c) and 2022 (d, e, f), and mean frequency counts in 2023 (g, h, i) of plots over-sown by strip till (a, d, g), broadcast (b, e, h) or direct drill (c, f, i) methods. Plots were sown with either Caucasian clover, lucerne, red clover, Talish clover or white clover.

Feed production

The pre-sowing application of herbicide (1L Glyphosate) had an effect on overall dry matter yield (kg DM/ha) at individual harvest times (Figure 13a). Overall production was slightly higher in NIL herbicide plots (10,585) compared with herbicide plots (9,856), though this advantage was solely based on an initial cut in November 2020, when herbicide plots were not harvested due to its effect on growth. At every harvest date following, DM yield was higher in plots that had received the pre-sowing herbicide application.

Overall DM yield (kg DM /ha) was highest in strip till plots (11,954), ahead of broadcast (11,627), and then direct drill (10,544) and Nil (10,611) plots were similar (Figure 13b). Greatest differences between sowing treatments were at the 2/2/2021 harvest. Overall DM yield was greatest in red clover (11,950) and lucerne (11,669), significantly higher than the nil sown plots (10,488) (Figure 13c).

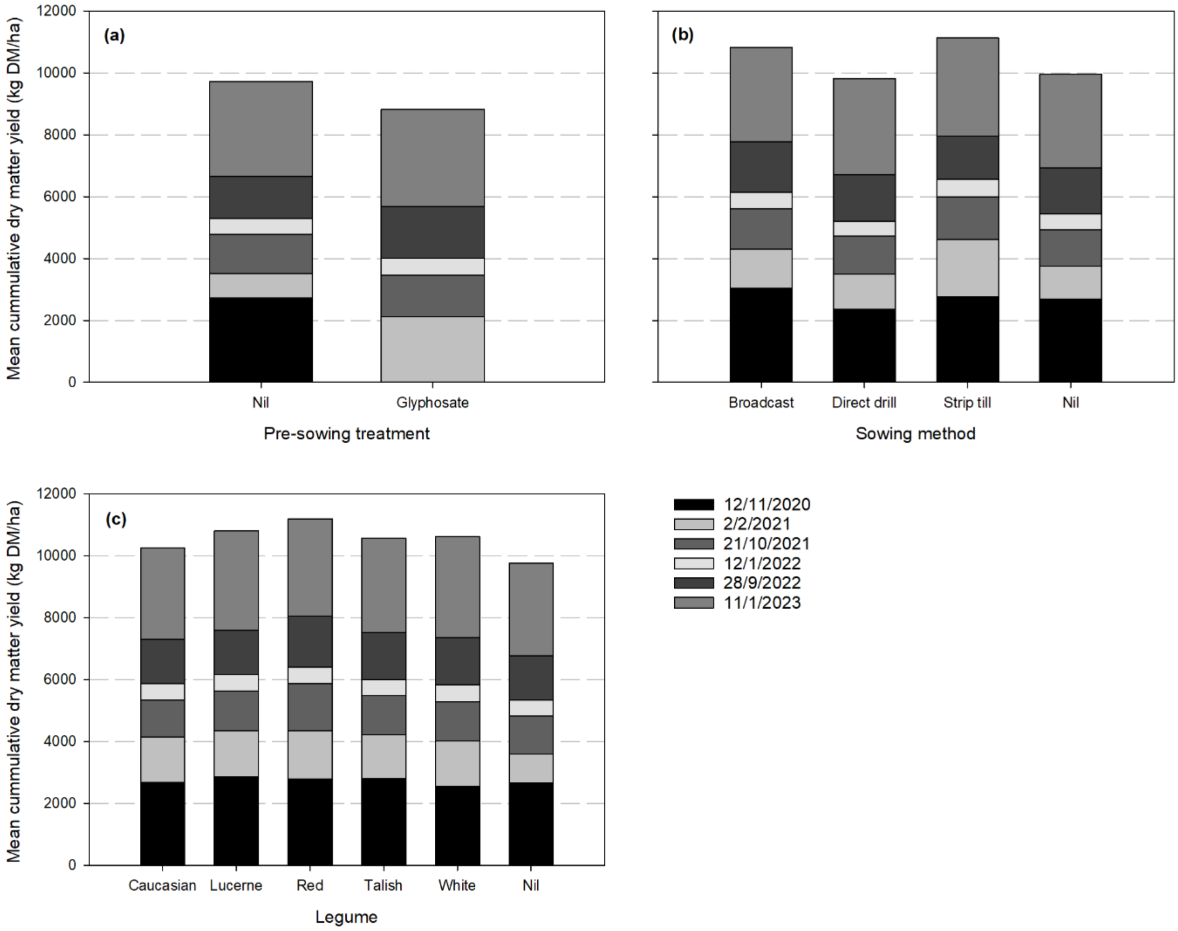

Figure 13 Effect of pre-sowing herbicide (a), sowing method (b), and sown legume (c) treatments on mean cumulative dry matter yield (kg DM/ha) across harvest dates between 12/11/2020 and 11/1/2023.

4.3 Experiment 3: Pot studies of screening waterlogging tolerance in legumes

Two pot studies were undertaken at the Mt. Pleasant Laboratories site in Prospect, Launceston. The first was a screening of waterlogging tolerance in trefoil (*Lotus corniculatus* L., *Lotus pedunculatus* L., and *Lotus tenuis* L.), while the second was a much larger screening of strawberry clover (*Trifolium fragiferum* L.) germplasm.

4.3.1 Trefoil screening

The first screening included both strawberry clover and trefoil spp. However, the more prostrate nature of strawberry clover meant that leaves were often submerged in water outside of the pot and subsequently decayed. This was not an issue for the more erect growing trefoil entries. As such we here provide the results for the *Lotus* entries only. Results suggest waterlogging had a significant negative effect on root dry matter of trefoil entries (Figure 14). However, there was no statistically significant effect on shoot dry matter (Figure 14). There was also no significant waterlogging treatment*lotus species/selection interaction although some appeared to be more affected than others. This requires further evaluation with a greater number of plants to reduce some of the variation in the data.

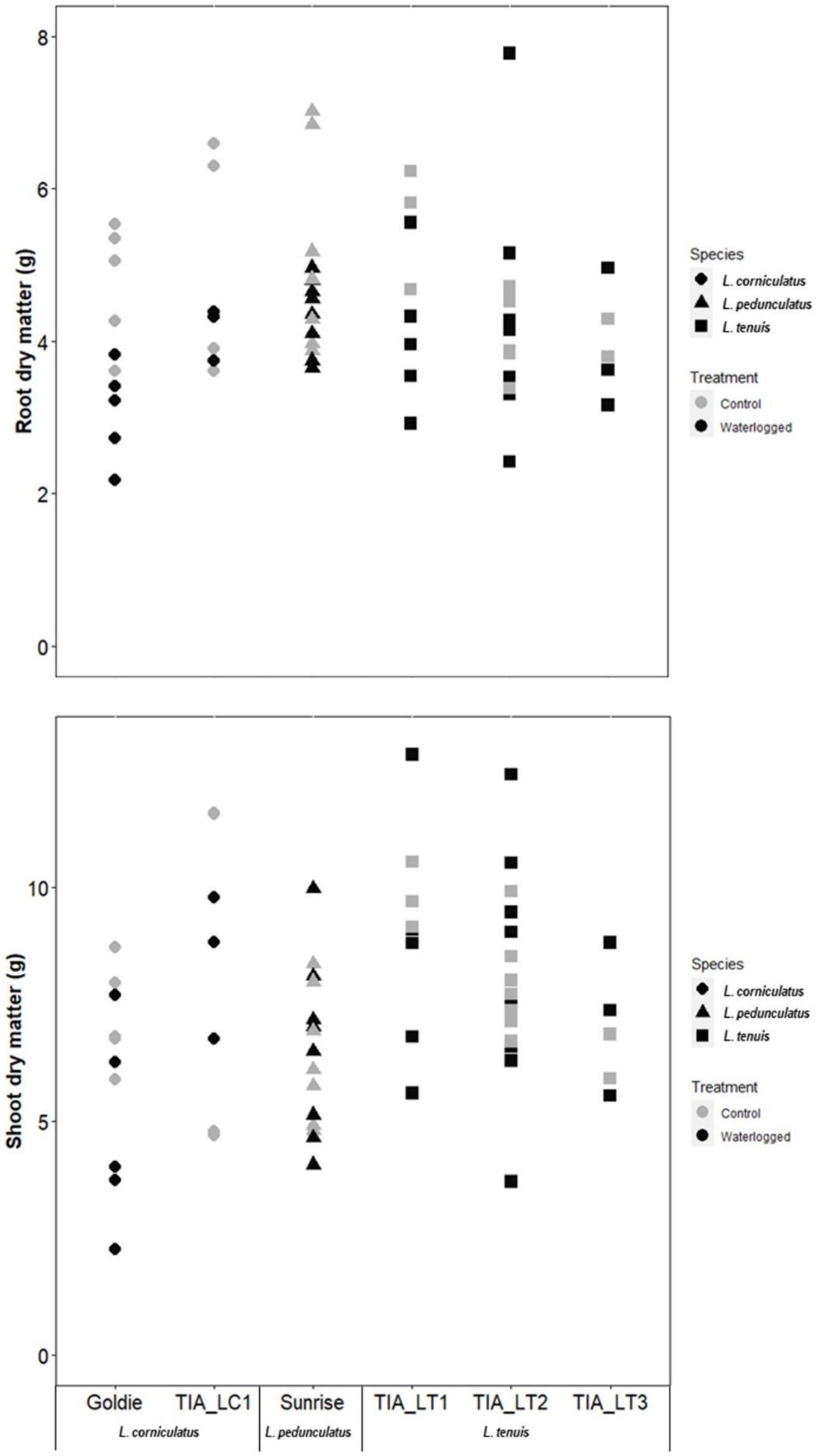

Figure 14 Root and shoot dry matter (g per plant) of Lotus corniculatus (diamonds), L. pedunculatus (triangles) and L. tenuis (squares) after waterlogged (black points) and control (grey points) treatments for 28 days.

4.3.2 Strawberry clover screening

Results presented in Appendix 8.2.1 as submitted paper manuscript

4.4 Experiment 4: Field evaluation of waterlogging tolerance in legumes

Field evaluation of waterlogging tolerance proved challenging due to the competitive nature of the previous pasture, even though it was sprayed out. There was little difference between the overall dry matter of plots sown to different legume species (Figure 15). There was a positive effect of sowing the legume with perennial ryegrass on overall yield. Dry matter contribution of the sown legume component was low at the 25/5/2023 harvest (Figure 16). Sown grass made up the biggest proportion of the sward, and in Nil plots this was replaced with other volunteer grasses.

