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Sheep production from Tedera

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Abstract

Tedera (*Bituminaria bituminosa* C.H Stirt. vars. *albomarginata*) is a traditional forage species in the Canary Islands, Spain, ideally suited to Mediterranean-like climates to provide high quality green forage for grazing animals. A series of experiments from 2013 to 2016 were conducted at Kojonup and Dandaragan in Western Australia: (a) to evaluate palatability and animal production grazing pure stands of tedera in the four seasons; (b) to evaluate grazing in mixtures with annual species and (c) to evaluate grazing tedera as a sole diet during summer and autumn to fill the feed-gap without the need for hand-feeding. The results of this project allowed us to conclude that: (a) no health issues have been observed in any of the grazing experiments; (b) palatability is not an issue, even though there are differences in palatability among accessions, sheep graze all the accessions and the differences in production were not related to differences in palatability and (c) that tedera can be utilized as a substitute for grain as a maintenance feed for stock, and/or as a production feed during summer/autumn to either finish prime lambs, flush ewes in the lead up to joining or achieve weight gain for twin bearing ewes in late pregnancy to increase twin lamb survival.

Executive Summary

The profitability and sustainability of livestock industries in southern Australia is severely constrained by the quantity and quality of the forage available over summer and autumn. To fill this ‘feed-gap’, an outstanding candidate was identified – tedera (*Bituminaria bituminosa* C.H. Stirt. var. *albomarginata* and var. *crassiuscula*). Tedera is a traditional forage legume from the Canary Islands, Spain utilized to produce goat cheese. While tedera appears to be an ideal option to fill the feed-gap there was no published information where it has been grazed as a green monoculture by sheep. Even though the authors are not aware of any report in the literature or anecdotal evidence/report by researchers or farmers that tedera had caused any health problems in grazing livestock; it was important to conduct a staged series of experiments to investigate possible health issues; to conduct sufficient ‘duty-of-care’ testing to ensure that tedera was suitable for grazing by sheep.

Hence, we have conducted three duty-of-care experiments to explore animal health issues. In the first experiment, young sheep were fed fresh green tedera (leaf and edible stem) as a sole diet for 35 days in an animal house. Sheep grew as was predicted by the *in vivo* digestibility of the fresh tedera and suffered no health issues. In the second experiment, young sheep grazed on a monoculture of tedera in full sunlight for 21 days. On average, they gained 1.6 kg in liveweight and 0.3 of a condition score and experienced no health issues. In the third experiment the effects of tedera on rumen microbial fermentation and degradation of furanocoumarins were explored using the Rumen Simulation Technique (RUSITEC). Tedera was fermented without any negative effects on the rumen microbial populations. Digestibility and fermentability parameters were comparable to lucerne (*Medicago sativa* L.) hay.

Therefore once ‘duty-of-care’ aspects had been addressed, tedera’s potential value for Australian livestock production was modelled using a whole farm bioeconomic linear programming model which represents the biological, physical, technical and managerial relationships of a mixed farm in a specific region. Production of dry matter and it’s crude protein content and *in vitro* dry matter digestibility from regional experiments on the seasonal production of tedera in southwestern Australia provided the parameters for modelling purposes. The modelled increase in farm profit was up to 58% because the model chose to grow and graze tedera to replace the high cost of hand-feeding grain and hay over summer and autumn and run higher stocking rates over the whole farm.

To date experimental grazing of tedera by sheep has only been of relative short duration, therefore a series of experiments from 2013 to 2016 were conducted as part of this project:

- **Grazing pure stands of tedera in winter, spring, summer and autumn at Dandaragan**

The first hypothesis that naïve sheep would show the same relative preference (palatability) for accessions of tedera in the four seasons was rejected. The results for the relative preference among the seven accessions in the four seasons to date strongly suggested that the ranking changed between seasons.

The second hypothesis that the gain in liveweight and condition score of sheep constrained to single accessions at the same grazing pressure would be the same for all accessions and seasons was rejected as the sheep had growth rates significantly different between accessions and seasons. There was little consistency between accessions for relative preference but reasonable consistency for growth rate. Accessions T31 and T48 stand out as moderate to high producers of DM/ha as well as high and consistent growth rate of the sheep grazing them. Importantly, sheep grazing these accessions continued to grow at around 200 g/head/day even in summer when the sheep grazing the other five accessions only maintained liveweight, all be it in good body condition.

The third hypothesis that preference of naïve sheep among tedera accessions fed fresh in pens will rank the same as the preferences of sheep in the field study was rejected as the ranking of preference for the two methods was different. In addition, relative preference/palatability estimated by grazing in common or by feeding freshly cut edible leaf and stem to sheep in pens was not clearly related to performance (growth rate) nor were they related to the key measures of nutritive value (CP, DMD or ME).

The fourth hypothesis that the voluntary feed intake (VFI) of fresh leaf and stem of tedera by sheep will be greater if they have had previous experience of grazing tedera relative to the VFI of naïve sheep was accepted as a regression analysis of the data indicated that the experienced animals ate more.

The fifth hypothesis that the VFI fed in pens of wilted leaf and stem of tedera would be greater than fresh leaf and stem of tedera was rejected as there was no effect of wilting on preference.

- **Grazing tedera in mixtures with annual species at Kojonup**

Based on the results of previous seasonal grazing experiments at Mount Barker Research Station, Dandaragan and the grazing of the spaced plant experiments at Buntine, Newdegate and Mount Barker, we hypothesized that tedera would be less preferred during winter and spring in comparison with annual ryegrass and subclover and that tedera would be mainly grazed during summer and autumn. This hypothesis was rejected for a number of possible reasons: (a) there was a much higher relative palatability of tedera compared to the annual pasture causing the tedera to be grazed to the ground independent of the stocking rates in winter and spring whereas the competing annual pasture was less grazed and therefore better able to regrow before the next grazing; (b) the district experienced a decile 9 growing season resulting in very high competition for light in winter and spring and light and water in late spring and early summer and thereby disadvantaging tedera.

The experiment also highlighted that tedera is adapted to different soils in different ways in the Kojonup environment. It performed best in the deep sandy duplex soils and in the mid to upper slopes. In addition it was clear that;

1. tedera is a palatable species that can be overgrazed in a mix swards if not managed properly.
2. excessive competition can reduce persistence therefore the time of grazing/removing of competition is important.
3. summer and autumn are the most valuable times to graze tedera, therefore management practises have to be put in place to allow conservation of tedera for that time.

- **Production and persistence of tedera through winter and early spring with or without competition of annual pasture based on plot studies**

We hypothesized that tedera production would be significantly reduced by annual species competition. This hypothesis was accepted. The number of tedera plants was not significantly affected by the competition imposed by the annual species. There was an average of 1.5, 2.3 and 1.8 plants/m^2 for the 14 October 2015, 23 February 2016 and 3 May 2016 respectively. However, total biomass produced by the tedera plants without competition was significantly higher than with competition on the 14 October 2015. On average, plants with competition were only 30% of the weight of plants without competition. However, the tedera plants recovered after the annuals senesced and the same biomass per plant was recorded for the 23 February 2016 and 3 May 2016 harvest. Hence, it was clear that the mix of tedera and annual pasture had the best annual production and seasonal distribution of edible biomass.

- **Grazing trial during summer and autumn at Dandaragan 2014/15, Dandaragan 2016 and Kojonup 2016**

We hypothesized that (i) tedera plants would not survive continuous grazing during summer and autumn; (ii) tedera stocked at 10 sheep/ha would at least maintain their weight and condition score without hand-feeding during the whole grazing period and (iii) that rotational grazing (14 days on and 70 days off) would improve the production of the sheep (liveweight and condition score) compared with continuous grazing.

The first hypothesis was rejected, plant density of tedera did not significantly decline due to being continuously grazed or rotationally grazed during summer and autumn at all three experimental sites.

The second hypothesis was accepted. In the three experiments, there was no hand-feeding and with a stocking rate of 10 sheep/ha, during summer and autumn in Mediterranean-like climates, sheep at least maintained liveweight and condition score while grazing a monoculture of tedera.

The third hypothesis was partially rejected. The sheep in the continuously grazed treatment performed as well as the sheep in the rotationally grazed treatment. However, at Dandaragan in 2014-15 the rotational grazing treatment extended the duration of maintenance feeding by 28 days because the plots rotationally grazed produced more DM over the 140 days of grazing when there was no significant rainfall until May 2015.

All the animal production experiments conducted as part of this project allowed us to conclude that:

- No health issues have been observed in any of the grazing experiments.
- Palatability is not an issue, even though there are differences in palatability among accessions, sheep graze all the accessions and the differences in production were not related to differences in palatability.
- Tedera can be utilized as;
    - a substitute for grain as a maintenance feed for stock from mid-summer to late-autumn,
    - a production feed during early-summer to either finish prime lambs, flush ewes in the lead up to joining or achieve weight gain for twin bearing ewes in late pregnancy to increase twin lamb survival.
    - a combination of production feeding of lambs and maintenance feeding of older animals. The selective grazing of tedera from leaf to stem provides an opportunity to utilise the feed as both a feed to gain weight and a feed to maintain weight if a follower flock is used in a rotation grazing system.

Future research and development of tedera should focus on the development of the agronomy package for the first commercial cultivar of tedera. Tedera should be sown in the right place, at the right time, in the right way, managed to favour it’s establishment and subsequently grazed at times of the year recommended to maximize farm profit.

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1 Background

The profitability and sustainability of livestock industries in southern Australia is severely constrained by the quantity and quality of the forage available over summer and autumn (Dear and Ewing 2008; Young *et al.* 2011). To fill this 'feed-gap', potential new forage species were sought through an extensive, worldwide search for perennial forage legumes that would adapt to Mediterranean environments typical of much of southern Australia. An outstanding candidate was identified – tedera (*Bituminaria bituminosa* C.H. Stirt. var. *albomarginata* and var. *crassiuscula*) (Real *et al.* 2011; Real *et al.* 2013; Real *et al.* 2014). Tedera is a traditional forage legume grazed directly by goats as part of a mixed sward of native plants or cut-and-carried and fed as hay to goats by farmers from the Canary Islands, Spain to produce goat cheese (Méndez and Fernández 1990; Pazos-Navarro *et al.* 2013).

While tedera appears to be an ideal option to fill the feed-gap there was no published information where it has been grazed as a green monoculture by sheep. Hence, it was important to conduct a staged series of experiments to investigate possible health issues; to conduct sufficient 'duty-of-care' testing to ensure that tedera was suitable for grazing by sheep (Revell and Revell 2007). The authors are not aware of any report in the literature or anecdotal evidence/report by researchers or farmers in the country of origin (Canary Islands, Spain (Méndez and Fernández 1990; Méndez *et al.* 1991)) that tedera had caused any health problems in grazing livestock. Nonetheless, from chemical analysis (Méndez *et al.* 2001; Pecetti *et al.* 2007; Tava *et al.* 2007; del Rio *et al.* 2010) there was the potential for problems as tedera contained varying concentrations of two furanocoumarins: psoralen and angelicin. Furanocoumarins are a large family of chemical compounds, and some of them such as xanthotoxin and bergapten that are not present in tedera have been linked to photosensitisation in sheep grazing Dutchman's breeches (*Thamnosma texana* (Gray) Torr.) (Oertli *et al.* 1983; Oertli *et al.* 1984).

Hence, we have conducted three duty-of-care experiments to explore animal health issues. In the first experiment, young sheep (Merino wethers) were fed fresh green tedera (leaf and edible stem) as a sole diet for 35 days in an animal house. Sheep grew as was predicted by the *in vivo* digestibility of the fresh tedera and suffered no health issues. These sheep were not exposed to direct sunlight in the animal house, therefore the possible photosensitisation caused by furanocoumarins was not considered in this experiment (Oldham *et al.* 2015). In the second experiment, young sheep grazed on a monoculture of tedera in full sunlight for 21 days. On average, they gained 1.6 kg in liveweight and 0.3 of a condition score (van Burgel *et al.* 2011) and experienced no health issues (Oldham *et al.* 2013). In the third experiment the effects of tedera on rumen microbial fermentation and degradation of furanocoumarins were explored using the Rumen Simulation Technique (RUSITEC). Tedera was fermented without any negative effects on the rumen microbial populations. Digestibility and fermentability parameters were comparable to lucerne (*Medicago sativa* L.) hay. Furanocoumarins were efficiently degraded in the fermentation fluid and did not accumulate in the system, with some potential adaptation of microbes to degrade psoralen. These findings gave further support for tedera as a useful fodder without negative effects on rumen microbes and potentially on overall animal health (Ghaffari *et al.* 2014).

Therefore once 'duty-of-care' aspects had been addressed, tedera's potential value for Australian livestock production was modelled using a whole farm bioeconomic linear programming model which represents the biological, physical, technical and managerial relationships of a mixed farm in a specific region (MIDAS). Production of dry matter (kg/ha) and it's crude protein content (CP) and *in vitro* dry matter digestibility (DMD) from regional experiments on the seasonal production of tedera in southwestern Australia provided the parameters for modelling purposes (Real and Kidd 2012; Suriyagoda *et al.* 2013). The modelled increase in farm profit was up to 58% because the model chose to grow and graze tedera to replace the high cost of hand-feeding grain and hay over summer and autumn and run higher stocking rates over the whole farm (Finlayson *et al.* 2012).

To date experimental grazing of tedera by sheep has only been of relative short duration, therefore a series of experiments from 2013 to 2016 were conducted as part of this project:

- **Grazing pure stands of tedera in winter, spring, summer and autumn at Dandaragan.** We hypothesized that (i) naïve sheep would show the same relative preference (palatability) for accessions of tedera in the four seasons; (ii) the gain in liveweight and condition score of sheep constrained to single accessions at the same grazing pressure would be the same for all accessions and seasons; (iii) preference of naïve sheep among tedera accessions fed fresh in pens would rank the same as the preferences of sheep in the field study; (iv) the voluntary feed intake (VFI) by sheep fed fresh leaf and stem of tedera in pens would be greater if they have had previous experience of grazing tedera relative to the VFI of naïve sheep; (v) the VFI fed wilted leaf and stem of tedera in pens would be greater than fresh leaf and stem of tedera.

- **Grazing tedera in mixtures with annual species at Kojonup**. We hypothesized that tedera would be less preferred during winter and spring in comparison with annual ryegrass and subclover and that tedera would be mainly grazed during summer and autumn.

- **Production and persistence of tedera through winter and early spring with or without competition of annual pasture based on plot studies.** We hypothesized that tedera production would be significantly reduced by annual species competition.

- **Grazing trial during summer and autumn at Dandaragan 2014/15, Dandaragan 2016 and Kojonup 2016.** We hypothesized that (i) tedera plants would not survive continuous grazing during summer and autumn; (ii) tedera stocked at 10 sheep/ha would at least maintain their weight and condition score without hand-feeding during the whole grazing period and (iii) that rotational grazing (14 days on and 70 days off) would improve the production of the sheep (live weight and condition score) compared with continuous grazing.

- **Calibration of Near Infrared Spectrophotometry (NIRS) for tedera quality.** We hypothesized that a NIRS equation could be developed.

2 Project objectives

1. Evaluated the performance of animals grazing tedera pastures, in comparison with subclover/ryegrass pastures, using rotational grazing.
2. Evaluated the quantity and quality of tedera plant responses to animal grazing throughout the year.
3. Identified any potential health impacts of continuous grazing of tedera over the summer-autumn period of 2014-15 in WA.
4. Evaluate alternative strategies to increase the proportion of tedera in a mixed pasture sward to develop a feed-wedge of tedera in the summer-autumn period in the high rainfall zone of Western Australia.
5. Provide recommendations to MLA for required research and development to ensure the provision of effective recommendations for the adoption of tedera by sheep producers.

3 Methodology

3.1 Experimental sites

3.1.1 Dandaragan – Bidgerabbie farm

J.A.V. Brown & Sons, Bidgerabbie farm at Dandaragan is located 120 km north of Perth (Lat: S 30:49:54.393; Long: E 115:45:50.609) in a 460 mm historical annual rainfall environment with access to irrigation. The soil was a deep red sand (WA Soil Group 445: (Schoknecht and Pathan 2013) with $pH_{(CaCl2)}$ 5.0 and was supplemented with 150 kg/ha of super/potash fertiliser prior to seeding (Table 1). In September 2011, 1.4 ha was sown at a rate of 10 kg/ha using a cone-seeder at a sowing depth of 2.5 cm and a row spacing of 55 cm with seven accessions of tedera These accessions were T4, T27, T31, T42, T43, T48 and T52 and their description can be found in Real *et al.* (2014). Tedera seeds were inoculated with rhizobium WSM 4083. Post-emergent weeds were controlled with an application of Broadstrike® herbicide at 40 g/ha. The site was irrigated once or twice per month (10-20 mm per application) over the 2011/12 summer. Photos 1a to 1d show the tedera site from sowing in September 2011 to April 2012.

Photos 1. Establishment of tedera at Dandaragan – a) 7 September 2011; b) 1 December 2011; c) 6 February 2012 and d) 10 April 2012

On the 3 October 2013, an extra 1.6 ha was sown at 12 kg/ha with a mix of the seven tedera accessions using a commercial scale (6m wide) combine seeder. Tedera seeds were inoculated with rhizobium WSM 4083 and treated with the insecticide Confidor® at a rate of 20g of imidacloprid of a.i./100 kg seed and fungicide Apron® at a rate of 35 g of metalaxyl-M of a.i./100 kg seed. An average of 10 seedlings/m^2 had established. Three weeks after sowing, the site was sprayed with the broadleaf herbicide Broadstrike® at a rate of 40 g flumetsulan of a.i./ha to control pigweed (*Portulaca oleracea* L.) and the grass selective herbicide Select® at a rate of 120 g clethodim of a.i./ha to control annual ryegrass. The 3.0

ha of tedera (new 1.6 ha sown in 2013 plus 1.4 ha sown in 2011) was used for the experiments from 2013 to 2016.

3.1.2 Kojonup – Barrule farm

During winter 2013, a 20 ha paddock was selected at Barrule farm (David and Lyn Mathwin); 13 km west from Kojonup (Lat: S 33:55:19.88; Long: E 117:18:10.098) in a historical 530mm rainfall environment. The site was sown to oats in 2011 and oats, allowed to regenerate in 2012, were cut for hay in spring 2012. The soil was a yellow/brown deep sandy duplex (WA Soil Group 407; (Schoknecht and Pathan 2013) and characteristics are presented in Table 1. Within the paddock, 12 ha were marked and divided into 12, 1 ha plots (Figure 1). The site was limed with 1.5 tonne/ha of lime and 0.7 tonne/ha of dolomite. It was grazed with sheep for three weeks to reduce the amount of ryegrass (*Lolium rigidum* Gaudin) and subclover (*Trifolium subterraneum* L.) prior to spraying glyphosate (Roundup®) at a rate of 540 g of a.i./ha. Three weeks after the glyphosate spray, the site was cultivated lightly to encourage germination of annual ryegrass, which was sprayed with a desiccant (SpraySeed®) at a rate of 135 g paraquat/115 g diquat of a.i./ha four days prior to sowing. Eight of these 12 plots were randomly selected and sown with a commercial scale air seeder (Photo 2) on the 28 August 2013. The seeding rate was 12 kg/ha of an inoculated (rhizobium WSM 4083) tedera composite of seven accessions (T4, T27, T31, T42, T43, T48, T52) sown at 3 to 5 cm of depth and fertilized with 100 kg/ha of NPK Plus (N 7.0%; P 7.5%; K 5.0%; Ca 6.0%; S 8% plus trace elements). Two weeks after seeding, the site was sprayed with Talstar® at a rate of 20 g bifenthrin of a.i./ha to control Red legged earth mite (*Halotydeus destructor*). Six weeks after sowing, the site was sprayed with the grass selective herbicide Select® at a rate of 240 g clethodim of a.i./ha to control annual ryegrass.

