FUTURE FARM INDUSTRIES CRC

MEAT & LIVESTOCK AUSTRALIA

final report

Project code: B.GSM.0003 – P1 DP03

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Date published: July 2014

ISBN: 9781740362306

PUBLISHED BY
Meat & Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

Enrich Phase 3

Demonstrating resilient, healthy and profitable livestock systems with multipurpose shrubs

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

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Abstract

The Enrich project aimed to provide knowledge and development into sustainable grazing systems, with multiple benefits, for farmers in low-medium rainfall areas through the incorporation of Australian perennial shrubs. Previous project work has identified several shrub species with desirable productivity, nutritive value or bioactive properties. However, the effect of grazing these species together on livestock production had not been tested. Testing at two sites found that sheep could gain weight grazing shrub-based systems without supplementary feeding during autumn, a time typically associated with a feed shortage. Shrub-based systems, when used in conjunction with companion pasture, have the potential to increase livestock productivity and improve feedbase stability, as well as delivering environmental benefits. Work towards developing a variety of old man saltbush with higher digestibility and palatability to sheep reached the final stages of commercialisation with a pre-commercial 'research release'. Substantial amounts of awareness-raising activities were conducted including field days and various media to facilitate adoption. A booklet was also developed to aid landholders to apply shrub-based systems on farm. Practice change due to Enrich research was assessed to have occurred on more than 500 farms.

Executive summary

Shrub-based grazing systems offer landholders a practical method to enhance the natural resource management of agricultural land whilst contributing to farm productivity. Improvements in natural resource management occur by increasing ground cover, reducing wind and surface water erosion, managing ground water, and providing habitat for invertebrates, birds and reptiles. Such systems have the potential to increase farm profitability by reducing the amount of supplementary feeding over dry periods, deferring the grazing of regenerating annual pastures on other parts of the farm (leading to increased feed availability), and by allowing production on land classes unsuitable and uneconomic for cropping.

The Enrich research project began in 2005 with the aim to improve the sustainability and productivity of low rainfall grazing systems by incorporating forage shrubs. It included a large scale systematic investigation of Australian shrubs that are mostly new to agriculture. It did not set out to find a single 'silver bullet' species but evaluated plants as part of a grazing system where a sum of the benefits of all plants would potentially be greater than from one species alone. It also considered the potential of plants *in situ* to enrich the health and performance of grazing livestock through their innate chemical properties. This meant that the range of attributes included in the assessment of species was wide ranging and included potential benefits not commonly considered in forage evaluation programs.

From an initial list of 101 species, detailed field and laboratory studies in previous project phases listed 10 species as having the most potential for new low-rainfall, shrub-based grazing systems. Most of these are not currently used in commercial agriculture.

A key recommendation from a project review of Enrich conducted in 2011 was to define the benefits to livestock at a field scale. Therefore a primary aim of this latter project phase was to quantify live weight of sheep grazing diverse shrub-based systems.

At two sites (Monarto, SA and Quairading, WA), livestock gained weight during autumn, a time in which sheep in many southern Australian grazing systems typically lose weight, by grazing a mixture of shrubs and companion pasture, without the cost and labour requirements of supplementary feeding. In the WA experiment, the control sheep grazing unimproved pasture required 14 kg of supplementary grain during the 8 weeks to maintain weight while the sheep grazing the shrub-pasture mix required no supplementary feeding.

The potential advantages offered by forage shrubs can only be realised when coupled with appropriate management. Animal behaviour-based management does offer an opportunity to modify the diet selection of livestock. Providing animals with experiences of a particular plant (or combinations of plants) through the managed introduction of the new feed source(s) can boost their intake of that plant. In particular, repeated short-term exposure to forage shrubs may be a practical option to increase preference and intake of such species. In both studies, sheep included a broad array of species in their diet.

Old man saltbush (OMSB) is a key forage shrub species and has been planted in saline and arid systems in Australia for many decades. However, there have been few systematic plant improvement activities involving OMSB. A research program was initiated in 2001 to identify OMSB plants with 1) higher organic matter

digestibility (energy value), 2) improved 'palatability' to livestock, and 3) higher biomass production.

From an initial assessment of 60 000 OMSB shrubs in previous work, this project planted the best 12 genotypes at 13 sites across southern Australia. The field research was supported by animal house feeding studies and laboratory research. This work has now culminated into the final stages of plant commercialisation. Due to very high demand from WA producer groups wanting to trial the new material, the Future Farm Industries CRC is making 4 genotypes available through a pre-commercial "research release" in 2014. This will allow further information to be gathered on the cost of establishment and to determine performance at paddock scales, compared to local varieties. Each of the 4 genotypes has significantly higher digestibility and relative palatability than currently available lines; however improved profitability at the paddock scale is yet to be quantified.