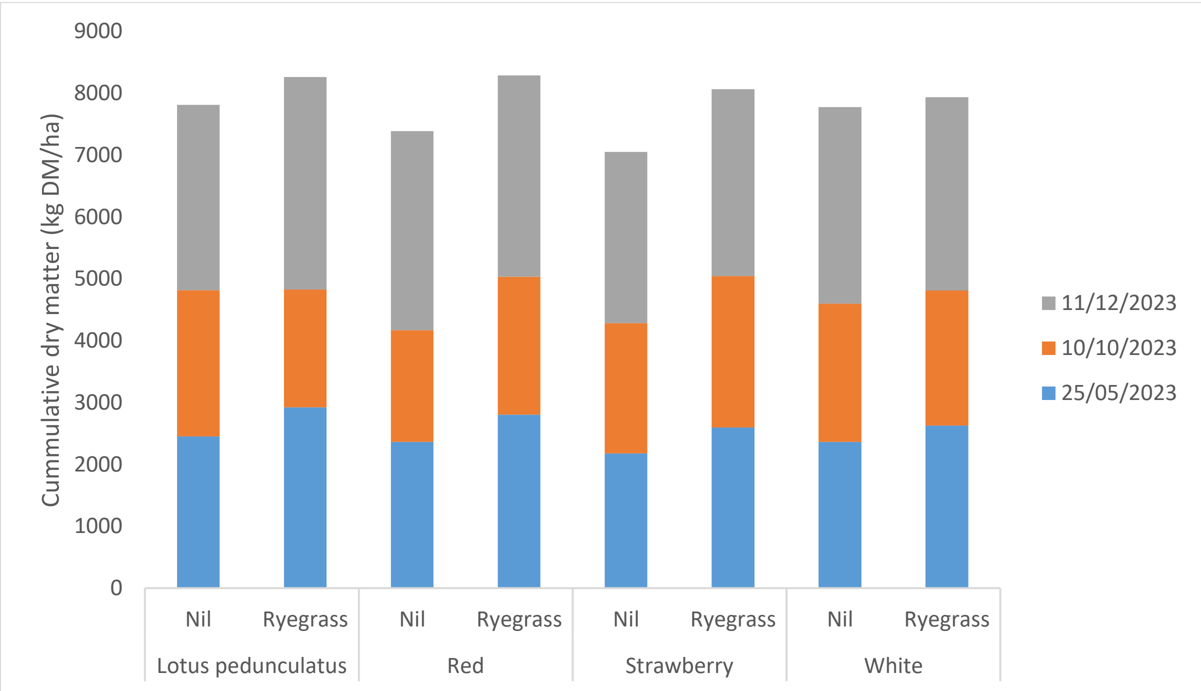

Figure 15 Cumulative dry matter (kg DM/ha) of plots sown to four legumes: Lotus pedunculatus, red clover, strawberry clover, and white clover, son with and without (Nil) perennial ryegrass

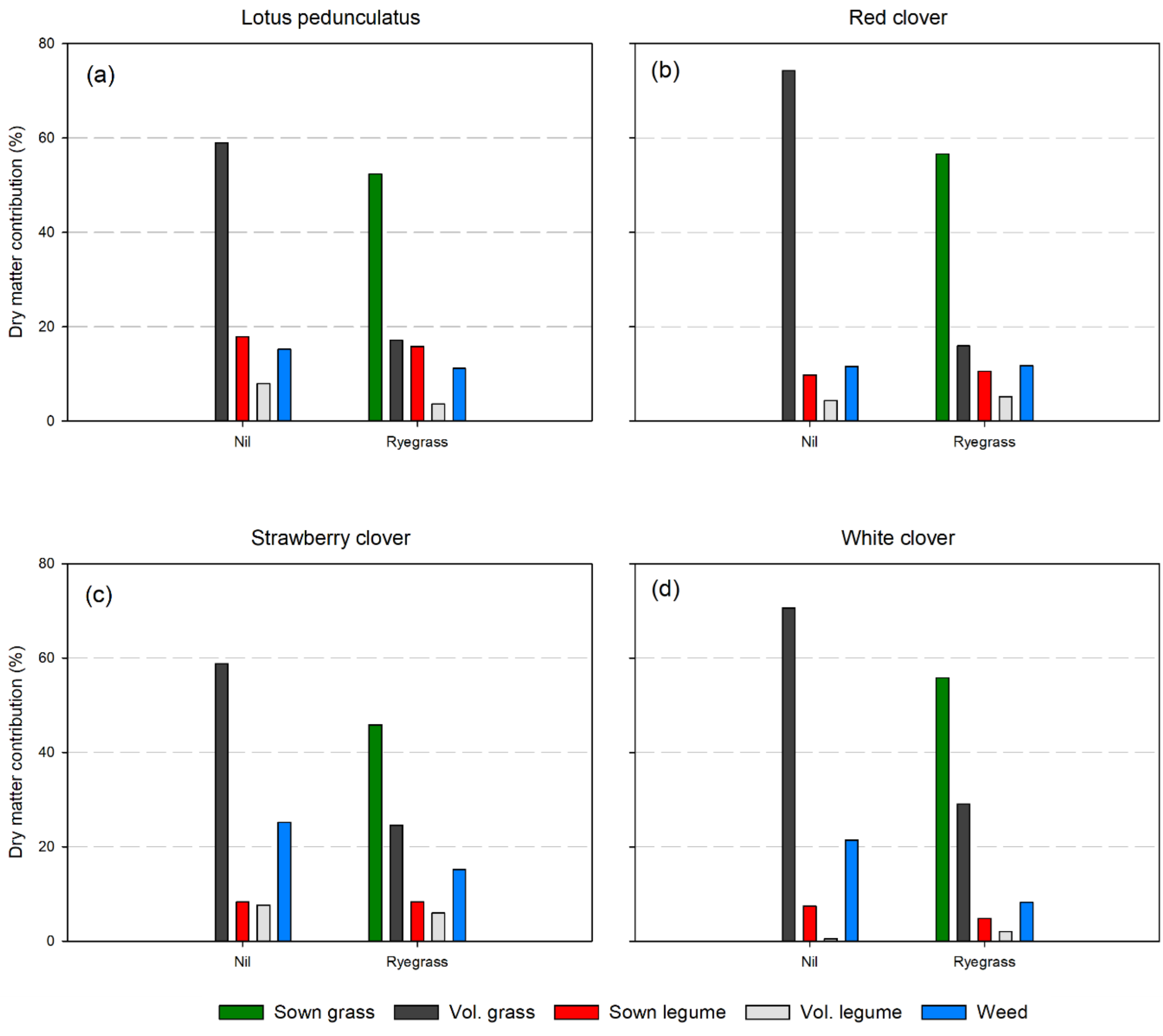

Figure 16 Proportional dry matter contribution (%) of pasture mix components across four legumes species; (a) Lotus pedunculatus, (b) red clover), (c) strawberry clover and (d) white clover, sown with and without perennial ryegrass. From harvested material 25/5/2023.

Feed nutritional analysis showed seasonal differences between separated legume material of different species (Table 14). For all legumes, NDF declined from May to October and again to December. This is to be expected as May samples, having been through autumn were quite dry and had a higher proportion of stem to leaf, whereas December samples had higher proportions of leaf. There were no clear trends in CP, though white clover was higher in May and October compared to the other legumes. White clover also had the higher ME results along with strawberry clover, while red clover and lotus were consistently lower (Table 14).

In combined herbage from plots that were sown with and without perennial ryegrass, CP was higher in NIL plots in May, October and December, though DMD and WSC was lower at all times (Table 15). These differences are most likely being driven by differences between the grass components of the mixtures as the % of legume between NIL and ryegrass sown plots was little (Figure 16). Overall, NDF was lowest during October in line with the vegetative state of the grass component. The largest difference between the CP and ME was in May and this reflects the challenge producers face in maintaining growth rates during autumn compared to spring. In the case of these field experiments, there wasn't sufficient quantities of the legume component to be able to overcome this issue. The analysis of the legume component on its own shows higher levels of CP and ME, particularly in white clover and strawberry clover, and highlights the potential to improve overall feed quality if the proportion of clover can be increased.

Table 14 Individual species nutritional analysis of herbage harvested in May, October, and December 2023.

Species	NDF %			CP %			DMD %			ME (MJ/kg DM)			WSC %		
	May	Oct	Dec	May	Oct	Dec	May	Oct	Dec	May	Oct	Dec	May	Oct	Dec
White clover	29.9	25.3	16.9	27.1	27.2	24.5	71.1	79.7	76.4	10.9	12.4	12.1	7.6	8.3	10.9
Red clover	36.8	33.1	23.4	24.6	24.5	26.9	59.6	67.2	67.8	8.4	9.3	10.1	5.4	9.0	7.3
Strawberry clover	32.1	26.2	20.4	24.7	22.1	23.3	68.2	77.5	75.3	10.4	12.3	11.9	5.5	9.4	8.6
Lotus pedunculatus	35.6	27.7	21.2	22.7	23.2	25.9	57.8	68.2	63.4	8	10.0	9.3	6.7	9.3	6.0

Note: NDF – Neutral detergent fibre (NIR), CP – Crude protein (NIR), DMD – Dry matter digestibility (NIR), ME – Metabolisable energy (by calculation from NIR), WSC – Water soluble carbohydrates (NIR). These results are and average of 2 plots and contained only separated legume material.

Table 15 Combined species nutritional analysis of herbage harvested in May, October, and December 2023.

Species	NDF %			CP %			DMD %			ME (MJ/kg DM)			WSC %		
	May	Oct	Dec	May	Oct	Dec	May	Oct	Dec	May	Oct	Dec	May	Oct	Dec
White clover + NIL	47.2	40.6	50.9	18.4	17.0	12.6	60.2	75.8	69.7	8.7	11.5	10.3	6.0	15.5	14.3
White clover + PRG	50.7	41.2	50.4	15.1	13.6	12.1	61.2	77.8	71.9	8.9	11.9	10.8	9.5	22.1	17.8
Red clover + NIL	47.5	39.1	50.0	18.8	17.7	14.1	60.6	74.9	71.2	8.8	11.3	10.7	6.5	14.9	14.8
Red clover + PRG	47.9	40.9	47.3	17.7	14.7	12.9	62.4	77.0	73.4	9.1	11.6	11.0	8.7	19.4	18.6
Strawberry clover + NIL	48.3	42.4	49.1	19.3	17.9	14.3	59.3	74.0	71.0	8.5	11.1	10.6	4.4	12.7	14.7
Strawberry clover + PRG	50.4	39.7	47.8	16.2	13.3	11.9	60.4	78.0	74.2	8.6	12.0	11.2	7.6	21.9	19.9
Lotus pedunculatus + NIL	46.0	41.5	48.5	19.7	19.0	15.2	60.0	71.9	70.6	8.7	10.7	10.5	5.7	11.2	13.3
Lotus pedunculatus + PRG	49.0	37.0	48.7	17.3	14.1	11.3	60.1	79.6	72.3	8.7	12.0	11.0	7.7	22.4	19.5

Note: NDF – Neutral detergent fibre (NIR), CP – Crude protein (NIR), DMD – Dry matter digestibility (NIR), ME – Metabolisable energy (by calculation from NIR), WSC – Water soluble carbohydrates (NIR), PRG – perennial ryegrass, NIL – legume sown alone, but with volunteer grass. These results are and average of 2 plots.