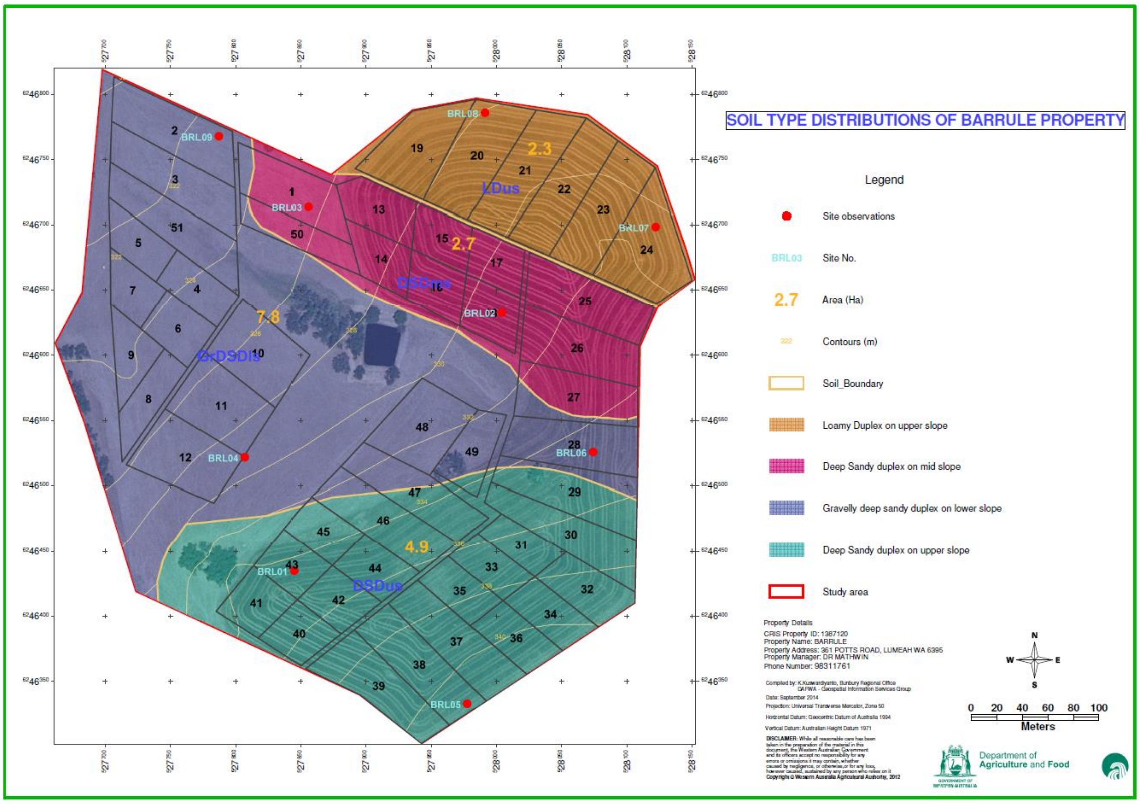


Figure 1. A comprehensive soil survey of the experimental site at 'Barrule', Kojonup

Photo 2. Sowing at 'Barrule', Kojonup on the 28 August 2013

The establishment count conducted on the 4 November 2013, had an average of 8.9 seedlings/m^2. This seedling number is considered optimum in agreement with the studies conducted by Real and Kidd (2012) and Suriyagoda *et al.* (2013) at three sites in Western Australia (Mount Barker, Newdegate and Buntine), evaluating densities of 1, 2, 4, 8 and 16 plants/m^2, where maximum production was achieved with 8 and 16 plants/m^2.

The site received very little rain during January 2014 (0.0mm), February 2014 (2.2 mm) and March 2014 (2.2 mm), however, tedera was able to establish.

Table 1: Soil analysis of the top 10cm and 10 to 30cm for Kojonup and Dandaragan

		Barrule	Barrule	Bidgerabbie	Bidgerabbie
Code	Units	0-10cm	10-30cm	0-10cm	10-30cm
Colour		BRBK	GRYW	DKBR	BROR
Gravel	%	0	5	0	0
Texture		2	2	2	2
Ammonium Nitrogen	mg/Kg	13	2	3	4
Nitrate Nitrogen	mg/Kg	34	10	8	5
Phosphorus Colwell	mg/Kg	39	16	91	32
Potassium Colwell	mg/Kg	248	68	207	43
Sulphur	mg/Kg	28	14	4	8.5
Organic Carbon	%	2	1	1	0.32
Conductivity	dS/m	0.2	0.1	0.1	0.038
pH Level (CaCl2)	pH	4.9	4.7	6.2	4.3
pH Level (H2O)	pH	5.6	5.5	7.2	5.0
DTPA Copper	mg/Kg	0.51	0.26	0.86	0.36
DTPA Iron	mg/Kg	140.52	96.75	38.54	165.07
DTPA Manganese	mg/Kg	14.12	1.48	2.77	0.66
DTPA Zinc	mg/Kg	1.45	0.17	1.77	0.17
Exc. Aluminium	meq/100g	0.14	0.21	< 0.001	0.221
Exc. Calcium	meq/100g	5.86	1.45	3.17	0.54
Exc. Magnesium	meq/100g	1.05	0.48	0.49	0.17
Exc. Potassium	meq/100g	0.60	0.17	0.53	0.11
Exc. Sodium	meq/100g	0.26	0.17	0.12	0.07
Boron Hot CaCl2	mg/Kg	0.52	0.25	0.39	0.46

Herein after these two sites will be referred in the report as Dandaragan and Kojonup.

3.2 Grazing pure stands of tedera in winter, spring, summer and autumn at Dandaragan

Site plan (Figure 2) and photos (Photo 3) are presented for Experiments 1, 2 and 3. These experiments were conducted only in the 2011 tedera sowing area of 1.4 ha. After grazing in May 2012 (Oldham *et al.* 2013), the whole site received a uniform mowing to a standard height of 10 cm above ground level on 9 February 2013. During 2013-14, mowing was used after each experimental grazing to return each accession of tedera to a standard cutting height of 10 cm.

- Experiment 1 – to allow all the seven accessions to be grazed in common.
- Experiment 2 – to allow exclusive grazing of each of the seven accessions.
- Experiment 3 - to allow for a randomised and replicated pen trial to validate and rank relative preference of sheep (experienced vs. naïve) fed each of the seven accessions (fresh vs wilted), from a sub-section of the grazed plots, by measuring the voluntary feed intake of sheep over 120 minutes.

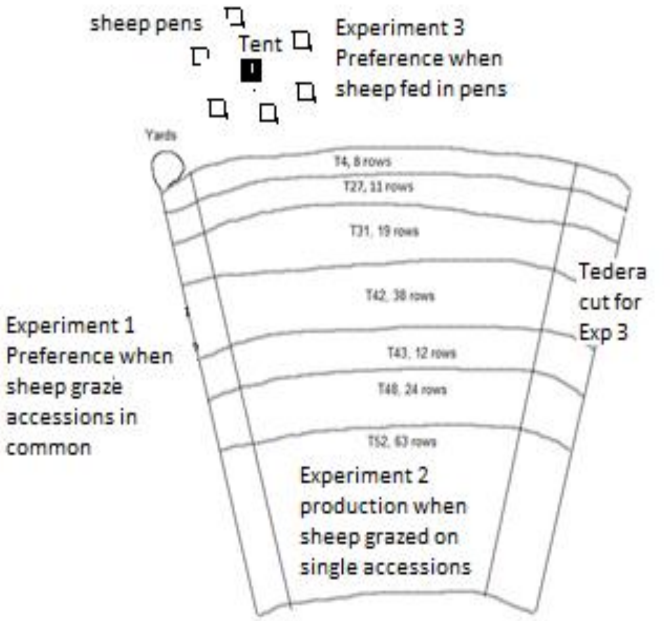


Figure 2. The layout of seven accessions of tedera in the 1.4 ha sown in 2011

(a) Experiment 1. Sheep grazing the seven accessions of tedera in common (Note – yards and sheep weighing scales in the foreground)

(b) Experiment 2. Sheep grazing each of the seven accessions of tedera separately

(c) Experiment 3. Cutting fresh tedera from each of seven accessions each morning for use in the pen feeding

(d) Experiment 3. Six pens x two sheep/pen x 14 feeders/pen x two feeders for each of seven accessions of tedera (Note – central location of tent for weighing individual feeders)

Photo 3. Grazing and pen feeding studies at Dandaragan in May 2014 (3.2).

3.2.1 Sheep selection (Experiment 1, grazing across seven accessions; Experiment 2, grazing within each of seven accessions)

On the day before the start of each grazing, a group of ~200 sheep that had never grazed tedera ('naïve sheep') were drafted at random from a commercial flock of 500 young merino ewes (born July 2012). These young ewes had been given a 5:1 vaccine for clostridial diseases (marking and weaning) and were drenched for worms and given cobalt and selenium bullets. The selected sheep were tagged with a unique electronic tag, weighed and condition scored. The new electronic tag was cross referenced to the sheep's existing farm tag in case of lost electronic tags during grazing. The liveweight and condition scores were used initially to select sheep within 2 standard deviations of the mean liveweight (LW) and condition score (CS) of the whole group. The data file of LW and CS was used to randomly allocate them to treatment groups after stratification on liveweight and condition score. At 9:00 am the next day (Day 0) the auto draft on the electronic weigh scales was used to select the sheep allocated to the various treatments/plots.

3.2.2 Sheep management during grazing (Experiment 1, grazing across seven accessions; Experiment 2, grazing within each of seven accessions)

The liveweight and condition score of the sheep were measured starting at 9:00 am on Day -1, 3, 7, 10 and 14. The sheep were yarded each day during the first week and individually checked for redness and oedema on the face and ears. If clinical evidence of photosensitization was observed, the sheep would have been bled to confirm inflammatory changes by means of plasma haptoglobin. During the second week, the sheep were observed three times per day using binoculars and they were closely observed individually on Days 10 and 14 during weighing.

3.2.3 Calculation of sheep per subdivision (Experiment 1, grazing across seven accessions; Experiment 2, grazing within each of seven accessions)

On Day -3, the total feed on offer (kg DM/ha and per grazing unit; tedera plus inter-row) was estimated for Experiment 1 and Experiment 2. For tedera the feed on offer in each accession was estimated from 5 random sites within each accession (5 x 7 = 35) in Experiment 1 and 10 random sites within each of the seven accessions (10 x 7 = 70) in Experiment 2. At each site 1m of row was cut to a standard height of 10 cm, dried at 60°C for four days and DM weights recorded. For the annual species (mainly capeweed (*Arctotheca calendula* (L.) Levyns) and annual grasses) in the inter-row a calibrated visual estimation (n=30 estimates across the seven accession in Experiment 1 and within each accession in Experiment 2), for each accession was used (Cayley and Bird 1996). The total feed on offer was then used to calculate the number of sheep to graze the accession during the experimental phase based on a target intake of 50% of the total feed on offer in seven days for Experiment 1 and 14 days for Experiment 2.

For example, young sheep weighing 40 kg eat around 3% of their liveweight per day of a good quality diet (DMD $\geq$ 65%) or 1.2 kg DM/head/day or 17 kg DM in 14 days (Freer *et al.* 1997). Therefore, if the tedera plus inter-row at Day 0 was ~ 480 kg DM/accession; a grazing pressure of one sheep/34 kg DM (twice the estimated intake of one sheep) at the start of grazing would equal 14 sheep. The actual number of sheep introduced into each accession of tedera at the start of each grazing (Day 0) was calculated based on the measured feed on offer for that accession in each season.

3.2.4 Nutritive Value (Experiment 1, grazing across seven accessions; Experiment 2, grazing within each of seven accessions)

At each cutting, samples were dried at 60°C for four days and samples analysed for their nutritive value using appropriate wet chemistry methods in a NATA accredited laboratory in NSW DPI laboratory. The key elements of nutritive value presented in this report are crude protein (CP), digestibility of dry matter (DMD) and metabolisable energy (ME).

3.2.5 Measurement of relative preference (Experiment 1, grazing across seven accessions)

The difference in the tedera DM on offer between the paired cutting sites was used to estimate the relative intake of each accession during the grazing periods (Day 0 to 4 or Day 4 to 7). The relative preference (α) among the tedera accessions was calculated from the initial forage biomass (kg/accession/section) and the estimated intake using the Chesson-Manly selection index (Chesson 1983) which uses the following formula;

$$\alpha_i = \ln\left((n_{i0} - r_i)/n_{i0}\right) / \sum_{j=1}^{m} \ln\left((n_{j0} - r_j)/n_{j0}\right), \quad i = 1, \ldots, m$$

- r_i is the quantity of the forage type *i*
- *i* is the consumers diet and
- n_{io} is the quantity of forage type *i* available initially to the sheep
- m is the number of forage choices (i.e. seven accessions).

For α_i = 1/m = 0.142 which indicates a neutral relative preference for that accession. If α is > 0.142 then the sheep is showing a high preference for that accession and if α is < 0.142 it is exhibiting a low preference for that accession. The range of values for α_i usually vary from 0 (forage type *i* is not selected in the diet) to 1 (forage type *i* is exclusively selected in the diet) (Thomas *et al.* 2010).

3.2.6 Experiment 3 – pen trial run in parallel with, and during the autumn 2014 and final grazing of Experiments 1 and 2

3.2.6.1 Experiment 3A

- Six pens: Three pens with experienced sheep (sheep that had previously grazed tedera for 14 days); three pens with naïve sheep (sheep from the same flock that had no prior experience of grazing tedera).
- Two sheep per pen
- 14 feeders per pen: two feeders for each of the seven accessions
- Measuring VFI once per day (60 and 120 minutes) for six days

3.2.6.2 Experiment 3B

- Six pens (3m x 3m): Three pens with naïve sheep fed fresh tedera; three pens with naïve sheep fed wilted tedera
- Two sheep per pen (N=12)
- 14 feeders per pen: two feeders for each of the seven accessions
- Measuring VFI at 4 intervals over two hours (i.e. 30, 60, 90 and 120 minutes) for five days

3.2.6.3 Acclimatisation to new feed and feeding conditions

In order to acclimatise the 40 selected sheep to the change in diet from dry pasture plus a supplement of lupins to the maintenance diet of lupins plus commercial pellets fed in small feeders under shelter they were yarded in a large pen (18 m x 18 m) fed to maintenance (a mixture of lupins (10%), Macco 101 pellets (90%) for five days prior to the start of Experiment 3 (Figure 3a).

3.2.6.4 Experimental pens

There were six pens of 9 m^2 provided with a water trough. The water trough was located on the tent side of the pen and all pens were arranged about a central tent that was used for weighing and recording (see Figures 2, 3(b) and Photo 3 (d)). There were a minimum of two staff on site during the daylight hours for the duration of Experiment 3.

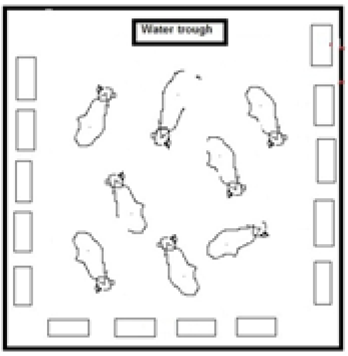


Fig 3(a). Training area (approx 18m x 18m) with multiple sheep, multiple small feeders, fed a maintenance diet of pellets, 1/2 in am and 1/2 in pm

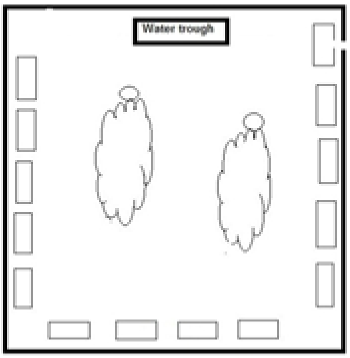


Fig 3(b). Experimental pens (3m x 3m) with 2 sheep and 14 feeders - 2 replicates of 7 accessions of tedera randomly allocated each feed

Figure 3. Schematics of the pen feeding experiment illustrating (a) the training area for acclimatisation of the experimental sheep to the feeders, feed and conditions to be used prior to the commencement of the overall experiment; (b) the layout of the feeders.

Once tagged, weighed and condition scored, 12 sheep (six experienced and six naïve) were randomly allocated to the six pens for Experiment 3. The pens were 9 m^2 and each contained two sheep (see Figure 3b). The sheep were weighed and condition scored into and out of the experimental pens.

3.2.6.5 Randomisation of the treatments and the pens

The treatments naïve *or* experienced sheep were randomly distributed among the pens. Also the seven accessions of tedera were randomly allocated between the 14 feeders (two replicates of each accession in each pen) before each preference test. This was done for each of the six pens.

3.2.6.6 Measurements of preference

To measure VFI we calculated the average differences of feed offered and and feed remaining from the feeders during 60-minute intervals over two hours. At each measurement all the feeders were removed and weighed and then returned at the same time to minimise disturbance. At the end of each preference test the refusals from each feeder were measured and the average intake per accession was recorded. The preference test was conducted once per day (~ 10 am). Note during each preference test, each feeder was loaded with 250 g (two feeders per accession) for all the accessions. In summary 3,500 g of fresh tedera (~875 g DM) was offered per pen of two sheep per day (250 g of fresh tedera x two feeders x seven accessions once per day). This represented about half of the feed required daily to maintain the LW and CS of the sheep.

3.2.6.7 Feeding between preference tests

Each day after the preference test (approx. 4:00 pm) the sheep/pen were fed sufficient pellets to complete a maintenance ration over each 24 hour period.

3.2.6.8 Tedera for pen experiments

One week prior to the commencement of Experiment 3, the FOO was assessed in the tedera plots and an area was annexed off (eastern boundary) from Experiment 2 to provide sufficient fresh cut material for the pen trial (see Figure 2).

3.3 Grazing tedera in mixtures with annual species at Kojonup

3.3.1 Tedera and annual pasture

Tedera was sown in August 2013 as described in Section 3.1.2. The first summer and autumn were very dry (Decile 1; Appendix 1) and was followed by an early break of season starting on 7 May 2014. The subsequent even germination of sub-clover and ryegrass resulted in an average FOO across the whole site of 734 kg/DM/ha on 27 June 2014, therefore annual pastures were not sown.

3.3.2 Experimental site

Pasture. Three pasture treatments with four replicates were established at the Kojonup site (Figure 4):

- **A** – annual pasture alone grazed in a short rotation 14 days on and 28 days off. Three plots per replicate of 1/3 ha each;
- **ATS** - annual pasture plus tedera grazed in a short rotation 14 days on and 28 days off. Three plots per replicate of 1/3 ha each;
- **ATL** – annual pasture plus tedera grazed in a long rotation 14 days on and 70 days off. Six plots per replicate of 1/6 ha each.

