final report

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Legumes in Kikuyu

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Abstract

The legumes in kikuyu project was undertaken to improve the productivity of kikuyu pastures in the south-east coastal zone of Western Australia through introducing legumes. The ideal partner for kikuyu, a summer-active grass, is a leguminous winter-active annual. There are challenges ensuring the success of this partnership which were examined during this project.

A paddock scale trial was set up by sowing various legume pasture species at a traditional Autumn sowing and an earlier Summer sowing date. The kikuyu was supressed before seeding and there was an unsprayed, unseeded plot. Pasture composition was monitored over three years and the yellow serradella proved to be the best performer after that time. Some other varieties were impressive early, but did not persist into later years which was a key criteria for the farmer.

One of the key findings is the importance of active management of a pasture paddock. Doing something almost always is better than doing nothing to an unproductive stand.

Executive summary

On the Esperance sandplain, kikuyu is a dominant pasture species because it has the ability to stabilise delicate sandy soils and convert summer rainfall to valuable livestock feed. However, over time the feed value and quantity diminishes and legumes disappear from the sward. Farmers perceive this is a major restriction to the current production system and have identified a need to improve the way kikuyu is managed or face removing it from the system.

The missing component is a productive legume pasture growing over the cooler months when kikuyu is not actively growing. This should provide more feed during winter and spring, and bring nitrogen to the subsoil for the kikuyu to feed off when the soil warms up. This is not always the case. Often when the soil temperatures drop, the growth of kikuyu slows down but does not go completely dormant, continuing to compete with young seedlings. This is a problem especially during May and June when a dry period is experienced. There is also a lot of local interest in research done on summer sowing legumes to get a better establishment and free up seeding equipment over the traditional autumn/winter period for sowing crops. This had been extensively trialled in Mediterranean wheatbelt areas but not as much on the coastal sandplain.

The project was conducted on ‘The Duke’ property, situated on the south coast within sight of the magnificent beaches along the Esperance coast. The property owners run 5,600 head of Dorper/Wiltshire cross sheep on 2,500ha. The farm is split into 20ha paddocks and run under a rotational grazing system, with pastures being intensively grazed every 6 weeks.

Rainfall for the property is 650mm and up to a third of this rain can fall in summer. The dominant soil type is deep, white sand. Soil pH hovers around 5 and subsoil pH can drop as low as 4.4. This soil characteristically has a low ability to retain nutrients and moisture. This is a hostile situation for establishing and maintaining traditional high productivity pastures. In the past, wind erosion caused significant damage to the soil and kikuyu was identified as an important addition to the system to ameroilate its impact.

Kikuyu helped stabilise the soil and utilise summer rainfall events. Kikuyu provided green feed over summer and into autumn when winter pastures were not actively growing. As time went on, kikuyu began to dominate the sward and out-compete the valuable winter pasture. Hoggarts decided that it was time to closely examine the species structure of the sward and introduce one (or more) winter active legumes.

As part of the legumes in kikuyu project, alternative legumes were sown at different times into a kikuyu paddock to establish a year-round green feed source for sheep production with the aim of increasing the production of kikuyu through summer (more N) and having a productive legume pasture over the winter months. A 22ha paddock was sown in summer with an airseeder, then again at the traditional autumn sowing with Bartolo bladder clover, Dalkeith sub-clover, Avilla, Margurita and Santorini serradella.

At the end of the project it has become obvious that serradella is the best legume suited to kikuyu pastures on the Esperance sandplain. The introduction of serradella in the trial site and over several paddocks around the farm have demonstrated that it does increase the overall standard of pasture.

Kikuyu is active when soil temp is higher than 14°C and becomes more active as soil temperature increases. Kikuyu is very efficient at utilising moisture and nitrogen, either applied or existing in the soil. It has a deep root system (>1m) which is useful in seeking out moisture. Eventually kikuyu covers surrounding soil and forms a dense thatch which can act as an insulative layer against soil temperature fluctuations, a mulch layer on non-wetting sands improving water infiltration, and can be utilised as a rich source of stored nutrients for the kikuyu. This thatch layer means kikuyu is a very hardy pasture plant and capable of sustaining itself under challenging conditions.

However, often the kikuyu material is so dense that annual pasture seedlings will struggle to establish roots which can access the soil for moisture and nutrients. This is a common problem in Esperance sandplain when a 'false break' is experienced. Early rains cause a mass germination (often of clover) followed by an extended dry period where the seedlings fail to access soil moisture below the thatch and die off.

Kikuyu also creates an isolated band of fertile soil in the top 5-10cm in which legume roots will fail to penetrate beyond, further compounding the problems associated with competing for moisture and nutrients. Often compaction can occur in the infertile subsoil below this band.

Knockdown of old kikuyu stand has the following flow-on effects

- Breakdown of kikuyu organic matter increases the soil carbon and gradually releases nutrients stored in roots and runners.
- Stops kikuyu using autumn and winter soil moisture which should be used for legume establishment (see photos in Appendix 2)
- Reduces competition for emerging annual pasture seedlings especially during false break scenario. This leads to significantly higher annual pasture survival
- When kikuyu 'wakes up' again it will attempt to recolonise the area and produce new leaves which are high in nutrients and vigorous.
- Kikuyu will recycle the nutrients from decaying organic material in the soil
- In the trial, sheep were observed to have preferentially grazed sprayed areas over the unsprayed plot.
- Bare patches did occur on sprayed out area where sheep chose to camp

Year 2014- A good strike of all legumes seeded was achieved. Most impressive was Bartolo Bladder clover and Margurita serradella. The paddock was excluded from grazing and legumes were allowed to set seed. Towards early spring, it became apparent that there was a background sub-clover present although this was not obvious in previous years.

Year 2015- As expected, the very hardseeded legumes were all but absent this year due to the seedbank remaining too hard for significant numbers of germination. In a mixed cropping/grazing situation this year would be a good one to plant a crop and control weeds to prepare for future pasture phase. Kikuyu growth was impressive where sprayed out. Control plot performed poorly and sheep seemed to avoid grazing or camping on it all year.

Year 2016- Kikuyu had almost reverted back to starting cover levels before spraying out. There is a noticeable difference in length of kikuyu between control and treatment plots and a slightly darker green colour. The topsoil horizon is not as clearly defined and the subsoil is slightly darker in colour, suggesting deposition of carbon from root decomposition. Legumes are flourishing with a rejuvenation of background subterranean clover and introduced Santorini and Margurita serradella performing better than Avilla serradella. The Bartolo has not persisted.

Year 2017- Santorini Serradella has increased in number and is spreading through the paddock in dung. Avilla Serradella has emerged and is looking good. Margurita numbers are reduced but is still plentiful. Red clover symptoms was found on the sub-clover in May and has reduced numbers but towards the end of the year some plants had recovered and new plants have germinated and grown unaffected. Some Bartolo was found in October (this is the first time it has been found since seeding) but plants were noticeably smaller and not thriving despite successful nodulation. Bartolo is susceptible to potassium and phosphorus deficiency and this could be causing these symptoms. Kikuyu is back to original groundcover levels but does appear to be performing better than before the trial commenced.

Kikuyu is a widespread pasture species across the coastal sandplain in Esperance and in many higher rainfall areas. It is estimated to cover 150,000ha across Western Australia.

The two main benefits from having a productive kikuyu stand are utlilising summer and autumn rainfall events and increasing stocking rates. In the Esperance zone, it is common for a third of annual rainfall to occur between December and March. Utilisation of this rainfall is key to reducing supplementary feeding and increasing holding capacity of the whole farm over the warmer months. It also has many soil health benefits for the white sands in building organic carbon levels (from 0 without kikuyu to over 2% in an established stand) storing nutrients which would otherwise leach through the root zone, and reducing wind erosion by providing ground cover and water damage following summer storms.

In the past, there has been a lot of discussion about the ideal legume partner for kikuyu, and serradella appears to be favoured in many instances on the sandplain. Improved breeding of new serradella species performed remarkably well, as shown in this project. By integrating a suitable partner legume for kikuyu, farmers can keep the benefits of kikuyu based pasture while reaping the benefits of having a productive winter legume as well.

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1 Background

The legumes in kikuyu producer demonstration site was established on a typical run-down kikuyu paddock which did not have a background legume present and was considered unproductive by the farmer. The introduction of several legumes and the chemical renovation of the kikuyu aimed to improve the overall productivity of the paddock after several years. The farmer highlighted the importance of this change occurring over several years because there are ways to improve the pasture quality for short term gain, but the real value is in ongoing improvement with limited ongoing investment.

Kikuyu was introduced to Esperance Sandplain because it will grow on sandy soils where nothing else would. It protects damaged soil subject to wind erosion. Most valuable of all, it provides summer feed by utilising summer rainfall events. The Esperance system is very different to the environment kikuyu has evolved to suit and we have failed to replicate those conditions.

Native Environment	**Esperance Grazing System**
1000-1600mm	<650mm
Fertile loam	Infertile white sands
Heavy crash grazing	Set stocking
High stocking rate while grazed	Grazing stocking rate 9DSE
Regular grass fires regenerate	No regeneration
Pasture height 30cm	Pasture height 2-5cm

Kikuyu is highly competitive for nutrients and water to the point of out-competing itself. At the break of season, more rainfall is required to germinate winter-active annuals due to moisture depleted subsoil. Old (rank) kikuyu is unpalatable and low in nutrients. It can induce nutrient deficiencies, particularly calcium deficiency which is a risk in pregnant and lactating stock.

Fig. 1: Taken in February 2015 illustrating the hostile topsoil conditions. The dry soil has fallen away and left behind plant matter which forms the 'thatch' layer.

It forms a layer of 'thatch' which acts like a mulch and prevents other plants accessing sunlight and soil moisture. Livestock will actively avoid rank kikuyu and seek out more palatable feed. The stock will favourably graze the more palatable legumes, the legumes fail to set seed which depletes seed reserves and over time legumes can disappear from the sward. Once kikuyu is allowed to go rank the only option is to renovate mechanically and/or chemically.

The Australian experience with kikuyu assumed winters were cold enough to 'shut down' kikuyu over winter. This does not happen on the Esperance coastal plain. Kikuyu growth slows when soil temperature drops below 14-15°C which occurs as late as June and will rise again in September depending on the season. Therefore the effective growing season for winter active annual pasture is probably only 3-4 months without suppression of kikuyu.

The ideal winter-active partner for kikuyu will have

- early root vigour to reach moist soil below the thatch
- a short growing season, or ability to set seed without an extended growing season
- set a large number of seeds
- a staggered germination pattern to hedge against false breaks
- ability to establish with limited soil nutrients

Unfortunately, weeds such as silvergrass or capeweed fit this niche very well and can become a problem. Serradella is a notable exception and has been found to suit kikuyu in a long-term grazing scenario with little management. Sub-clover can be very productive as well, but the population can reduce over time without intervention.

2 Project objectives

The objectives set out at the commencement of the project were to examine the following

1. Compare summer sowing to conventional autumn sowing as an establishment method when sowing legumes into kikuyu
2. Assess the feed production of kikuyu to determine the benefits over time of incorporation of legumes to increase the paddock stocking rate
3. Demonstrate management techniques to maintain the legume seed bank for continued legume regeneration

3 Methodology

This project was conducted at 'The Duke' property, Orleans Bay Road, Condingup, WA. A 22ha paddock (600m long, 350m wide) with sand to deep sand gradient, was used as the trial site. Initial pasture composition of the site was dominated by kikuyu with very little clover. At the commencement of the trial, the sheep grazed out the sub-clover and trampled the kikuyu rendering the pasture relatively unproductive with a distinct 'thatch' on top of the soil.