4.5 Extension and adoption

4.5.1 Field days and paddock walks

Field days and paddock walks were a key knowledge extension mechanism used in the project (Table 16). Seeing legumes in mixed pastures allowed a number of learning opportunities including species identification, evaluation of nodulation and the importance of rhizobia, discussions on sowing equipment, and results and findings from the project. Researchers from other MLA funded projects contributed to some of the field days including:

Richard Hayes (NSW DPI – 'P.PSH.1030 - Extending the boundaries of legume adaptation through better soil management')

Richard Culvenor (CSIRO - 'P.PSH.1048 - Perennial pasture and forage combinations to extend summer feed in Southern NSW')

Gordon Refshauge (NSW DPI – Various MLA projects around nutrition in sheep)

A list of field days and paddock walks are provided in.

4.5.2 Formal presentations

There have been a number of opportunities to present about our research throughout the project (Table 17). These have included local presentations to the regional reference group, presentations to local farmer groups, as well as presentations to SALRC groups that assist in setting RD&A priorities for the red meat industry. Presentations were given of experimental results and on farm demonstrations at Red Meat Updates (largest red meat producer conference in Tasmania) to over 350 producers and advisors in 2022 and 2025.

Table 16 A summary of paddock walks and field days where content from the project was either discussed or presented.

Date	Audience	Number	Content	Location
21-10-21	NW producers & industry	40	Research overview	Stanley
23-11-21	Midlands producers & industry	70	Research overview	Campbell Town
18-3-22	Circular Head Beef Group	30	Demonstration trial presentation	Alcomie
7-7-22	Circular Head Beef Group	30	Research update	Forest
26-7-22	NW producers & industry	10	New sowings walk	Alcomie/Marrawah
27-7-22	Midlands producers + industry	10	New sowings walk	Campbell Town
17-11-22	Circular Head Beef Group	20	Research update	Stanley
28-2-23	WA Producer Group Tour	30	Research overview	Pipers River
31-3-23	Circular Head Beef Group	30	New sowings walk	Authur River
6-4-23	Tamar Producers Group	15	Research findings	Launceston
30-5-23	SALRC Vic/Tas Regional meeting	12	Research overview + walk	Marrawah
2-11-23	Circular Head Beef Group	20	Research findings	Montagu
20-11-23	Midlands producers & industry	35	Research findings + walk	Longford
21-11-23	Midlands producers & industry	15	Research findings + walk	Woodbury
23-11-23	MLA Updates	400	Legumes for Southern Australia	Bendigo
28/2/24	North-west dairy and beef producers	60	Providing project update and in-field technical presentation on importance of legumes in pastures	TIA Elliot Open Day
1/5/24	Northern Midlands Producer Group	8	Advice provided on 'Sudden Death in Lambs grazing legumes' PDS	Longford
23/5/24	TAS Farm Innovation Hub in collaboration with NRM North to King Island producers - Managing breeders and pastures through dry times	40	Research update to producers and paddock discussion on species selection for managing dry times.	King Island
31/5/24	George River catchment group - NRM North workshop 'diverse pastures for soil health'	25	Research update and paddock discussion on species selection and feed base management.	St. Helens
22-10-24	Pinion led producer demonstration site project 'Improving lamb survival on leguminous pasture' (L.PDS.2406)	11	Providing technical knowledge of legume feed base management and demonstration on conducting pasture feed tests	Campbell Town

Note: Number refers to an approximate number of producers, advisors and industry representatives. Some presentations were in conjunction with externally organised producer groups.

Table 17 A summary of formal presentations where content from the project was presented

Date	Audience	Number	Content	Location	
4-2-21	Farmers for Climate Action	10	Research overview	Online	
23-2-22	Regional reference group (NW)	5	Dinner project update	Marrawah, Tas	
6-4-22	Mitchell River Better Beef Network – Gippsland	10	Research overview	Online	
19-5-22	Regional reference group (NW)	10	Research update	Stanley, Tas	
30-5-22	LPP Final Stakeholder Meeting	50	Research update	Sydney, Tas	
1-6-22	Pasture Updates – Wagga Wagga	160	Research overview	Wagga Wagga, NSW	
2-6-22	Pasture Updates – Leeton	50	Research overview	Leeton, NSW	
29-6-22	Derwent Catchment Producer Group	10	Research overview	Hamilton, Tas	
28-7-22	Red Meat Updates + MILE Truck display	100 + 70	Research overview	Launceston, Tas	
12-12-22	Regional reference group	5	Project discussion	Marrawah, Tas	
8-2-23	Tasmanian Beef Trust Committee	7	Research overview	Launceston, Tas	
16-2-23	Nutrien Conference	40	Pasture species selection	Melbourne, Vic	Nutrien professional development conference
28-3-23	SALRC Council	25	Feedbase research incl. legumes	Sydney, NSW	
6-4-23	Tamar Producers Group	15	Research overview	Launceston	
6-6-23	Feedbase thinktank	30	Contributor	Canberra, ACT	
6-7-23	Australian Grassland Association	55	Strawberry clover review + research	Perth, WA	
29-11-23	SALRC Victorian and Tasmanian branches	20	Future feedbase R&D priorities	Melbourne, Vic	
13-3-24	Elders agronomists	5	Project update and species selection	Elizabeth Town, Tas	Elders professional development workshop
5-8-24	Perennial Pasture Systems (Vic) Tas Tour	15	Research overview	Launceston, Tas	
5-9-24	Tamar Producers Group	15	Research update	Launceston, Tas	
11-2-25	Circular Head Beef Group +		Species selection and establishment	Smithton, Tas	In conjunction with Pinion facilitate producer group
13-2-25	Northern Midlands Beef Group		Species selection and establishment	Longford, Tas	In conjunction with Pinion facilitate producer group
17-3-25	King Island red meat producers		Species selection and establishment	Currie, Tas	In conjunction with Tasmanian Drought and Innovation Hub
8-4-25	Flinders Island red meat producers		Species selection and establishment	Whitemark, Tas	In conjunction with Tasmanian Drought and Innovation Hub
25-7-25	Red Meat Updates		Involve and Partner highlights	Launceston	

Note: Number refers to an approximate number of producers and industry representatives. Some presentations were in conjunction with externally organised producer groups.

Table 18 Summary of communication activities and reach of media outlets

Date	Activity	Medium	Outlet	Reach
4-2-21	Farmers for Climate Action	Seminar	Zoom, recorded and available via YouTube https://protect-au.mimecast.com/s/BnckCq7BJXt5MD8gfZhhGP?domain=youtu.be	40 live, 110 views
9-9-21	Legume Article	Print	Tasmanian Country Newspaper	24,000
1-10-21	21/10 Stanley Field Day Promotion	Print	Tasmanian Country Newspaper	24,000
8-10-21	21/10 Stanley Field Day Promotion	Print	Tasmanian Country Newspaper	24,000
5-10-21	Fosterville Field Day Promotion	Print	Tasmanian Country Newspaper	24,000
5-11-21	Legumes in the Field Article – LPP Project & Field Day	Print	Tasmanian Country Newspaper	24,000
4-11-21	Video update of Fosterville Legume trial	Video	YouTube/Twitter/Eventbrite https://www.youtube.com/watch?v=WmXODrGNMuY&t=10s.	100
12-11-21	Fosterville Field Day Promotion	Print	Tasmanian Country Newspaper	24,000
19-11-21	LPP Project & Fosterville Field Day	E Newsletter	Tasmanian Institute of Agriculture Newsletter	2,000
24-11-21	Interview on LPP Project and Fosterville Field Day	Radio	ABC Morning Rural Report	27,000
24-11-21	Interview on LPP Project and Fosterville Field Day	Radio	ABC Country Hour https://www.abc.net.au/radio/programs/tas-country-hour/tasmanian-country-hour/13636396.	52,000
3-12-21	Legumes in the Field Article – LPP Project & Field Day	Print	Tasmanian Country Newspaper	24,000
26-1-23	Promoting new experimental plot drill used in research	Facebook, Instagram, Linkedin and Twitter	Tasmanian Institute of Agriculture Social Media Channels	10,700
31-7-23	Promoting presentation at Australian Grassland Association Symposium	Facebook, Instagram, Linkedin and Twitter	Tasmanian Institute of Agriculture Social Media Channels	10,700
3-10-23	Midlands project update	E Newsletter	Tasmanian Institute of Agriculture. Distributed to 1,768 active subscribers.	1,768
5-10-23	Midlands project update	Facebook, Instagram, Linkedin and Twitter	Tasmanian Institute of Agriculture Social Media Channels	10,700
3-11-23	Legume field day promotion	Facebook, Instagram, Linkedin and Twitter	Tasmanian Institute of Agriculture Social Media Channels	10,700
3-11-23	Legume field day promotion	E Newsletter	Tasmanian Institute of Agriculture. Distributed to 2,683 active subscribers.	2,683
10-11-23	Experimental site video	Facebook, Instagram, Linkedin and Twitter	Tasmanian Institute of Agriculture Social Media Channels	10,700
10-11-23	North-West project update	E Newsletter	Tasmanian Institute of Agriculture. Distributed to 1,753 active subscribers	1,753
22-11-23	North-West project update	Facebook, Instagram, Linkedin and Twitter	Tasmanian Institute of Agriculture Social Media Channels	10,700
24-11-23	Legume field day post-event promotion	Facebook, Instagram, Linkedin and Twitter	Tasmanian Institute of Agriculture Social Media Channels	10,700
29-11-23	Legume field day article	E Newsletter	Tasmanian Institute of Agriculture Industry Newsletter. Distributed to 2,771 active subscribers	2,771
7-12-23	Legume field day interview	Radio	ABC Country Hour	52,000

			https://www.abc.net.au/listen/programs/tas-country-hour/tasmanian-country-hour/103180380	
1-10-24	Research update to producers and showcase of Involve and Partner farms	Print	Feedback Magazine article - https://www.mla.com.au/globalassets/mla-corporate/news-and-events/documents/publications/mla-feedback-spring-2024-web.pdf	
2021-23	Twitter	Social media	Rowan Smith's twitter account Regular photo and observation updates from experimental sites	~250 follow

4.6 Involve and partner

Producer facing case study handouts have been produced and are attached as appendices. Abbreviated versions are reported here.

Table 19 Involve and partner farms participating in pasture renovation activities and associated focus of the studies. Size (farm size managed? How many hectares sown in the study paddocks?