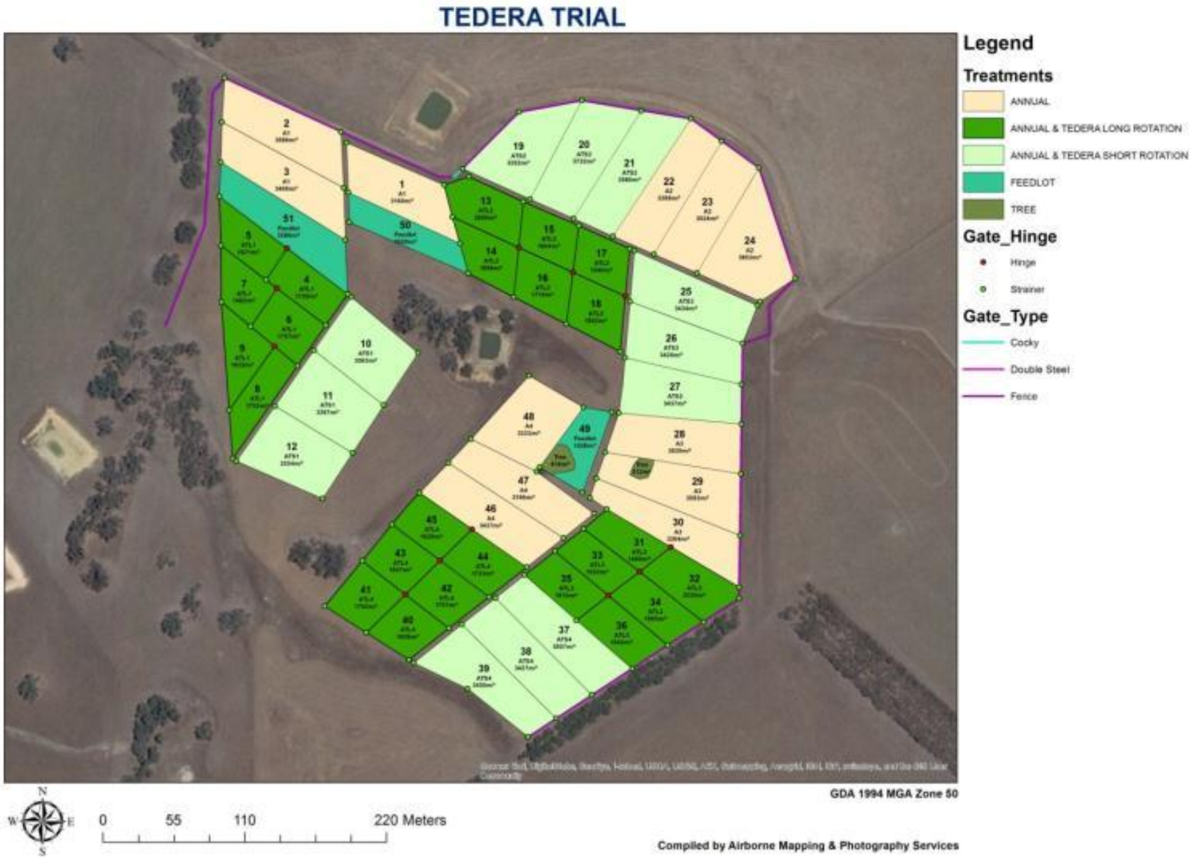


Figure 4. The layout of the plots and laneways on the experimental site at Kojonup

3.3.3 Experimental sheep and pasture measurements

Sheep. 160 nine-month-old merino ewes were selected from a commercial flock after weighing and condition scoring to ensure minimal variation in liveweight and condition scores. After stratification for liveweight and condition score 96 ewes were randomly allocated to the established plots on 10 July 2014 and stocked at 8 DSE (3 treatments x 4 replicates). The remaining 64 'spare' sheep were maintained on a break-out-area on the trial site. The stocking rate was reassessed and increased due to the increased pasture growth rates at the time to 10 DSE on 19 August 2014. The sheep were shorn on 12 November 2014. The liveweight and condition score of each sheep was measured every 14 days throughout the grazing period. On 17 December the ewes were artificially inseminated by laparoscopy using frozen-thawed semen from a single terminal sire and returned to their plots (with back up merino rams for a fortnight). The ewes were pregnancy scanned on 2 February 2015. The final liveweight and condition score measurements were made on 5 February at the termination of the grazing experiment.

Pasture quantity. Every fortnight throughout the period of the experiment, feed on offer (FOO; Kg DM/ha) from the annual pasture and tedera in the plot just grazed and the plot to be grazed (4 replicates per treatment) were measured by calibrated visual assessment (Cayley and Bird 1996).

Pasture growth rate. The monthly pasture growth rate (PGR; kg DM/ha/day) for each plot within each treatment were calculated from the FOO at the start of grazing minus the FOO at the end of the last grazing of that plot providing a rolling monthly average of the PGR through the growing period.

A selection of photos depicting a typical site visit is shown in Photo 4.

(a) Covered sheep yards

(b) Sheep grazing plot 25 (annual pasture plus tedera; ATS3)

(c) Annual pasture plus tedera, 14 days after grazing (right side of fence; plot 30, ATL3)

(d) Host farmer, David Mathwin and team tedera (Oldham and Dobbe) doing FOO calibration cuts

Photo 4. Various images of the Kojonup experimental site

3.4 Production and persistence of tedera with or without competition of annual pasture based on plot studies at Kojonup

On the 29 April 2015, four replicates of three pasture treatments (tedera only, tedera plus annual species and annual species only) were selected and pegged in plots of 5 m x 10 m. On the 30 April 2015, the tedera only plots were sprayed with the grass selective herbicide Clethodim @ 500 ml/ha and the broad-leaf herbicide Flumetsulan @ 40 g/ha. On the 1 July 2015, all treatments and replicates were spread with 60 kg/ha of fertiliser (N 14.1; P 14.1; S 9.2; Cu 0.10; Zn 0.20). On the 23 July 2015, the tedera only treatment was sprayed again with the grass selective herbicide Clethodim @ 500 ml/ha. On the 14 October 2015, 23 February 2016 and 3 May 2016, all tedera plants in the four replicates of the tedera only and tedera plus annual species treatments were counted and cut to a 5 cm height. Biomass cuts were done to the annual species in the tedera plus annual species and annual species only with three 0.1 m^2 quadrats per plot. All plant samples were oven dried at 60°C for 72 hours and dry weights taken.

3.5 Grazing trial during summer and autumn at Dandaragan 2014/15, Dandaragan 2016 and Kojonup 2016

3.5.1 Plant material

The same mix of seven accessions of tedera was used for all grazing trials. These accessions were T4, T27, T31, T42, T43, T48 and T52 and their description can be found in Real *et al.* (2014).

3.5.2 Site description

Two grazing experiments were conducted in 2014/15 and 2016 at Dandaragan and one grazing experiment in 2016 at Kojonup. At Dandaragan, the total area established to tedera was 3.0 ha. There was an area of 1.4 ha established with an experimental cone-seeder in 2011 and 1.6 ha was established with a commercial combine seeder in 2013. At Kojonup, a subset of 2.4 ha of the 8 ha established in winter 2013 were utilized for the summer and autumn grazing trial.

3.5.3 Climate

Monthly rainfall, maximum air temperature and minimum relative humidity data from August 2014 to April 2016 at Dandaragan and Kojonup experimental sites are presented in Appendix 1. The Dandaragan experiment in 2014/15 was very dry during December 2014 and January 2015 with high temperatures and low relative humidity. From February to April 2015, rainfall was on average 22 mm per month. At Dandaragan and Kojonup there was a dry spring in 2015 and early summer of 2016, being February 2016 very dry and hot, but rainfall was around 60 mm per month in March and April 2016.

3.5.4 Pasture management prior to start of experiments

Prior to commencement of the 2014/15 experiment, the Dandaragan site was subjected to a heavy grazing in May 2014 followed by mowing to 10 cm height on 22 August 2014 (Photo 5).


Photo 5. Mowing tedera at Dandaragan on 22 August 2014

The re-growth from the 22 August 2014 was accumulated until the start of the grazing experiment on 2 December 2014. Following the completion of the experiment at the end of May 2015, the site was crash grazed (450 sheep for 3 days) to remove residual material. The tedera then remained un-grazed until the start of grazing on the 2 February 2016.

The Kojonup grazing experiment commenced on the 9 February 2016. At this site, during 2015 growing season, the pasture was chemically manipulated to suppress annual species and promote tedera growth as follows. On the 30 April 2015 the Kojonup site was sprayed with 500 ml/ha of Clethodim (240 g/L), 40g/ha Flumetsulam (800 g/kg) and 100 ml/ha Bifenthrin (25 g/L) to control grasses, clover and insects. A second grass control was carried out on the 27 July 2015 using 2 L/ha of Propyzamide (500 g/L). A second broad leaf application of 5 g/ha Metosulam (100 g/L) and 90 g/ha Metribuzin (750 g/kg) was sprayed on the 26 August 2015 with both capeweed and subclover controlled. The herbicide applications followed recommendations of herbicide trials conducted at Kojonup during summer 2014 (Moore 2014) and winter and spring 2014 (J Moore pers. comm.). However, the application of the broadleaf herbicides Metosulan and Metribuzin also affected tedera, therefore no grazing occurred to allow it’s recovery. The Kojonup site received a maintenance level of fertiliser on 1 July 2015 by topdressing 60 kg/ha Agstar Extra™ (N:14.1, P:14.1, S:9.2, Cu: 0.10, Zn 0.20) while the Dandaragan site was not re-fertilised during 2015.

3.5.5 Grazing treatments

Two methods of grazing management of a monoculture of tedera were assessed: (a) continuous grazing and (b) rotational grazing with 14 days of grazing followed by 70 days of recovery. At Dandaragan for the 2014/15 and 2016 experiments, a single 1.5 ha area (approximately half from the 2011 and half from the 2013 seedings) judged to have a plant density typical of the entire area, was selected for the continuous grazing treatment and the remaining plot of 1.5 ha was divided into six sub-plots of 0.25 ha for the rotational grazing treatment. Similarly, at Kojonup for the 2016 experiment, the 2.4 ha site was divided into two areas of 1.2 ha that were judged to have a similar plant density of tedera. One plot was randomly selected for the continuously grazed treatment and the remaining 1.2 ha was divided into six sub-plots of 0.2 ha for the rotationally grazed treatment.

3.5.6 Duration and time of grazing

For the Dandaragan 2014/15 experiment, the continuously grazed treatment (CG) was grazed from the 2 December 2014 to the 24 March 2015 (113 days). The rotationally grazed treatment (RG) was grazed from the 2 December 2014 to the 21 April 2015 (141 days). At the end of the growing season in WA, mixed farming systems have dry annual pasture residues and cropping stubbles available to feed the grazing animals. Once stubbles have been grazed or are of poor quality due to summer rains, normal farm practice is to start hand-feeding on dry pasture residues. This typically occurs in February-March but when feeding begins and how much is fed is year dependent (Thompson *et al.* 2011). Following the success of the experiment in 2014/15 it was decided to delay the start of the experiment in 2016 until early February to better match the grazing period with normal farm hand-feeding practices. Therefore, the Dandaragan and Kojonup 2016 experiments were grazed from 2 February 2016 to 26 April 2016 and from 9 February 2016 to 3 May 2016, respectively.

3.5.7 Experimental sheep

The same stocking rate of 10 sheep/ha was adopted for the three experiments. On the first day of grazing, 30 young sheep (Merino wethers; approximately 9 months of age) that had never grazed tedera were drafted at random from a commercial flock of around 500 at Dandaragan in December 2014 and in February 2016. At Kojonup, 24 young sheep were also drafted at random from a commercial flock of around 500 in February 2016. All these sheep had been previously been given a 5:1 vaccine for clostridial diseases (marking and weaning) and were drenched for internal parasites and selenium prior to the commencement of the experiment. The selected sheep were randomly assigned to the two grazing treatments, tagged, weighed and condition scored (van Burgel *et al.* 2011). Throughout the period of experimental grazing, sheep were supplied with a complete macro and trace mineral mix for sheep (Macco Feeds Australia, Williams WA, Australia), at 150 g/sheep.week (John Milton; Independent Laboratory Services). At the end of the each experiment, all the experimental sheep were returned to their flocks of origin.

3.5.8 Commercial sheep

At Kojonup in 2016, the flock from which the experimental sheep had been selected were managed by the farmer and rotationally grazed eight paddocks close to the experimental site. Three of paddocks were a mix of lucerne and dry residue of annual species (mainly annual ryegrass and subclover). The remaining five paddocks were dry residue of annuals species only. Stocking rate over the whole area was at 6.2 sheep/ha. Hand-feeding of either oats or barley grain was undertaken during the entire period at a rate of 170 g/sheep.day. On the 19 April 2016, a random sample of 30 of these commercial sheep were weighed and conditioned scored.

3.5.9 Experiment measurements

Weather records

- Automated Department of Agriculture and Food Western Australia (DAFWA) weather stations (AWS Junior, MEA 104, Australia) were located at both sites.

Tedera measurements

- Feed on Offer (FOO; kg DM/ha) - FOO of tedera was estimated at each experiment from 30 randomly selected sampling sites (1 m^2 of tedera) within each plot. At each experiment, a score of 0 (no tedera) to 5 (highest tedera on offer) was assigned. At day zero, two cuts of each score were cut and dried at 60°C and used to calibrate the scores to the FOO. At Dandaragan 2014/15, a new calibration cut done at beginning of the second full rotation was similar to the first calibration cut so they were combined and used throughout. In 2016 at Dandaragan and Kojonup, at the beginning of the fourth fortnight, which was the half way point of the first full rotation, a new calibration cut for the continuous grazing plots was done. This calibration captured the change in available tedera biomass composition from the initial high leaf to edible stem ratio to the decreased leaf to edible stem ratio as a result of grazing where the sheep showed a clear preference for leaf at the start of grazing. Depending on the date, either the first or second calibration (or a weighted average) was used.

- Persistence – the survival of tedera plants was estimated from the plant counts within three permanent areas (2 m x 2 m) pegged with steel fence posts, where the location was chosen at random within each plot. Plants within each permanent area were counted at the start and end of the grazing period.
- Nutritive value - Before the start of grazing at both sites in each year, a bulk sample compiled using the toe cut method (Cayley and Bird 1996) comprising leaf and edible stem (≤ 5 mm diameter) was used to make up a 100% leaf fraction sample and a 100% stem fraction sample for nutritive value analysis using near infra-red spectrophotometry (Adriansz *et al.* 2016). Crude protein (CP), acid detergent fibre (ADF), ashes (ASH), dry matter digestibility (DMD) and metabolisable energy (ME) were assessed.

Sheep measurements

- Live weight and Condition Score - the experimental sheep were weighed using Tru-Test loadbars and Tru-Test XR3000 data logger and condition scored directly from their plots every 14 days (van Burgel *et al.* 2011).

3.5.10 Statistical analyses

At each site, live weights, condition score, pasture biomass and pasture persistence at different times during the experiment were statistically compared to assess differences between continuous grazing and rotational grazing. Standard errors and least significant differences ($p<0.05$) were calculated and in many cases the statistical comparisons could be done with a paired or unpaired t-test. The live weight and condition score comparisons were based on measurements of each animal, while the pasture biomass and persistence was based on multiple pasture measurements. At each site there was just one true replication of both treatments due to the scale of operations, so the statistical comparison is confounded with any potential differences arising from the location of the paddocks. Having three experiments helped to overcome this limitation with more confidence attached to results that were similar between sites.

3.6 Calibration of Near Infrared Spectrophotometry for tedera quality

Near Infrared Spectroscopy (NIRS) technology can be used to measure nutritive value of tedera after a calibration equation has been adjusted. For this purpose, the plant nutritive value has to be determined by wet chemistry and spectra information used to calibrate the equation.

Using a standard approach, four sets of seasonal samples were collected (35 samples each season) for seven accessions of tedera from Dandaragan. This model was used to maximise the range in characteristics and enhance the variability amongst samples, including leaf and stem dominant samples.

The samples were ground in a UDY Sample Mill to pass through a 1.0 mm screen and analysed for 11 nutritive attributes by appropriate wet chemistry methods in a NATA accredited laboratory. The ground samples were scanned in triplicate using the coarse sample cell in a FOSS XDS NIR instrument to develop calibrations for each of the 11 nutritive attributes (Acid Detergent Fibre (ADF), Acid Detergent Lignin (AD-L), Neutral Detergent Fibre (NDF), Non-Structural Carbohydrates (NSC), Crude Protein (CP), Fat, Ash, Organic Matter (OM), Dry Matter Digestibility (DMD), Digestible Organic Matter in DM (DOMD) and Metabolisable Energy (ME). The spectral range selected was 800-2498 nm to facilitate transferability of the calibrations to other NIR instruments. All calibrations were developed using a Standard Normal Variate and Detrend treatment with cross validation segments of 20. Validation sets of 47 samples were compared with calibration sets of 97 samples to develop the optimum calibration for each nutritive attribute - on the premise of principal components with the lowest SECV and maximum RPD values (Adriansz *et al.* 2016).

3.7 Animal ethical approvals

Approvals to conduct animal research work reported in this manuscript were granted by the Animal Ethics Committee of the Department of Agriculture and Food Western Australia. The 2013 to 2016 research activities had approval numbers AEC 1-14-03, AEC 5-14-17 and AEC 15-5-16.

4 Results

4.1 Grazing pure stands of tedera in winter, spring, summer and autumn at Dandaragan

4.1.1 General

At the four seasons there was no indication of photosensitisation or any other illness in any of the sheep.

4.1.2 Experiment 1, grazing across seven accessions

In Experiment 1, the grazing pressure was calculated to leave approximately 50% of the starting DM on offer after seven days. The relative preference and ranking (R) of the seven accession of tedera across the four seasons using the Chesson-Manly selection index for all grazings of the Dandaragan site is presented in Table 2.

Table 2. The relative preference and ranking (R) of the seven accession of tedera across the four seasons using the Chesson-Manly selection index for all grazings of the Dandaragan site to date.

Tedera	winter 2013	R	spring 2013	R	summer 2014	R	autumn 2014	R
T4	-0.018	6	0.037	6	-0.032	7	0.212	1
T27	0.191	3	0.310	1	0.076	6	0.146	4
T31	0.132	4	0.147	3	0.145	3	0.137	5
T42	-0.135	7	0.269	2	0.112	4	-0.001	7
T43	0.092	5	0.130	5	0.216	2	0.202	2
T48	0.394	1	-0.027	7	0.091	5	0.187	3
T52	0.344	2	0.136	4	0.391	1	0.118	6

As measured using the Chesson-Manly selection index the sheep expressed a preference for some accessions of tedera, however these differences were not consistent among seasons.

4.1.3 Experiment 2, grazing within seven accessions

After grazing in each season the whole site was mowed to a uniform height of 10 cm and allowed to regrow for approximately 70 days before the next grazing. Hence, the values shown in Table 3 can be read as the relative productivity of the seven different accessions between seasons and for the year.

Table 3. The feed on offer (FOO; kg DM/ha) immediately before the start of grazing in each of the seven accessions at the Dandaragan site in each of the four seasons and for the year.

Tedera	**winter 2013**		**spring 2013**		**summer 2014**		**autumn 2014**		**Annual 2013-14**	
T4	1366	a	1712	c	1260	e	397	c	4735	c
T27	990	ab	2151	ab	1554	de	482	bc	5177	bc
T31	1681	a	1875	bc	2605	a	594	ab	6755	a
T42	562	b	1790	bc	1699	cd	390	c	4441	c
T43	1396	a	2341	a	2195	ab	491	bc	6423	a
T48	1611	a	1963	bc	1754	cd	719	a	6047	ab
T52	1879	a	2423	a	1953	bc	691	ab	6946	a
Av	*1355*		*2036*		*1860*		*538*		5789	

Accessions that share a common letter are not significantly different (p<0.05)

In Experiment *2,* the grazing pressure was designed to leave approximately 50% of the starting DM on offer after 14 days. The change in tedera on offer (DM kg/ha) during grazing for each season is presented in Table 4.

Table 4. Change in tedera on offer (DM kg/ha) during grazing.

Winter 2013								
Accession	Sheep #	0	4	7	11	14	% eaten	Sig. @ 0.05
T4	10	1366	1207	803	382	0	100%	a
T27	8	990	974	1070	872	510	48%	e
T31	20	1681	1310	887	469	112	93%	bc
T42	26	562	535	430	384	191	66%	de
T43	7	1396	1274	1131	1225	915	34%	e
T48	18	1611	1122	807	535	28	98%	b
T52	45	1879	1945	1062	846	374	80%	cd
Average		1355	1195	884	673	304	78%	

Table 4 continued over the page

Table 4. Change in tedera on offer (DM kg/ha) during grazing (continued)

Spring 2013								
Accession	Sheep #	0	4	7	11	14	% eaten	Sig. @ 0.05
T4	14	1712	1289	328	0	0	100%	a
T27	10	2151	2119	1343	1104	895	58%	d
T31	16	1875	1740	901	442	210	89%	b
T42	27	1790	2211	1420	1245	868	52%	d
T43	10	2341	2282	1313	984	835	64%	d
T48	17	1963	1696	1279	787	632	68%	cd
T52	48	2423	1770	930	459	264	89%	bc
Average		2036	1872	1073	837	617	70%	
Summer 2014								
Accession	Sheep #	0	4	7	11	14	% eaten	Sig. @ 0.05
T4	3	1260	933	1364	1049	926	27%	bc
T27	4	1554	1466	1496	1203	1171	25%	bc
T31	11	2605	1772	1513	1352	1005	61%	a
T42	14	1699	1245	1499	1150	924	46%	ab
T43	5	2195	2013	1735	1494	1615	26%	bc
T48	8	1754	1509	1834	1713	1682	4%	c
T52	19	1953	1642	1554	1403	1103	44%	ab
Average		1860	1511	1571	1338	1204	33%	
Autumn 2014								
Accession	Sheep #	0	4	7	11	14	% eaten	Sig. @ 0.05
T4	3	397	268	183	124	57	86%	a
T27	3	482	321	383	367	295	39%	b
T31	5	594	414	486	429	455	23%	bc
T42	7	390	494	419	274	167	57%	b
T43	3	491	491	551	643	624	-27%	c
T48	6	719	677	586	559	382	47%	b
T52	11	691	631	439	483	457	34%	b
Average		538	471	435	411	348	37%	

Accessions that share a common letter are not significantly different (p<0.05)

The winter and spring 2013 were grazed to 78% and 70% respectively, with some accessions like T4 being completely grazed before the 14 days. These grazing levels were more than the target of 50%. The summer and autumn 2014 were grazed to 33% and 37%, less than the target of 50%.