The aim is delivery of a commercial cultivar of OMSB in 2015. Producer interest in the "research release" in 2014 has been high and 250,000 plants have been ordered. Demand has been much greater than available stock.

Awareness raising activities included communication through the media, presentations at field days and similar events, the production of a booklet, contributions to industry publications, an updated webpage and the making of dedicated on-line videos. Partnering with regional groups to conduct local scale research was also an integral strategy to engage with next and end users. Aiding community or producer groups (e.g. Landcare or farming systems groups) in the application of new grants for forage shrub plantings was also a strategy to raise awareness and generate practice change. Successful grants allowed nurseries to be engaged in the propagation of plants for new sites, thereby allowing these key next users to gain experience and learn the methods needed for successful commercial propagation of new species. There were over 6,600 industry interactions with Enrich/old man saltbush events. This included producers (farmers), researchers, advisers and other associated coordinators participating in Enrich / OMSB delivery events, the majority of which were based in South Australia and Western Australia. It was estimated that at least 583 landholders have changed farm practice either by changing grazing management practices on existing forage shrubs or by planting recommended species as a result of the project.

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1. Background

The Enrich project was co-funded by the Future Farm Industries CRC and Meat and Livestock Australia, and conducted by SARDI, CSIRO, UWA, DEWNR, NSW DPI and DEPI Vic.

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The Enrich project was a collaborative effort of numerous researchers, extension staff and land managers across southern Australia. It began in 2005 to explore the potential of native perennial shrubs to provide new forage options for low-medium rainfall areas with prolonged dry periods and/or for soils that are marginal for other farm enterprises such as cropping. The project combined the use of Australian plants with management approaches that take into account the nutritional behaviours of grazing herbivores. In particular, it differs from previous work on forage shrubs on four main hypotheses:

1) There is potential for Australian native plants to be used in grazing systems, to capitalise on their proven adaptation to the environment and particularly their drought tolerance.

2) Increasing the diversity of shrub-based grazing systems can lead to increased feed utilisation, feedbase stability, nutrition and ultimately animal performance. That is because animals seek to consume a mixed diet to avoid excess toxins and nutrient deficiencies.

3) Shrub-based grazing systems can deliver multiple benefits to landholders, livestock and the community. In particular, there is potential to improve animal health and production through providing diets which may have positive effects on rumen (gut) function such as reducing methane emissions from livestock or mitigating intestinal worm burdens.

4) Grazing management based on the principles of animal behaviour and physiology can be practically applied to modify the diet selection of livestock and successfully graze diverse forage mixes.

Bioeconomic modelling has suggested that southern Australian wheatbelt farms could increase whole farm profit by up to 15-20% through including 10-20% of the farm area to forage shrubs The inclusion of perennial forage shrubs into mixed farms can increase whole farm profit by reducing supplementary feeding during autumn (a time of feed shortage), deferring the grazing of regenerating annual pastures on other parts of the farm, leading to increased feed availability. (Monjardino et al. 2010)[1].

[1] Monjardino M., Revell D., and Pannell D.J. (2010). The potential contribution of forage shrubs to economic returns and environmental management in Australian dryland agricultural systems. Agricultural Systems 103, 187-197.

There are also a host of non-monetary benefits arising from planting forage shrubs including better water use (Lefroy et al. 2005)[2] and reduced risk of soil erosion (Ewel 1999)[3] due to their perennial nature and deep rooting ability. The addition of plants of a shrub growth form creates a new vegetation layer or strata, resulting in increased biodiversity compared with more simple agricultural landscapes. Increases in bird and invertebrate numbers have been recorded by the addition of *Atriplex nummularia* (old man saltbush) in the SA Mallee (Collard and Fisher 2010)[4].

Previous studies have identified several Australian shrub species which have the potential as forages across different soil types and environments (Kotze et al. 2009[5]; Durmic et al. 2010[6]; Emms et al. 2013[7]). To aid landholders in selecting appropriate species for a given location, a simple decision tool was developed using prompts primarily based on soil characteristics.