Region	Location	Farm	Size (ha)	AAR (mm)	Producer	Enterprise	Case study focus	Status
North-west	Marrawah	Shamford Park	340	1150	Stafford Ives-Heres	Beef breeding	Hump and hollow and coastal pasture renovation	Sown
North-west	Arthur River	Killara	1457	1150	Andrew Pilkington	Beef breeding	Hump and hollow pasture renovation	Sown
North-west	Marrawah	Westmore	2700	1150	Aiden Coombe	Beef finishing	Over-sowing pasture renovation	
North-west	Stanley	Western Plains	620	810	Iain Bruce	Beef breeding and finishing	Mixed pasture renovation	Sown
North-west	Alcomie	Borrowah Pastoral	500	1250	Brett McGlone	Bullock fattener	Alternative pasture mixes to perennial ryegrass and white clover	Sown
Midlands	Longford	Cluden Newry	800	620	Jock Hughes	Beef stud and meat sheep	Site 1: Diversifying pure clover swards with broadcasting	Sown
							Site 2: Deep rooted perennial pasture mix	Sown
Midlands	Kempton	Mount Vernon	3441	420-450	Emma Boon	Wool and meat sheep	Long-term perennial pasture renovation	Sown
Midlands	Woodbury	Ratharney	1820	425	Chris Headlam	Wool and meat sheep	Site 1: Long-term perennial pasture renovation	Sown
							Site 2: Replicated legume experiment examining lucerne, strawberry clover and serradella	Sown
Midlands (Derwent Valley)	Bothwell	Ratho & Umtali	2600	500 & 800	John Ramsay	Comp ewes and lamb finishing	Site 1: Replicated legume experiment examining lucerne and serradella	Sown
							Site 2: New pasture demo site	Sown
Midlands (Derwent Valley)	Bothwell	Thorpe Farm			Will Bignell		Legumes for challenging soil types	Sown
Midlands	Nile	Horefield	230	626	John Simpson	Agistment	Diverse pasture to handle winter wet and summer dry	Sown
Midlands	Bothwell	Thorpe	2900	500	Will Bignell	Comp ewes and lamb finishing	Resilient perennial pasture mixes	Sown
Northern Midlands	Perth	Scone	600	630	Knox Heggaton & Dylan Browning	Sheep	Deep rooted mixed perennial legume pastures	Sown

4.6.1 Full pasture renovation with increased legumes in Northwest Tasmania

4.6.2 Alcomie

Introduction to the farm

Brett McGlone runs a 500ha bullock fattening property at Alcomie in Northwest Tasmania. The area is known for red krasnoezen soils and high rainfall (1250 mm AAR). It is very much perennial ryegrass and white clover country, but Brett was interested in diversifying his feedbase with some deeper-rooted perennial species to extend the growing season and provide some resilience during periods of extended moisture stress. Increasing the content of legumes was also a goal to improve feed quality.

Site 1

In autumn 2022 into a sprayed our degraded perennial ryegrass pasture. Four pasture mixes were sown based on high (25 kg/ha) and low (15 kg/ha) rates of perennial ryegrass, cocksfoot (5 kg/ha), and coloured brome (20 kg/ha). Each mix was sown with 5 kg/ha red clover, 2 kg/ha white clover, and 1 kg/ha strawberry clover.

Low soil moisture meant that leaf area on the existing pasture was low and this contributed to much of the dormant pasture returning. Background perennial ryegrass dominated the mixes and there was generally lower amounts of legume (Figure 17). This was reflected in dry matter cuts being very similar between the mixes. Large cracks developed during summer providing home for crickets that also put pressure on the establishing pasture.

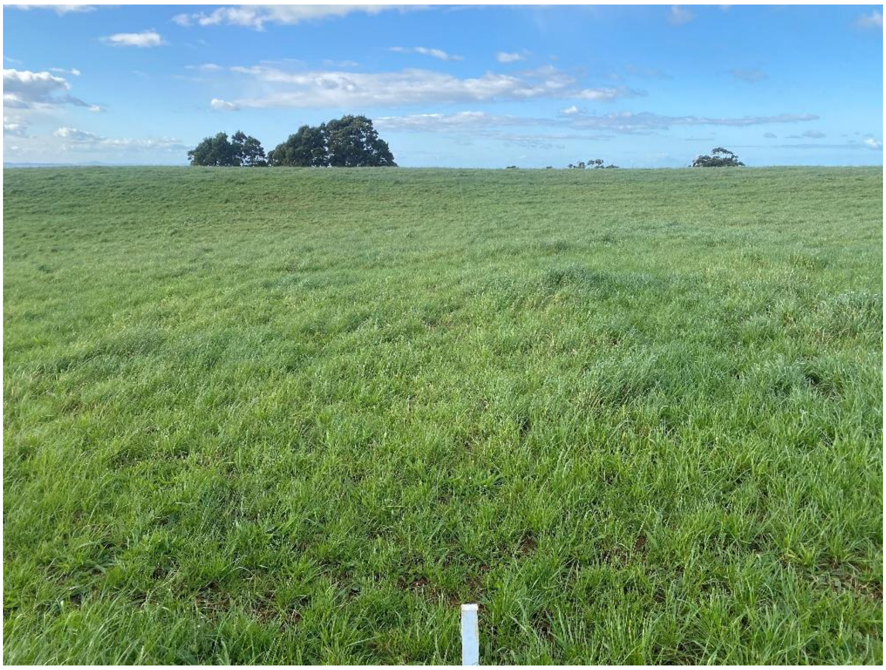

Figure 17 Sown pasture mixes dominated by background perennial ryegrass at Alcomie, north-west Tasmania

Key takeaways

- Preparation is key when trying to significantly change pasture species. Using a crop prior to permanent pasture sowing allows control of existing weed and volunteer species.

- Perennial ryegrass is extremely competitive due to early vigour. Sowing in autumn enhances that as its able to grow leaf area before soil and air temperature cool and day length declines.
- A dry summer meant large cracks formed in the soil, providing a great habitat with crickets that then fed on the establishing pasture.

Site 2

Brett sprayed out a 5ha paddock in February 2024 and direct drilled a mix of 4 kg/ha Interval Rape and 0.5 kg/ha Barkant Turnips as a break crop to assist with weed control and provide valuable winter feed. The crop was sown with 100 kg/ha of DAP (18% N, 20 % P) and received an additional application of 150 kg/ha of urea (46 % N) during the crops growing phase. The fodder crop was grazed over August/September. After grazing, the paddock was sprayed out, including a preventative insecticide, and lightly cultivated prior to sowing.

Two pasture mixes were sown on 2/10/24 to compare the establishment, persistence and overall suitability of each mix in Brett's feedbase system. Mix 1 contained 15kg/ha perennial ryegrass, 4.2 kg/ha red clover, 2kg ha white clover and 1 kg/ha of plantain. Mix 2 contained 3 kg/ha cocksfoot, 5 kg/ha of lucerne, 3.2 kg/ha of red clover, and 1 kg/ha chicory. The seed was sown with slug bait to reduce the risk of seedling loss from slug attack, a problem that is common in the mid-high rainfall zones of Tasmania. One of the main issues that was encountered in the establishment of the pasture mixes was the persistent browsing by wild ducks. The chicory appeared to be the most affected by this browsing.

Establishment has been very good with a high proportion of chicory and legumes in Mix 2. Cocksfoot has been slower to establish and was shaded out by the chicory. It is expected that during summer cocksfoot will continue to grow and become more dominant as the pasture ages.

Key takeaways

- Rotation with a turnip crop allowed grass weeds to be controlled.
- Cultivation and broadcast roller sowing resulted in impressive germination of legumes and herbs
- Spring sowing was to the advantage of the legumes and herbs

Figure 18 Mixed pasture (Mix 1) showing high proportion of plantain with perennial ryegrass at Alcomie. Seed was sown into a cultivated seed bed with a broadcast roller drill.

Figure 19 High legume and herb content of spring sown mixed pasture with cocksfoot at Alcomie. Seed was sown into a cultivated seed bed with a broadcast roller drill.

4.6.3 Stanley

Introduction to the farm

Traditionally, mid-high rainfall areas on the North-West coast of Tasmania are known to grow some of the most productive perennial ryegrass and clover pastures in the state. The grazing region around Stanley has mild winters due to coastal influences. Despite this, winter wet conditions can cause issues with pasture utilisation as pastures can become muddy and spoiled in drizzly/rainy weather, increasing pasture wastage. Summer dry conditions can also hinder the persistence of shallow rooted perennial pasture species. To combat these issues, Iain Bruce is growing a deep-rooted perennial pasture mix of cocksfoot, prairie grass and lucerne. Iain believes that cocksfoot is stronger in its ability to stand up in winter conditions. Unlike ryegrass that tends to be pushed into the mud and underutilised in wet conditions, cocksfoot tend to stronger in these conditions. In addition, the deep rooting structure of the mix will be more resilient in dry conditions and be able to utilise summer rainfall more effectively. With other paddocks sown to perennial ryegrass on his property, growing this alternative pasture mix provides diversity to the whole-farm feed base.

Activity

The establishment and growth of a mixed pasture sown in spring 2022 was monitored. The pasture was sown with 4 kg/ha of cocksfoot, 2 kg/ha of prairie grass, and 8 kg/ha lucerne. Lucerne is generally grown as a monoculture, in part due to competition issues during establishment when sown as part of a pasture mix. Typically, Iain aims to have spring sown perennial pastures in the ground by the end of August. The free draining ferrosols of the peninsula allow for spring sowing, which advantages legume establishment due to rising soil temperatures. Paddocks earmarked for renovation are sprayed out with glyphosate and left for a few weeks before being cultivated with a mouldboard plough, rotary hoed, seeded with a rotera airseeder drill and rolled following sowing. The slower establishment of the cocksfoot and prairie grass compared to perennial ryegrass aided the establishment of the lucerne. In addition, the paddock did not receive fertiliser at the time of sowing, which reduced competition from establishing grasses and advantaged lucerne establishment. Iain noted that slugs were a large issue effecting pasture establishment in the area. To combat this, slug bait was applied with the seed at sowing and a further applications of slug bait was spread 14 days later.

Dry matter composition of the pasture was measured by drying individual components of the pasture at three dates during spring 2023 and autumn 2024. While barely contributing in spring, lucerne started to produce more dry matter in autumn (Figure 20). Self-regenerated /white clover contributed 30% of the dry matter in December 2023. This self-regeneration is aided by the full cultivation of the paddock prior to sowing. Iain noted that germination and establishment rates of the cocksfoot were quite high and that he has since lowered those rates in consequent mixes in an attempt to advantage the lucerne even more.

Table 20 Nutritive value of pasture samples taken from pasture mix at Western Plains, Stanley

Date	NDF %	CP %	DMD %	ME MJ/kg DM	kg DM/ha
24/10/2023	51.2	14.3	60.5	9.1	2279
12/12/2023	46.2	16.7	71.6	11.2	1066
7/5/2024	51.1	23.3	69.2	10.6	494
11/11/2024	50.8	13.8	70.8	10.4	2003

Note: Grazing occurred following the pasture sampling. Pasture was not sampled prior to every grazing.