During the experiment the naïve sheep used in the experiment were drawn from the same flock but were older and heavier as the experiment progressed from winter 2013 to autumn

2014 (~ 11 months of age and weighed 36 kg in winter 2013 to ~ 21 months of age weighing 53 kg in autumn 2014). However, they were always in similar body condition (≥3 CS) and with the exception of summer they grew at > 150 g/head/day (Table 5). However, within each season the growth rate (GR; g/head/day) of the sheep varied between the seven accessions of tedera from high (> 200 g/head/day) to low (< 100 g/head/day). Nonetheless, the GR of the sheep grazing T31 and T48 stand out as being consistently high and that of the sheep grazing T52 as consistently low. In addition, it is important to note that the sheep ate sufficient of all the accessions to at least maintain themselves in forward store body condition (CS ≥ 3) with no health issues.

Table 5. The average growth rate (GR, g/head/day) over 14 days for the sheep grazing tedera in winter 2013, spring 2013, summer 2014 and autumn 2014.

Accession	**Winter 2013**		**Spring 2013**		**Summer 2014**		**Autumn 2014**		Average	
T4	94	d			-51	b	233	ab	102	de
T27	201	ab	47	c	-26	b	-48	c	43	e
T31	232	a	236	a	227	a	291	ab	247	a
T42	155	bc	175	ab	81	b	330	a	185	bc
T43	197	abc	225	a	29	b	152	bc	151	cd
T48	183	abc	244	a	192	a	248	ab	217	ab
T52	122	cd	90	bc	71	b	178	bc	115	de
Average	169		169		75		201		151	

Accessions that share a common letter are not significantly different (p<0.05)

4.1.4 Experiment 3 - pen trial run in parallel with, and during the autumn 2014 and final grazing of Experiments 1 and 2

4.1.4.1 Efficacy of the hand-feeding regime for both experiments 3A and 3B

All the experimental sheep maintained their LW (~51.5 kg) and CS (~3.2) over the 13 days of the experiment demonstrating the efficacy of the hand feeding regime.

4.1.4.2 Experiment 3A

Overall, the experienced sheep ate (70% of feed offered in the first 60 minutes) more tedera than the naïve sheep (56%) throughout the six days of the experiment (Figure 5). There was a similar strong linear increase in the amount eaten each day for both groups of sheep. A regression analysis of the data in Figure 5 indicated the lines were significantly different (p<0.001) and had significantly different slopes (p<0.05).

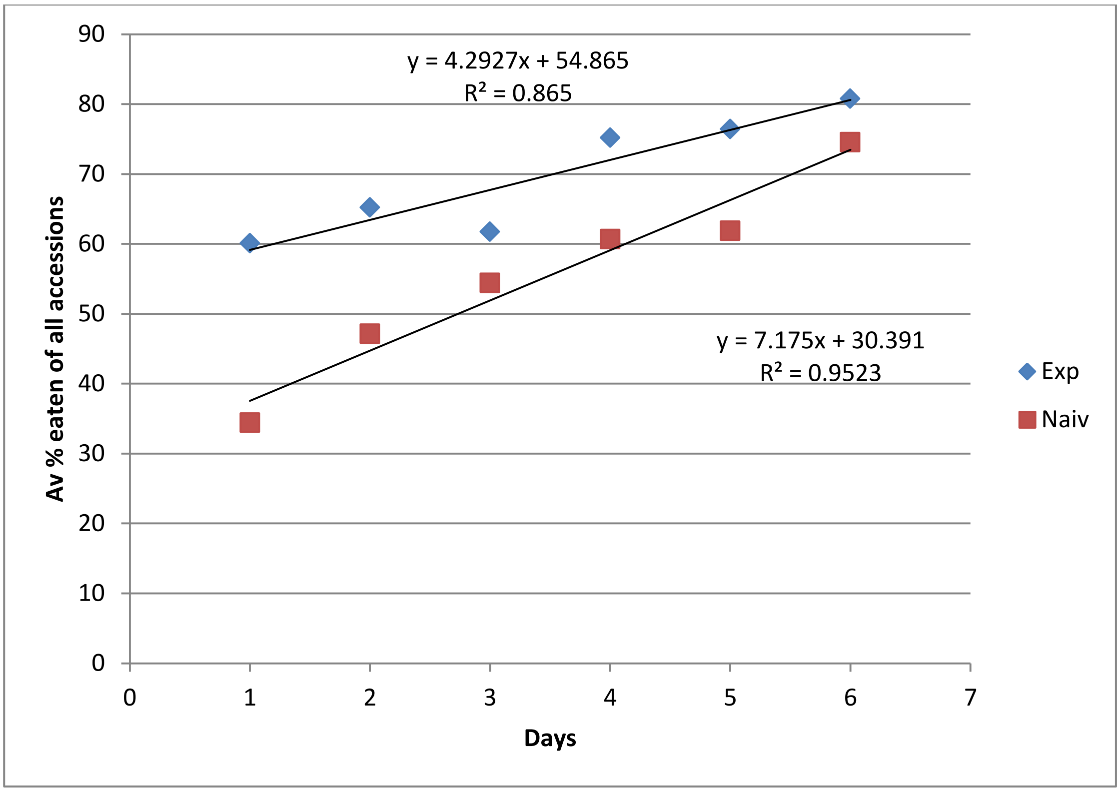
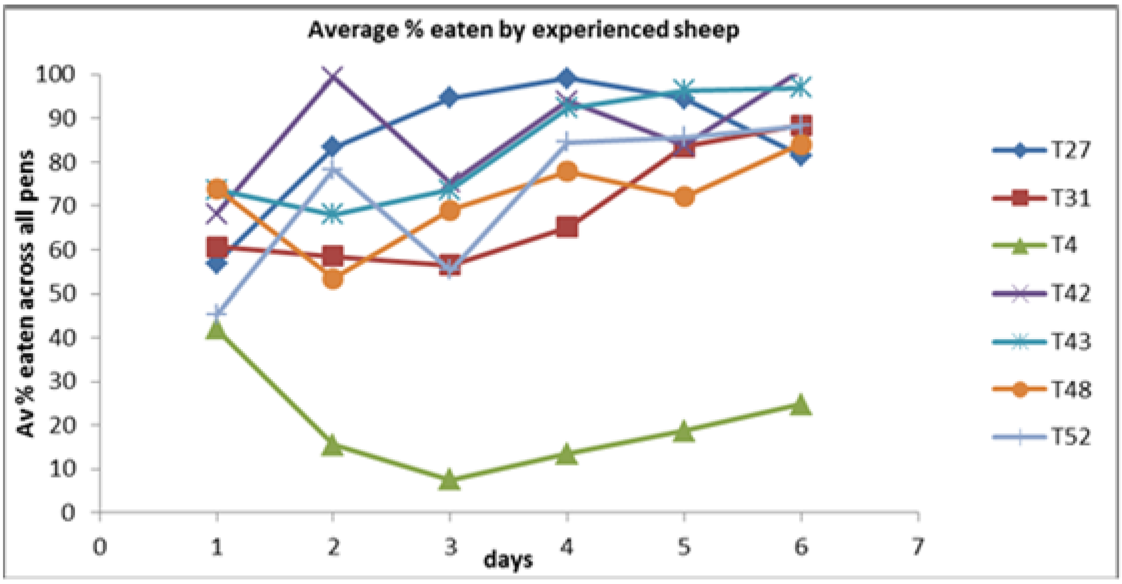


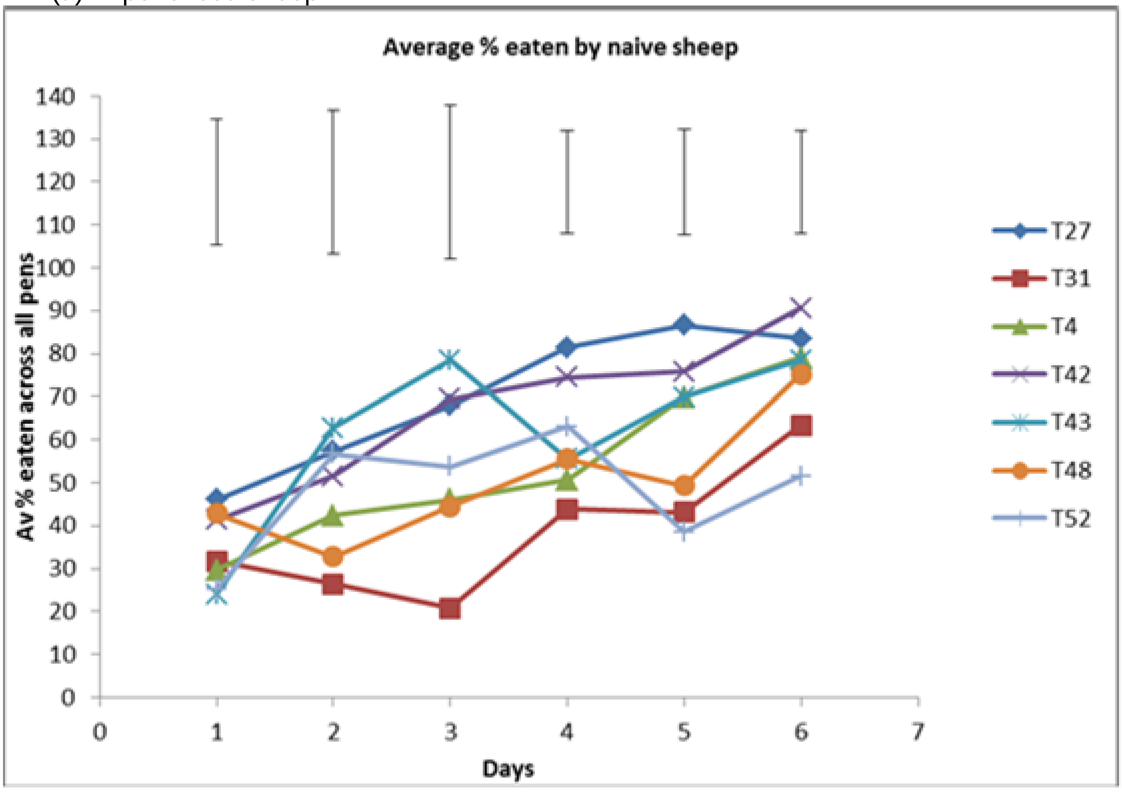
Figure 5. The average % of the tedera offer that was eaten in the first 60 minutes by the experienced (diamond) and naïve (square) sheep over the six days of the experiment (4.1.4)

The intake of the tedera was measured at the end of the first 60 minutes (average % of the initial fresh tedera, 2 x 250 g, eaten from each of the seven accessions). The feeders were then returned to the pens and the % eaten reassessed after a further 60 minutes of exposure to the sheep. Typically, the sheep ate from every feeder but only the experienced group ever ate all of the tedera in the first 60 minutes (see Figure 6a and 6b). Nonetheless, the sheep in some pens did eat all of some accessions in the first 60 minutes. All further analysis is based on the relative intake in the first 60 minutes.

The intake of tedera accession T42 by the sheep that had previously (summer 2014) grazed exclusively on this accession was high but not different from accessions T27 and T43 (Figure 6a). In fact the relative ranking (% eaten in the first 60 minutes) of each accession of tedera eaten was remarkably consistent over the 6 days of feeding for both the experienced and naïve sheep (Figure 6). However, the dramatic exception was the intake of accession T4 by the experienced sheep (Figure 6a). In this case each of three pens of two sheep expressed a clear aversion to eating T4 after the first day.



(a) Experienced sheep



(b) Naïve sheep

Figure 6. The % of each accession of tedera eaten in the first 60 minutes each day for (a) the experienced sheep and (b) for the naïve sheep. The bars represent LSD intervals at 5% significance level for comparing accessions within (a) or (b)

The relationship between two methods for assessing preference by sheep amongst the seven accession of tedera and the performance of sheep when constrained to a single accession of tedera is shown in Table 6. In this table the rank order (1 is best and 7 is worst) has been assigned on a simple numerical difference and therefore makes no assumptions about statistical differences. Nonetheless, it appears that clear differences in the growth rate of accessions (or groups of accessions) are not well predicted by either method of assessing preference.

Table 6. The relative merits of the seven accessions of tedera in autumn 2014 when assessed by relative intake when sheep fed in pens are given choice of freshly cut edible leaf and stem (Experiment 3) or relative intake when sheep are given choice of areas of each grazed in common (Experiment 1) or the relative growth rate of sheep when they are grazed exclusively on a particular accession i.e. where choice is removed (Experiment 2)

Accession	Experiment 3. Av % eaten (Pen)		Rank	Experiment 1. Chesson-Manly Index	Rank	Experiment 2. Growth rate (g/head/day)		Rank
T4*	60	b	2	0.212	1	233	ab	2
T27	78	a	1	0.146	4	-48	c	4
T31	53	b	2	0.137	5	291	ab	2
T42	77	a	1	-0.001	7	330	a	1
T43	73	a	1	0.202	2	152	bc	3
T48	61	b	2	0.187	3	248	ab	2
T52	60	b	2	0.118	6	178	bc	3

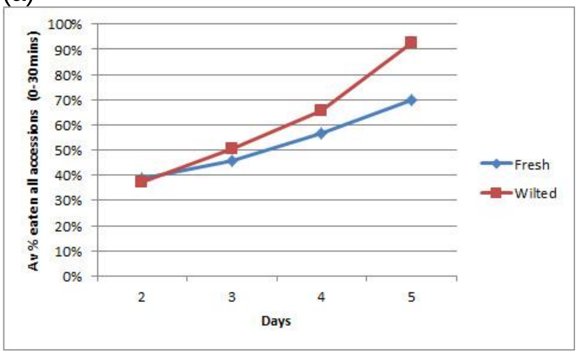
*The data for Experiment 3, T4 only included in the results for the naïve group of sheep
Accessions that share a common letter are not significantly different ($p<0.05$)

4.1.4.3 Experiment 3B

The results from this pen experiment are based on four days of records from the five days experiment. Day1 of the five-day pen experiment was affected by rain. Voluntary feed intake measurements were collected at four 30 minute intervals (30, 60, 90 and 120 minutes). In a similar manner to Experiment 3A the general trend of the discrimination by the sheep of the feeds was evidenced following the initial 30 and 60minutes intervals.

The results were generated using an analysis of variance (block (pen) x treatment x accession) as total percentage eaten of all accessions and over the four days of the experiment (Figure 7 and 8).

(a)



(b)

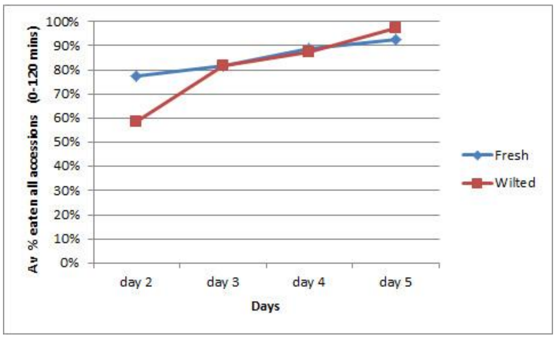


Figure 7. Comparison of average % eaten of fresh and wilted tedera (combined accessions) over the four days in (a) first 30 minutes; (b) two hours

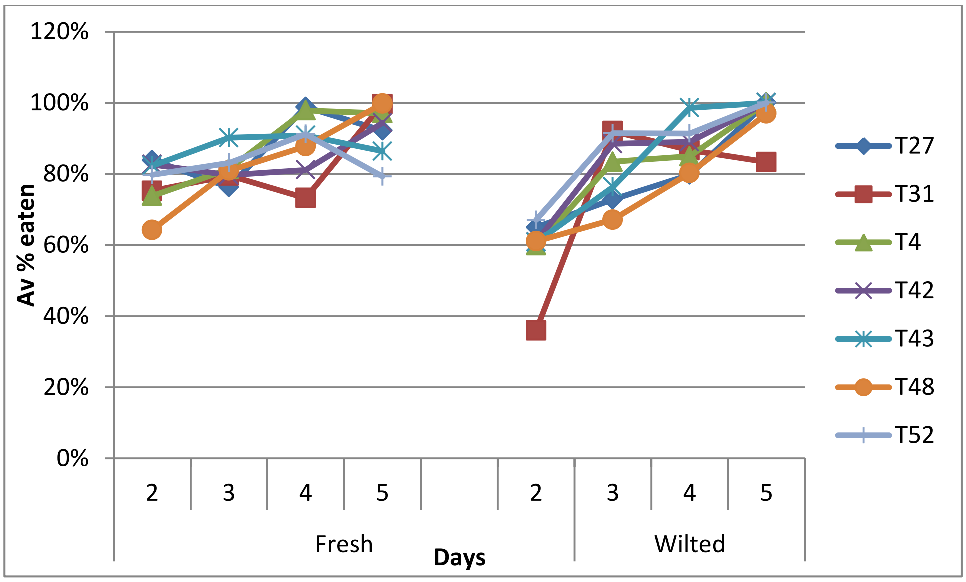


Figure 8. The average % eaten (0-120 mins) of each accession over the 4 days of both feed types (fresh and wilted tedera)

At all feed intervals (averaged across the 4 days) there was no significant difference between the two feed types (30 minutes P: 0.431; 60 minutes P: 0.927; 90 minutes P: 0.801 and P: 120 minutes 0.920). Sheep did not discriminate significantly between fresh and wilted tedera.

4.1.5 Nutritive value of tedera

It is important to note that the data analysed in this section were samples whose nutritive attributes were arrived at using appropriate wet chemistry methods in a NATA accredited laboratory in NSW DPI laboratory. The key elements of nutritive value presented in this section are crude protein (CP), digestibility of dry matter (DMD) and metabolisable energy (ME). The seven accession of tedera differed in their CP but not in DMD or ME (Table 7).

Table 7. The concentration of crude protein (CP), digestibility of dry matter (DMD) and metabolisable energy (ME) of the seven accession of tedera in samples of edible leaf and stem taken before grazing.

Attribute	Accession of tedera								Significance @ 0.05
	4	27	31	42	43	48	52	LSD	F pr.
CP	17.27	15.37	13.97	14.44	13.75	13.88	15.29	1.99	0.014
DMD	72.22	70.41	70.54	72.98	70.77	73.50	71.92	3.77	NS
ME	10.80	10.49	10.51	10.93	10.55	11.02	10.75	0.65	NS

All three attributes of nutritive value were affected by the season of grazing (Table 8) but there was no season by accession interaction; i.e. the effect of season was not different for any of the seven accessions of tedera.

Table 8. The concentration of crude protein (CP), digestibility of dry matter (DMD) and metabolisable energy (ME) of the seven accession of tedera in samples of edible leaf and stem taken at each season of the experiment.