The appropriate management of species, as a grazing system and as part of the whole farm, was also considered important for maximising their potential. In particular we have explored ways in which diverse forage systems can be grazed successfully by modifying the grazing behaviour of livestock. The use of stocking density, exploiting the social nature of livestock with 'peer' experienced animals and managing the exposure to new forages, particularly by providing exposure very early in life (including *in utero*) are potentially important management strategies.

The first aim of this project (Enrich Phase 3) was to measure the increases in animal production from grazing shrub-based systems. This was in response to a project review conducted in 2011 which included the need to define the benefits to livestock from shrubs at a field scale. The second aim was to begin the process of integrating suitable shrub species and lines into commercial production systems A significant part of this was the development of a commercial variety(ies) (initially clonal varieties but possibly seed lines) of old man saltbush with higher digestibility and higher palatability to sheep. This included engagement with next and end users.

[2] Lefroy E.C., Flugge F., Avery A., and Hume I. (2005) Potential of current perennial plant-based farming systems to deliver salinity management outcomes and improve prospects for native biodiversity: a review. Australian Journal of Experimental Agriculture 45, 1357-1367.

[3] Ewel J.J. (1999) Natural systems as models for the design of sustainable systems of land use. Agroforestry Systems 45, 1-21.

[4] Collard S. J., and Fisher A. M. (2010). Shrub-based plantings of woody perennial vegetation in temperate Australian agricultural landscapes: What benefits for native biodiversity? Ecological Management and Restoration 11, 31-35.

[5] Kotze, A.C., O'Grady, J., Emms, J., Toovey, A.F., Hughes, S., Jessop, P., Bennell, M., Vercoe, P.E., and Revell, D.K. (2009). Exploring the anthelmintic properties of Australian native shrubs with respect to their potential role in livestock grazing systems. Parasitology 136, 1065-1080.

[6] Durmic, Z., Hutton, P., Revell, D.K., Emms, J., Hughes, S., and Vercoe, P.E. (2010). In vitro fermentative traits of Australian woody perennial plant species that may be considered as potential sources of feed for grazing ruminants. Animal Feed Science and Technology 160, 98-109.

[7] Emms J., Vercoe P.E., Hughes S., Jessop P., Norman H.C., Kilminster T., Kotze A., Durmic Z., Phillips N., and Revell D.K. (2013) Making decisions to identify forage shrub species for versatile grazing systems. In 'Proceedings of the 22nd International Grassland Congress, Sydney'. (International Grasslands Organisation) 1372-1373.

2. Project objectives

The objectives of the project were:

- Quantify the gains in animal liveweight and condition when grazing diverse shrub-based grazing systems over periods otherwise experiencing feed shortage, and measure indicators of rumen function and health.
- Develop an improved old man saltbush variety with particular attention to organic matter digestibility, palatability and productivity.
- Practice change on 500 farms.
- Deliver the updated animal–shrub package to 3,000 producers.
- Release clonal old man saltbush cultivar(s) to commercial partners to suit major regions with saline and non saline soils across southern Australia.
- Develop a case for commercialisaton and locate commercial partners for Enrich species.
- Convert existing 'researcher databases' on characteristics and traits of Enrich shrub species to an integrated and more user-friendly database as a legacy of Enrich phases 1-3.

3. Methodology

3.1 Quantifying the gains in animal liveweight and condition when grazing diverse shrub-based grazing systems including indicators of rumen function and health

Two paddock studies were conducted; one in WA (Quairading S 32.1326, E 117.3797) and one in SA (Monarto S 35.12080 E 139.13763). Both sites experience a Mediterranean environment characterised by winter rainfall and summer drought. The average annual rainfall at Quairading is 366mm and 383mm at Monarto. The Quairading site was established in the previous Enrich phase with support from Wheatbelt East Regional Organisation of Councils (through a Caring for Our Country grant). The Monarto site is a modification of a site similarly established through the previous phases of Enrich. Each site was designed to test underlying principles on the utilisation of forage shrubs, to inform grazing practices and improve the advice provided to producers.

3.1.1 Quairading site

The aim of the Quairading experiment was to determine whether a shrub-based forage system has higher animal productivity than a conventional 'unimproved' pasture system. In particular, it examined the benefit of a diverse shrub-based system in an autumn feed gap, compared to an autumn herbaceous pasture.