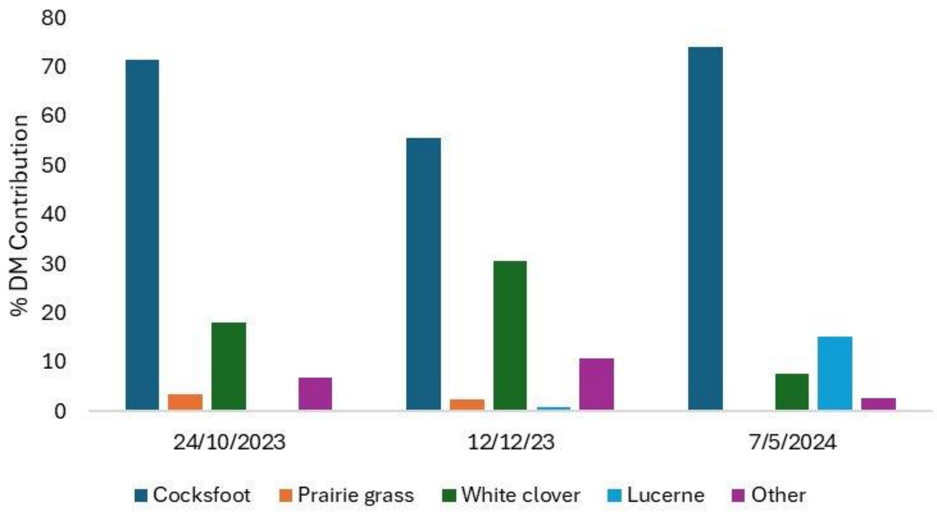

Figure 20 Proportion of dry matter contribution by species at three sampling times at Western Plains, Stanley.

Key takeaways

- Lucerne can successfully be established in mixed swards with cocksfoot providing the grass component is kept to a low sowing rate.
- White clover will self-regenerate from the seedbank, especially when the paddock is cultivated prior to sowing.
- Spring sowing suits the establishment of the slow establishing perennial legumes

Figure 21 Cocksfoot, prairie grass and lucerne mixed pasture at Western Plains, Stanley

4.6.4 Arthur River

Introduction to the farm

Killara Pastoral, owned and operated by Andrew and David Pilkington and father Steve, is a 1455 ha property near Arthur River in Tasmania's North-West. The Pilkington family run a 1120 head cow-calf operation with weaned calves typically grown out to weights of 450 kg on an additional 243 ha property at Montagu. With an average annual rainfall of 1150 mm, the Pilkington family face waterlogging challenges like many other farms in the area. To alleviate these challenges, an extensive pasture renovation phase was conducted at *Killara*. Their aim was to improve drainage in winter waterlogged areas and establish perennial pastures that will persist and increase animal production. The formation of hump and hollow drainage involves the removal of topsoil from the hollows which can pose a challenge when establishing pastures in these areas. The hollows can have low pH levels and nutrient retention is difficult due to persistent waterlogging. The hollows often become a sacrifice area of the paddock, allowing the humps sufficient drainage to improve pasture production particularly during the wetter months.

Activity

Undesirable and unproductive species that significantly reduce pasture production and grazing profitability are common in waterlogged areas. The Pilkingtons identified areas of Killara that had become degraded over time and overgrown with pin rushes, which are an indicator species of poorly drained areas. In these areas, hump and hollow drains were formed, with the pin rushes mounded up onto the humps.

As part of our Involve and Partner activities we followed the pasture improvement program in two paddocks that have had hump and hollow drainage installed as well as full pasture renovation. Following drainage works, the paddocks were disced, rotary hoed and dolomite lime applied to increase the pH of the soil. In March 2022, a pasture mix of perennial ryegrass and white clover were broadcast sown and rolled into Paddock 1. Paddock 2, was sown in March 2023 after receiving the same paddock preparation as Paddock 1. This paddock was sown with a mix of perennial ryegrass, white clover, red clover, strawberry clover and chicory.

Figure 22 Inspecting hump and hollow pasture renovation at Arthur River with Andrew and Steve Pilkington. Strips were sown with cocksfoot and high levels of red, white and strawberry clovers, with good establishment. Plots were sown with a direct drill.

Figure 23 Inspecting hump and hollow pasture renovation at Arthur River. Seed bed was cultivated and the seed broadcast and rolled with very good germination and outstanding ground cover. From left: Gary Martin (TIA), Rowan Smith (TIA), and producers Andrew, David and Steve Pilkington.

Key takeaways

- Hump and hollow drainage and cultivation of sags and rushes is a major investment, but has allowed for an improved establishment of the new pasture
- With better drainage, a wider range of pasture species can be sown
- Strawberry clover is particularly well adapted to the hollows and low-lying areas that waterlog.

4.6.5 Full pasture renovation with increased legumes in the Midlands, Tasmania

4.6.6 Longford

Introduction to the farm

When Jock Hughes took over the lease of the property, he was quick to identify pastures that were underperforming, acknowledging that he needed to lift production as soon as possible to realise the productivity potential of the lease block. Extensive soil testing was conducted with the aid of an agronomist and capital fertiliser was applied in Summer 2024 to fix any underlying fertility limitations.

Activity

One paddock identified as being problematic was a runout lucerne stand on a very light and sandy soil. The paddock had high levels of grass and broadleaf weeds and low numbers of perennial pasture species. In Autumn 2024, the paddock was sprayed out and an annual ryegrass was direct drilled into the paddock to provide quick winter feed.

The paddock was then sprayed out again in spring and sown down to a business as usual perennial ryegrass and clover mix of Jocks choosing. It was perennial ryegrass @ 16kg/ha, red clover and two white clover cultivars at 1.1 kg/ha respectively. As part of our Involve and Partner activities, we have sown a strip of an alternative perennial pasture mix in this paddock to assess persistence and dry matter production. The trial mix is continental cocksfoot @ 3 kg/ha, Mediterranean cocksfoot @ 2 kg/ha, red clover @ 2 kg/ha, strawberry clover @ 2 kg/ha, lucerne @ 1 kg/ha and chicory @ 0.5 kg/ha. It is hoped that this mix will be able to tolerate summer dry conditions and take advantage of moisture when it becomes available.

Figure 24 Cocksfoot based mixed pasture with establishing red and strawberry clover.

4.6.7 Nile

Introduction to the farm

John and Kate Simpson have been experimenting with pasture mixes to fill feed gaps on their 230-ha property at Nile. Like many mixed cropping/grazing enterprises, juggling cropping rotations and the availability of water for irrigating fodder or pasture has been a challenge. In addition, seasonal rainfall patterns at Nile leave paddocks waterlogged in winter and extremely dry and compacted in summer.

Activity

In autumn 2023, the Simpsons trialled two different pasture mixes following a canola crop. Mix 1 was a recommended blend from a local seed merchant and contained 13.9 kg/ha of perennial ryegrass, 8.3 kg tall fescue, 2.7 kg/ha chicory, 2.8 kg/ha red clover, 2.8 kg/ha Persian clover, and 1.7 kg/ha Timothy. Mix 2 was a TIA recommended blend containing 6.6 kg/ha cocksfoot, 4.4 kg/ha phalaris, 8.8 kg/ha red clover, 2.2 kg/ha strawberry clover, and 2.2 kg/ha chicory. The Autumn break came late and by this time, soil temperatures had dropped, meaning a very slow and late establishment of the sown perennial pasture. The chicory and clover content in the pasture mixes were particularly affected by these cold conditions as they favour sowing into warmer soil temperatures.

Pasture cuts were taken from each pasture mix in mid-November 2023 and the dry matter composition of each mix was calculated (Figure 1). We found that 72% of dry matter in the diverse pasture mix consisted of ryegrass and the TIA mix contained 21% background ryegrass. In addition, the TIA mix contained a higher legume and chicory content compared to the diverse mix. Although background ryegrass was the dominant grass component of the TIA mix, phalaris (13%) and cocksfoot (12.3%) were also present.

Feed quality testing has been undertaken four times and the results are displayed in Table 21. Nutritional quality appeared slightly higher in Mix 2 on all occasions. Quality was at it's lowest during Autumn. Frequency scores and dry matter composition reflected higher amounts of legumes and herbs in Mix 2 (Figure 25), while the dry matter contribution of other weedy grasses was higher in Mix 1 (Figure 26). A visual comparison is provided in Figure 27.

Key takeaways

- The cocksfoot-based mixes provided higher quality feed later into the growing season and was able to respond to rainfall.
- Higher proportions of legumes and herbs could be in part attributed to the higher sowing rate of red clover, but also the competition between the main grasses sown in each mix and the legume component.

Table 21 Nutritive value of pasture samples taken from two pasture mixes at Nile

Date	Pasture Mix	NDF %	CP %	DMD %	ME MJ/kg DM	kg DM/ha
13/11/2023	Mix 1	49.9	12.1	69.4	10.2	2279
	Mix 2	41.9	16.4	72.9	10.8	1544
6/2/2024	Mix 1	55.9	10.6	60.1	8.3	1066
	Mix 2	53.7	12.5	60.3	9.1	1350
29/8/2024	Mix 1	49.5	20.9	70.8	10.4	494
	Mix 2	44.6	26.0	70.2	10.6	1117
6/11/2024	Mix 1	48.2	9.8	74.2	10.9	2096
	Mix 2	44.3	15.5	72.4	11.0	2003

Note: Grazing occurred following the pasture sampling. Pasture was not sampled on prior every grazing.

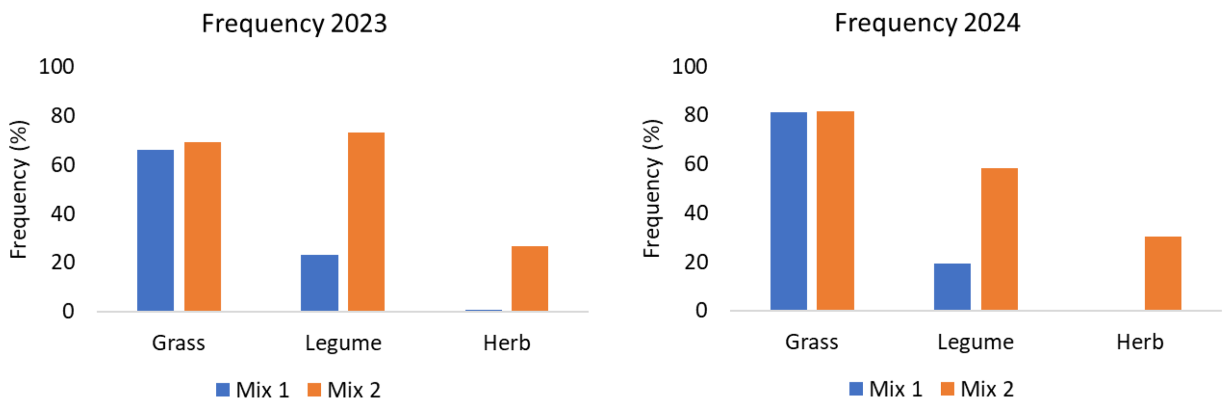

Figure 25 Changes in frequency of pasture functional groups over 12 months (14/7/2023 and 17/5/2024). This technique uses the Evergraze method of presence within 100 10 x 10 cm squares.