Attribute	Season of grazing					Significance @ 0.05
	Winter	Spring	Summer	Autumn	LSD	F pr.
CP	13.77	15.27	12.57	17.90	1.21	<0.001
DMD	72.76	69.58	74.09	70.20	2.70	0.002
ME	10.90	10.35	11.12	10.45	0.46	0.002

The CP content of the edible leaf and stem of tedera did not vary over the 14 days of grazing. By contrast, the DMD and ME decreased during grazing; presumably as the ratio of leaf to stem decreased (Table 9).

Table 9. The concentration of crude protein (CP), digestibility of dry matter (DMD) and metabolisable energy (ME) of the seven accession of tedera in samples of edible leaf and stem taken during grazing across the four season of the experiment.

Attribute	Day of grazing						Significance @ 0.05
	0	3	7	10	14	LSD	F pr.
CP	15.75	14.61	15.01	14.64	13.69	1.78	NS
DMD	72.73	75.07	72.39	71.43	68.34	3.05	0.002
ME	10.89	11.29	10.83	10.67	10.14	0.52	0.002

4.2 Grazing tedera in mixtures with annual species at Kojonup

4.2.1 Pasture production

The average total annual production from each of the treatments is presented in Table 10.

- **A** – annual pasture alone
- **ATL –** annual pasture plus tedera grazed in a long rotation (14 days on and 70 days off)
- **ATS** - annual pasture plus tedera grazed in a short rotation (14 days on and 28 days off)

The 2014 season had very good rainfall, optimal for annual species growth (Appendix 1).

Table 10. Annual production of the three pasture treatments at Kojonup in 2014.

Treatment	Average total annual pasture plus tedera (kg DM/ha)	Total tedera (kg DM/ha)	Annual only (kg DM/ha)	% tedera
A	8499		8499	0.0
ATL	9990	648	9342	6.5
ATS	10943	716	10227	6.5

The average pasture growth rate (PGR) for each treatment is shown in Figure 9. During the growing season the tedera appears to be substituted for annual production in the tedera treatments hence there is no additional production from tedera during this period.

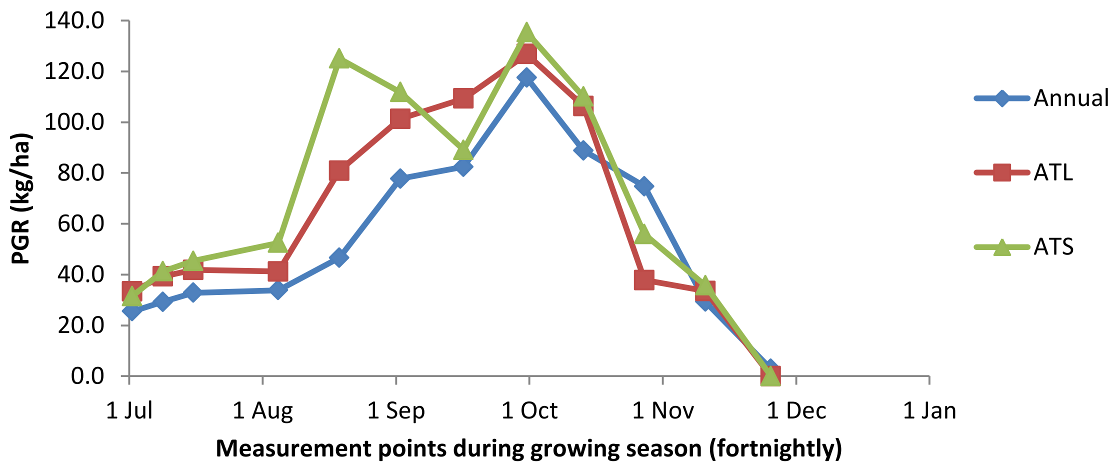


Figure 9. PGR for the three pasture treatments (4.2.1).

The annual pasture also produced a uniform and good balance of legume and grass across the whole site (Table 11).

Table 11. Average pasture composition of the annual pasture (BOTANAL of all 48 plots; % of green biomass) at the experimental site at Kojonup on 26th June 2014.

Treatment	Sub-clover	Ryegrass	Other	bare ground
A	36	56	6	0
ATL	38	45	14	3
ATS	37	48	13	2
LSD (p<0.05)	13	14	8	5

Tedera was sown into the ATS and ATL plots on the 28 August 2013. Since sowing, the germination and persistence of the tedera was monitored by mapping the seedlings on fixed 5 m transects established in each plot (N=36). Just after the break-of-season in 2014 the overall establishment of tedera was 5.8 seedlings/m of row or 12 seedlings/m^2. The establishment was similar across all of the plots with tedera (Table 12).

Table 12. Average number of tedera seedlings/m of monitoring transect (each 5m long) just after the break-of-season (26th June 2014) in each replicate of the pastures sown to tedera.

Treatment replicate	Seedlings	
ATL1	4.7	a
ATS1	6.8	a
ATL2	5.8	a
ATS2	5.5	a
ATL3	5.5	a
ATS3	6.5	a
ATL4	5.8	a
ATS4	5.5	a

Treatment replicates that share a common letter are not significantly different ($p<0.05$)

The contribution (% of the total DM on offer) of the tedera to the total FOO for the ATL and ATS treatments at the beginning and end of the growing season is shown in Table 13. There was no effect of the replicates (blocks) on the total FOO produced for the growing season and there was a similar number of tedera plants/m^2 in all replicates at the break–of-season (Table 12). Hence, in the first growing season of the annual pasture since the tedera was sown, the tedera grew better on the higher, more sandy and well drained part of the site (replicates 3 and 4; Figure 3 – Deep sandy duplex on upper slope) than the lower, less sandy and less well drained areas (replicates 1 and 2; Figures 1 and 4).

Table 13. The percentage of the feed on offer (FOO; kg DM/ha) on (a) 27th June and (b) 28th October that was tedera (4.2.1)

(a)

Pasture treatment	Tedera - % of the total biomass 27th June 2014			
	Replicate			
	1	2	3	4
ATL	7 b	9 b	36 a	31 a
ATS	13 bc	9 c	17 b	33 a

(b)

Pasture treatment	Tedera - % of the total biomass 28th Oct 2014			
	Replicate			
	1	2	3	4
ATL	1 b	3 b	16 a	19 a
ATS	5 a	1 b	6 a	11 a

Replicates within treatments that share a common letter are not significantly different ($p<0.05$)

4.2.2 Sheep production

The liveweight of the young ewes since they were introduced to the site in July are presented in Figure 10. As previously stated FOO values equal at least the best 10 years in the last 100 for the Kojonup district. Hence, it was not surprising that the ewes grew similarly in all treatments and replicates until the annual pastures senesced. There was no significant difference between the sheep live weights in the three treatments pre-shearing, except in the 11 November 2014 that the two tedera treatments were significantly better than the annual treatment (Figure 10). The significant difference between the two tedera treatments and the annual treatment is maintained post- shearing until the end of the trial (Figure 11).

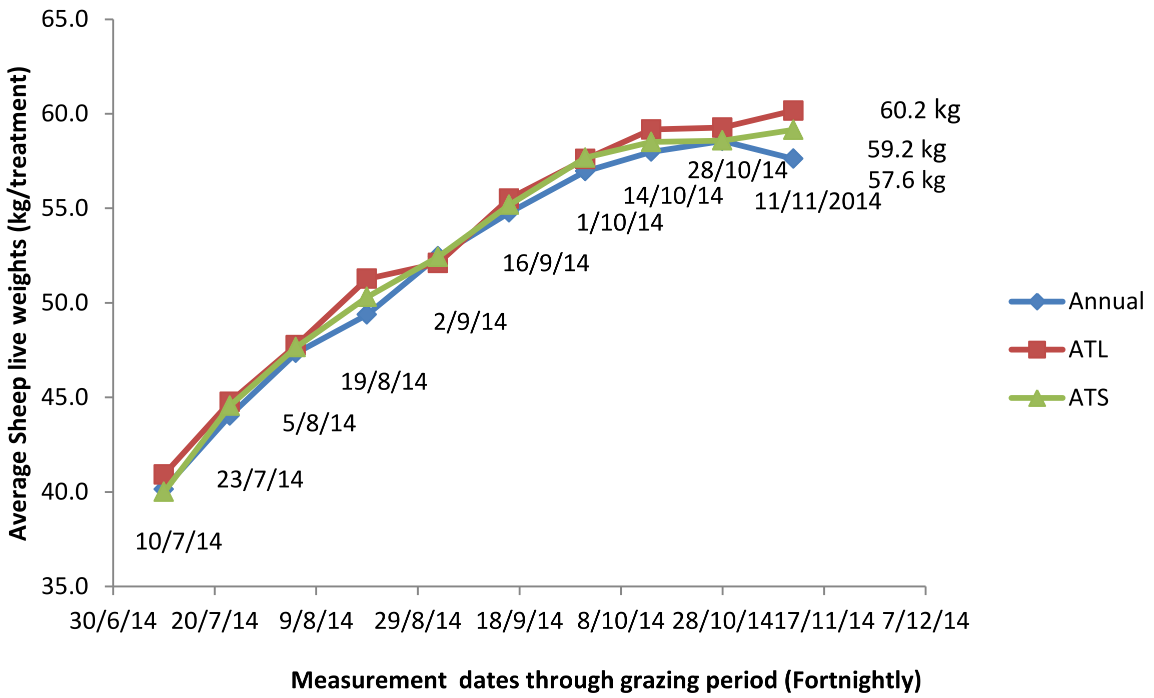


Figure 10. Average sheep liveweight (pre-shearing) from the 10th June 2014 to the 11th Nov. 2014

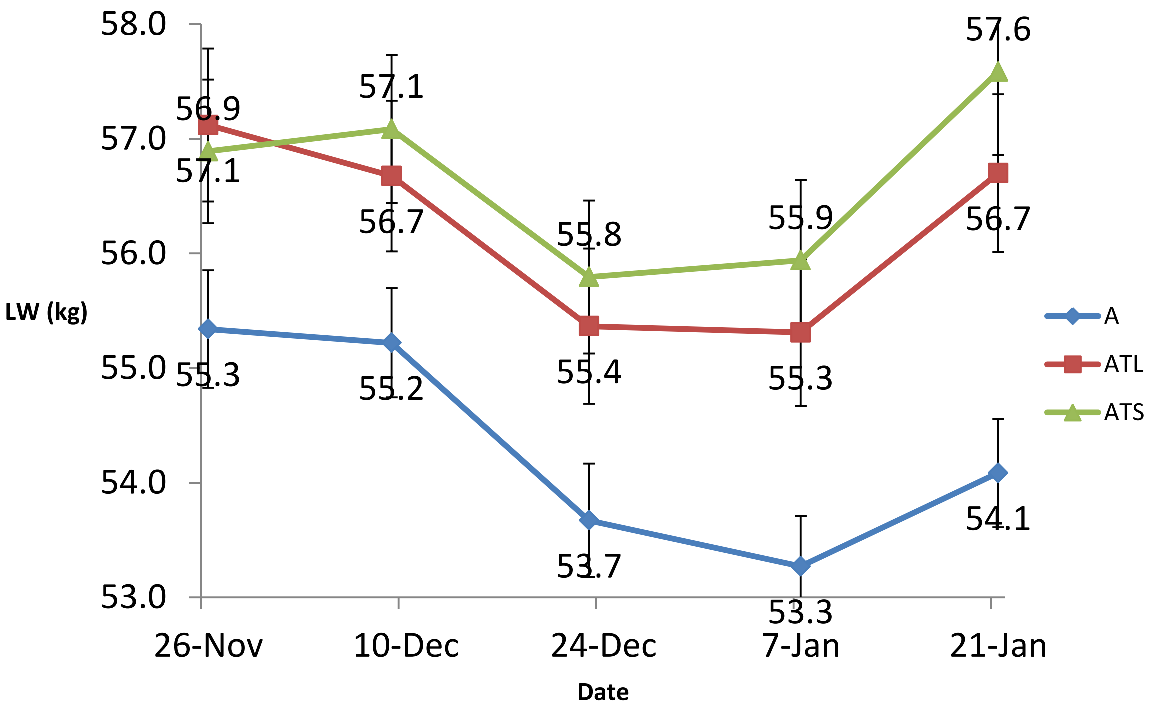


Figure 11. Post-shearing sheep live weights up to the 21 January, (Shearing was 12 November 2014)

4.2.3 Sheep health

There were no health issues with the sheep grazing the tedera in combination with annual pasture. Sheep were treated for intestinal parasites at the commencement of the experiment and tested for faecal worm counts on a monthly basis and further drenching was not required.

Pregnancy testing indicates that there was no significant difference between experimental treatments on pregnancy 62% or twinning 8%.

4.3 Production and persistence of tedera with or without competition of annual pasture based on plot studies at Kojonup

The number of tedera plants/m^2, total biomass per plot and biomass per plant are presented in Table 14.

Table 14. Number of tedera plants, total biomass per plot and biomass per plant

	Number of tedera plants/m^2	Biomass per tedera plant (g)	Biomass Kg/ha
14 October 2015			
Tedera	1.6a	14.7a	244b
Tedera plus annuals	1.3a	4.5b	4443a
Annuals			4302a
LSD (5%)	0.45	7.2	803
23 February 2016			
Tedera	2.2a	23a	518a
Tedera plus annuals	2.3a	22a	548a
Annuals			0b
LSD (5%)	0.50	12	374
3 May 2016			
Tedera	1.7a	20a	353b
Tedera plus annuals	1.9a	25a	2761a
Annuals			2491a
LSD (5%)	0.8	8.1	623

The number of tedera plants was not significantly affected by the competition imposed by the annual species. There was an average of 1.5, 2.3 and 1.8 plants/m^2 for the 14 October 2015, 23 February 2016 and 3 May 2016 respectively. Total biomass produced by the tedera plants without competition was significantly higher than with competition on the 14 October 2015. On average, plants with competition were only 30% of the weight of plants without competition. However, the same biomass per plant was recorded for the 23 February 2016 and 3 May 2016 harvest. The biomass production/ha was compared for the three treatments. The tedera only treatment was less productive on the 14 October 2015 and 3 May 2016, but in the middle of summer, when there is no annual species production, produced >500 kg/ha. The tedera plus annual treatment produced the same as the annual only treatment on the 14 October 2015 and 3 May 2016, but had the additional production of >500 at the 23 February 2016 harvest.

4.4 Grazing trial during summer and autumn at Dandaragan 2014/15, Dandaragan 2016 and Kojonup 2016

4.4.1 Tedera production

The tedera production for the continuously and rotationally grazed plots at Dandaragan in 2014/15 is presented in Figure 12. For the continuously grazed treatment, FOO declined linearly at 27 kg DM/ha.day from the 2 December 2014 until the 27 January 2015. Thereafter FOO was maintained at around 500 kg DM/ha until 24 March 2015 when the treatment was de-stocked. For the rotationally grazed plots, the six plots were grazed in order from RG-2 to RG-7. After every grazing, FOO declined dramatically to ≤ 600 kg DM/ha, thereafter the plants recovered and FOO increased until the next grazing at an average of 13 kg DM/ha.day. This re-growth, allowed the rotationally grazed treatment to be extended in comparison with the continuously grazed treatment and grazing was finished on the 21 April 2015 instead of the 24 March 2015 for the continuously grazed treatment. For the plots that were grazed last in the rotation, a decline in quantity was observed due to some drop of old leaves as the season progressed. For example, the last plot in the rotation (RG-7) started the experiment with 1400 kg DM/ha and by the time of starting it's grazing, it had 1000 kg DM/ha.

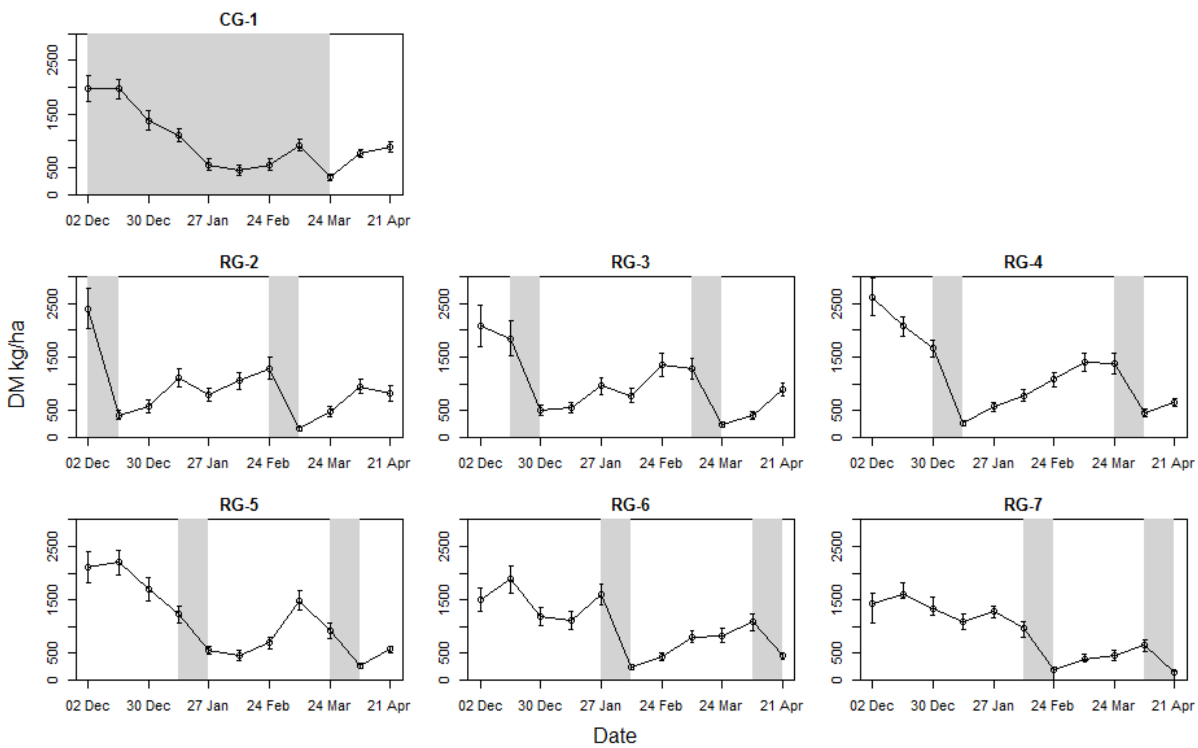


Figure 12. Tedera feed on offer for the continuously grazed (CG-1) and rotationally grazed (RG2-RG-7) treatment plots at Dandaragan in 2014-15. Shaded area indicates grazing times. Error bars are the standard error based on variation between the 30 sampling sites estimates, ignoring calibration curve error.

The tedera production at Dandaragan 2016 and Kojonup 2016 are presented in Figures 13 and 14 respectively. At Dandaragan, the FOO at the start of grazing on 2 February 2016 was 500 kg DM/ha, much less than the previous year which started at 2000 kg DM/ha. At Kojonup the FOO at the start of grazing (900 kg DM/ha) was greater than Dandaragan 2016 but less than Dandaragan 2014-15. For the continuously grazed plot, a steady decline in FOO was observed for the first 56 days of the grazing period at both sites (7 kg DM/ha.day and 14 kg DM/ha.day for Dandaragan and Kojonup respectively). Thereafter FOO was maintained at between 100 and 200 kg DM/ha until the 26 April 2016 (Dandaragan) and the 3 May 2016 (Kojonup) when the treatments were de-stocked. For the rotationally grazed plots, the six plots were grazed in order from RG-2 to RG-7. At the start of grazing in each plot FOO was on average 700 kg DM/ha at Dandaragan and 1000 kg DM/ha at Kojonup. However, grazing rotationally for 14 days reduced the FOO at Dandaragan by an average of only 200 kg DM/ha over the first three plots, and reduced FOO by 600 kg DM/ha in the next two plots. However in the last plot, following good rainfall in March and April, FOO increased by 200 kg DM/ha. By contrast at Kojonup, grazing typically reduced the FOO from around 1000 kg DM/ha to < 200 kg DM/ha (bare stumps 5 to 10 cm high). At both sites, the tedera responded to grazing by rapid and sustained growth within 14 days of the sheep being removed. At both sites, grazing management treatments were finished after one rotation because there was an early break of the season with good rains in late March and April 2016; therefore, there was no need to extend the duration of the trial. This decision coincided with the farmers stopping their hand-feeding of sheep at both sites.