Five species of shrubs - *Atriplex nummularia* (old man saltbush), *Atriplex amnicola* (river saltbush), *Enchylaena tomentosa* (ruby saltbush), *Rhagodia preissii* (rhagodia) and *Eremophila glabra* (tar bush) - were planted as seedlings in three replicated plots of ~3.36 ha each in spring 2010. The shrubs were planted in double rows, 2m apart, with shrubs at intervals of ~1.5m within each row. As *E. glabra* did not establish well

at the site, no data on *E. glabra* are presented here. For each species, five double rows were planted in 2010, with inter-row spaces of 5m sown to a mix of annual pasture, mostly annual ryegrass and barley.

Merino wethers (n = 120) aged ~10 months were randomly allocated to two groups balanced for liveweight, the shrub system (n = 60) and the standard system (n = 60). Both groups were divided into three replicates (n = 20 sheep per replicate). At the start of the experiment, the sheep weighed an average of 35.7 kg (s.e. 0.26 kg) and had an average condition score of 2.5 (1–5 scale; Suiter 1994)[8]. Liveweight gain, condition score, and feed intake were measured over an 8-week period from April to May 2012. All animals were weighed at the same time of day on each occasion (0900–1000 hours) to minimise variation associated with changes in gut fill.

Each group of 20 sheep in the shrub system grazed 20m strips within their allocated plot, which provided an area of 0.28 ha. The width of the strips was determined so that the estimated feed on offer from both the shrubs and the inter-row pasture represented 130% of weekly requirements (maintenance plus growth). The shrubs were grazed at a high stocking rate, equivalent to 71 sheep/ha, and the sheep were moved on a weekly basis to a new strip within their allocated paddock. Over the 8 weeks of grazing, 2.24 ha of the shrub plot was used for each group of 20 sheep, which was equivalent to a stocking rate over this period of 8.9 sheep/ha. This strip-grazing approach was taken to ensure that, in each week, there was sufficient grazing pressure to encourage consumption of the novel shrub species, and the movement to a new strip each week ensured that the sheep had access to the full range of shrub species each week. No supplementary feed (i.e. no hand-feeding) was provided to the sheep in the shrub system.

The amount of edible dry matter provided by the shrubs was estimated using the 'Adelaide' technique (Andrew et al. 1979)[9]. After grazing, the percentage of leaf removal from 50% of the shrubs in each plot was assessed visually using a 0–5 scale corresponding to 0%, 20%, 40%, 60%, 80%, and 100% removal. Shrub intake was calculated from the edible biomass on offer pre-grazing and the proportion of leaf removed during grazing.

Pasture biomass was assessed from 20 quadrat cuts of the interrow during each week of grazing, and the difference in biomass between pre- and post-grazing was used to estimate pasture intake.

The amount of supplementary feed provided to sheep in the standard system was adjusted during the course of the experiment to ensure that the sheep maintained liveweight. The amount of supplementary grain fed was 100 g/head/day for the first 3 weeks, 200 g/head/day in week 4, 300 g/head/day in week 5, and 400 g/ head/day in weeks 6–8.

[8] Suiter, J. (1994) Body condition scoring of sheep and goats. Farmnote. Department of Agriculture, Western Australia, South Perth, WA.

[9] Andrew, M.H., Noble, I.R., and Lange R.T. (1979). A non-destructive method for estimating the weight of forage on shrubs. Australian Rangelands Journal 1, 225–231.

Food intake, liveweight and condition score of sheep in the shrub system was compared with that of sheep in the standard system group using ANOVA with repeated-measures (weeks).

3.1.2 Monarto site

At Monarto the aims were to determine 1) whether animal live weight is increased when grazing diverse shrub-based forage systems, and 2) if animals having previously experienced brief but frequent exposures to their current diet have higher intake & better performance than animals with no prior experience of their diet.

The experiment was conducted with four treatments each replicated two times. The treatments were:

1) Experienced sheep with diverse shrub-based systems
2) Naïve (no prior experience) sheep with diverse shrub-based systems
3) Experienced sheep with monoculture shrub-based systems
4) Naïve (no prior experience) sheep with monoculture shrub-based systems