Within the site the following treatments were applied:

Plot 1	Summer knockdown spray	March Sown	Bartolo Bladder Clover
Plot 2	Summer knockdown spray	March Sown	Avilla Serradella
Plot 3	Summer knockdown spray	Not sown	No seed
Plot 4	Summer knockdown spray	March Sown	Margurita Serradella
Plot 5	No Spray	Not sown	Untreated control
Plot 6	Autumn knockdown spray	May sown	Bartolo Bladder Clover
Plot 7	Autumn knockdown spray	May sown	Santorini Serradella
Plot 8	Autumn knockdown spray	May sown	Dalkeith Subterranean Clover
Plot 9	Autumn knockdown spray	May sown	Margurita Serradella

Legumes sown in summer (February) and autumn (May) across the length of the paddock to include a soil type gradient.

In summer 2014, a kikuyu suppression was applied (2L/ha Glyphosate) and Margurita Serradella enhanced pod, Avilla Serradella enhanced pod and Bartolo bladder clover scarified seed was sown.

In autumn 2014, a kikuyu suppression was applied (2L/ha glyphosate) and Margurita serradella scarified seed, Santorini serradella scarified seed, Dalkeith sub-clover seed and Bartolo bladder clover seed was sown.

Between the two 'time of sowing' treatments is an unseeded, unsupressed control plot.

Plots were 200m x 20m and the control plot was 40m wide.

Kikuyu suppressed with the following mix:

2L/ha Glyphosate, 2% Liase and 0.3% wetter

2 weeks prior to sowing for each time of sowing.

Objective 1: Comparison of summer sowing to conventional autumn sowing as an establishment method when sowing legumes into kikuyu

Plant cuts and pasture counts were carried out on each of the plots to compare pasture establishment and regeneration.

Botonal method was used to determine yield and composition of the pasture cuts.

Photographs of the quadrats sampled for biomass were taken at the time of the cuts to allow a visual comparison of the plots.

A fixed point photography point was established to gauge the change in the trial over time.

Objective 2: Assessed the feed production of kikuyu to determine the benefits over time of incorporation of legumes to increase the paddock stocking rate

On an annual basis, soil testing to 10cm with soil core testing to 80cm occurring twice (beginning and end of project) to determine if there are changes in soil at depth

Pasture cuts and weed counts

Botonal method was used to determine pasture composition and yield

Photographs of the quadrats taken for biomass taken at the same time as cuts to allow a visual comparison.

Feed quality test done in 2016 to compare control plot to supressed kikuyu after difference in kikuyu length and colour were observed.

Objective 3: Demonstrated management techniques to maintain the legume seed bank for continued legume regeneration.

In 2015, 2016 and 2017 germination counts were performed to ascertain the regeneration (and past success of seed set) throughout autumn and early winter to account for different hardseed breakdown patterns of the various legume varieties sown. Visual assessment of seed set performance of each variety. Photographs taken where germination counts were performed

The paddock was managed throughout the project in accordance with 'farmer practice' to ensure legumes were tested in a real world situation. The management practices carried out include

- fertiliser application,
- grazing under rotational grazing, in 2014 the paddock was not grazed at all during growing season to maximise legume seed set,
- insect (heliothis 2015) spray to reduce damage to serradella pods,
- weed management- paddock was slashed in late spring to stop seed set of grass weeds.

3.1 Grazing

The paddock remained unstocked for the duration of the establishment period (sowing to seed set 2014). In subsequent years, the paddock was grazed in accordance to the farmer's standard grazing routine. This routine is based on rotational grazing with one week intensive grazing (on average 32DSE/ha) and three/four week rest.

Grazing observations were made by the farmer daily when the sheep were grazing the trial paddock to determine preferential grazing of one plot over another.

3.2 Weed control

Slashing and spray-topping with 0.5L/ha glyphosate was done at correct timing to allow seed set of legumes and prevent seed set of grass weeds. Namely Silvergrass (*Vulpia myuros)*, Hares Tail grass (*Lagurus ovatus)*, Soft Brome grass (Bromus hordeaeceous), Brome grass (Bromus rigidus), Barley grass (Hordeum leporinum).

3.3 Insect pest control

Monitoring for insects was done at 6 weekly intervals. Only one spray was required to control Native budworm (*Heliothis)* in spring 2015 with 400mL alphacyermethrin. Other insects found at below threshold levels were redlegged earthmite, balaustium mite, aphids.

The presence of aphids coincided with observations of a virus on clover plants in June 2017, which disappeared within weeks. It is unknown to what extent this affected the total clover biomass. Some dead plants were found and others failed to thrive post infection while other plants made a full recovery. The occurrence of systemic clover death is not uncommon in the Esperance region and requires greater scientific investigation into a wider issue of what has come to be known as 'Red Clover Syndrome' because symptoms and indicative factors (such as the presence of aphids) are inconsistent between cases.

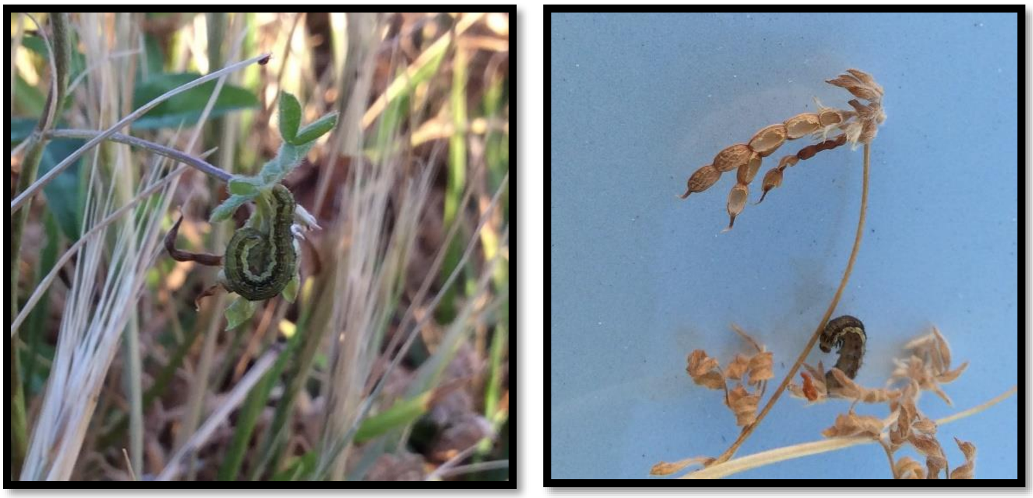


Fig 2: Heliothis caterpillar and damage in Margurita serradella

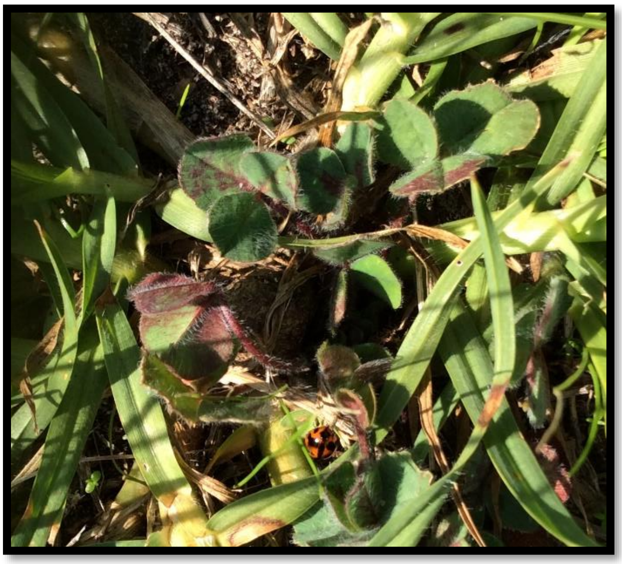


Fig 3: Clover affected by a virus with aphids present and a predatory ladybird

3.4 Fertiliser trial

Ron Master, DPIRD, recommended we undertake a simple demonstration trial focusing on Nitrogen and Sulfur, and the effect it has on kikuyu growth in spring. We already know kikuyu responds very well to applied nitrogen (given adequate soil moisture) and farmers in the West Australian Southern region have been using Gibberellic acid with some success, although this success has not been reflected in the limited trial work conducted in Esperance to date. Anecdotal evidence suggests there is a response from applies S, however this needs to be explored further. This trial did show a visual difference, unfortunately received 150mm of rain in a week before DM cuts and leaf tissue testing was due to occur. Nitrogen and Sulfur are very mobile within the soil solution and leach readily so were absent at the scheduled time of testing.

Treatments:

- Standard application rate of 20kg/ha of sulphur will be used.
- Gypsum @ 170kg/ha (S 29kg/ha)
- Ammonium sulphate @ 120kg/ha (S 29 + N 25kg/ha)
- Urea @ 54kg/ha (N 25kg/ha)
- Giberellic acid @ 20gm/ha + Urea @ 54kg/ha
- Giberellic acid @ 20gm/ha
- Control
- 2 replicates of each strip in a randomised pattern.

Basal application rates across all plots except the control were Double phos @ 68kg/ha (Not superphosphate or SR super to eliminate S) and Muriate of Potash @ 100kg/ha

3.5 Communications activities

Date	Activity	Description	Audience
2014, 2015, 2017	ASHEEP Spring Field Day	Site visit with a walk across plots. Pasture researchers from DPIRD, Murdoch University attended each year and helped facilitate discussions and answer farmer's questions.	Attendance 40, 68, 56
2014, 2015, 2017	ASHEEP AGM	Annual conference. A 15 minute update on the Legumes in Kikuyu project progress and key learnings	Attendance approx. 80
2014, 2015, 2017	ASHEEP Newsletter	Distributed to ASHEEP membership	176 current members Farmers representing approximately 340,000ha 43 Agribusiness
	Social media	Occasional posts about the trial and legumes/pasture successes.	302 facebook, 311 twitter (66% from WA, 63% between 25-34)
2017 June	MLA Feedback Magazine	Case study of the farmers and what they got out of the project. Online link shared on social media.	45,000 readers Australia wide
2015 August	MLA Pasture Updates	A 30 minute presentation on the project.	47 attendees 64% farmers representing total 27,105ha
2014	Project sign	Installed at the front gate of the property.	Photo in appendix

4 Results

4.1 Qualitative assessments

Selective grazing: In 2015 and 2016 the property owner observed that sheep were avoiding the control plot on more than one occasion. The observations found that sheep were not grazing or camping on it in favour of the treatment plots, particularly Margurita Serradella which started to develop bare areas on a hill prone to wind erosion, so the stock were removed early. The farmer expressed that it was difficult to manage the grazing levels of different plots because the sheep would graze some harder than others and overgraze them, potentially impacting the recovery rates of that plot. Whereas the sheep would hardly graze others, and shorten the length of time stock could be held in the trial paddock. Perhaps a better design would have involved one treatment per paddock.

Fig 4: Sheep grazing the trial

Several farmers on the 2017 ASHEEP Spring Field Day expressed surprised at the difference between 2014 field day and 2017 field day in terms of the quality of the pasture and the feed on offer (FOO).

Fig 5: Pasture in April at the beginning of the project 2014 (Right) and the end 2017 (left).

The farmer anecdotally observed that lambs finished on the improved (serradella) pasture seemed to fatten at a faster rate than previous years. However because of the rotational grazing system, and across a number of different seasons, it is very difficult to attribute this to any one factor.

There was a significant difference in stored soil moisture between the sprayed and unsprayed kikuyu plots. The presence of readily accessible soil moisture in a dry autumn is crucial to the successful establishment of a winter pasture.

Fig. 6: One year after kikuyu was sprayed out (right) the soil has much more available moisture, whereas in the unsprayed control (left), the subsoil is completely dry. Photos were taken 20m apart.