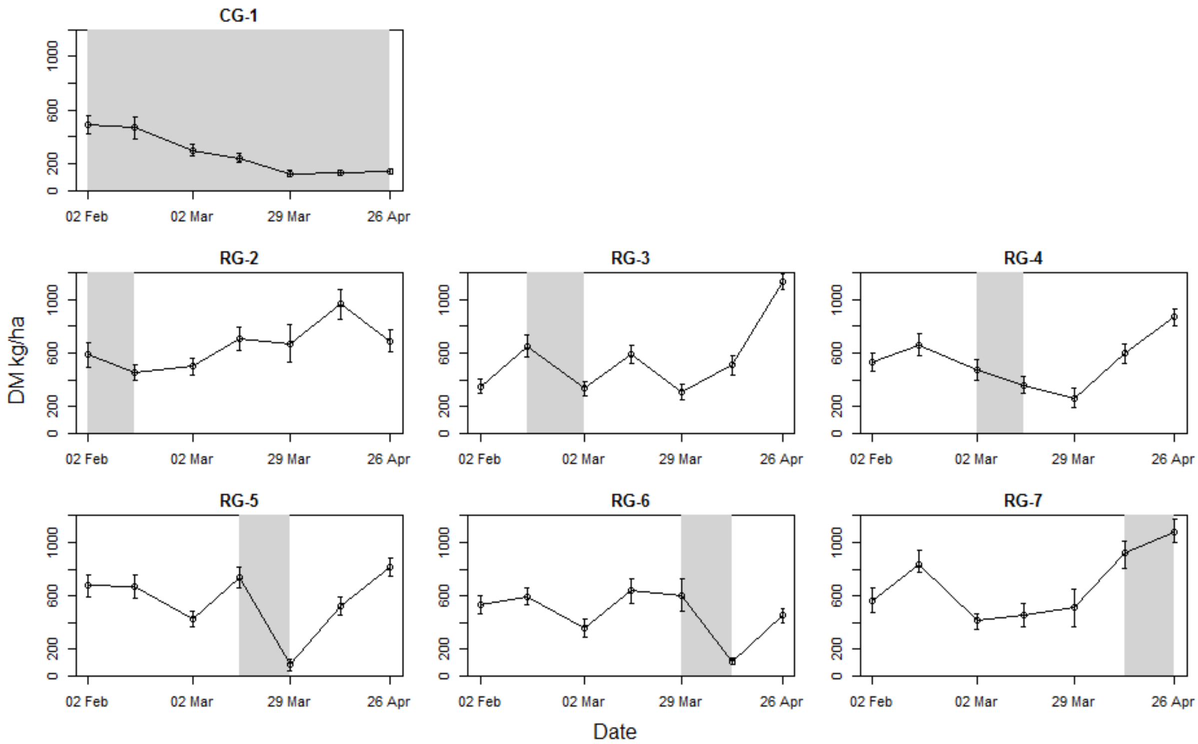


Figure 13. Tedera feed on offer for the continuously grazed (CG-1) and rotationally grazed (RG2-RG-7) treatment plots at Dandaragan in 2016. Shaded area indicates grazing times. Error bars are the standard error based on variation between the 30 sampling sites estimates, ignoring calibration curve error.

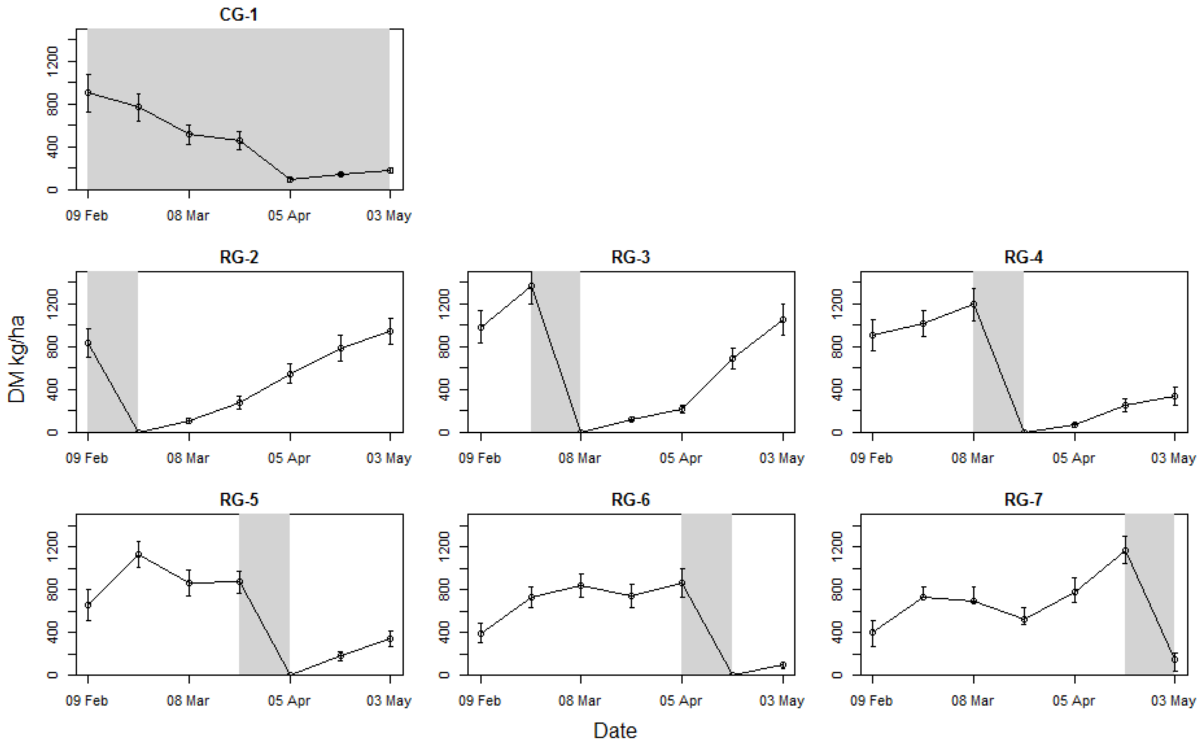


Figure 14. Tedera feed on offer for the continuously grazed (CG-1) and rotationally grazed (RG2-RG-7) treatment plots at Kojonup 2016. Shaded area indicates grazing times. Error bars are the standard error based on variation between the 30 sampling sites estimates, ignoring calibration curve error.

4.4.2 Plant persistence

At Dandaragan 2014/15 and 2016, there was no significant reduction in plant numbers due to the summer and autumn grazings (Table 15) for both grazing treatments. This result clearly demonstrates the extreme tolerance of tedera of grazing by sheep. At Kojonup 2016, both treatments had a similar reduction in plant number for the whole grazing period of 0.75 and 0.76 plants/m^2 for the CG and the RG. Due to the higher replication of the rotational grazing (6 plots x 3 areas) this difference was significant while it was not significant for the CG with only three sampling areas.

Table 15. Average density (plants/m^2) of green/actively growing tedera plants at the start and end of the trials for continuous grazing (CG) and rotational grazing (RG).

Trial	Treatment	Start of grazing	End of grazing	SED*	Significance[A]
Dandaragan 2014/15	CG	2.50	3.00	0.38	n.s.
	RG	2.82	2.64	0.23	n.s.
Dandaragan 2016	CG	1.67	1.42	0.14	n.s.
	RG	1.61	1.42	0.12	n.s.(p=0.115)
Kojonup 2016	CG	3.67	2.92	0.38	n.s.
	RG	3.00	2.24	0.14	p<0.001

[A] CG comparison based on only three areas compared to 18 for RG.

4.4.3 Nutritive value

The tedera samples taken from the field were separated into leaf and stem fractions in the laboratories of DAFWA. The quality results for metabolisable energy (ME), dry matter digestibility (DMD), crude protein (CP), acid detergent fibre (ADF) and ashes (ASH) analysed using near infra-red spectrophotometry (NIR; Adriansz *et al.* 2016) are presented in Table 16 for the three experimental sites. The DM in tedera plants before grazing in summer-autumn was partitioned into 46% leaf and 54% edible stem for Dandaragan 2014 and 79% leaf and 21% edible stem for Kojonup 2016. Data for Dandaragan 2016 is not available.

Table 16. Tedera quality results for metabolisable energy (ME), dry matter digestibility (DMD), crude protein (CP), acid detergent fibre (ADF) and ashes (ASH) analysed using near infra-red spectrophotometry.

Site	Plant part	ME	DMD	CP	ADF	ASH
Dandaragan 2014/15	Leaf	10.9	67.5	11.5	25.3	6.8
	Stem	9.6	61.9	7.8	35.3	4.6
Dandaragan 2016	Leaf	10.0	60.9	13.5	25.7	9.1
	Stem	8.3	53.0	7.8	41.7	5.4
Kojonup 2016	Leaf	10.4	65.3	12.6	26.6	6.4
	Stem	9.2	58.4	8.9	38.6	3.9
l.s.d.		0.9	5.3	2.0	4.8	0.9

4.4.4 Sheep production

The liveweight and condition score of the sheep for the duration of the experiment for the continuously and rotationally grazed treatments at Dandaragan in 2014/15, Dandaragan 2016 and Kojonup 2016 are presented in Figure 15 and Figure 16. For all experiments, the sheep in the continuously grazed treatments had significantly improved production in the initial period when there was more tedera and choice between leaf and edible stem (Photo 6).

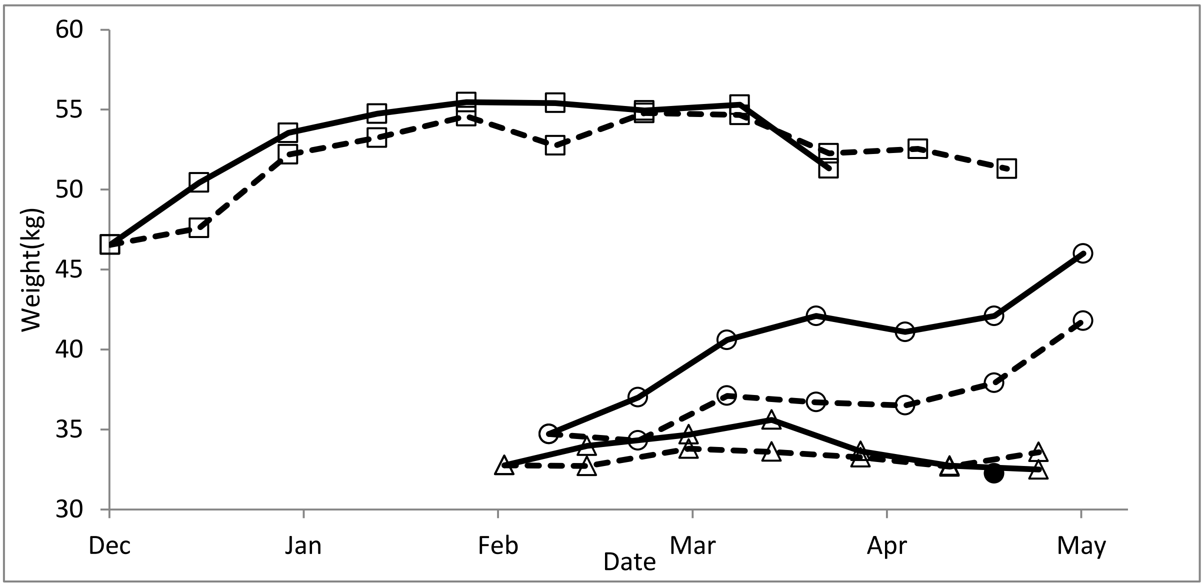


Figure 15. Live weight for the continuously (solid lines) and rotationally (dashed lines) grazed sheep for Dandaragan 2014/15 (squares), Dandaragan 2016 (triangles) and Kojonup 2016 (circles). The average l.s.d. for comparing between grazing methods is 1.8, 1.0 and 1.4 kg respectively. The solid circle in mid-April is the average live weight of 30 sheep drawn at random from the source flock after typical summer-autumn management by the farmer.

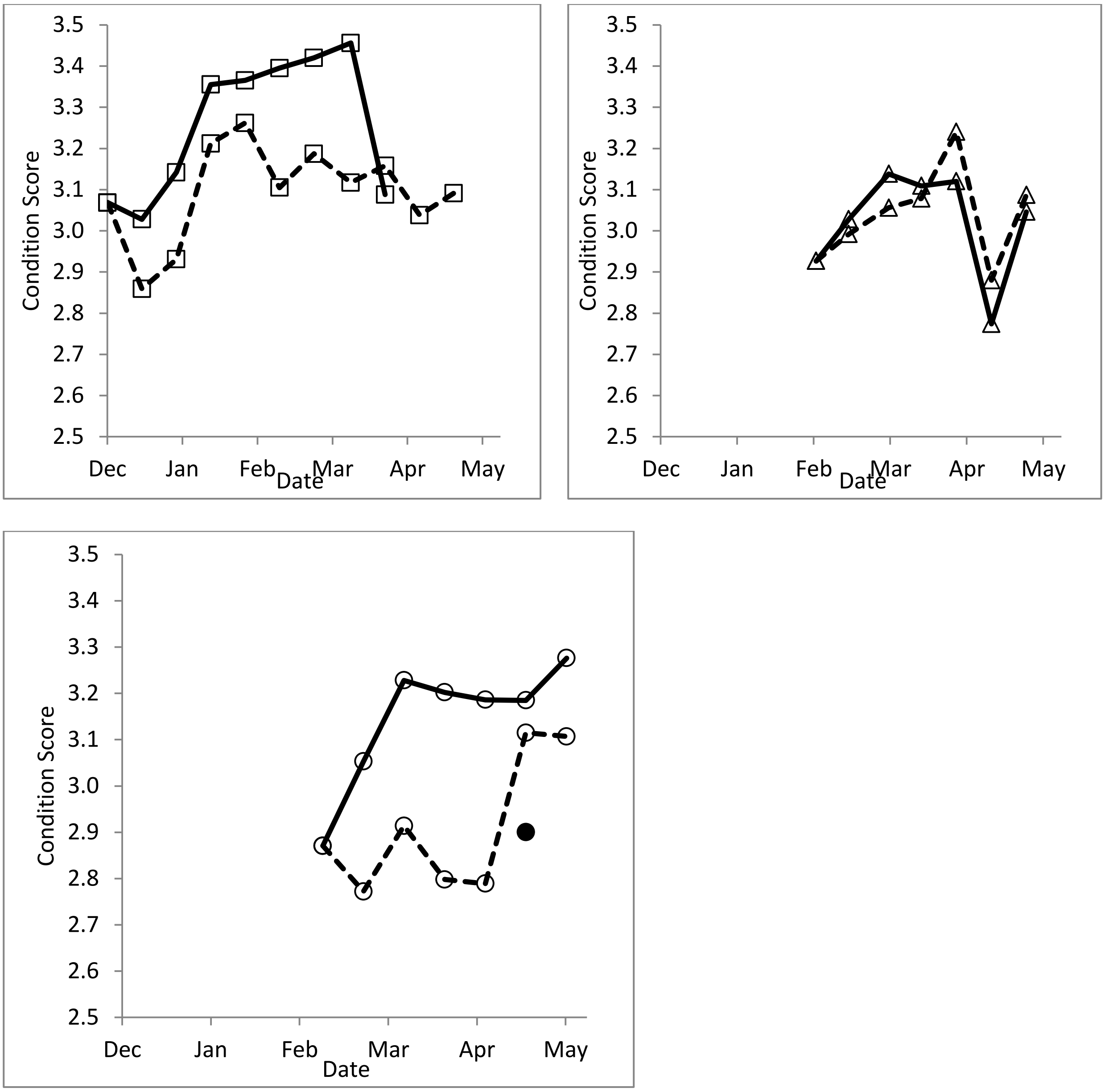


Figure16. Condition score for the continuously (solid lines) and rotationally (dashed lines) grazed sheep for Dandaragan 2014/15 (squares), Dandaragan 2016 (triangles) and Kojonup 2016 (circles). The average l.s.d. for comparing between grazing methods is 0.16, 0.17 and 0.14 respectively. The solid circle in mid-April is the average live weight of 30 sheep drawn at random from the source flock after typical summer-autumn management by the farmer.


(a) after 30 days of grazing (30 December 2014)


(b) after 56 days of grazing (27 January 2015)


(c) grazed plant showing new growth (27 January 2015)


(d) after 84 of grazing (24 February 2015)


(e) after 112 days of grazing (24 March 2015)


(f) after 23 days of recovery (21 April 2015)

Photo 6. Dandaragan 2014-15, Continuous grazing treatment

At Dandaragan 2014/15, the difference reduced over time so that there was no significant difference in the sheep performance between the two grazing treatments for liveweight and condition score at the 24 March 2015 when the continuously grazed treatment was terminated. By contrast, the sheep in the rotationally grazed treatment continued to graze and maintain live weight and condition score another month; until the 21 April 2015 (Photo 7).


(a) before start of grazing (2 December 2014)


(b) plot after 14 days of grazing (30 December 2014)


(c) plot after 70 days of recovery (24 February 2015)


(d) plot after second 14 days of grazing (10 March 2015)


(e) plot after 42 days of recovery (21 April 2015)


(f – left of the fence) plot still to be grazed (27 January 2015); and (f- right of the fence) plot after 14 days of grazing (27 January 2015)

Photo 7. Dandaragan 2014-15, rotational grazing treatment

At Dandaragan 2016 the initial improved performance of the continuous group was reversed over time so that the sheep being rotationally grazed had significantly higher GR by the end of the experiment. By contrast, at Kojonup 2016, the sheep performance for continuous grazing was significantly better than the rotational grazing throughout the trial (see Figures 15 and 16 and Photos 8 and 9). At Kojonup the sheep of the same flock used to source the experimental sheep that were managed by the farmer (stocked at 6.2 sheep/ha and fed 170g of barley or oat grain daily) and they were about 6 kg lighter than the experimental sheep at the second last weighing (Figure 15).

(a) Plot 1 of the rotational grazing sequence before grazing on the 9 February 2016

(b) Plot 1 of the rotational grazing sequence after 14 days of grazing on the 23 February 2016

(c) Plot 1 of the rotational grazing sequence after 42 days of recovery on the 5 April 2016

Photo 8. Kojonup 2016, rotational grazing treatment


(a) Continuous grazing treatment before grazing on the 9 February 2016


(b) Continuous grazing treatment after 30 days of grazing on the 8 March 2016


(c) Continuous grazing treatment after 60 days of grazing on the 5 April 2016

Photo 9. Kojonup 2016, continuous grazing treatment

4.5 Calibration of Near Infrared Spectrophotometry for tedera quality

Eight of the 11 calibrations for nutritive attributes of tedera have RPD (SD of reference data**/** standard error of cross validation) values above 3.0 indicating the calibrations for ADF, CP, Fat, Ash, OM, DMD, DOMD and ME are sound and robust (Table 17). The calibrations for AD-L, NDF and NSC have quite large SECV values and RPD values under 3.0 indicating the calibrations for these three nutritive attributes of tedera are unsatisfactory for use using NIR, especially the calibration for AD-L (Adriansz *et al.* 2016).

Table 17: NIRS calibration statistics for 11 nutritive attributes of tedera (4.5)

Nutritive attribute	PC	SEC	RSQ	SECV	RPD
Acid Detergent Fibre (ADF)	4	0.88	0.98	0.96	6.39
Acid Detergent Lignin (AD-L)	1	1.61	0.25	1.65	1.12
Neutral Detergent Fibre (NDF)	3	2.95	0.87	3.15	2.55
Non-Structural Carbohydrates (NSC)	4	2.56	0.85	2.92	2.23
Crude Protein (CP)	9	0.38	0.99	0.45	7.61
Fat	10	0.11	0.97	0.13	4.58
Ash	9	0.33	0.94	0.38	3.44
Organic Matter (OM)	9	0.33	0.94	0.38	3.44
Dry Matter Digestibility (DMD)	4	1.45	0.95	1.53	4.05
Digestible Organic Matter in DM (DOMD)	4	1.25	0.94	1.32	3.97
Metabolisable Energy (ME)	4	0.25	0.95	0.26	4.03

PC = principal component factors; SEC = standard error of calibration;
RSQ = prediction regression coefficient;
SECV = standard error of cross validation; RPD = SD of reference data/SECV.