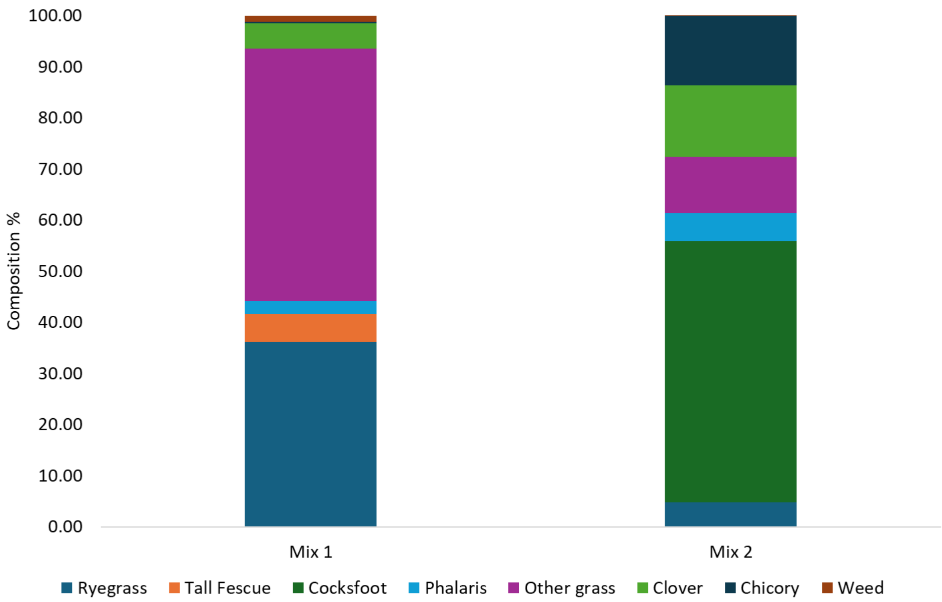

Figure 26 Comparison of dry matter composition of pasture species between two pasture mixes on samples taken in November 2024.

Figure 27 Comparison of Mix 1 (left) containing perennial ryegrass and Mix 2 (right) containing cocksfoot as the major grass species with the chicory and clover more apparent in Mix 2. Nile, November 2024.

4.6.8 Woodbury

Introduction to the farm

Midlands sheep producers, Chris and Claire Headlam farm a 1820 ha cropping and sheep farm at Woodbury in the Midlands of Tasmania. There has been significant irrigation expansion in the midlands of Tasmania, predominantly in areas of better soil types and on river valley flats. The recent irrigation expansion has led to increased areas of pasture and fodder crops being grown for intensive grazing in rotation with other cash crops. The Headlam's were are aiming to extend the grazing phase of their cropping rotation to compensate for a reduction in poppy area and provide a longer rest period for soils. The challenge is to find a long-term irrigated pasture mix that can achieve weight gains equivalent to lambs grazing annual crops of brassica or straight legume pastures (~300 g/day) without the risk of animal health issues.

Site 1

After harvesting poppies from a 90 ha pivot circle, a forage brassica/oat mix was planted in February 2022. This forage mix was grazed during autumn and winter. The paddock was then sprayed out, multi disced and drilled to a regenerative forage mix. A massive downpour shortly after sowing caused germination to fail. On 7 December 2022, a portion of the paddock was re-sown with the diverse forage mix that included cocksfoot @ 2.5 kg/ha, phalaris @ 2.5 kg/ha, red clover @ 8 kg/ha, lucerne @ 3 kg/ha, and chicory @ 2 kg/ha.

The pasture was initially dominated by chicory, favoured by the warm growing conditions. However, over time the composition has developed into a well balanced pasture of grasses, legume and herbs (Figure 28, Figure 29).

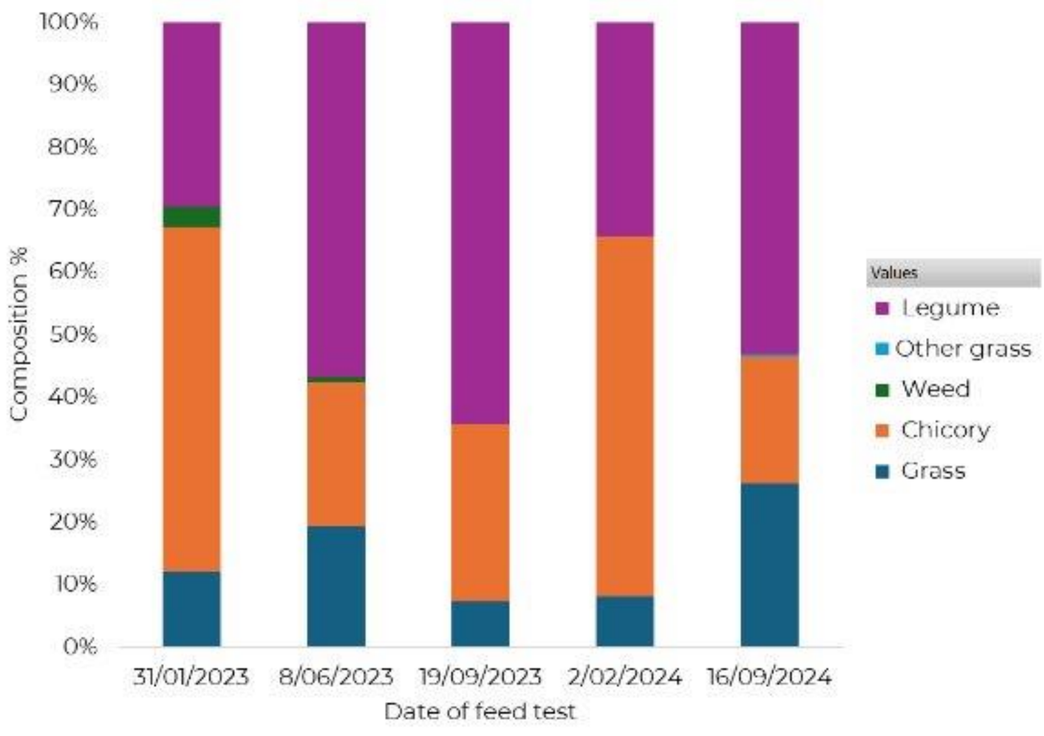

Figure 28 Composition by dry matter of grass, legume and herb components of the irrigated mixed pasture at Ratharney. Woodbury.

The pasture has been sampled for nutritional analysis throughout 2023 and 2024 (Table 22). It is evident that during the warmer months of January, September and November feed quality, particularly Metabolisable Energy (ME) and Dry Matter Digestibility (DMD) are greater compared with the winter month of June. Interestingly, the feed test values for February 2024 are only slightly better than those taken in June 2023. We attribute this to the reproductive stage of the pasture, particularly, the chicory as this had become rank and stalky. The legume component in the pasture in February 2024 (34%) was also low compared to other testing times, except for January 2023 (29.5%). We know that legumes have high crude protein (CP) values. CP is a measure of the nitrogen content in feed and animals that are actively growing have a greater requirement for protein in their diet compared to animals that are maintaining weight. Feeds with <6% CP are generally considered deficient and will limit rumen function. Therefore, have a stable legume component in the feed base can help to improve liveweight gains in stock and help to buffer reductions in feed quality when the other pasture species loose quality.

Table 22 Nutritional analysis of pasture samples taken from irrigated mixed pasture at Ratharney, Woodbury.

Date	DMD %	NDF %	CP %	ME MJ/kg DM
Jan 2023	73.0	33.0	19.3	11.4
June 2023	64.0	43.0	21.8	9.6
Sept 2023	78.0	27.0	29.2	11.9
Feb 2024	66.7	40.3	22.0	10.0
Sept 2024	78.5	28.9	28.2	12.1
Nov 2024	73.1	27.6	22.4	11.9

Key takeaways

- Summer sowing with irrigation favoured the herb and legume components of the sward.
- Over time grass has contributed more to the dry matter.
- Feed quality of this mix has been exceptional and consistent throughout the year

Figure 29 Irrigated mixed pasture dominated early by herbs and legumes at Rathaney, Woodbury.

Site 2

One of the main constraints to introducing perennial legumes into dryland pasture systems is establishment during dry conditions. Typically, the Headlams assess current seasonal conditions and weather forecasts before pulling the trigger on a pasture renovation. However, with the recent dry times and prospects of a changing climate, future opportunities and conditions for establishing pasture may not always be ideal. An example was seen this spring when the trial site at Ratharney was sprayed off on the 13th of September 2024 with good soil moisture available. The trial was sown on the 20th of September. From sowing until 27th of November, only 27.4 mm of rainfall fell, leaving soil moisture low and creating a harsh environment for legumes and grasses to establish.

Mixtures being trialled in this sowing were either based on phalaris or cocksfoot in combination with lucerne or strawberry clover. Plant counts were conducted on each pasture mix on the 22nd of November. Results demonstrate that phalaris numbers were higher than cocksfoot numbers. At the time of counting the establishing phalaris plants looked to be holding up well in the dry conditions, whereas the cocksfoot plants appeared less resilient and were quite brittle and fragile to touch. Mix 2 had a strong lucerne base and mix 4 had good numbers of both phalaris, lucerne and strawberry clover. The strawberry clover will continue to colonise bare areas of soil in the coming years if conditions allow.

We have also trialled two different species of serradella in one section of this trial site; pink serradella, which has an erect growth habit and relatively soft seeded and yellow serradella, which has a prostrate growth habit and a very high percentage of hard seeds. Serradella is an annual legume with a deeper rooting system compared to sub clover. In times of moisture deficit, serradella is able to access moisture further down in the soil profile compared to sub clover, allowing a longer growing season. Sub clover cannot tolerate prolonged periods of moisture deficit and will senesce, disappearing from the pasture until germination occurs in the following autumn. Serradella has adapted to deep, well drained soils with low pH and poor fertility. It is particularly tolerant of low phosphorus levels. We will continue to monitor the establishment and growth of the serradella at this site.

Figure 30 Left: Strawberry clover establishing with phalaris. Middle: Lucerne and strawberry clover combined. Right: Serradella establishing at Ratharney, Woodbury

Key takeaways

- So much of the success of a new pasture comes down to soil moisture, establishment becomes very patchy under moisture deficit
- Spring sowing serradella warrants further evaluation in the midlands of Tasmania.

4.6.9 Perth

Introduction to the farm

Over the years of managing the property *Scone*, near Perth in the Northern Midlands of Tasmania, Knox Heggaton and Dylan Browning have devised a pasture renovation strategy that has worked for their sheep grazing system. Traditionally, pastures earmarked for renovation have been sprayed out and cultivated in early spring and planted with a break crop of turnips. In the following year, a rape crop is sown to provide valuable summer feed for lambs. Finally, after a third roundup application, a perennial pasture mix is sown in Autumn and establishes over winter. However, in recent years perennial pastures sown in autumn have been affected by slugs, with some paddocks receiving 3-4 applications of slug bait. Additionally, some producers are commenting on the increasing unreliability of autumn rainfall to establish crops and perennial pastures before cold winter weather sets in. To combat these issues, Knox and Dylan are trialling spring sown perennial pasture mixes.