There was a small patch of Balansa clover to the side of the trial site and sub clover was not observed to be present at the commencement of the project, however it did come back after a year of not grazing the paddock. We do not know for certain what variety of sub-clover it is. Phil Nicholls from DPIRD was consulted to identify it but it does not appear to typify any one sub-clover variety and is most likely an outcross.

Additionally, a border was sown with a pasture mix and the leftover seed from the trial. This was not part of the project, but an initiative taken by the farmer just to see whether different pasture species would persist. This was inspired by work being done by Ron Master and Paul Sanford (DPIRD) where varieties and species not expected to do well in a variety trial performed much better than those recommended. Interestingly on 'The Duke', gland, arrowleaf and crimson clovers had persisted from sowing in 2014 to October 2017 despite popular opinion they do not suit the local environment. This observation suggests that in hindsight we could have included a wider range of species and cultivars in this project.

4.2 Germination counts

Plot	2014	2015	2016	2017
1. Bartolo 2014 Summer sown	3.1	6	0	0
2. Avilla 2014 Summer sown	0.9	2	1.9	15.1
3. No Seed	1.9	4.6	2.2	3
4. Margurita 2014 Summer sown	2.3	21.7	3.5	0.8
5. Untreated Control	1.6	9.3	3.2	4
6. Bartolo 2014 Autumn sown	21.7	12.3	0	0
7. Santorini 2014 Autumn sown	9.5	0.6	5.9	17.2
8. Dalkeith 2014 Autumn sown	7.3	83	5	16.6
9. Margurita 2014 Autumn sown	27.4	94	9.2	2.1

Germination counts taken in May each year show a gradual increase in Serradella population. The yellow serradellas, Santorini and Avilla appear to perform better than Margurita in the long-term. The control plot and plot number 3 show the presence of background clover.

Because germination counts were taken in May, the findings may not account for earlier germinations arising from summer rain or later germinations following winter rain. False breaks are common in this environment and can erode the seedbank of those varieties which are soft-seeded and germinate easily. Also, yellow serradellas have a staggered germination pattern as the hardseed breakdown can occur over several months and germination may not occur until well into winter.

Bartolo had all but vanished from the sward at the final inspection, with just 5 plants were found in total. All of which were stunted in appearance, with very small underdeveloped root systems - despite healthy nodulation being evident on the roots. Bartolo can be prone to phosphorus deficiency and is better suited to inland areas with heavier soil types rather than light coastal sands. It is also known to suffer from mildew, which was not found at this site (due to a lack of plants) but is a common disease in other plants in the Esperance zone.

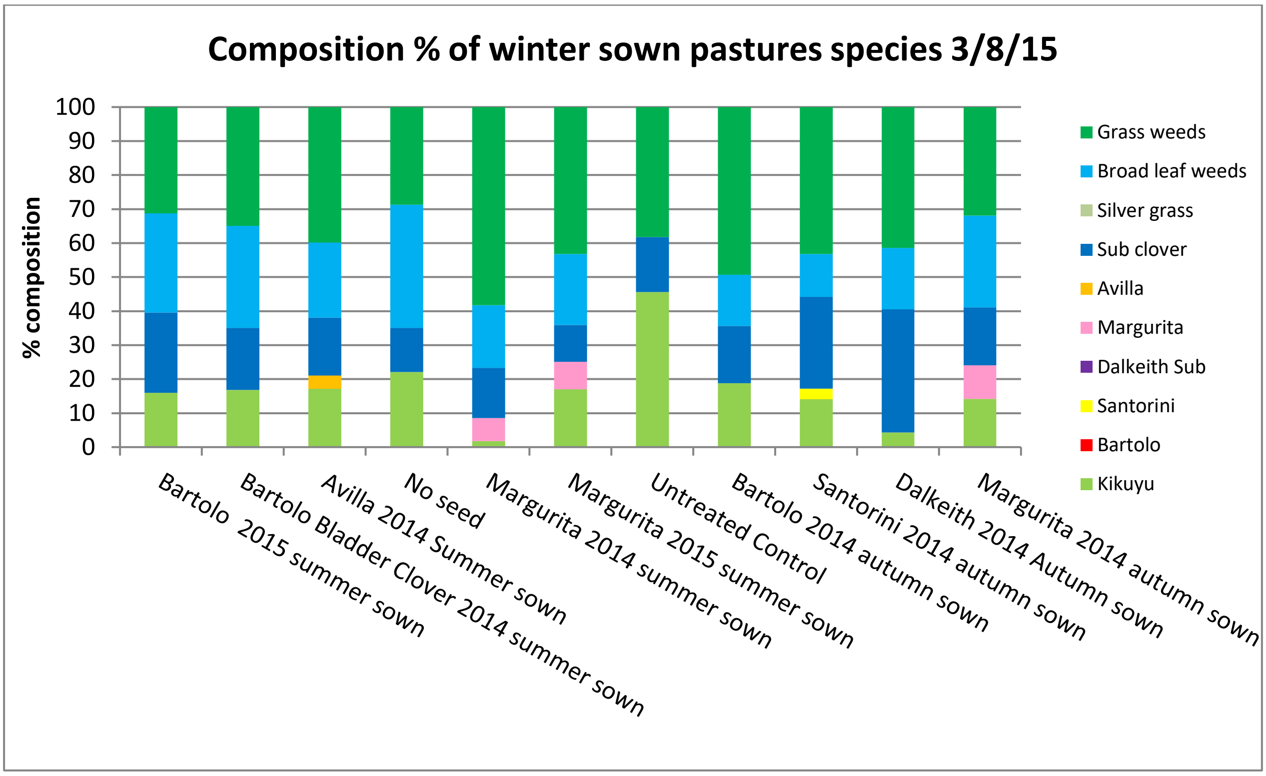
4.3 Botonal graphs

Botonal method, (a comprehensive sampling and computing procedure for estimating pasture yield and composition) was conducted in August each year to demonstrate the change in pasture composition over time. The botonal ratings, although subject to seasonal variation, provide a sound indicator of the composition of the whole sward.

Within the plot, at 10 sample points, plant species were ranked by in order of most common species. The result provided an average of the pasture composition in terms of the most commonly occurring species, so a plant species may be present but will not show up in botonal if it is not among the most common in any one sample. For example, in Plot 3 (2017) where no pasture was sown, Margurita and a yellow (most likely Avilla) Serradella were present, though it does not show up on the graphs

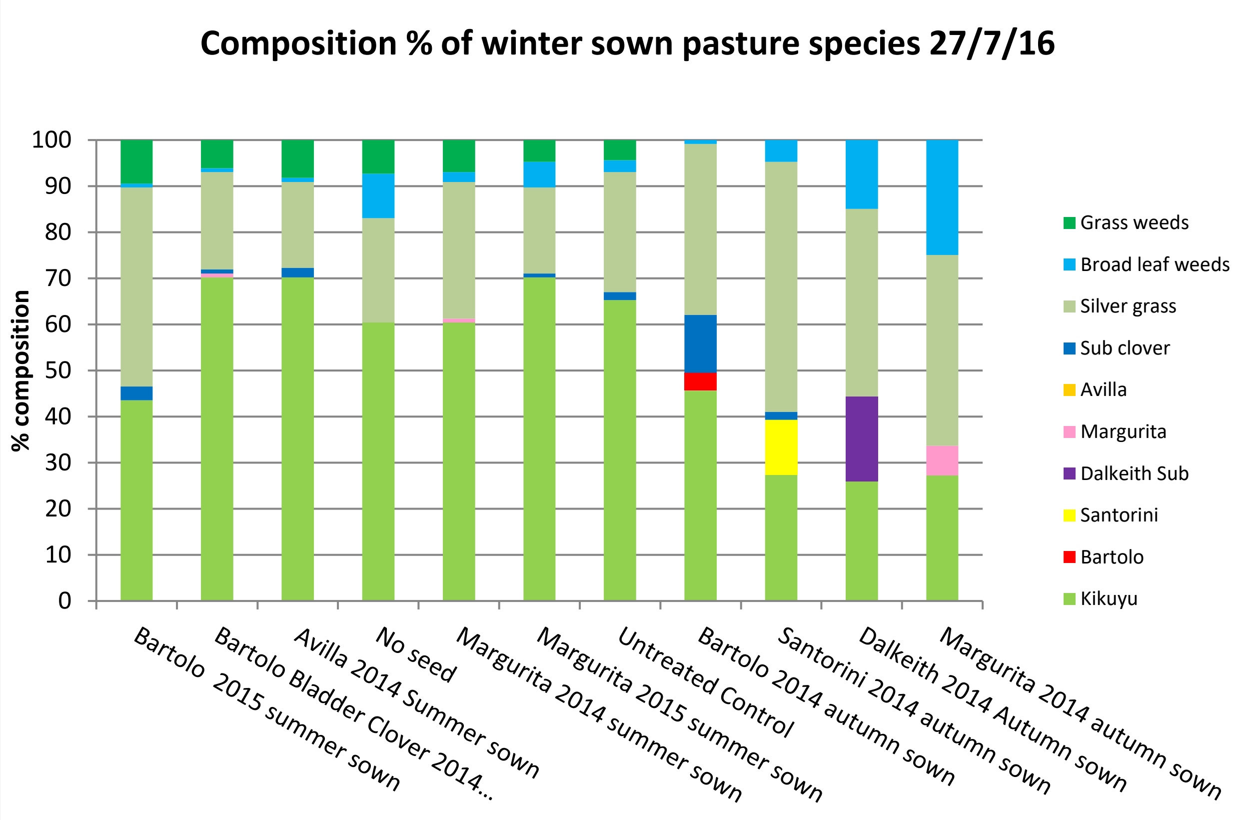
The first observation in 2015 found an absence of the more hardseeded legumes as expected. Silvergrass, brome grass and hares tail grass however, were increasing in the plots. Sub-clover has also become a major portion of the sward, although this was an unknown variety not the sown Dalkeith. Sub-clover has done well in Serradella plots and as a general observation there is more legume content in those plots. In these plots, both clover and Serradella were nodulating well.