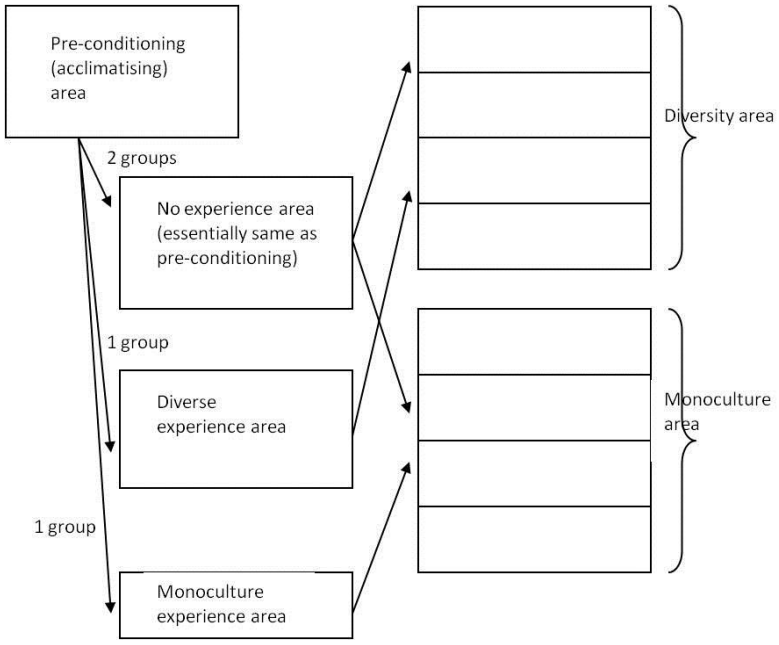

Figure 1: Schematic diagram of the experimental design

Prior shrub experience

In March 2012, 120 9-10 month old white Suffolk ewe hoggets were introduced to Monarto and acclimatised by grazing pasture for three weeks with hay fed *ad libitum*. Subsequently, sheep were weighed, balanced for liveweight and randomly allocated into one of three areas which would give a differing dietary experience of shrubs: experienced with a diverse mixture of shrub ('experienced-diverse' n = 30),

experienced with a monoculture of shrub ('experienced-monoculture'; n = 30) or not experienced with shrubs ('naïve'; n = 60).

Sheep were grazed in these areas for 16 days. The diverse shrub area comprised of a 1 ha plot planted with four species of shrubs, *Acacia ligulata* (sandhill wattle), *Atriplex amnicola*, *Atriplex nummularia* cv. Eyres Green and *Eremophila glabra*. Five accessions of *E. glabra* and two accessions of *A. ligulata* were planted. The other species consisted of a single accession. The monoculture shrub area comprised a 0.7ha plot with one species of shrub, *Atriplex nummularia* cv. Eyres Green. Eyres Green is a clonal cultivar. Sheep in the naïve group grazed in an area (2ha) on volunteer pasture for the experience period. To maintain an adequate level of pasture, sheep in the naïve group were given an extra 1ha of pasture after one week.

Edible biomass of the shrub species was estimated before grazing using the shortcut method of Andrew et al. (1979)[10]. Sheep preference was assessed using a modified scoring method based on Chippendale (1963)[11] four times (days 6, 9, 12 and 15) during the experience regime on every shrub. The percentage of leaf removal was calculated from this scoring method based on the equation $y = 0.0607x^2 - 0.1393x + 0.08$. Pasture biomass was obtained from cutting 20 random quadrats ($0.1m^2$) per experience regime at the same time as the assessment of shrub preference. Biomass samples were dried at 60ºC for 72 hours before weighing. All sheep were weighed and rumen fluid samples were taken at the beginning and end of the experience regime for analysis of volatile fatty acids and ammonia.

Main grazing period

After the experience regime, sheep were then randomly allocated into four treatment groups, each replicated two times: Experienced with diverse shrub system (n = 30, 15/replicate), Naïve with diverse shrub system (n = 30, 15/replicate), Experienced with monoculture shrub system (n = 30, 15/replicate), Naïve with monoculture shrub system (n = 30, 15/replicate).

The diverse shrub system consisted of four main plots (sheep from the two experience regimes replicated twice) of 0.79 ha each. Each main plot contained a range of different shrub species (Table 1). Shrub species were randomly planted in sub-plots consisting of 36 plants, using a 6 x 6 layout with 3m (inter-row) x 1.5m (intra-row) spacing for all species (2222 plants ha^{-1}). Species were established by planting seedlings in September and October 2006 or November 2010. Shrubs were planted into rows which had been deep ripped to a depth of 30-50cm prior to planting.

The monoculture shrub system consisted of four 0.7ha plots (sheep from the two experience regimes replicated twice) each containing the shrub *Atriplex nummularia* cv. Eyres Green. Shrubs had been planted in November 2006 into rows which had been deep ripped to a depth of 30-50cm prior to planting.