DAFWA's NIRS machines are set up for doing quality analysis of tedera.

5 Discussion

5.1 Grazing pure stands of tedera in winter, spring, summer and autumn at Dandaragan

General - In each season, naïve sheep were introduced to the tedera plots directly from commercial pastures for seven to 14 days. In every season, irrespective of the incidence of alternative grazing in the tedera inter-row space, it has taken three to four days for the sheep to begin to eat significant amounts of tedera. However, after starting to graze, they ate all seven accessions and there were no health issues.

The key measures of nutritive value (overall averages of 15% for CP, 72% for DMD and 11mj for ME) of the edible leaf and stem of tedera are indicative of forage on which sheep will gain weight (Freer *et al.* 1997). When the sheep grazed exclusively on each of the seven accessions for 14 days (Experiment 2) the GR (>200g/head/day) of sheep grazing accessions T31 and T48 reflected this analysis in all four seasons of the year. However, while in all cases sheep grazing the other five accessions of tedera at least maintained their liveweight and condition score, their growth rate varied widely between accessions and between seasons. The differences between accessions and seasons was not explained by differences in nutritive value as assessed by CP, DMD and ME or by preference as measured in (Experiment 1; 7 accessions grazed in common for 7 days) or when they were fed the seven accessions in pens (Experiment 3).

Specific;

- The first hypothesis that naïve sheep would show the same relative preference (palatability) for accessions of tedera in the four seasons was rejected. The results for the relative preference among the seven accessions in the four seasons to date (Experiment 1; Table 2) strongly suggested that the ranking (most preferred = 1 to least preferred = 7) changed between seasons.

- The second hypothesis that the gain in liveweight and condition score of sheep constrained to single accessions at the same grazing pressure would be the same for all accessions and seasons was rejected as the sheep had growth rates significantly different between accessions and seasons (Table 5). There was little consistency between accessions for relative preference (Experiment 1, Table 2) but reasonable consistency for growth rate (Experiment 2, Table 5). Accessions T31 and T48 stand out as moderate to high producers of DM/ha as well as high and consistent growth rate of the sheep grazing them (Table 5). Importantly, sheep grazing these accessions continued to grow at around 200 g/head/day even in summer when the sheep grazing the other five accessions only maintained liveweight, all be it in good body condition.

- The third hypothesis that preference of naïve sheep among tedera accessions fed fresh in pens will rank the same as the preferences of sheep in the field study (Experiment.1) was rejected as the ranking of preference for the two methods was different (Table 6). The relative preference/palatability estimated by grazing in common (Experiment 1) or by feeding freshly cut edible leaf and stem to sheep in pens (Experiment 3) was not clearly related to performance (growth rate) nor were they related to the key measures of nutritive value (CP, DMD or ME).

- The fourth hypothesis that the VFI of fresh leaf and stem of tedera by sheep will be greater if they have had previous experience of grazing tedera relative to the VFI of naïve sheep was accepted as a regression analysis of the data in Figure 5 indicated the average% eaten of all accessions were significantly different ($p<0.001$) and had significantly different slopes ($p<0.05$); the experienced animals ate more.

- The fifth hypothesis that the VFI fed in pens of wilted leaf and stem of tedera would be greater than fresh leaf and stem of tedera was rejected as there was no effect of wilting on preference; therefore under these wilting conditions preference does not appear to be controlled by the volatile compounds.

5.2 Grazing tedera in mixtures with annual species at Kojonup

General –. Based on the results of previous seasonal grazing experiments at Mount Barker Research Station, Dandaragan and the grazing of the spaced plant experiments at Buntine, Newdegate and Mount Barker (Real *et al.* 2014), it was assumed that the winter and spring production of tedera in the mixed swards (ATS and ATL) would be transferred to the summer and autumn. However this hypothesis was rejected for a number of possible reasons:

1. There was a much higher relative palatability of tedera compared to the annual pasture causing the tedera to be grazed to the ground independent of the stocking rates in winter and spring whereas the competing annual pasture was less grazed and therefore better able to regrow before the next grazing;

2. The district experienced a decile 9 growing season resulting in very high competition for light in winter and spring and light and water in late spring and early summer and thereby disadvantaging tedera;

The experiment has highlighted that tedera is adapted to different soils in different ways in the Kojonup environment. It has performed best in the deep sandy duplex soils and in the mid to upper slopes. In addition it has highlighted that tedera is a palatable species that can be overgrazed in a mix swards if not managed properly. Also, excessive competition can reduce persistence therefore the time of grazing/removing of competition is important.
As summer and autumn are the most valuable times to graze tedera, management practises have to be put in place to allow conservation of tedera for that time.

5.3 Production and persistence of tedera through winter and early spring with or without competition of annual pasture based on plot studies

The number of tedera plants was not significantly affected by the competition imposed by the annual species. There was an average of 1.5, 2.3 and 1.8 plants/m^2 for the 14 October 2015, 23 February 2016 and 3 May 2016 respectively. Total biomass produced by the tedera plants without competition was significantly higher than with competition on the 14 October 2015. On average, plants with competition were only 30% of the weight of plants without competition. However, the tedera plants recovered after the annuals senesced and the same biomass per plant was recorded for the 23 February 2016 and 3 May 2016 harvest. The biomass production/ha was compared for the three treatments. The tedera only treatment was less productive on the 14 October 2015 and 3 May 2016, but in the middle of summer, when there was no annual species production, produced >500 kg/ha. The tedera plus annual treatment produced the same as the annual only treatment on the 14 October 2015 and 3 May 2016, but had the additional production of >500 at the 23 February 2016 harvest, indicating that the mixed of tedera and annual pastures had the best annual production and seasonal distribution.

5.4 Grazing trial during summer and autumn at Dandaragan 2014/15, Dandaragan 2016 and Kojonup 2016

General – These three experiments clearly demonstrate that tedera can be reliably grown as a monoculture and preserved as green pasture to be grazed to reduce or eliminate expensive hand-feeding in summer and autumn using the simplest and least expensive grazing management; continuous grazing. In addition, significant biomass of tedera, of sufficient nutritive value, can be grown in late spring and set-stocked (continuously grazed) at commercial stocking rates from early December to potentially finish young sheep (plus 9 kg and 0.4 of a condition score) without the need to hand-feed. Alternatively, tedera could potentially be grazed by reproducing ewes in late spring-early summer to guarantee a moderate gain in liveweight during joining to maximise the conception of twins as has previously been shown by lupin grain (Knight *et al.* 1975) or direct grazing of the fodder shrub tagasaste (Oldham and Wilkins 1988). However, we still need to better understand how best to manage and utilize tedera (either grown as a monoculture or grown within an annual pasture) in winter-spring to maximise its contribution to the whole-farm profit.

Specific - We hypothesized that (i) tedera plants would not survive continuous grazing during summer and autumn; (ii) tedera stocked at 10 sheep/ha would at least maintain their weight and condition score without hand-feeding during the whole grazing period and (iii) that rotational grazing (14 days on and 70 days off) would improve the production of the sheep (liveweight and condition score) compared with continuous grazing.

The first hypothesis was rejected, plant density of tedera did not significantly decline due to being continuously grazed or rotationally grazed during summer and autumn at all three experimental sites. These results are in contrast with recommended grazing management for other perennial forage legumes utilized in Mediterranean–like climates such as lucerne (*Medicago sativa* L.) (Humphries *et al.* 2006) or similar to others such as tagasaste (*Chamaecytisus prolifer* var. *palmensis* (H. Christ) A. Hansen & Sunding) that can be grazed continuously or rotationally with cattle producing equivalent animal production (McNeill *et al.* 1996). In our experiments the retention of plant density; plant survival response to grazing in each experiment was during summer and autumn of only one year. Gutman *et al.* (2000) conducted a long-term experiment (1974 to 1990) in a Mediterranean herbaceous community in Israel grazed by cattle and studied the impact of grazing on *B. bituminosa* population. The authors concluded that *B. bituminosa* was able to grow under extreme grazing intensities and suggested that the mechanism to increase it's plant density over time was related to reduction in competition with companion species. Plant density of *B. bituminosa* increased more under long-term rotational grazing in comparison than with continuous grazing. Similar results were obtained by Sternberg *et al.* (2000) in a 4-year cattle grazing study in Israel in which *B. bituminosa* plant density was not affected by grazing treatments, but increased year to year, mainly in the continuous grazing and seasonal heavy and late grazing method.

The second hypothesis was accepted. In the three experiments, there was no hand-feeding and with a stocking rate of 10 sheep/ha, during summer and autumn in Mediterranean-like climates, sheep at least maintained liveweight and condition score (around 3, ideal for young sheep; (Thompson *et al.* 2011)) while grazing a monoculture of tedera. In 2014-15 at Dandaragan the sheep in both grazing treatments gained liveweight very rapidly over the first 28 days (>200 g/sheep.day). This daily gain is equivalent to the best daily gains reported for lambs grazing legumes, herbs or grasses (Kemp *et al.* 2010), indicating that if there is tedera leaves *ad libitum*, there is no restriction in quality to achieve excellent daily gains. Thereafter the sheep grew in a classic curvilinear response during the next 28 days, from the 30 December 2014 to the 27 January 2015. During this period the FOO from tedera declined steadily at about 30 kg DM/ha.day but remained above 500 kg DM/ha in the continuously grazed plot. The FOO at the start of grazing in the rotationally grazed plots remained ≥ 1200 kg DM/ha. Thereafter the sheep in both grazing treatments maintained their liveweight for another 42 days until 10 March 2015. During this time the tedera being continuously grazed put on new growth to peak at a FOO of 900 kg DM/ha in mid-March. However, grazing in this treatment was eventually terminated when the tedera was reduced to bare stumps about 10 cm high (a FOO of 300 kg DM/ha) and the sheep had finally started to lose weight and condition score on the 24 May 2015. It is worth noting that once the sheep were removed, that the tedera immediately responded by regrowing 400 kg DM/ha over the next 28 days. Similarly, the tedera in the rotationally grazed plots always responded to grazing by regrowing steadily in the time between grazings irrespective of summer-autumn rainfall; typically from a very low base of about 400 kg DM/ha. This resulted in a further 28 days of grazing at maintenance for the sheep in the rotationally grazed plots.

In 2016 grazing commenced two months later to better coincide with the typical start of hand-feeding on commercial farms in southwestern Australia. At both Dandaragan and Kojonup the tedera was a monoculture (achieved spontaneously at Dandaragan and with the use of chemical manipulation at Kojonup) but the FOO at the start of the experiment was substantially less than at Dandaragan in 2014-15, partially because of some spontaneous leaf drop from a peak DM in December and partially because of the relatively low rainfall in Spring 2015 and early summer 2016. Nonetheless, in the first 70 days of grazing the sheep gained or maintained liveweight and condition score in the absence of any contribution from other annual species (dry or green). Thereafter, interpretation of the sheep performance was made more complex by the substantial rainfall in late March and April that was sufficient to cause significant germination and growth of annual pasture species at Kojonup after mid-April. This complication was less so at Dandaragan where the long history of weed control at the site resulted in a much smaller seedbank of annual species.

The commercial sheep at Kojonup 2016 (same flock as our experimental sheep) were managed by the farmer to maintain weight as per normal farm practice as it is expensive to feed animals to gain weight by hand-feeding grain or hay during summer and autumn (Young *et al.* 2011). Our experimental sheep weighted on the same day as the commercial sheep (19 April 2016) were 5.4 kg heavier for the rotationally grazed treatment and 10.2 kg heavier for the continuously grazed treatment with no hand-feeding and a stocking rate of 10 sheep/ha instead of 6.2 sheep/ha and 170 g grain/sheep.day for the commercial sheep.

The third hypothesis was partially rejected. The sheep in the continuously grazed treatment performed as well as the sheep in the rotationally grazed treatment. However, at

Dandaragan in 2014-15 the rotational grazing treatment extended the duration of maintenance feeding by 28 days because the plots rotationally grazed produced more DM over the 140 days of grazing when there was no significant rainfall until May 2015. As expected from the results in 2014-15, the continuously grazed sheep at Kojonup in 2016 performed better than the sheep continuously grazed sheep at Dandaragan because they had sufficient tedera (FOO > 1500 vs ~600 kg DM/ha at Kojonup and Dandaragan respectively) and therefore had the potential to select a leaf rich; higher quality diet (Table 16). At Kojonup in 2016, the continuously grazed sheep also gained more weight (Figure 15) and a faster rate (176 vs 69 g/sheep.day) than the rotationally grazed sheep in the first 42 days presumably for the same reason. Thereafter the rain in late March and April 2016 germinated and grew a vigorous pasture after mid-April 2016 at Kojonup and the sheep that continuously grazed tedera transferred their preference to the annual pasture and continued their rapid gain in liveweight and condition score up to the 3 May 2016 when experiment was terminated. Similarly, the sheep that rotationally grazing tedera ate both the tedera and pasture FOO and were growing at a similar rate of 279 g/sheep.day in the final 14 days of the experiment. By contrast the sheep at Dandaragan in 2016 in both grazing management treatments were constrained by the starting DM available from tedera and the lack of annual species. Nonetheless, the sheep did maintain their liveweight and condition score (~3) throughout the 84 days of the experiment with no hand-feeding.

As expected leaf nutritive value (DMD, CP, ME; ADF and ASH Table 16) of tedera was significantly better than that of edible stem and there was not a significant different among the sites except for a small difference in DMD and ASH. The nutritive value of the tedera as offered was not analysed because sheep grazed selectively leaf in preference to edible stem. As grazing progressed and sheep ran out of the leaf fraction, leaf and stems were consumed at the same time and at the end of the grazing period, sheep were grazing mainly edible stems.

5.5 Calibration of Near Infrared Spectrophotometry (NIRS) for tedera quality

A NIRS equation was developed to enable relatively inexpensive estimation of the nutritive value of the edible leaf and stem of tedera.

5.6 Follow-up MIDAS modelling of tedera using measured animal production data

A pre-experimental modelling analysis (Finlayson *et al.* 2012) was carried out using the MIDAS model. It examined the contribution to profit and the area of tedera that would be grown in a mixed farming system with different levels of feed quality and leaf retention. The conclusion from the analysis was that tedera was likely to have an important role in southern Australian farming systems particularly the higher rainfall areas, and that further work with tedera in grazing trials was warranted. There were uncertainties in the grazing assumptions in the analysis associated with the in vivo feed quality of tedera and whether there were any anti-nutritional factors. This led to uncertainty on the level of animal production that could be expected from animals grazing tedera and therefore the best utilisation of tedera in the production system.

Longer term grazing trials have subsequently been carried out in WA during summer/autumn 2014/15 and 2016. These trials have quantified the liveweight change of animals grazing tedera and the change in the level of feed on offer as summer progresses. The trial included both continuous stocking and rotational grazing so data is available for different rates of defoliation with different opportunity for regrowth during this period of the year when the annual pastures are senesced.

A follow-up MIDAS analysis will be carried out utilising this extra animal and pasture growth information. The representation of the feed quality of tedera in the model will be calibrated to reflect the measurements taken in the grazing trials. This will allow more accurate calculation of the role and profitability of tedera in the farming system. The previous analysis concluded that tedera looked to have the most opportunity in the high rainfall regions of southern Australia and this analysis will be carried out using the Great Southern version of the MIDAS models which represents the 500-600mm rainfall zone in the south west of WA.

Previous analyses (Young *et al.* 2004) have shown that high quality out of season green feed is most valuable if used to increase meat production and this is likely the case with tedera. This analysis will focus on the animal production that can be achieved from tedera and will quantify the value of using tedera as:

1. A substitute for grain as a maintenance feed for stock
2. A production feed during summer/autumn to either finish prime lambs, flush ewes in the lead up to joining or achieve weight gain for twin bearing ewes in late pregnancy to increase twin lamb survival.
3. A combination of production feeding of lambs and maintenance feeding of older animals. The selective grazing of tedera from leaf to stem provides an opportunity to utilise the feed as both a feed to gain weight and a feed to maintain weight if a follower flock is used in a rotation grazing system.

These options for the alternative roles of tedera in the animal production system will be evaluated for both a merino flock focusing on wool production and a merino flock with a proportion of ewes mated to terminal sires to produce prime lambs. Sensitivity analysis will be included on the nutritive value of tedera in summer/autumn to determine the importance of this trait in both wool focused and meat focused production systems.

The analysis will further consolidate the profitability of tedera and focus the role it is likely to fill in the grazing system. The analysis will be published in a research journal such as Animal Production Science.

5.7 Extent to which each specific project objectives was met

1) Evaluated the performance of animals grazing tedera pastures, in comparison with subclover/ryegrass pastures, using rotational grazing.

This specific objective was met. The experiments highlighted that tedera is a palatable species that can be overgrazed in a mix sward if not managed properly. Also, excessive competition can reduce persistence therefore the time of grazing/removing of competition is important. As summer and autumn are the most valuable times to graze tedera, management practises have to be put in place to allow conservation of tedera for that time.

2) Evaluated the quantity and quality of tedera plant responses to animal grazing throughout the year.

This specific objective was met. In each season, naïve sheep were introduced to the tedera plots directly from commercial pastures for seven to 14 days. The key measures of nutritive value (overall averages of 15% for CP, 72% for DMD and 11mj for ME) of the edible leaf and stem of tedera are indicative of high quality forage for sheep production. When the sheep grazed exclusively on each of the seven accessions for 14 days (Experiment 2) the growth rate (>200g/head/day) of sheep grazing accessions T31 and T48 reflected this analysis in all four seasons of the year. However, while in all cases sheep grazing the other five accessions of tedera at least maintained their liveweight and condition score, their growth rate varied widely between accessions and between seasons. The differences between accessions and seasons was not explained by differences in nutritive value as assessed by CP, DMD and ME or by preference as measured in Experiment 1 when the seven accessions were grazed in common for seven days or in Experiment 3 when they were fed the seven accessions in pens.

The three summer and autumn grazing experiments clearly demonstrated that tedera can be reliably grown as a monoculture and preserved as green pasture to be grazed to reduce or eliminate expensive hand-feeding in summer and autumn using the simplest and least expensive grazing management; continuous grazing. In addition, significant biomass of tedera, of sufficient nutritive value, can be grown in late spring and set-stocked (continuously grazed) at commercial stocking rates from early December to potentially finish young sheep (plus 9 kg and 0.4 of a condition score) without the need to hand-feed. Alternatively, tedera could potentially be grazed by reproducing ewes in late spring-early summer to guarantee a moderate gain in liveweight during joining to maximise the conception of twins.

3) Identified any potential health impacts of continuous grazing of tedera over the summer-autumn period of 2014-15 in WA

This specific objective was met. There was no animal health issues in any of the experiments conducted during this project. Moreover, there is not known record or anecdotal evidence of any health issue grazing tedera that the authors are aware of.

4) Evaluate alternative strategies to increase the proportion of tedera in a mixed pasture sward to develop a feed-wedge of tedera in the summer-autumn period in the high rainfall zone of Western Australia.

This specific objective was mostly met. As highlighted in specific objective 2, tedera can be overgrazed in mixed swards and strategic grazing should be employed. While no specific strategies were developed, general guidelines were identified that may require further evaluation.

5) Provide recommendations to MLA for required research and development to ensure the provision of effective recommendations for the adoption of tedera by sheep producers.

This project provided animal health and production results to demonstrate the potential use and value of tedera for farmers. Even though there has been a large research effort and substantial progress in the development of tedera to-date, seeds of the first cultivar of tedera should be utilized to further advance and fine-tune the agronomy package to maximize success and encourage adoption. It is proposed to develp a project to establish a series of field trials: (a) to evaluate regional adaptation in different soils in WA, SA, NSW and VIC with a focus on low and medium rainfall Mediterranean environments; (b) to research establishment techniques (time of sowing, sowing depth, seed density and spatial configuration); (c) fertilization requirements; (d) herbicide tolerance; (e) population dynamics in a sward (original sown plants and recruits); (f) defoliation management to maximize green leaf production in the out-of-season period; (g) hard-seed softening pattern in the field and (h) summer and autumn grazing trials to validate livestock performance results from previous trials.