Table 1: Sward composition of winter sown pasture species, August 2015



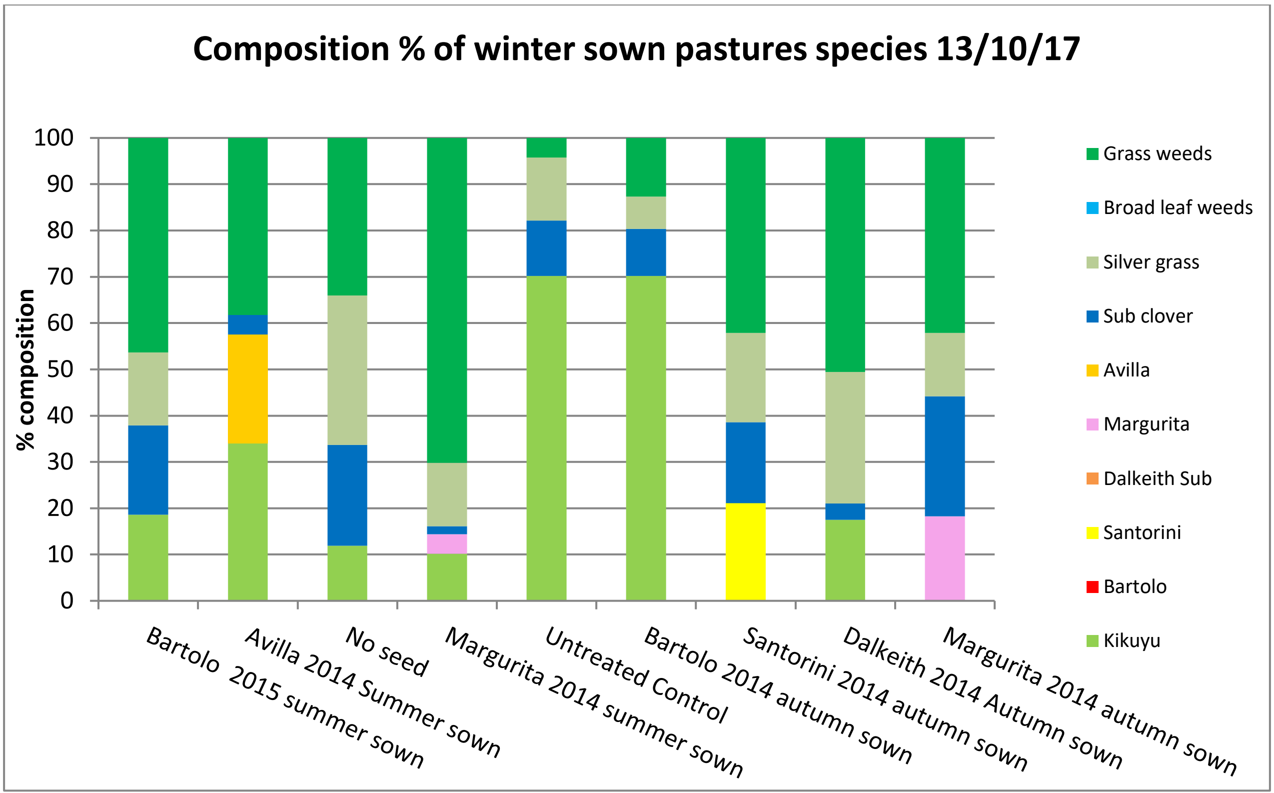
There was a severe false break in 2016, followed by an extended dry period from late April through to June. This was a challenge to legume establishment as demonstrated by the botonal analysis. Kikuyu was very much still actively growing and at the time of this count in July the soil temperature was above 14°C which is abnormally warm.

Table 2: Sward composition of winter sown pasture species, July 2016



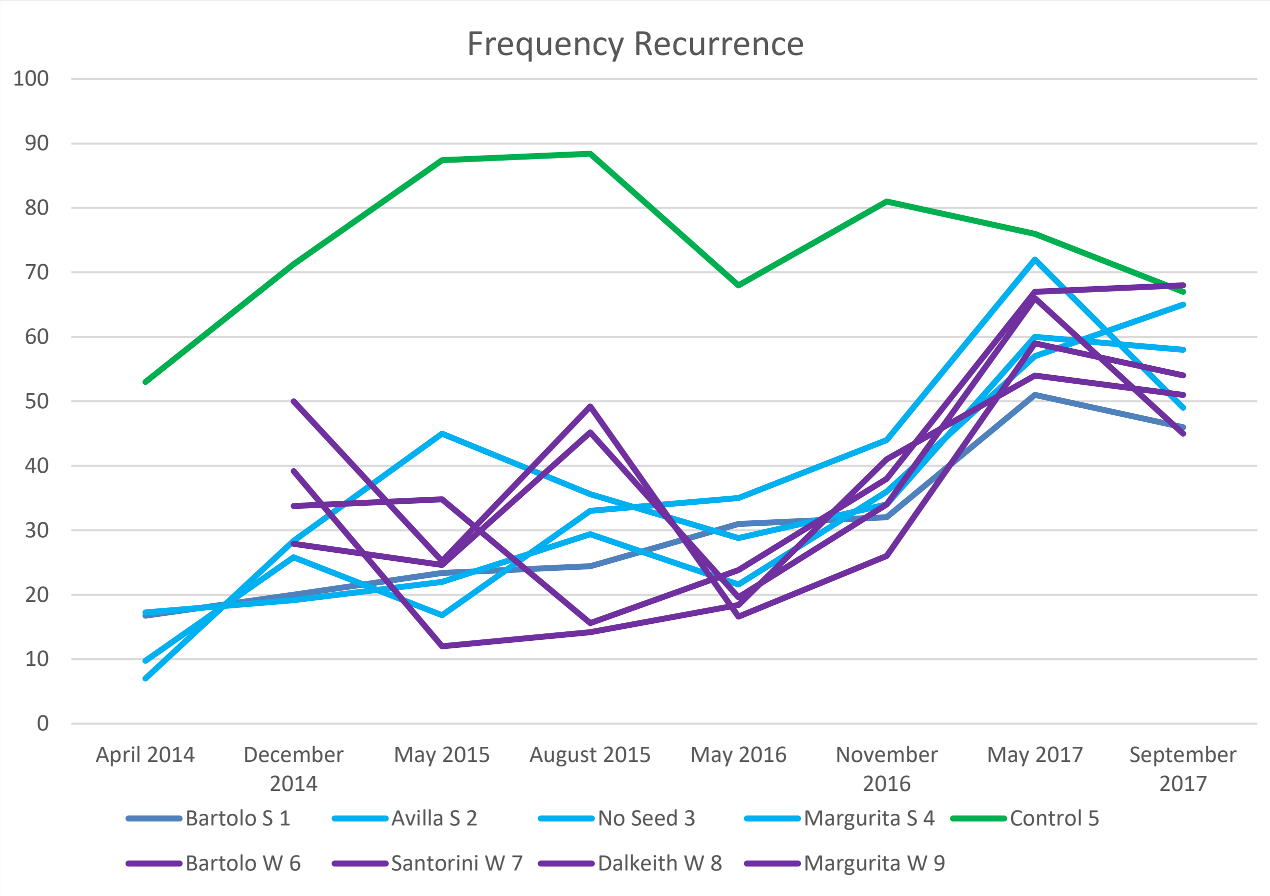
The 2017 botonal was interesting because the serradella plots showed more sub-clover and a higher total proportion of legume than other treatments. The Control and neighboring autumn sown Bartolo plot are almost identical in composition. Bearing in mind this was not a scientifically rigorous (replicated) trial, it appears that in the absence of a suitable annual, the primary pasture species will revert back to the site's original composition. Plot 3 (where sprayed out in summer 2014 but not sown with a legume species) serradella is scattered throughout, and sub-clover has persisted well. The most valuable information which we can gather from these graphs is that active management of the pasture will provide a better outcome than the untreated control.

Table 3: Sward composition of winter sown pasture species, October 2017



4.4 Frequency recurrence

Table 4: Frequency recurrence showing kikuyu groundcover in each plot over time



Frequency recurrence measurements were carried out to measure the groundcover percentage of kikuyu in each plot. Because kikuyu it is a stoloniferous grass with multiple growth points sprouting from runners, standard plant counts are not applicable. On a 1m x 1m pasture square, a grid is created with 10cm x 10cm squares. Counts are then done of how often kikuyu is present on the intersections of the gridlines representing a percentage of total groundcover.

In December 2014, eight months after chemical application and when the kikuyu was actively growing again, the summer sown plots showed a lower kikuyu cover, ranging from 28% to 19%. The autumn sown plots had a chemical application two weeks before seeding and has a higher kikuyu cover ranging from 27.9% to 50% kikuyu cover.

This finding indicates that spraying kikuyu when it is actively growing (and soil temperatures higher) is more effective than spraying in the cooler months. If maintaining overall ground cover is the priority, then a later spray is more suited. Ron Master, DPIRD, has demonstrated that a winter application of Clethodim (grass selective herbicide) can be beneficial to establishment and growth of winter annual legumes.

By the end of the project, the sprayed out treatment plots had recovered kikuyu ground cover to just below that of the Control plot. This shows that kikuyu will recover from a knockdown spray. It was observed that the kikuyu in the treatment plots grew taller and was slightly darker green than the control plot.

4.5 Soil and plant tests

Deep soil cores were collected on commencement of the trial and at again at the end in October 2017. The testing and data interpretation was done by Andrew Heinrich, agronomist, Farm and General in Esperance, and samples were analysed by CSBP Soil Laboratory, Perth

These tests were to examine and measure any changes to the soil profile which may have occurred during the trial. The main differences expected was an improvement in organic carbon in the soil horizon (significant as an indicator of biomass growth and decay), thus providing improvement in the sandy soil's ability to retain moisture and nutrients.

In addition, the tests sought to identify any improvement in nitrogen levels arising from the trial plots/methods. However this evidence was not forthcoming in the soil test results, most likely because the samples were taken in different seasons at different stages of the nitrogen cycle.

The final soil test carried out in 2017 found very little available nitrogen. Most of the nitrogen was tied up in plant matter and root nodules. When the organic matter breaks down in late spring/early summer, nutrients will be released and most likely immediately utilised by actively growing kikuyu.

Observations by the agronomist, Andrew Heinrich who conducted the soil testing confirmed that root matter (presumably kikuyu) was found active at depths of 70cm in the 2017 cores. This is a fantastic demonstration of the ability kikuyu has to send roots deep into the soil to seek out moisture and nutrients which are unavailable to other plants.

One of the key characteristics of established kikuyu stands in the region is the distinct carbon band in the top 10cm of the soil profile. This creates a situation where other plants will only grow in this band and observations have confirmed that taproots in this horizon will grow sideways instead of straight down. This growth habit was observed at the 2015 ASHEEP Spring Field Day, where visiting pasture scientists were surprised and compared that level of root deformity to sulfonurea damage in terms of restricting the plants.

The top 10cm is relatively hospitable place for roots to grow, however immediately below this horizon is a sub soil of pure white sand. While this project did not pinpoint the exact reason why roots do not penetrate this subsoil, local farmers suspect this is a combination of compaction zones and high soil acidity (perhaps aluminium toxicity), compounded by a general lack of soil moisture and nutrients.

During the growing season when the soil is continually wet there is no problem with the annuals living in this zone. However, in spring when the warmer temperatures arrive (and the all-important seed set) the topsoil dries out quickly leaving the plants and new seedlings vulnerable to moisture stress.

A major observation after spraying kikuyu is that when the roots begin to decay and free up the topsoil, the carbon 'topsoil' layer become more gradational and as shown in the pictures of 2017 cores where the darker soil fades out between 15 to 20cm. This potentially doubles the effective root zone and may be a factor in the more productive pasture seen at the site now.

The farmer has also begun applying molybdenum to the paddock, as soil test levels were quite low. Subterranean clover is known to suffer from molybdenum deficiency. This could also be a contributing factor to the success of the legume component in the sward.

Soil tests were collected on 10th February 2015 and submitted to CSBP soil laboratory for analysis. Six samples were collected, three in the untreated control (UTC) plot and three in neighbouring autumn plot at the top, middle and bottom of the slope. This sampling method serves three purposes, firstly, the soil sites are GPS logged and will be sampled in the same place next year to test whether the site has changed over time. Secondly, by sampling the control and autumn sown treatment plots close to each other, we hope to demonstrate any differences which may arise in soil changes by applying the legume 'treatment'. By sampling in the top of the hill, middle of slope (next to grazing cages and other set point sampling) and base of hill, we hope to eliminate any site discrepancies and repeat any findings in soil change between control and treatment plot across the three soil 'zones'. There were no samples taken from the summer sown plot because of a failure to establish and as such is not a reliable representation of the trial conditions.

Results arrived back 23-2-15 and are attached to this document. The most noticeable difference which springs out is all samples in the Control plot have less organic carbon and nitrogen than corresponding autumn sown samples. Most forms of soil N are stored in organic material so these two measurements often go hand in hand. This can be explained by the breakdown of old kikuyu thatch teamed with greater biomass production on the autumn sown plots.