Activity

Two paddocks were selected for pasture renovation with each paddock having a break crop of forage rape and ryegrass sown prior to a final desiccant spray in the first week of August 2024. The paddocks were heavily grazed in the second week of August to reduce plant residue. The new pasture was sown into the rape stubble on the 20th of August with a blend of 14-16-11 (14 % N, 16 % P, 11 % K) fertiliser. Each paddock was sown to a different pasture mix (Table 1) to assess how the different pasture mixes performed. The Mix 2 included 4kg/ ha cocksfoot, 2 kg/ha phalaris, 4 kg/ha red clover, 3 kg/ha lucerne, and 1 kg/ha strawberry clover. Establishment in each paddock was very slow, with wet and cold conditions persisting into October. Soil temperatures in the top 10 cm of the soil finally reached 10 degrees in the first week of October. From that point, soil temperatures started to rise but moisture became limiting. Plant counts of Mix 2 were higher (Figure 31), owing to differences in the sowing rates and also the paddock in which Mix 2 was sown had slightly better drainage.

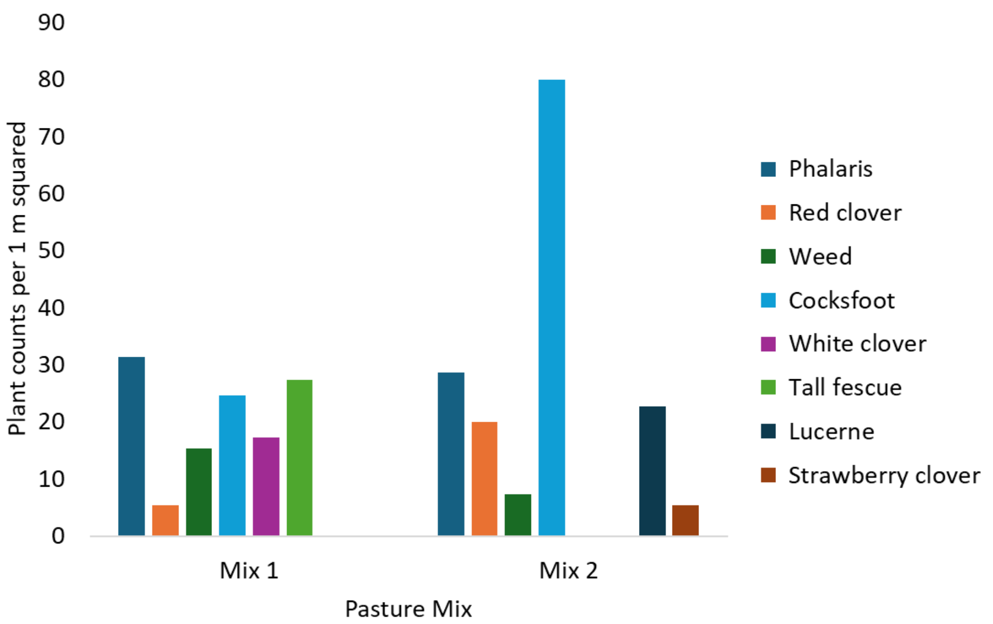

Figure 31 Plant counts (per m2) of pasture species in mixes 1 and 2 at Scone, Perth.

As a consequence of sowing into cool and wet soil temperatures, sown pasture species, particularly legumes are slower to establish. This left establishing pastures vulnerable to weed burden. Toad rush became a major issue in both paddocks and threatened to smother out establishing grass and legume plants as the wet and cool conditions were favourable to its growth. Once conditions started to warm there was also a large germination of fat hen in both paddocks.

Weed control using herbicide application was difficult in these paddocks. Firstly, Mix 2 contains a combination of both lucerne and clovers, which significantly reduced the chemical options available for use. Secondly, the slow growing conditions experienced through spring meant that the legumes were slow to develop their first few trifoliate leaves. Most selective herbicides safe to use in new legume pastures still require legumes to be a certain growth stage. This meant that spaying was delayed while the legumes grew to reach an adequate size. Lastly, October and November bought very dry conditions, meaning that both paddocks because moisture stressed towards the back half of spring. Best practice is to apply herbicide when all plants are actively growing. This ensures a more effective weed kill and minimises damage to non-target species.

On the 20th of November, both paddocks were sprayed with a selective herbicide targeting toad rush and fat hen. Pasture Mix 2 containing both grass, lucerne and clover received an application of Diflufenican and Bromoxynil. Initial observations on the 3rd of December 2024 showed yellowing on the lucerne plants and significant burn on the establishing clovers. Bromoxynil is recommended for use <20 degree. Temperatures in late November can be quite warm, which may have contributed to excess burning on non-target species. Pasture Mix 1 received a Thistrol Gold herbicide application on the same day. Initial observations also indicate some burning on the young clover plants in the paddock, though not as severe as Mix 1. Both sprays did an excellent job on the toad rush and fat\ hen in the paddock. We will continue to monitor how the legumes recover in both pasture mixes, though new growth on the legumes appeared unaffected.

Figure 32 Spray damage on old leaves of the lucerne (left) and red clover (right), with young leaves apparently unaffected. Target species toad rush dead amongst the sward. Photo taken 16 days after the spray application.

4.6.10 Bothwell

Introduction to the farm

Will Bignell runs a 2900 ha mixed cropping and lamb finishing enterprise near Bothwell in the Derwent Valley. Will has recently purchased a new block near his main property Thorpe, and has identified underperforming pastures as well as challenging soil conditions. Soil types on his new block are generally sandy loam however there are some low-lying areas that become waterlogged and are mildly saline.

Activity

Will is trialling a pasture mix specifically designed for the sandy loam soil types as well as a pasture mix that been designed for the more challenging saline areas. The trial paddocks underwent a 12-month chemical fallow. In October 2023, both paddocks received their first glyphosate spray, followed by a second application in March 2024. In early October 2024, a third and final glyphosate spray was applied and Kelly disc chains were used to knock down any standing dry matter in preparation for planting. Diammonium phosphate (DAP 18% N, 20.2% P) was applied at 150 kg/ha prior to a single pass with a multidisc. Both pasture mixes were sown on October 11th with an airseeder drill and rolled with a Cambridge roller.

The pasture mix for the sandy areas consisted of cocksfoot @ 2 kg/ha, phalaris @ 3 kg/ha, lucerne @ 5 kg/ha, strawberry clover @ 2 kg/ha, and red clover @ 1 kg/ha. The pasture mix for the low-lying waterlogging prone areas consisted of tall fescue @ 3 kg/ha, phalaris @ 3 kg/ha, strawberry clover @ 4 kg/ha, balansa clover 4 kg/ha, and Persian clover @ 4 kg/ha. Early observations are that the legume components of the pasture have established exceptionally well with Persian clover dominating one mix and lucerne dominating the other. The warm spring conditions and timely rainfall has aided their establishment (Figure 33).

Figure 33 Left: Strawberry and Persian clover with tall fescue. Right: Lucerne with cocksfoot at Bothwell.

4.6.11 Bothwell II

Introduction to the farm

John Ramsey runs an 1800 ha mixed cropping and sheep property at Bothwell, in the low rainfall Derwent Valley. In recent seasons, Bothwell, like much of Tasmania has experienced prolonged periods of dry and unseasonal weather conditions. Pasture species that could be relied upon in average-good seasonal conditions have struggled over this dry time and once moisture became available, were slow to recover. John Ramsay has noticed a steady decline in his pasture legume content at his property, Ratho, in Bothwell. John has identified that pasture production could be improved in his dryland pastures through increasing the proportion of legumes. However, legume establishment in these areas has been challenging due to low pH at depth, weed competition, particularly weedy annual grasses, mainly vulpia and increasingly unpredictable and unreliable autumn rains.

Activity

As part of TIA's Involve and Partner activities we are following the establishment of a legume experiment that has been sown on John's property to determine which legumes can persist in his challenging environment. The trial area was sown on an east facing bank with patches of hydrophobic sand as well as areas of soaks that became waterlogged over winter. A soil test of the area showed a pH of 6.01 (H20) at 10 cm. Once we conducted a soil test at 30 and 60 cm, we found that the pH at depth was very acidic (Table 1). Figure 1 shows the change in soil for three different soil depths.

The trial area was desiccated with Roundup in early September and sown on the 19th of September using a disk drill. The trial was sown with 100 kg/ha of DAP (18% N and 20% P) as well as 75 kg/ha of Calciprill. Pasture mixes have included either cocksfoot or phalaris with lucerne, strawberry clover with subterranean clover, or serradella. Serradella has been the pick of the establishing legumes and perhaps is the best suited to the acidic sandy soils (Figure 34). It is yet to be determined whether the spring sowing will give long enough for the serradella to set seed for germination next autumn.

Figure 34 Serradella establishing with phalaris on acidic sandy soils near Bothwell, Derwent Valley.

4.6.12 Project linkages

Livestock Productivity Partnership

The livestock Productivity Partnership provided opportunities to share knowledge across projects as well as collaborate on review papers. Richard Hayes (NSW DPI; Extending the boundaries of legume adaptation through better soil management), Richard Culvenor (CSIRO; Perennial pasture and forage combinations to extend summer feed in southern NSW) and Matthew Harrison (TIA; Exploring profitable, sustainable livestock businesses in an increasingly variable climate) all presented to producers. Richard Hayes participated in paddock walks and shared knowledge around liming. Review papers were written on strawberry clover with the assistance of authors from LPP partner organisations and co-authorship was provided to Warwick Badgery (NSW DPI) on Reducing enteric methane of ruminants in Australian grazing systems – a review of the role for temperate legumes and herbs. There have been some good linkages made that have added value in both directions.

Australian Grassland Association Symposium

Rowan Smith has been president of the Australian Grassland Association (AGA) and along with the committee organised a symposium held in Perth, WA in July 2023. The committee developed a theme based on pasture legumes - 'Pasture legumes for sustainable, productive systems'. It will be 11 years since the first AGA symposium, which itself was focused on legume research. Several papers from the Livestock Productivity Partnership projects were received and highlight the renewed interest in legumes in grazing systems. All published papers can be found in a special issue of Crop and Pasture Science: Volume 74 Number 7 & 8 AGA 2023 – Pasture legumes for sustainable productive systems CSIRO PUBLISHING | Crop and Pasture Science. This includes the review paper on strawberry clover as an output of the project https://www.publish.csiro.au/CP/CP22301

Future Drought Fund funded NRM South Drought Resilience Project

The Tasmanian Institute of Agriculture was contracted through NRM South and the Future Drought Fund to undertake re-establishment demonstrations at four sites on the East Coast and Midlands. This work builds off the re-establishment experiments in the current LPP project by sowing simpler designed, lower budget experiments/trials with one pasture mix. This has provided opportunities to raise awareness of the current project and extend project findings outside of the study region. Evaluation of strip tillage and direct drilling sowing methods for pasture renovation in low rainfall regions of Tasmania | Tasmanian Institute of Agriculture (utas.edu.au)

Future Drought Fund – Long-term trials

Findings from the current project will assist in designing pasture mixes and sowing methods for a recently funded project led by Deakin University. Pasture 365 - Investigating diversity in pastures to build resilience and support 365 days of feed production in southern temperate grazing enterprises. https://www.agriculture.gov.au/agriculture-land/farm-food-drought/drought/future-drought-fund/long-term-trials-drought-resilient-farming-practices-grants

5. Conclusion

In Tasmania, red meat productivity in the low-med rainfall zone will be maximised under irrigation where legumes such as white clover, red clover and lucerne can generate higher yields and higher feed on offer, which in turn increase intake and thus growth rates. With only 10-20% of farms covered by irrigation, establishing perennial legumes in dryland pastures will provide a large benefit to increasing stocking rates and livestock production.