6 Conclusions/recommendations

All the animal production experiments conducted as part of this project allowed us to conclude that:

- No health issues have been observed in any of the grazing experiments.
- Palatability is not an issue, even though there are differences in palatability among accessions, sheep graze all the accessions and the differences in production were not related to differences in palatability.
- Previous analyses (Young et al. 2004) have shown that high quality out of season green feed is most valuable if used to increase meat production and this is likely the case with tedera. Tedera experimental results indicate that it can be utilized as:
    - a substitute for grain as a maintenance feed for stock from mid-summer to late-autumn
    - a production feed during early-summer to either finish prime lambs, flush ewes in the lead up to joining or achieve weight gain for twin bearing ewes in late pregnancy to increase twin lamb survival.
    - a combination of production feeding of lambs and maintenance feeding of older animals. The selective grazing of tedera from leaf to stem provides an opportunity to utilise the feed as both a feed to gain weight and a feed to maintain weight if a follower flock is used in a rotation grazing system.

Future research and development of tedera should focus on the development of the agronomy package for the first cultivar of tedera. Tedera should be sown in the right place, at the right time, in the right way, managed to favour it's establishment and subsequently grazed at times of the year recommended to maximize farm profit.

7 Key messages

- No health issues have been observed in any of the grazing experiments.
- Palatability is not an issue, even though there are differences in palatability among accessions, sheep graze all the accessions and the differences in production were not related to differences in palatability.
- Previous analyses (Young et al. 2004) have shown that high quality out of season green feed is most valuable if used to increase meat production and this is likely the case with tedera. Tedera experimental results indicate that it can be utilized as:
    - a substitute for grain as a maintenance feed for stock from early-summer to late-autumn.
    - a production feed during early-summer to either finish prime lambs, flush ewes in the lead up to joining or achieve weight gain for twin bearing ewes in late pregnancy to increase twin lamb survival.
    - a combination of production feeding of lambs and maintenance feeding of older animals. The selective grazing of tedera from leaf to stem provides an opportunity to utilise the feed as both a feed to gain weight and a feed to maintain weight if a follower flock is used in a rotation grazing system.

8 Bibliography

Adriansz, TD, Hardy, JLM, Milton, JTB, Oldham, CM, Real, D (2016) NIR analysis for nutritive attributes of tedera (*Bituminaria bituminosa* var. *albomarginata*). In 'Australian Near Infrared Spectroscopy Group. Moama, NSW, Australia'. pp. 1-2.

Cayley, JWD, Bird, PR (1996) Techniques for measuring pastures. Technical Report 191. Victorian Department of Agriculture, Melbourne.

Chesson, J (1983) The estimation and analysis of preference and its relationship to foraging models. *Ecology* 1297-1304.

Dear, BS, Ewing, MA (2008) The search for new pasture plants to achieve more sustainable production systems in southern Australia. *Australian Journal of Experimental Agriculture* **48**, 387-396.

del Rio, JA, Ortuño, A, Pérez, I, Bennett, RG, Real, D, Correal, E (2010) Furanocoumarin content in *Bituminaria bituminosa* varieties and *Cullen* species. In 'CIHEAM: Options Méditerranéennes. Alicante, Spain'. (Eds C Porqueddu, S Ríos Ruiz) Volume 92 pp. 67-70.

Finlayson, JD, Real, D, Nordblom, T, Revell, C, Ewing, MA, Kingwell, R (2012) Farm level assessments of a novel drought tolerant forage: Tedera (*Bituminaria bituminosa* C.H.Stirt var. *albomarginata*). *Agricultural Systems* **112**, 38-47.

Freer, M, Moore, AD, Donnelly, JR (1997) GRAZPLAN: Decision support systems for Australian grazing enterprises—II. The animal biology model for feed intake, production and reproduction and the GrazFeed DSS. *Agricultural Systems* **54**, 77-126.

Ghaffari, MH, Durmic, Z, Real, D, Vercoe, P, Smith, G, Oldham, C (2014) Furanocoumarins in tedera do not affect ruminal fermentation in continuous culture. *Animal Production Science* **55**, -544-550.

Gutman, M, Perevolotsky, A, Sternberg, M (2000) Grazing effects on a perennial legume, *Bituminaria bituminosa* (L.) Stirton, in a Mediterranean rangeland. In 'Cahiers Options Mediterraneennes. 2000. 45: 299-303. 3 ref. (Ed. L Sulas)

Humphries, AW, Kobelt, ET, Bellotti, WD, Auricht, GC (2006) Tolerance of Australian lucerne (Medicago sativa) germplasm to grazing by sheep. *Australian Journal of Experimental Agriculture* **46**, 1263-1270.

Kemp, PD, Kenyon, PR, Morris, ST (2010) The use of legume and herb forage species to create high performance pastures for sheep and cattle grazing systems. *Revista Brasileira de Zootecnia* **39**, 169-174.

Knight, T, Oldham, C, Lindsay, D (1975) Studies in ovine infertility in agricultural regions in Western Australia: the influence of a supplement of lupins (*Lupinus angustifolius* cv. Uniwhite) at joining on the reproductive performance of ewes. *Australian Journal of Agricultural Research* **26**, 567-575.

McNeill, DM, Allen, GM, Edwards, NJ, Oldham, CM (1996) The productivity of tagasaste as determined by the performance of cattle grazing it on a rotational versus continuous basis. *Proceedings of the Australian Society of Animal Production* **21**, 411.

Méndez, P, Díaz, E, Rivero, R (2001) 'Contenido en cumarinas del forraje verde de tedera (*Bituminaria bituminosa)*, XLI Reunión científica de la S.E.E.P.'.

Méndez, P, Fernández , M (1990) 'Interés forrajero de las variedades de *Bituminaria bituminosa* (L.) Stirton ("tedera") de Canarias, XXX Reunión científica de la sociedad Española para el estudio de los pastos.' Donostia-San Sabastian, del 4 al 8 de junio de 1990.

Méndez, P, Fernández, M, Santos, A (1991) Variedades de *Bituminaria bituminosa* (L.) Stirton (Leguminosae) en el archipélago canario. *Pastos* **20-21**, 157-166.

Moore, J (2014) Tedera tolerance of herbicides and small crumbweed control. In '19th Australasian Weeds Conference. pp. 20-23.

Oertli, EH, Beier, RC, Ivie, GW, Rowe, LD (1984) Linear furocoumarins and other constituents from *Thamnosma texana*. *Phytochemistry* **23**, 439-441.

Oertli, EH, Rowe, LD, Lovering, SL, Ivie, GW, Bailey, EM (1983) Phototoxic effect of *Thamnosma texana* (Dutchman's breeches) in sheep. *American Journal of Veterinary Research* **44**, 1126-1129.
Oldham, CM, Real, D, Bailey, HJ, Thomas, D, Van Burgel, AJ, Vercoe, P, Correal, E, Rios, S (2013) Australian and Spanish scientists are collaborating in the domestication of tedera: young merino sheep grazing a monoculture of tedera in autumn showed preference for certain accessions but no signs of ill health. *Crop & Pasture Science* **64**, 399-408.
Oldham, CM, Wilkins, JF (1988) The ovulation rate and embryo mortality among adult Merino ewes grazed on Tagasaste (an evergreen perennial shrub), lupin stubble or pasture. . *Proceedings of the Australian Society of Animal Production* **17**, 450.
Oldham, CM, Wood, D, Milton, J, Real, D, Vercoe, P, van Burgel, AJ (2015) An animal house study on utilisation of fresh tedera (Bituminaria bituminosa var. albomarginata and crassiuscula) by Merino wethers. *Animal Production Science* **55**, 617-624.
Pazos-Navarro, M, Dabauza, M, Correal, E, Walker, D, del Rio, JA, Ortuño, A, Méndez, P, Santos, A, Ríos, S, Martínez-Frances, V, Real, D (2013) Legumes for grazing and health: the case of *Bituminaria bituminosa*. In 'Legumes: Types, Nutritional Composition and Health Benefits ' (Eds H Satou, R Nakamura.) pp. 1-39. (Nova Science Publishers, Inc.: New York, USA)
Pecetti, L, Tava, A, Pagnotta, MA, Russi, L (2007) Variation in forage quality and chemical composition among Italian accessions of Bituminaria bituminosa (L.) Stirt. *journal of Science of Food and Agriculture* **87**, 985-991.
Real, D, Kidd, D (2012) Forage production of the drought tolerant Mediterranean forage legume tedera (*Bituminaria bituminosa* var. *albomarginata*) in the medium-rainfall zone of southern Western Australia as affected by plant density and cutting frequency. In 'New approaches for grassland research in a context of climate and socio-economic changes. (Eds Z Acar, A Lopez-Francos, C Porqueddu) Volume 102 pp. 387-390. (Options Mediterraneennes Series A: Mediterranean Seminars 2012:
Real, D, Li, GD, Clark, S, Albertsen, TO, Hayes, RC, Denton, MD, D'Antuono, MF, Dear, BS (2011) Evaluation of perennial forage legumes and herbs in six Mediterranean environments. *Chilean Journal of Agricultural Research* **71**, 357-369.
Real, D, Oldham, CM, Nelson, MN, Croser, J, Castello, M, Gherardi, S, Finlayson, J, Revell, C, Pradhan, A, O'Hara, GW, Correal, E (2013) Tedera: from a promising novel species to a commercial pasture option for Mediterranean southern Australia. In 'Proceedings 22nd International Grassland Congress: Revitalising grasslands to sustain our communities. Sydney, Australia'. (Eds DL Michalk, GD Millar, WB Badgery, KM Broadfoot) pp. 301-303. (CSIRO Publishing:
Real, D, Oldham, CM, Nelson, MN, Croser, J, Castello, M, Verbyla, A, Pradhan, A, Van Burgel, A, Méndez, P, Correal, E, Teakle, NL, Revell, CK, Ewing, MA (2014) Evaluation and breeding of tedera for Mediterranean climates in southern Australia. *Crop and Pasture Science* **65**, 1114-1131.
Revell, C, Revell, D (2007) Meeting 'duty of care' obligations when developing new pasture species. *Field Crops Research* **104**, 95-102.
Schoknecht, NR, Pathan, S (2013) 'Soil groups of Western Australia: a simple guide to the main soils of Western Australia (4th Edition) ' (Department of Agriculture and Food , Western Australia:
Sternberg, M, Gutman, M, Perevolotsky, A, Ungar, ED, Kigel, J (2000) Vegetation response to grazing management in a Mediterranean herbaceous community: a functional group approach. *Journal of Applied Ecology* **37**, 224-237.
Suriyagoda, LDB, Real, D, Renton, M, Lambers, H, Ryan, MH (2013) Establishment, survival, and herbage production of novel, summer-active perennial pasture legumes in the low-rainfall cropping zone of Western Australia as affected by plant density and cutting frequency. *Crop and Pasture Science* **64**, 71-85.

Tava, A, Pecetti, L, Ricci, M, Pagnotta, MA, Russi, L (2007) Volatile compounds from leaves and flowers of *Bituminaria bituminosa* (L.) Stirt. (Fabaceae) from Italy. *Flavour and Fragrance Journal* **22**, 363-370.

Thomas, DT, Milton, JTB, Revell, CK, Ewing, MA, Dynes, RA, Murray, K, Lindsay, DR (2010) Preference of sheep among annual legumes is more closely related to plant nutritive characteristics as plants mature. *Animal Production Science* **50**, 114-123.

Thompson, AN, Ferguson, MB, Campbell, AJD, Gordon, DJ, Kearney, GA, Oldham, CM, Paganoni, BL (2011) Improving the nutrition of Merino ewes during pregnancy and lactation increases weaning weight and survival of progeny but does not affect their mature size. *Animal Production Science* **51**, 784-793.

van Burgel, AJ, Oldham, CM, Behrendt, R, Curnow, M, Gordon, DJ, Thompson, AN (2011) The merit of condition score and fat score as alternatives to liveweight for managing the nutrition of ewes. *Animal Production Science* **51**, 834-841.

Young, JM, Bathgate, AD, Sanford, P (2004) MIDAS Insights on profitably utilising Perennial Plants on the South Coast of WA.

Young, JM, Thompson, AN, Curnow, M, Oldham, CM (2011) Whole-farm profit and the optimum maternal liveweight profile of Merino ewe flocks lambing in winter and spring are influenced by the effects of ewe nutrition on the progeny's survival and lifetime wool production. *Animal Production Science* **51**, 821-833.

9 Appendix

9.1 Weather data for Dandaragan for the duration of the experimental period

Month	Min AirTemp (degC)	Ave AirTemp (degC)	Max AirTemp (degC)	Min Humidity (%)	Ave Humidity (%)	Max Humidity (%)	RainTotal (mm)	
Jun-13	0.6	11.5	21.9	26.7	71.4	93.8	32.4	a
Jul-13	-2.0	10.5	22.1	24.1	73.7	94.5	68.4	a
Aug-13	2.0	12.5	26.1	16.3	80.4	94.6	69.2	a
Sep-13	1.3	13.1	24.4	37.4	78.4	94.3	65.0	a
Oct-13	2.6	17.4	40.1	10.3	61.3	94.1	17.0	a
Nov-13	8.9	22.4	39.5	6.8	48.3	92.7	0.6	a
Dec-13	10.7	23.0	43.5	6.6	51.4	99.0	0.0 (a)	
Jan-14	9.3	24.8	45.2	7.2	52.7	97.9	2.0 (a)	
Feb-14	14.6	25.7	39.2	14.0	47.1	96.1	0.0 (a)	
Mar-14	7.6	23.6	39.4	7.7	55.0	98.7	8.6	
Apr-14	5.6	19.4	37.0	13.7	61.9	98.7	67.2	
May-14	6.0	19.7	25.6	34.8	82.4	100.0	93.0	
Jun-14	0.5	11.9	25.4	23.2	76.0	100.0	66.8	
Jul-14	2.0	12.1	24.9	24.2	82.8	100.0	107.8	
Aug-14	1.9	14.3	27.4	19.4	76.2	99.9	60.2	
Sep-14	2.2	14.6	34.6	13.1	79.5	99.9	74.2	
Oct-14	3.8	17.1	37.1	10.8	69.5	99.9	25.6	
Nov-14	5.6	19.0	39.7	7.6	61.7	99.0	16.6	
Dec-14	10.1	21.9	42.5	5.4	53.4	98.1	3.0	
Jan-15	12.2	25.4	44.0	6.4	46.6	97.2	2.2	
Feb-15	12.2	26.6	42.9	8.9	49.8	97.2	20.2	a
Mar-15	11.6	22.6	39.7	8.9	56.3	98.1	28.6	a
Apr-15	7.7	19.6	32.5	17.2	57.7	98.6	19.0	a
May-15	2.3	14.4	26.2	11.6	64.7	98.9	35.2	a
Jun-15	2.4	14.1	26.1	23.8	73.1	100.0	41.4	
Jul-15	0.4	12.5	24.7	23.3	77.4	100.0	76.0	
Aug-15	2.5	12.5	25.7	23.5	82.1	100.0	78.6	
Sep-15	0.3	13.6	32.5	12.6	69.8	98.9	20.6	
Oct-15	2.7	18.8	36.4	9.3	64.1	100.0	5.4	
Nov-15	4.8	21.6	42.3	7.6	58.1	98.9	7.4	
Dec-15	7.0	22.6	44.2	5.3	51.2	97.3	7.2	
Jan-16	12.6	25.4	44.2	10.5	53.2	95.9	19.6	
Feb-16	9.3	25.0	44.9	6.1	46.1	95.6	1.0	

Month	Min AirTemp (degC)	Ave AirTemp (degC)	Max AirTemp (degC)	Min Humidity (%)	Ave Humidity (%)	Max Humidity (%)	RainTotal (mm)	
Mar-16	10.7	23.4	42.3	11.0	59.1	97.3	64.4	
Apr-16	11.0	19.5	35.1	18.2	70.8	97.4	55.6	
May-16	4.2	16.6	27.1	21.9	76.4	98.5	54.6	b

a= patched metadata from DAFWA weather station, MZ - ANOWSTNMZ001 – Moora
b= 26 days

9.2 Weather data for Kojonup for the duration of the experimental period

Month	Min AirTemp (degC)	Ave AirTemp (degC)	Max AirTemp (degC)	Min Humidity (%)	Ave Humidity (%)	Max Humidity (%)	RainTotal (mm)	
Jun-13	2.1	10.9	19.1	35.9	82.4	100.0	19.2	a
Jul-13	-2.4	9.7	19.2	34.6	82.6	100.0	59.0	a
Aug-13	2.8	11.7	22.0	35.1	85.8	100.0	76.4	a
Sep-13	2.9	11.9	21.1	39.1	81.8	100.0	107.6	a
Oct-13	1.0	14.2	35.6	16.0	73.7	99.9	27.8	a
Nov-13	4.8	18.2	34.6	9.6	59.6	97.3	3.0	a
Dec-13	5.3	19.0	41.7	0.3	37.5	100.0	6.8	
Jan-14	4.2	21.3	43.2	9.5	57.0	99.4	0.0	
Feb-14	5.6	19.9	35.1	12.9	59.8	99.5	2.2	
Mar-14	5.0	19.3	37.8	10.5	63.3	98.2	2.4	
Apr-14	1.2	16.4	34.0	15.9	67.5	99.6	12.2	
May-14	3.0	13.3	21.5	39.0	85.3	100.0	117.6	
Jun-14	-1.0	10.4	21.3	37.4	82.4	100.0	42.4	
Jul-14	-0.7	9.9	18.3	48.6	86.6	99.9	101.6	
Aug-14	-0.5	11.1	21.3	33.8	81.5	99.9	72.4	
Sep-14	-0.9	12.0	26.8	32.9	81.9	99.9	46.4	
Oct-14	0.6	13.9	28.5	15.3	77.9	99.9	65.6	
Nov-14	0.5	16.1	33.6	11.8	66.1	99.4	18.6	
Dec-14	2.7	18.0	41.6	7.2	60.2	97.5	3.8	
Jan-15	5.1	21.3	41.6	11.2	54.1	97.8	0.4	
Feb-15	5.2	21.9	39.0	10.0	58.4	96.8	14.4	
Mar-15	3.6	18.5	39.7	10.7	65.1	96.4	26.8	
Apr-15	3.0	14.9	28.0	23.7	73.3	99.0	69.2	
May-15	-2.1	10.1	25.7	15.9	77.5	99.5	18.2	
Jun-15	-1.3	11.3	22.6	32.8	81.4	99.8	42.6	

Month	Min AirTemp (degC)	Ave AirTemp (degC)	Max AirTemp (degC)	Min Humidity (%)	Ave Humidity (%)	Max Humidity (%)	RainTotal (mm)
Jul-15	-3.6	9.7	19.8	38.6	83.3	99.9	64.6
Aug-15	-0.3	10.1	25.6	26.2	84.3	99.8	35.4
Sep-15	-0.4	11.3	27.6	21.2	74.8	98.7	25.0
Oct-15	-2.4	16.4	35.5	12.2	66.9	98.9	24.6
Nov-15	3.1	17.9	38.1	12.0	63.7	98.8	5.8
Dec-15	6.8	19.0	40.6	5.5	56.9	96.8	38.4
Jan-16	10.7	21.0	38.0	11.3	63.7	96.1	94.2
Feb-16	3.9	20.1	40.6	7.9	60.9	96.9	6.4
Mar-16	6.3	18.9	35.7	17.6	70.9	97.4	78.0
Apr-16	3.5	15.6	29.1	30.7	79.6	98.0	44.8
May-16	-0.2	11.2	22.8	34.1	83.5	99.3	73.2

a= patched metadata from DAFWA weather station, KA - ASWWSTNKA001 – Katanning