The breakdown of organic material will cause an initial tie-up, and then release of nitrogen into the soil. The autumn sown plot should have more organic carbon present in the soil because of the increased biomass produced in 2014. Much higher legume production occurred in the autumn sown plots throughout 2014 which should cause higher residual nitrogen once the plant breaks down, given the roots were nodulating which should have been the case since ALOSCA was included at seeding.

Feed quality test conducted in June 2016 comparing the kikuyu in the control plot with the sprayed out plot next to it in an attempt to quantify why sheep were preferentially grazing the sprayed out plots and avoiding the control plot. Unfortunately, there was very little difference between the two samples. When collecting the samples, the sprayed plot had longer leaves which were easier to grab and pull. They felt softer and not as 'prickly' to the touch. Not a legitimate measure of palatability but perhaps this is why the sheep grazed the way they did. There were some nutritional issues pointed out by John Milton including Calcium (deficiency) Sulfur (deficiency) and Molybdenum (high) as a result of fertiliser application by the farmer to encourage clover growth

5 Discussion

Objective 1: Comparison of summer sowing to conventional autumn sowing as an establishment method when sowing legumes into kikuyu

Unfortunately, in any of the methods used to try to capture differences between time of sowing, we did not find significant benefit in sowing at either time. Summer sowing is a technique which is very successful in establishing hardseeded legumes in other areas. It may not have worked in this trial because the sowing date was too late due to seed availability. In DPIRD trials on the Esperance sandplain examining summer sowing, similar results were encountered. It seems that the herbicide application necessary for pre-seeding a legume had more impact than the timing of the seeding itself.

Objective 2: Assessed the feed production of kikuyu to determine the benefits over time of incorporation of legumes to increase the paddock stocking rate

The botanical composition showed an increase in legume content over the three year trial. The nutritional values alone would suggest that the total pasture quality would increase with a growing proportion of legumes in the sward. There is also the effect of nitrogen being bought into the soil through biological nitrogen fixation from active rhizobia on the legume roots. All legumes in this trial were examined and found to be nodulating in every year. Unfortunately, nitrogen is very mobile within the soil and within plants so a soil test will not necessarily show accurately the amount of N in the system. Kikuyu is also a very efficient plant at sourcing N and will use it as soon as it becomes available.

	Crude Protein (% dry matter)	Metabolisable energy (MJ/kg of dry matter
Kikuyu	15.5	8.2
Serradella	19-25	10-12
Sub-clover	17	11

At the end of the trial period, there were no bare patches caused by sheep overgrazing. There was an even distribution of legumes throughout the whole paddock. Despite being heavily grazed, the pasture recovered well from grazing and easily held the usual stocking rate. It was able to be grazed for slightly longer periods of time indicating a higher stocking capacity with the increased legume content.

The farmer anecdotally observed that lambs finished on the improved (serradella) pasture seemed to fatten at a faster rate than previous years. However because of the rotational grazing system, it is very difficult to attribute this to any one factor.

Objective 3: Demonstrated management techniques to maintain the legume seed bank for continued legume regeneration.

The germination counts conducted over three years show that there is an increased number of serradella and sub-clover plants at the end of the project. The serradella has also spread across the paddock and is now being introduced to other paddocks on the farm as part of an ongoing pasture improvement program. There is no doubt that the introduction of a legume improves the quality of kikuyu feed. Interestingly by resting the trial paddock over seed set in the initial year to allow sown legumes to set seed, the original sub-clover (of which there were very few plants) set seed as well and is now a dominant legume across the site

Inferences and insights from the data

- Renovating an old kikuyu stand can improve overall productivity.
- Adding a legume into the pasture system has several benefits
- When establishing hardseeded legumes the second year after sowing will have reduced germination. Use this as an opportunity to manage differently. For example sow a fodder or grain crop and use herbicides to control weeds.

Practical implications for industry

- Kikuyu is a widespread pasture species across the coastal sandplain in Esperance and in many higher rainfall areas. It is estimated to cover 150,000ha across Western Australia.

Unanswered questions

- Some scenarios which were raised but not examined include
    - Soil fertility- the response of kikuyu to NxSxGibberellic acid trial and get measurements before rain. Aim to increase grass production in late autumn and early winter
    - Finding a cost effective control method for simazine tolerant silvergrass in a clover and serradella pasture
    - Clover response to molybdenum.
    - Timing of the initial kikuyu knockdown and glyphosate vs clethodim vs gramoxone.
    - Non-chemical methods of renovating kikuyu such as heavy grazing, burning or mechanical methods.
    - Is there some form of symbiosis between serradella and sub-clover?
    - What other legumes would persist well? Some examples of varieties to try are vetch, arrowleaf, crimson and gland clover all of which have persisted unexpectedly at this and other sites in the area.

Draft extension messages

- Old kikuyu stands can be resurrected and used in high pressure grazing scenarios.
- It is important to be aware of the seed bank (of legumes and weeds) and ensure good seed set.
- Serradella thrives in the Esperance coastal sandplain.
- Plan ahead for summer sowing.

What could have been improved

- Sow a wider variety of pastures.
- Sow the summer sown plots earlier- this was suggested by Angelo Loi as a reason why our attempt at summer sowing did not show huge advantage over autumn

sown. In reality we were limited by availability of seed before March- something to bear in mind for anyone who is planning to do summer sowing.

- Dry matter cuts were not continued because the sheep camped around and moved the cages by digging around them and scratching on them. Moving the cages was each cut was giving a false representation of the pasture quantity. We needed to either stop using DM cuts as a measure, or increase the cuts being taken by 10 fold to get a significant sample size which was not practical on a demonstration this size due to a lack of site uniformity.
- More accurate measurements to quantify observations. For example: Fit GPS trackers to sheep or install motion sensing trail cameras when grazing the paddock to show where grazing is occurring, and whether the renovated kikuyu is being grazed more often than control plot. Also sink telemetric moisture meters side by side in sprayed vs unsprayed kikuyu to demonstrate the effectiveness of kikuyu at utilising soil moisture reserves at depth, and how much rainfall is required to germinate and sustain legume seedlings with and without kikuyu competition.
- Conduct weed control (silvergrass) demonstration across the trial. Looking at timing of application, suitable chemicals and effect on legume content and total biomass. DPIRD research has shown there are limited options which can be economically utilized to reduce silvergrass without compromising legumes.
- Include pre and post event surveys to gauge audience responses at field days

6 Conclusions/recommendations

6.1 Composition:

1. A diverse, productive sward that needs little assistance to thrive is still the holy grail

On commencement to this project, the farmer described that one benefit he would like to see from this trial is finding the right pasture mix for his system. That is, a pasture that will remain productive in the long-term with little effort from the farmer to 'look after' it beyond normal management. The most significant step we made towards this goal was the introduction of several varieties of Serradella which have flourished and seem to have lifted the overall productivity of the stand. We see the potential for more experimentation to achieve this goal.

2. Kikuyu will recover from glyphosate spray and seems to be better off for it.

The nature of kikuyu is that it has the ability to recover quickly using available moisture and nutrients. Its competitive habit can be its downfall and the occasional thinning out reinvigorates the stand.

3. Less kikuyu leads to more annuals good (legumes) or bad (silvergrass) which is why seed bank is an important focus point

With the removal of kikuyu (after spraying) comes bare ground from which germinates whatever viable seeds are in the annual seedbank whether it be every weed in the district or a productive pasture legume. The management of the seed bank is a vital tool in determining the pasture composition for subsequent years, and particularly important with very hardseeded legumes which will form the basis of the seedbank for years to come.

4. Serradella is a good fit for the Esperance climate and white coastal sand soil type.

It has been long known that Serradella fits in this climate zone and is testament to many years of cultivar selection that there is a range to choose from today. Each variety has it's niche and with a blend of the varieties, a very productive stand can be achieved quite easily.

5. Subclover still dominates in a good year but has issues. For example red clover syndrome, aphid borne virus, selective grazing, false breaks. One or all these events can happen in a year and impact population.

It was unexpected how well the original subclover performed in this paddock given that it had not been found for several years. All it needed was a chance to set seed and it replenish the seed bank and has performed better than serradellas across the paddock. Unfortunately the initial germination does not all survive through to seed set. Seedling death does occur often from false breaks and summer rain. Through autumn the ground can be covered in clover seedlings and a month later be completely bare if there is no follow-up rain. There is no doubt this affects the seed bank. This occurs quite regularly in Esperance. Some years there is follow up rain and the subclover forms the basis for a productive winter pasture.

Sheep love to graze clover because it is sweet and easy to eat. Seed production is impacted by heavy or consistent grazing without giving it the chance to recover.

Red Leaf clover syndrome, as it has come to be known, is a phenomenon where entire stands across the paddock, farm or district can turn red and die off completely in a matter of 2-6 weeks. There have been many researchers who have shown interest in this, but as yet no one answer has been found. ASHEEP will continue to pursue avenues of investigation into what this is and how we can best manage it.

6.2 Production:

1. More legumes leads to more soil available nitrogen which drives kikuyu growth
   Kikuyu is very efficient at finding and using nitrogen due to its extensive root system and ability to store (starch in rhizomes) and redirect energy towards the type of growth required (root, runner or leaf growth) depending on what the plant needs. Nodulating legumes create soil nitrogen from thin air. Therein lies a valuable symbiosis.

2. New kikuyu growth after spraying highly favoured by sheep for grazing
   Once a thatched kikuyu stand is broken, the plant seeks to actively recolonize ground again by rapid growth of runners and leaves. The breaking down or composting of dying organic matter creates a soil environment suitable for plant growth and both kikuyu and annual plants (good and bad) grow much better. New growth on sprayed vs unsprayed showed little difference in terms of nutritional composition BUT more importantly was longer and easier to pull up (graze) making it more suitable for a pasture.

3. Feedback from farmers attending ASHEEP Spring Field Days was that there was a big change in the pasture from the establishment year to 3 years later.

6.3 Management:

1. The most important element is managing the seed bank.
   So this means getting good seed set in the legumes and reducing seed set of weeds. Allowing the background subclover to set seed may have been just as beneficial as introducing the new species.

2. Fertility is very important for a healthy pasture. Kikuyu responds very well to N. Legumes manganese
   Esperance sandplain soils by nature tend to low OC, low buffering capacity, slightly acidic, non-wetting, low P and K and leach out N and S readily. So it stands to reason that regular fertiliser application with robust rates will improve pasture growth, allowing steps to be taken to increase stocking rate and overall farm productivity and profitability. The initial soil tests revealed a manganese deficiency, which clover requires higher levels of. The farmer then applied a CZmang to the super application. This may have contributed to the regeneration of the subclover in the sward.

3. A kikuyu pasture benefits from renovation and presence of one or more appropriate legumes.
   Kikuyu originates from the grasslands of Africa where the plants which utilise available moisture and withstand hard grazing will prevail. We are familiar with scenes from a David Attenborough documentary of herds of thousands of antelope and the like cover lush grasslands and graze it so hard that at the end there is very little green material left. This is kikuyu's home and in a set-stocked low fertility environment, we have failed to replicate it's natural system of expiry and renewal. Improving the soil through use of fertilisers and nodulating legumes, and grazing in a crash and recovery manner better match the environment that kikuyu has evolved to suit.

4. Effective kikuyu suppression occurs when the plant is actively growing.
   Plants translocate herbicide better when they are actively growing due to the flow of fluids around the plant. Kikuyu is not different and can be very difficult to target when it is not actively growing. This means there must be fresh growth so avoid spraying (or increase the rate and adjuvant) if the soil is dry or if the soil temp is below 14°C as this is when the plant goes into survival mode. adequate moisture

5. Most importantly choose cultivars and species which suit the environment and farming style.
   This project reinforced existing knowledge that Serradella suits kikuyu pastures on the Esperance sandplain. What we learned was there were other varieties that persisted by accident- arrowleaf clover, crimson clover and performed better than expected- will grow successfully in this specific environment. There is scope to explore more in this topic.