[10] Andrew, M.H., Noble, I.R., and Lange R.T. (1979). A non-destructive method for estimating the weight of forage on shrubs. Australian Rangelands Journal 1, 225–231.
[11] Chippendale, G.M. (1963). The effects of grazing on topfeed in Central Australia. Australian Journal of Experimental Agriculture and Animal Husbandry 3, 30-34.

Edible biomass of the shrub species was estimated before grazing on the 24 central shrubs in each sub-plot using the shortcut method of Andrew et al. (1979)[12]. Sheep preference was assessed on every shrub using the scoring method described above twice per week during the duration of grazing. This method was used to estimate the removal of biomass during grazing.

Pasture biomass was obtained from cutting 20 random quadrats ($0.1m^2$) per main plot before grazing and then twice per week during the duration of grazing. Quadrats taken in eight pasture cages (one per main plot) at two times were used to estimate pasture growth during the experimental period. Biomass samples were dried at 60ºC for 72 hours before weighing. The difference in pasture biomass during two periods - pre grazing and day 21 of grazing and day 21 and post grazing - was used to estimate pasture intake.

Sheep liveweight was measured every 10 days on all animals and rumen fluid was taken from five animals per main plot four weeks after sheep were introduced to the main treatment. The total pasture and shrub intake, liveweight and rumen fluid of sheep in the four treatments was compared using ANOVA with the experience and diet combination as well as time as factors. Significant differences between treatment means were compared at a 5 % significance level using Least Significant Difference (LSD).

[12] Andrew, M.H., Noble, I.R., and Lange R.T. (1979). A non-destructive method for estimating the weight of forage on shrubs. Australian Rangelands Journal 1, 225–231.

Table 1: Species composition (number of plants) of the diverse shrub treatment across the four plots

Experience regime	Experience		naïve	
Plot	1	2	1	2
Acacia iteaphylla	31	36	36	
Acacia ligulata	164	179	175	165
Acacia loderi	17			
Acacia pendula			2	
Acacia pycnantha			23	
Acacia saligna				35
Atriplex amnicola	35	35	36	35
Atriplex cinerea		3	34	
Atriplex nummularia	238	248	247	252
Atriplex paludosa	34	35	29	34
Atriplex rhagodioides	70			
Atriplex semibaccata				33
Atriplex vesicaria	46	44	14	77
Chameacytisis prolifer			32	
Chenopodium nitrariaceum	66	70	70	69
Enchylaena tomentosa	108	151	109	138
Eremophila bignoniiflora		11	9	
Eremophila glabra	218	210	204	209
Eremophila longifolia			23	7
Eremophila maculata	2	33	0	2
Kennedia nigricans	27	27	22	28
Kennedia prorepens	15		13	
Maireana astroticha		21		
Maireana brevifolia	27	43	93	18
Maireana georgei	36			
Maireana pyramidata	36	28	35	53
Maireana sedifolia			35	
Maireana tomentosa	19			32
Rhagodia candolleana	69	70	70	70
Rhagodia crassifolia		36	34	36
Rhagodia parabolica		36	24	36
Rhagodia preissii	35	36	36	36
Rhagodia spinescens	35	35	35	55

3.2 In vivo animal performance trials for old man saltbush clone(s)

An *in vivo* feeding experiment was conducted from January to March 2014 to see if laboratory predictions of the energy value of saltbush varieties were accurate. This was critical as energy (digestibility) was our primary plant improvement target. This was the third *in vivo* feeding experiment during the project. The first examined 3 'types' of old man saltbush and 5 other chenopods (Norman et al. 2010[13]), the second examined old man saltbush at a provenance level (from the first generation experiment at Tammin) and this final one focused on the 4 most promising clonal

[13] Norman, H.C., Wilmot, M.G., Barrett-Lennard, E.G., and Masters D.G. (2010) Sheep production, plant growth and nutritive value of a saltbush-based pasture system subject to rotational grazing or set stocking. Small Ruminant Research 91, 103-109.

lines and an industry cultivar. Combined, we now have 15 saltbush calibration standards with organic matter digestibility (OMD) ranging from 44 to 69%. These samples are now being used to retest and refine Near Infrared Spectroscopy (NIRS) predictions of digestibility.