Establishing and getting perennial legume species to persist in the low-med rainfall zone remains a significant challenge. Few species offer significant herbage production with long-term persistence. Lucerne offers the best potential on favourable soils, though further work on maximising it's establishment and production in mixed swards is warranted. Red clover can provide quality dry matter production, though persistence after long periods of moisture stress is compromised. The importance of subterranean clover (an annual) in mixed low rainfall pastures should not be underestimated and warrants better management.

Some experimental sowings failed in this project, despite good preparation and planning. This demonstrates the dilemma and risks producers face when deciding whether or not to renovate pastures – relatively high rate of failure compared to high rainfall or irrigated pastures. While many influential factors such as ground preparation, weed control, and subsequent grazing can be controlled and managed, much of the success in dryland pasture renovation comes down to how favourable the seasonal conditions are during the first 12-18 months after sowing.

5.1 Key findings

- Alternate row and matrix sowing spatially separate grass and legume components of mixed pasture seed blends and provide alternatives to direct drilling in mixed rows. However, they only provide a marginal benefit over direct drilling in mixed rows in terms of overall dry matter. They also had no effect on increasing the dry matter contribution of slow establishing perennial legumes such as Caucasian clover and Talish clover. Dry matter contribution of legumes was greatest in lucerne and red clover plots.
- Broadcast sowing methods are reliant on favourable surface soil moisture to aide germination. Broadcast methods will work best where the soil is cultivated or where there is sufficient bare ground for seed soil contact and will be advantaged by rolling or treading by livestock.
- Some form of competition reduction is required for successful germination and early establishment of perennial legumes in phalaris dominant pastures. Non-lethal pre-sowing herbicide application had the greatest effect, and the strip till sowing method worked best where herbicide application wasn't used.
- Strawberry clover germplasm appears quite consistent in its ability to tolerate waterlogging. Any further development work on strawberry clover should be focussed on increasing DM yield potential by selecting from within exiting cultivars or novel germplasm.
- Involve and partner activities on farm has encouraged producers to trial high legume content pasture mixes and novel sowing methods. To date 8 producers have directly engaged with some sowing 1ha of high legume mix amongst a larger paddock sowing, while others have taken the recommendation and sown the whole paddock (total approx. 50 ha). This aspect of the project has a further 17 months to run and we aim to expand the area on those farms and new farms.
- Red meat producers have shown good engagement by attending field days at involve and partner farms (quantify). Direct exposure of 40 producers and service providers in each

region to the project has raised awareness of appropriate sowing techniques for rainfall zones and highlighted reasons for sowing failures.
- On-farm demonstrations have led to the sowing of new pasture mixes based on mixes sown in the demonstrations.

5.2 Benefits to industry

This project has raised awareness of the important role legumes can play in red meat grazing systems. Tasmanian representatives from major seed companies have indicated and increased interest in legumes within pasture mixtures being sold. They identified that the spike in synthetic nitrogen prices during 2022 brought into focus nitrogen fixation through the rhizobia symbiosis and increased interest in how to get the most out of legumes. They also indicated that there were more farmers prepared to try species and mixtures that they haven't tried before. In terms of success, seed reps have seen modest improvement over the last 20 years with better establishment, liming, use of phosphorus and trace elements, knowledge of herbicide options and grazing management improving. Also identified was a subtle shift towards better quality feed rather than just more overall dry matter. Greater success has been seen where there has been assistance from agronomists and farm advisors.

Recommendation: Continue to work closely with seed company representatives, farm advisors and agronomists to extend research. More can be done to improve knowledge of merchandise store staff at the front line of seed sales, when producers have not been advised what to purchase by agronomists. Closed presentations to agronomy companies as professional development opportunities may be required to get good attendance.

Higher proportions of legumes in mixes have been successful for growing and finishing lambs, particularly under irrigation and this project has highlighted options for diversifying such mixes. There has been some acknowledgment that lowering the sowing rate of grasses, in particular perennial ryegrass and raising the legume sowing rate will assist in establishing and producing higher legume content. One sed rep noted that less legume seed was now being sold on its own and a greater proportion is incorporated into pre-mixed propriety and custom seed blends, mostly due to convenience. White clover, lucerne, and subterranean clover remain the backbone of rainfed grazing systems. This project has raised the awareness of strawberry clover as an adaptable plant for the medium rainfall zone, and it acknowledged that there had been a steady increase in sales in the last 10 years, albeit from a low base. It's being used in medium rainfall mixes with phalaris and cocksfoot, though seed supply can be variable and this can impact consistent sales. There has been increasing demand for annuals like Persian clover, balansa and vetch in mixtures with Italian and annual ryegrass or oats for quick grazing and fodder conservation.

Recommendation: Continue to promote the characteristics of a wide range of legumes in suitable contexts through on-farm demonstrations. The Evergraze slogan of 'right plant, right place, right purpose' remains a key message.

6. Future research and recommendations

6.1 Key successes

The waterlogging screening study identified that waterlogging tolerance was reasonably consistent across a broad range of germplasm. Furthermore, variation in phenotypes within existing cultivars and wildtype accessions would allow selection and breeding work to improve on current cultivars.

This could be done without the risk of losing waterlogging tolerance. Strawberry clover as a species is quite flexible to persisting through waterlogging and moisture deficits. With climatic events becoming more extreme, strawberry clover may become a legume we rely upon in pasture mixes more.

Recommendation: Develop higher DM producing cultivars of strawberry clover and increase the sowing rate in mixed pasture blends.

The involve and partner activities have proven a great way to engage producers on their own farms and an extension tool for engaging their peers within the region. We have found producers much prefer to visit a commercial farm and hear from a producer's experience than visit an experimental site on a research station. Working in with existing producer groups and presenting at their farm visits or paddock walks has proven more engaging and less organising.

Recommendation: Use existing producer group events to extend project results and use involve and partner farms as places to hold organised events where research can be presented, but outcomes demonstrated. Increase the number of involve and partner farms.

6.2 Key challenges

Renovating pastures with slow establishing perennials without the use of herbicides in the low-med rainfall zone is problematic; competition from the existing pasture is strong. Annuals that have great vigour appear to have an advantage in this scenario. The strip till sowing method offers a competition reduction and reports of it working well have been with pasture mixes containing a vast number of species, both annual and perennial. Furthermore, such reports have involved repeated sowing over several years rather than just one renovation.

Recommendation: Further research needs to be undertaken to investigate whether these diverse multispecies sowings with strip till machines over multiple years is economic.

There were several challenges experienced throughout the project. The nature of dryland pasture establishment in the low-med rainfall zone is that some new pastures will fail to establish for a range of reasons, some of which cannot be forecast; lack of rainfall, weed incursions, pests and diseases, and soil constraints. As with all field trials, project teams make their best efforts to reduce such risks. In this project, at least 1 site has established for each of the experiments, but a number have failed meaning there is a lack of site and experimental replication. Efforts we made in subsequent years to establish more sites.

Recommendation: Prepare and sow more experiments/sites than necessary and then chose which ones to continue to monitor and evaluate. Some sites will fail.

Building in postgraduate research into the project with deliverables presented a challenge for two reasons. There is a shortage of suitable domestic PhD candidates willing to undertake studies in pasture science. Covid-19 made it virtually impossible for any international students to begin studies in 2020. We were also unfortunate to have 1 student start a candidature, but the student terminated within the first year of starting due to personal reasons. As such, the project team had to pick up much of the planned activity and deliverables on top of other scheduled project work. This also meant that many of the very detailed measurements could not be taken. Writing student studies into projects assists in matching scholarship funding from University's but does leave the project exposed if there are deliverables associated with those studies.

Recommendation: Write student studies into projects but leave the deliverables as bonuses rather than being essential to the research. Have contingencies in place if student projects fail.

6.3 Opportunities

The Future Drought Fund Long Term Trials funding through the Pasture 365 project (https://www.utas.edu.au/tia/research/research-projects/project/livestock-production/developing-drought-resilient-pastures) has offered a continued focus on mixed pastures and the role legumes play in pasture mixes. This project has included ‘satellite farms’ alongside research intensive sites, in much the same way as this project did with ‘involve and partner’. This has engaged more red meat producers, producers that had seen or been to involve and partner site and wanted to be involved in the satellite farms. The key focus in this project is to use species diversity within the paddock and across the farm to reduce feed gaps and build long-term resilience. Deep rooted species like cocksfoot, lucerne and chicory have been identified as key species for future grazing systems that will be more regularly under moisture deficit.

Recommendation: Opportunity exists to utilise these focal research sites and add value. For instance, while basic feed quality analysis is being conducted on pasture mixes, this could be extended to look at their effect on enteric methane production either in vitro or by picking the best mixes and establishing grazing studies.

7. References

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8. Appendix

8.1 Published research articles

8.1.1 Strawberry clover (Trifolium fragiferum): current status and future role in Australian agriculture

Smith R. W., Penrose B., Langworthy A. D., Humphries A. W., Harris C. A., Rogers M. E., Nichols P. G. H., Hayes R. C. (2023) Strawberry clover (*Trifolium fragiferum* L.): current status and future role in Australian agriculture. Crop & Pasture Science 74, 680-699. https://doi.org/10.1071/CP22301

8.2 Submitted research articles

8.2.1 Genetic diversity for winter waterlogging tolerance in strawberry clover (Trifolium fragiferum L.)

Langworthy, A.D., Penrose, B., Manik, S.M.N, Hunt, I.G., Smith, R.W. () Genetic diversity for winter waterlogging tolerance in strawberry clover (*Trifolium fragiferum* L.). Being resubmitted to another journal

8.3 Contributed research articles

8.3.1 Reducing enteric methane of ruminants in Australian grazing systems – a review of the role for temperate legumes and herbs

Badgery Warwick, Li Guangdi, Simmons Aaron, Wood Jennifer, Smith Rowan, Peck David, Ingram Lachlan, Durmic Zoey, Cowie Annette, Humphries Alan, Hutton Peter, Winslow Emma, Vercoe Phil, Eckard Richard (2023) Reducing enteric methane of ruminants in Australian grazing systems – a review of the role for temperate legumes and herbs. Crop & Pasture Science 74, 661-679. https://doi.org/10.1071/CP22299

8.4 Extension materials

8.4.1 Project highlights booklet

https://www.utas.edu.au/__data/assets/pdf_file/0011/1828442/Publication_Legumes-publication_2025.pdf

8.4.2 Advantaging legumes factsheet

8.4.3 Interactive map of project activities