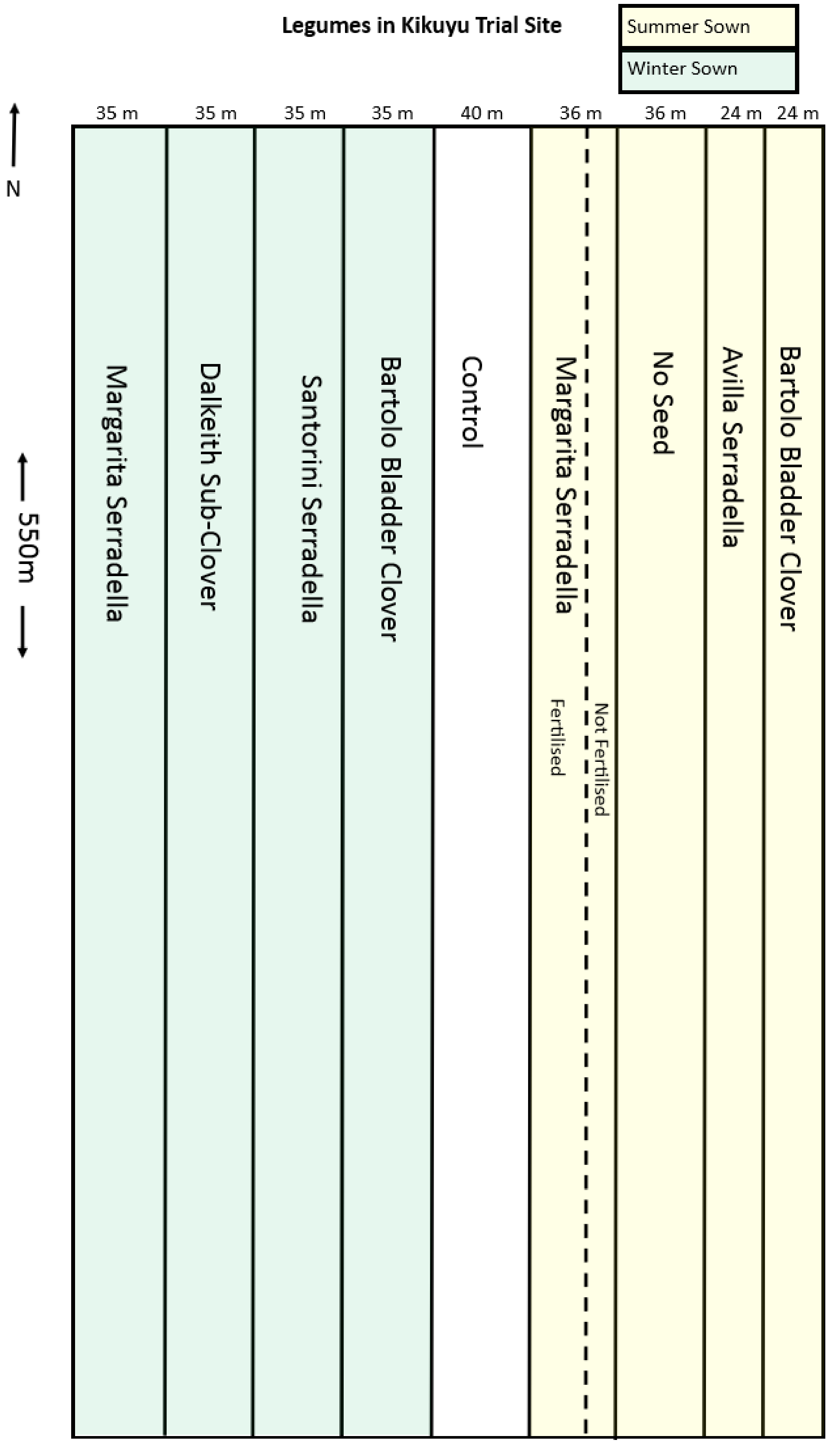
   Farming style must match the cultivars which are chosen and some people just prefer some to others. For example a soft seeded clover and ryegrass mix will perform exceptionally well in this rainfall but requires high inputs and will not persist. Whereas the kikuyu Serradella subclover mix may suit a self-regenerating lower 'maintenance' system. This is up to the individual to choose, and having the correct information freely available.

7 Bibliography

Sanford, P, Master, R & Dobbe, E 2018, Improving subtropical pastures on the south coast oftrazxcgtrew234dfnjhbvc3224458bvcxzaq3weetyuioop[]fc Western Australia, Bulletin 4892,Department of Primary Industries and Regional Development, western Australia, Perth.

8 Appendices

8.1 Appendix 1: Trial map



8.2 Appendix 2- Fertiliser trial

Treatments

Standard application rate of 20kg/ha of sulphur used. Treatments include the following,

Gypsum @ 170kg/ha (S 29kg/ha)

Ammonium sulphate @ 120kg/ha (S 29 + N 25kg/ha)

Urea @ 54kg/ha (N 25kg/ha)

Projib @ 20gm/ha + Urea @ 54kg/ha

Projib @ 20gm/ha

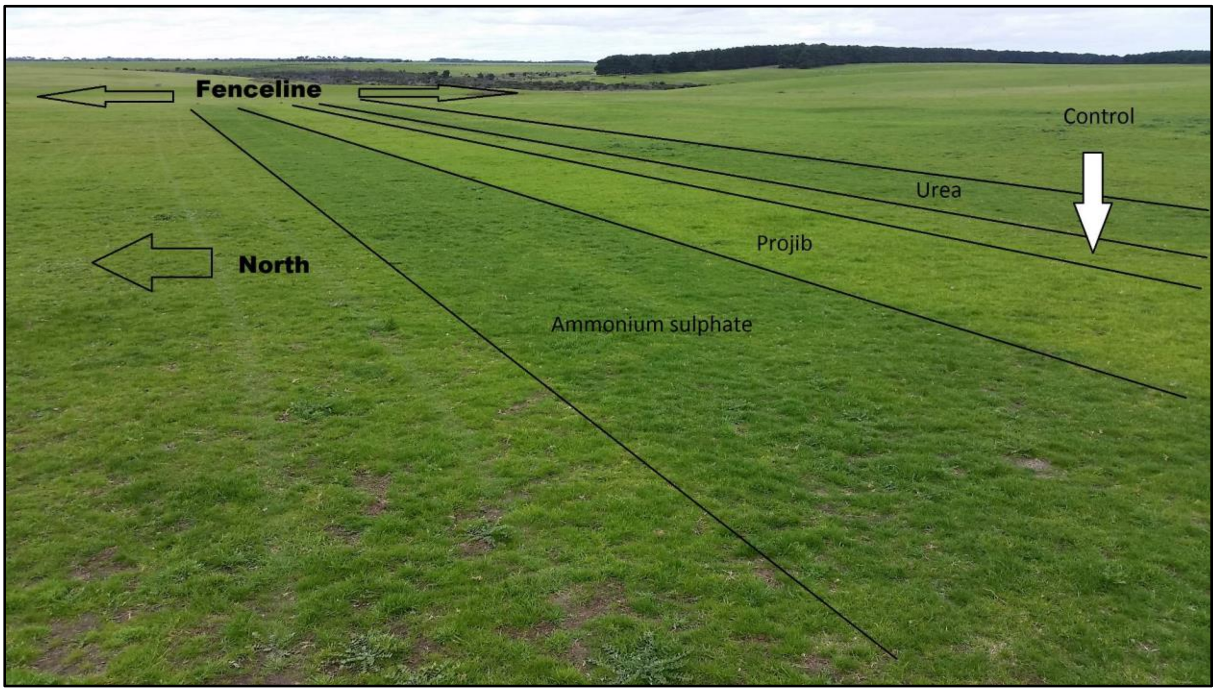
Control

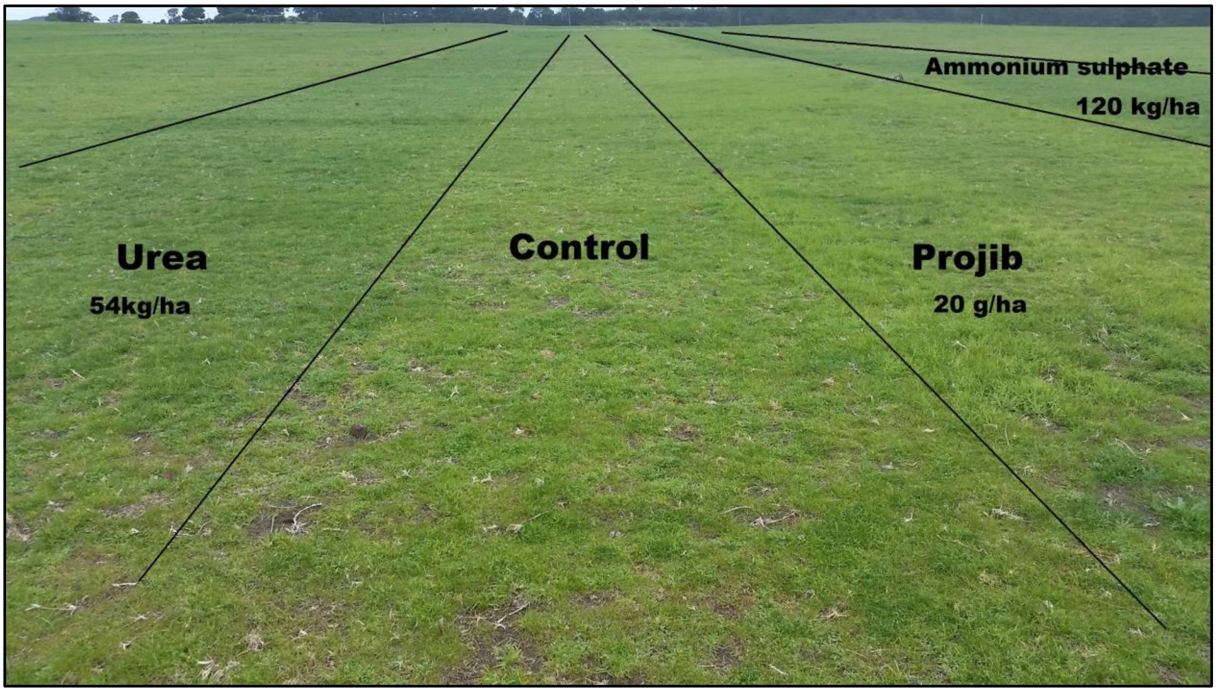
2 replicates of each strip in a randomised pattern.

Basal application rates across all plots except the control will be

Double phos @ 68kg/ha (Not superphosphate or SR super)

Potash @ 100kg/ha


Fenceline
Control
Urea
Projib
North
Ammonium sulphate


Ammonium sulphate
120 kg/ha
Urea
54kg/ha
Control
Projib
20 g/ha

8.3 Appendix 3- Feed quality tests

Feed quality test conducted in June 2016 comparing the kikuyu in the control plot with the sprayed out plot next to it in an attempt to quantify why sheep were preferentially grazing the sprayed out plots and avoiding the control plot. Unfortunately, there was very little difference between the two samples. When collecting the samples, the sprayed plot had longer leaves which were easier to grab and pull. They felt softer and not as 'prickly' to the touch. Not a legitimate measure of palatability but perhaps this is why the sheep grazed the way they did. There were some nutritional issues pointed out by John Milton including calcium (deficiency) Sulfur (deficiency) and Molybdenum (high) as a result of fertiliser application by the farmer to encourage clover growth.