For the third experiment, 2.5 t of leaves and small stems, representing 5 clonal varieties, were handpicked from the same paddock in Tammin. One of the varieties was the commercial variety Eyre's Green (Topline Nursery, SA). The CRC lines tested were the four that were selected for the 'research release' in 2014. Material was collected on 12 visits over a year, dried at 65°C in a fan forced oven and thoroughly mixed before feeding. Each variety was fed to 9 sheep housed in individual metabolism crates. The saltbush variety was fed as 50% of the diet with the balance being chaffed hay. We included hay in the diet as (a) the salt in saltbush restricts intake to below maintenance levels and (b) sheep in the field do not voluntarily eat more than 60% saltbush. Six sheep were also fed 100% chaffed hay to determine its digestibility. Sheep were offered 1 kg of dry matter per day (approximately the maintenance level of feeding). After a week of adaptation to the saltbush, a full faeces and urine collection was conducted for 7 days.

3.3 Elite old man saltbush seed line(s) generated for future research

Any new saltbush variety will normally be sold as nursery raised vegetative cuttings as this is the only proven way to ensure that genotypes have the elite nutritional traits. However, the final output of the project was to generate isolated plantations of the clones to generate seed lines with known parentage. If plants generated from seed of the elite saltbush lines compare favourably with their clonal parents, farmers will benefit with a 50% reduction in plant purchase costs. Further, we wanted to generate seed to explore the opportunity for direct seeding in the field. Traits of interest included germination rates from bracts and debracted seed, seed size, dormancy and 'threshability' (ease of removal of seeds from bracts).

Three WA nursery seed production sites were established in Tammin, Mokine and Clackline, each with about 1000 plants representing 9 elite females and one of the 3 males (clones 15, 58 and 87). In summer 2014, we harvested bracts from females at the sites where clones 58 and 87 were the representative males. The site with clone 15 failed to seed due to heavy predation by kangaroos. Over 1kg of bracts were harvested from each of the female clonal varieties at the other two sites. There were no seeds in the bracts from the clone 58 site, indicating incompatibility due to differences in timing of flowering and pollen production. Clone 87 proved a better male parent - all data presented in this report is therefore from the site in Tammin where clone 87 was the only male. Seed ecology literature suggests that seed traits tend to be determined by the female parent so the data concerning seed size, bract size and germinability should be good indicators of the potential of the female clone as a parent.

3.4 Practice change

Awareness raising

Awareness raising was an essential component in the overall adoption strategy. Awareness raising activities have included wider communication through the media and presentations at field days and similar events, the production of a booklet, contributions to industry publications, an updated webpage and the making of dedicated on-line videos. Partnering with regional groups to conduct local scale research has also been an integral strategy to engage with next and end users. Aiding community or producer groups (e.g. Landcare, farming systems groups or NRM organisations) in the application of new grants for forage shrub planting and demonstrations was also a strategy to raise awareness and generate practice change.

Assessment of practice change

By definition, for the purposes of the project, 'practice change' was deemed to have occurred when a landholder had undertaken one or more of the following practices:

- integrating complementary herbaceous pasture species into the shrub-based grazing system
- manipulating learnt behaviour and training of livestock to improve shrub utilisation
- utilising the shrub feedbase regularly (at least annually) and not solely as a drought reserve (through strategic fencing and / or vegetation management), including utilisation of saltbush to improve productivity
- inclusion of a range of 'Enrich shrub species' into the grazing system (this practice change will be very limited in the life of the CRC due to availability of the shrub species), including the purchase of new cultivars.

To calculate the extent of practice change, analysis was required across a range of different data sources. These sources include data collected across southern Australia from:

- evaluation forms collected from project leader led Enrich or Old Man Saltbush (OMSB) specific field days, workshops or farm walks
- evaluation forms collected at events where Enrich relevant delivery was a component in an otherwise wider agenda non-specific industry association field days, at which raising Enrich awareness was conducted
- interviews held with consultancy groups involved in forage shrub delivery
- information provided from nurseries about Enrich relevant forage shrub seedling sales
- evaluation data captured via accredited salinity training events (Saltland Knowledge Exchange)
- landholder responses to forage shrub related incentive programs
- other informed person surveys.

4. Results

4.1 Quantifying the gains in animal liveweight and condition when grazing diverse shrub-based grazing systems including indicators of rumen function and health