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12 June, 2016

Dear Emma and Anita,

Herewith is the comprehensive Wet Chemistry analysis report for the 2 x Kikuyu pasture samples. My apology for the delay with this report since we last spoke - I've been a tad busy since then. All results, except Dry Matter (DM), are expressed on a Dry Matter basis.

Attribute	Control	Winter sown
Dry Matter (DM, % as received)	28.3	29.7
Crude Protein (CP, %)	15.5	15.7
Acid Detergent Fibre (ADF, %)	26.8	27.0
Neutral Detergent Fibre (NDF, %)	59.8	60.9
Non-structural Carbohydrates (NSC, %)	10.2	9.4
Ash (ASH, %)	11.4	11.2
Ether Extract (FAT, %)	3.1	2.8
Digestible Dry Matter (DDM, %)	57.3	55.9
Metabolisable Energy (ME, MJ/Kg)	8.2	8.0
Phosphorus (P, g/Kg)	4.8	3.8
Potassium (K, g/Kg)	39.8	40.2
Sulphur (S, g/Kg)	2.0	2.0
Sodium (Na, g/Kg)	1.1	0.8
Calcium (Ca, g/Kg)	3.3	3.4
Magnesium (Mg, g/Kg)	2.7	2.6
Chloride (Cl, g/Kg)	18.4	17.2
Copper (Cu, mg/Kg)	7	6
Zinc (Zn, mg/Kg)	19	16
Manganese (Mn, mg/Kg)	22	20
Iron (Fe, mg/Kg)	139	141
Cobalt (Co, mg/Kg)	0.17	0.16
Molybdenum (Mo, mg/Kg)	2.87	2.32
Selenium (Se, mg/Kg)	0.061	0.049
Boron (B, mg/Kg)	18	16

CP = Crude Protein - The amount of true protein and non-protein-nitrogen in a feed that ultimately provides the building blocks of the body, the amino acids. CP is calculated as Nitrogen content x 6.25.

ADF = Acid Detergent Fibre - The residue that remains after extraction of feed material with an acid detergent solution. ADF gives an indication of the fibre material that may be indigestible to ruminants.

2.

NDF = Neutral Detergent Fibre - The residue remaining after extraction of feeds with a neutral detergent solution - mostly cell walls that provide "Rumen-fill", especially when stock consume roughage diets.

NSC = Non-structural Carbohydrates - The readily fermentable carbohydrate in plants that is determined as: 100 - (NDF + CP + Fat + Ash). The NSC consists of water soluble carbohydrates and starch.

ASH = The inorganic residue after total combustion of the organic constituents in a feed. Ash contains the minerals, which do not contribute energy. 100 – Ash (% in DM) = Organic Matter (OM, % in DM).

FAT = The residue remaining after evaporation of the solvent used in a continuous process to extract the lipids and pigments from a known weight of a feedstuff. Fat is the highest energy yielding nutrient.

DDM = Digestible Dry Matter - The difference between the DM consumed and the DM excreted in the faeces, expressed as a percentage of the DM consumed. DDM is estimated using a laboratory procedure calibrated against DDM values for feedstuffs measured with live animals, usually sheep.

ME = Metabolisable Energy - The energy in the feed available to the animal to maintain body activity and growth etc. ME is expressed as Mega Joules (MJ) per kg DM and was calculated from DDM using the Australian Fodder Industry Association Ltd derived equation of: ME = 0.172 x DDM% - 1.615.

The DM for both samples is of the order to be expected and while the CP values are very respectable, some of the CP may be as non-protein-nitrogen not yet assimilated into True protein. The ADF values are modest, but the NDF values are quite high and along with the quite high Ash and low NSC values will have all contributed to hold-down DDM and ME to these quite modest values. These levels of CP should be able to support growth of stock, but the utilization of the CP will be limited by the quite modest ME values, which are only at levels sufficient to maintain stock. This can often be the case with C4 grasses like Kikuyu. The levels of Fat are around that to be expected for this type of forage material.

The levels of Phosphorus and Potassium in both samples are quite high and well above the requirements of sheep and cattle. The level of Magnesium is Ok, but Calcium is quite low making the Ca:P ratio undesirably low at less than 1:1, especially for the Control sample. Furthermore, it is possible that plant available Calcium may be limiting plant growth. The level of Sulphur is Ok, but could be higher for optimum utilization of the CP, especially by young, wool sheep. Sodium is at or below the minimum requirement for sheep and cattle and may further impact on animal performance if the high level of Potassium was to affect Magnesium absorption, despite that Magnesium is Ok. The Chloride in these samples is fairly high and inconsistent with the low levels of Sodium. The levels of Copper, Zinc and Manganese in these samples should meet the minimum requirements for most sheep and cattle, but may be marginal for optimum growth of young stock. The levels of Cobalt may support minimal growth of stock, but the Selenium levels are very low and some form of supplemental Selenium would be needed for stock grazing these Kikuyu pastures. With Molybdenum in both samples above 2.0 mg/kg DM, if the levels of Sulphur and Iron were higher this may adversely affect Copper absorption and metabolism. Nitrate at under 40 mg/kg DM in both samples should not be a problem for stock grazing these pastures.

Kind regards and best wishes,

J.B. Milton.

Dr John T.B. Milton Director of ILS
Order of the Crown of Thailand, BAgrSci(Hons), PhD.

Please Note: Due care and attention is taken in providing these professional comments, but no responsibility is accepted for any inappropriate action taken in response to these comments.

8.4 Appendix 4: Soil test

Deep cores taken in 2014 at commencement of trial

Soil & Plant Analysis Laboratory

Farm & General EOPP **ANALYSIS REPORT** Generated: 11/04/2014 3:07:22 PM

Lab No		XQS14091	XQS14092	XQS14093	XQS14094	XQS14095	XQS14096	XQS14103	XQS14104
Name Code		NORTH 20-30	NORTH 30-40	NORTH 40-50	NORTH 50-60	NORTH 60-70	MID 20-30	MID 30-40	MID 40-50
Customer		7/4/14	7/4/14	7/4/14	7/4/14	7/4/14	7/4/14	7/4/14	7/4/14
		ASHEEP HOGGART SUBS	ASHEEP HOGGART SUBS	ASHEEP HOGGART SUBS	ASHEEP HOGGARTS SUBS	ASHEEP HOGGARTS SUBS	ASHEEP HOGGARTS SUBS	ASHEEP HOGGARTS SUBS	ASHEEP HOGGARTS SUBS
Depth		20-30	30-40	40-50	50-60	60-70	20-30	30-40	40-50
		7	7	8	14	17	5	6	4
Phosphorus Colwell	mg/Kg	34	23	18	19	24	19	18	< 15
Potassium Colwell	mg/Kg	0.37	0.25	0.24	0.89	0.10	0.28	0.11	0.10
Organic Carbon	%	0.016	0.015	0.011	0.011	0.013	0.011	< 0.010	< 0.010
Conductivity	dS/m	5.3	5.2	5.4	5.4	5.4	4.9	5.0	5.1
pH Level (CaCl2)	pH	6.0	6.2	6.4	6.2	6.2	5.9	5.6	5.6
pH Level (H2O)	pH	0.70	0.71	0.64	0.62	0.59	1.33	0.96	0.84
Aluminium CaCl2	mg/Kg								

CSBP Limited ABN 81 008 668 371

Soil & Plant Analysis Laboratory

ANALYSIS REPORT

Generated: 11/04/2014 3:07:22 PM

Lab No		XQS14105	XQS14106	XQS14107	XQS14108	XQS14109	XQS14110	XQS14111
Name								
Code		MID 50-60	MID 60-70	SOUTH 20-30	SOUTH 30-40	SOUTH 40-50	SOUTH 50-60	SOUTH 50-60
Customer		7/4/14	7/4/14	7/4/14	7/4/14	7/4/14	7/4/14	7/4/14
Depth		ASHEEP HOGGARTS SUBS	ASHEEP HOGGARTS SUBS	ASHEEP HOGGARTS SUBS	ASHEEP HOGGARTS SUBS	ASHEEP HOGGARTS SUBS	ASHEEP HOGGARTS SUBS	ASHEEP HOGGARTS SUBS
		50-60	60-70	20-30	30-40	40-50	50-60	50-60
Phosphorus Colwell	mg/Kg	5	5	8	11	15	27	9
Potassium Colwell	mg/Kg	< 15	< 15	19	18	25	34	33
Organic Carbon	%	0.11	0.05	0.19	0.25	0.14	0.15	0.13
Conductivity	dS/m	0.010	< 0.010	0.011	0.010	0.011	0.015	0.015
pH Level (CaCl2)	pH	4.9	5.4	5.1	4.9	4.7	4.7	4.8
pH Level (H2O)	pH	5.5	5.9	5.6	5.4	5.3	5.3	5.4
Aluminium CaCl2	mg/Kg	0.82	0.99	1.03	1.61	3.37	3.64	1.80

CSBP Limited ABN 81 008 668 371

Lab No		XQS14091	XQS14092	XQS14093	XQS14094	XQS14095	XQS14096	XQS14103	XQS14104
Name									
Code		NORTH 20-30	NORTH 30-40	NORTH 40-50	NORTH 50-60	NORTH 60-70	MID 20-30	MID 30-40	MID 40-50
Customer		7/4/14	7/4/14	7/4/14	7/4/14	7/4/14	7/4/14	7/4/14	7/4/14
Depth		ASHEEP HOGGA RTS SUBS	ASHEEP HOGGA RTS SUBS	ASHEEP HOGGA RTS SUBS	ASHEEP HOGGA RTS SUBS	ASHEEP HOGGA RTS SUBS	ASHEEP HOGGA RTS SUBS	ASHEEP HOGGA RTS SUBS	ASHEEP HOGGA RTS SUBS
		20-30	30-40	40-50	50-60	60-70	20-30	30-40	40-50
Phosphorus Colwell	mg/Kg	7	7	8	14	17	5	6	4
Potassium Colwell	mg/Kg	34	23	18	19	24	19	18	< 15
Organic Carbon	%	0.37	0.25	0.24	0.89	0.10	0.28	0.11	0.10
Conductivity	dS/m	0.016	0.015	0.011	0.011	0.013	0.011	< 0.010	< 0.010
pH Level (CaCl2)	pH	5.3	5.2	5.4	5.4	5.4	4.9	5.0	5.1
pH Level (H2O)	pH	6.0	6.2	6.4	6.2	6.2	5.9	5.6	5.6
Aluminium CaCl2	mg/Kg	0.70	0.71	0.64	0.62	0.59	1.33	0.96	0.84

Soil test topsoil results 2014

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SUMMIT FERTILIZERS

Client number 9008 Nick Donkin

Date	Paddock Name	Lab number	S/No:	P	K	S	Cu	Zn	Org C	p H Calc	Ec	PBI	Texture	Gravel	Color	Nitrate N	Ammonium	Ex Ca	Ex Mg	Ex Na	Ex K	Al
2/04/2014	TRANSECT A	XDS14049	A	14	84	4	0.27	0.87	1.3	5.2	0.06	8.8	1	5	GRBR	4	3	0	0	0	0	0.7
2/04/2014	TRANSECT A	XDS14156	B	9	41	3	0	0	0	5.5	0.03	0	0	0	*	2	11	0	0	0	0	0.5
2/04/2014	TRANSECT A	XDS14157	C	10	24	2	0	0	0	5.3	0.02	0	0	0	*	3	1	0	0	0	0	1.3
2/04/2014	TRANSECT B	XDS14050	A	20	136	7	0.5	1.49	2.19	5.4	0.1	5.7	1	5	GR	4	17	0	0	0	0	0.9
2/04/2014	TRANSECT B	XDS14158	B	9	41	2	0	0	0	4.4	0.02	0	0	0	*	2	1	0	0	0	0	2.5
2/04/2014	TRANSECT B	XDS14159	C	10	34	2	0	0	0	4.4	0.02	0	0	0	*	2	1	0	0	0	0	2.8

8.5 Appendix 5- soil test results

Deep core soil tests 2017

	Lab No	4SS17007	4SS17008	4SS17009	4SS17010	4SS17011	4SS17012	4SS17013
	Name	Hill Top	Hill Top	Hill Top	Hill Top	Hill Top	Hill Top	Hill Top
	Code	18/10/17	18/10/17	18/10/17	18/10/17	18/10/17	18/10/17	18/10/17
	Customer	ASheep	ASheep	ASheep	ASheep	ASheep	ASheep	ASheep
	Depth	0-10	10-20	20-30	30-40	40-50	50-60	60-70
Colour		GRBR	GR	LTGR	GRBR	BRWH	YWBR	BRYW
Gravel	%	5	0	0	0	0	0	0
Texture		1.5	1.5	1.5	1.5	1.5	1.5	1.5
Ammonium Nitrogen	mg/Kg	1	< 1	< 1	< 1	< 1	< 1	< 1
Nitrate Nitrogen	mg/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Phosphorus Colwell	mg/Kg	8	8	7	9	12	37	35
Potassium Colwell	mg/Kg	52	44	46	28	21	31	31
Sulphur	mg/Kg	3.5	3.9	1.7	1.1	0.8	1.0	1.9
Organic Carbon	%	1.25	0.72	0.26	0.23	0.18	0.19	0.23
Conductivity	dS/m	0.030	0.022	0.014	0.012	0.012	0.015	0.016
pH Level (CaCl2)	pH	6.1	6.2	6.2	6.0	6.1	5.8	5.3
pH Level (H2O)	pH	6.8	6.7	6.8	6.7	6.7	6.3	6.2
Aluminium CaCl2	mg/Kg	0.26	< 0.20	< 0.20	0.25	0.27	0.62	2.55

Fig 7: Cross-section of Hill Top soil test site

Lab No		4SS17014	4SS17015	4SS17016	4SS17017	4SS17018	4SS17019	4SS17020
Name		Mid Slope	Mid Slope	Mid Slope	Mid Slope	Mid Slope	Mid Slope	Mid Slope
Code		18/10/17	18/10/17	18/10/17	18/10/17	18/10/17	18/10/17	18/10/17
Customer		ASheep	ASheep	ASheep	ASheep	ASheep	ASheep	ASheep
Depth		0-10	10-20	20-30	30-40	40-50	50-60	60-70
Colour		DKGR	GR	LTGR	GRWH	BRWH	BRWH	YWBR
Gravel	%	0	0	0	0	0	0	0
Texture		1.5	1.5	1.5	1.5	1.5	1.5	1.5
Ammonium Nitrogen	mg/Kg	2	< 1	< 1	< 1	< 1	< 1	< 1
Nitrate Nitrogen	mg/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Phosphorus Colwell	mg/Kg	11	7	11	7	7	9	16
Potassium Colwell	mg/Kg	79	41	28	< 15	< 15	18	20
Sulphur	mg/Kg	4.9	5.8	2.3	1.2	0.9	0.8	1.7
Organic Carbon	%	1.64	0.85	0.37	0.20	0.17	0.17	0.17
Conductivity	dS/m	0.034	0.024	0.013	0.010	0.010	0.010	0.013
pH Level (CaCl2)	pH	5.8	5.2	5.7	5.9	5.8	5.7	5.5
pH Level (H2O)	pH	6.4	6.3	6.3	6.4	6.4	6.3	6.2
Aluminium CaCl2	mg/Kg	0.51	0.60	0.46	0.56	0.45	0.83	1.17

Figure 8: Cross-section of 'Mid slope' soil test site

Lab No		4SS17021	4SS17022	4SS17023	4SS17024	4SS17025	4SS17026	4SS17027
Name		North Rise	North Rise	North Rise	North Rise	North Rise	North Rise	North Rise
Code		18/10/17	18/10/17	18/10/17	18/10/17	18/10/17	18/10/17	18/10/17
Customer		ASheep	ASheep	ASheep	ASheep	ASheep	ASheep	ASheep
Depth		0-10	10-20	20-30	30-40	40-50	50-60	60-70
Colour		GR	GR	LTGR	GRWH	GRWH	GRWH	YWBR
Gravel	%	0	0	0	0	0	0	0
Texture		1.5	1.5	1.5	1.5	1.5	1.5	1.5
Ammonium Nitrogen	mg/Kg	1	< 1	< 1	< 1	< 1	< 1	< 1
Nitrate Nitrogen	mg/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Phosphorus Colwell	mg/Kg	15	7	5	8	9	7	12
Potassium Colwell	mg/Kg	78	50	27	< 15	< 15	19	40
Sulphur	mg/Kg	6.4	2.7	1.0	1.1	1.3	1.7	2.1
Organic Carbon	%	1.66	0.75	0.34	0.21	0.17	0.17	0.17
Conductivity	dS/m	0.032	0.018	0.010	0.010	0.011	0.014	0.016
pH Level (CaCl2)	pH	5.6	5.5	5.8	5.7	6.0	5.9	6.1
pH Level (H2O)	pH	6.3	6.3	6.4	6.4	6.5	6.5	6.6
Aluminium CaCl2	mg/Kg	0.61	0.57	0.37	0.68	0.33	0.67	0.27

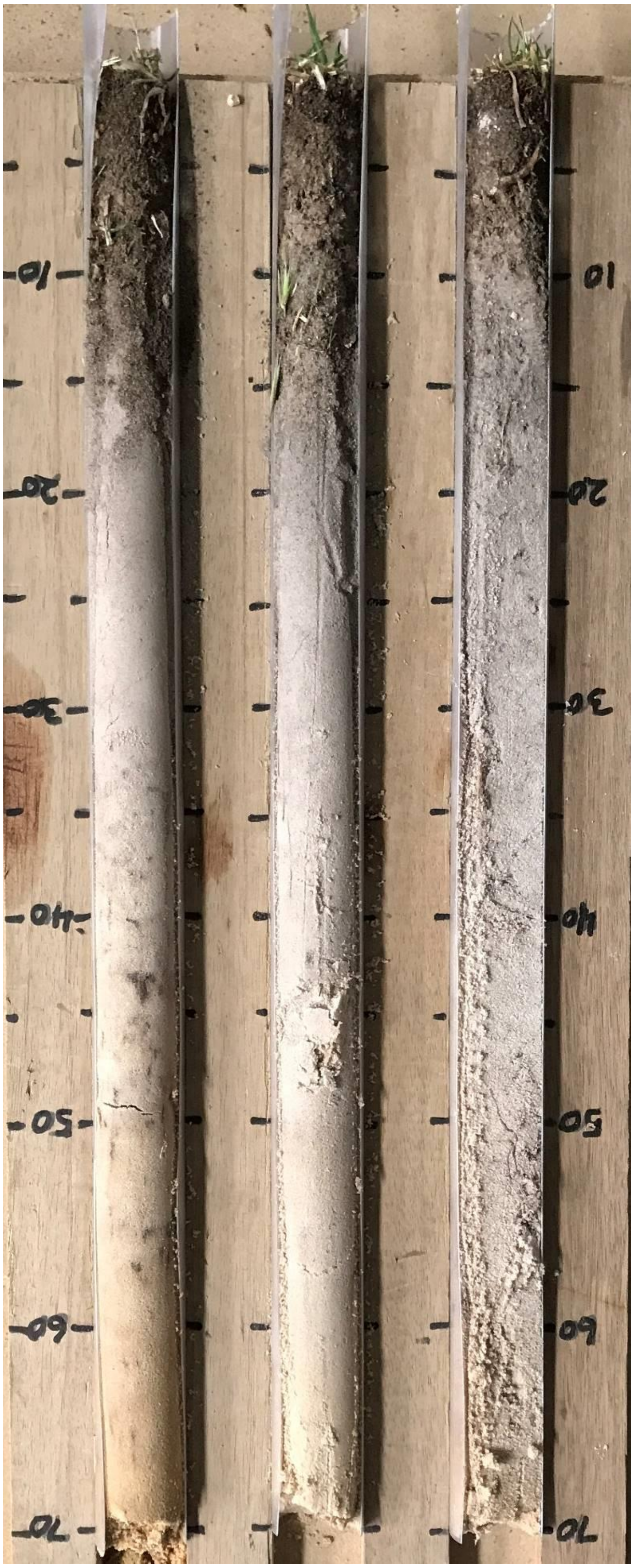

Fig 9: Photo of cross section of 'North rise' soil test site

8.6 Appendix 6- Signage

A sign was put up at the entrance to ‘The Duke’ farm along Duke of Orleans Bay Road which is a popular holiday spot for local famers and tourists. It is estimated 10,000 visitors travel on this road each year.

8.7 Appendix 7- Feedback magazine case study

ON FARM
SHEEP

Serradella success

Alan and Bec Hoggart (pictured above with their children Paisley, 7 and Charlie, 9) have been involved in a three-year legume trial with their local ASHEEP (Association for Sheep Husbandry, Excellence, Evaluation and Production) grower group as part of MLA's Producer Research Site program.

ASHEEP wanted to investigate using serradellas in kikuyu pastures, given sub-clovers have been patchy in the past few years on the south coast of WA due to red clover disease, which causes a reddening of the leaf and plant die-back.

The trial on the Hoggarts' property involved testing two varieties of serradella and sowing at different times of the year.

Preparation for legume sowing:

- summer – kikuyu was heavily grazed and sprayed in early autumn
- autumn – kikuyu was heavily grazed until May and sprayed before sowing.

Legume sowing involved:

- summer – Margurita serradella at 25kg/ha and unscarified Bartolo bladder clover at 20kg/ha in February
- autumn – Santorini and Margurita serradellas at 10kg/ha and Bartolo bladder clover at 10kg/ha in May
- seed placement at a depth of 1cm on 30cm row spacings.

Of the two varieties of serradella, Alan found Santorini performed the best on his property.

"In my experience, Santorini has more tolerance to grazing by sheep and has added value to our lower-grade pastures," he said.

"Santorini gets going a lot quicker without competition, but it will establish in a kikuyu pasture with the right management. Once established, it persists without too much intervention in a rotational grazing operation."

Although other producers on the south coast of WA have had success with summer sowing, Alan leans towards autumn sowing.

"Our property has areas of light, sandy soil prone to erosion, so we don't crop. We needed to improve our lighter-soil pastures with varieties that persist with minimal intervention," he said.

"We had average rainfalls of 540mm over the three years of the trial, and found planting into existing pasture in summer didn't work for us, because the kikuyu takes too much moisture away from the legumes.

"Sowing in autumn gave the seedlings more access to moisture because of increased winter rain and decreased kikuyu activity." ■

LESSONS LEARNED

- Santorini was the best performing serradella.
- Autumn sowing is the most suitable in the enterprise.
- Good management is important for establishment.

Alan Hoggart
E: alan.hoggart@bigpond.com

SNAPSHOT: Alan and Bec Hoggart, Condingup, Western Australia

Property:	Enterprise:	Livestock:	Pasture:	Soil:	Rainfall:
2,500ha	Ewes for prime lamb production	5,600 Dorper/ Wiltshire ewes	Clover, serradella, ryegrass and kikuyu	Predominantly black clay, sand over gravel to deep sand	650mm

8.8 Appendix 8: Fixed point photos

Fig 10: June 2014

Figure 11: July 2015

Figure 12: November 2016 serradella

Figure 13: May 2017