4.1.1 Quairading site (WA)

The mean intake of forage shrubs for sheep in the shrub system increased ($P < 0.001$) during the 8 weeks of grazing from 220 g/ head/day over the first 4 weeks to 600 g/head/day during the final week, with the two *Atriplex* species making the largest contribution during the last 4 weeks of grazing (**Figure 2**). The intake of *A. amnicola* and *E. tomentosa* did not vary significantly from week to week (average intake of 156 and 37 g/head/day, respectively). The intake of *A. nummularia* increased 4-fold ($P < 0.001$) in week 5, from 38 to 158 g/head/day and then doubled ($P < 0.001$) to 320 g/head/day during the final weeks of grazing. The intake of *R. preissii* showed a similar pattern of change to that of *A. nummularia*; it doubled from week 5 to week 6, but the average amount of *R. preissii* consumed was much lower, peaking at just 60 g/head.day in week 7. The proportion of edible leaf material consumed during the experimental period was: 70–90% of *A. amnicola* per week; 40% of *E. tomentosa* for the first 3 weeks, increasing to 90–100%by weeks 7 and 8;20%of *A. nummularia* during the first 3 weeks, increasing to 80–100% during the last 3 weeks;10%of *R. preissii* during the first 5 weeks, increasing to 50% by week 8 although with higher variability between the three groups than for the other species.

The mean intake of inter-row pasture by sheep in the shrub system was calculated as 1.4 kg DM/sheep/day (across weeks s.e. 0.14 kg DM/sheep/day). Observations when making the pasture quadrat cuts suggested that this might be an overestimate due to losses of plant material caused by trampling associated with the high grazing pressure. When this value was used, the intake of shrubs constituted an average of 24% of total DM intake during the 8 weeks of grazing, increasing from 16% in week 1 to 51% in week 8.

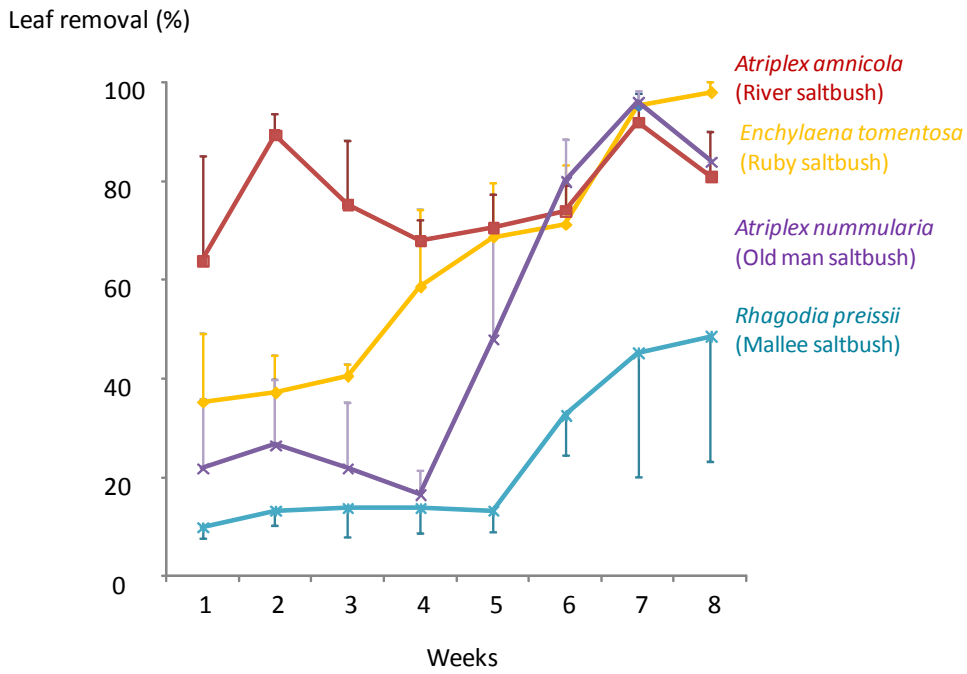

Figure 2: Dry matter intake of the four shrub species on offer by sheep in the shrub treatment over the 8-week grazing period

There was no significant change in the liveweight of sheep in the standard system treatment during the 8-week grazing period, nor was there any change in the liveweight of the sheep in the shrub system treatment for the first 4 weeks of grazing (**Figure 3**). However, liveweight increased over the final 4 weeks of grazing for sheep in the shrub system, such that they finished the 8-week grazing period at an average weight of 39.0 kg, which was 2.8 kg heavier ($P < 0.05$) than the starting weight of both groups and the finishing weight of sheep in the standard system (36.2 kg). The rate of weight gain averaged 63 g/head.day for sheep in the shrub system, exceeding ($P < 0.01$) the weight maintenance of sheep in the standard system (average daily gain of 4 g/head.day). There was no significant change in condition score during the experiment, with all groups commencing the experiment with a condition score of 2.5 (s.e. 0.006) and finishing with a condition score of 2.7 (s.e. 0.028).

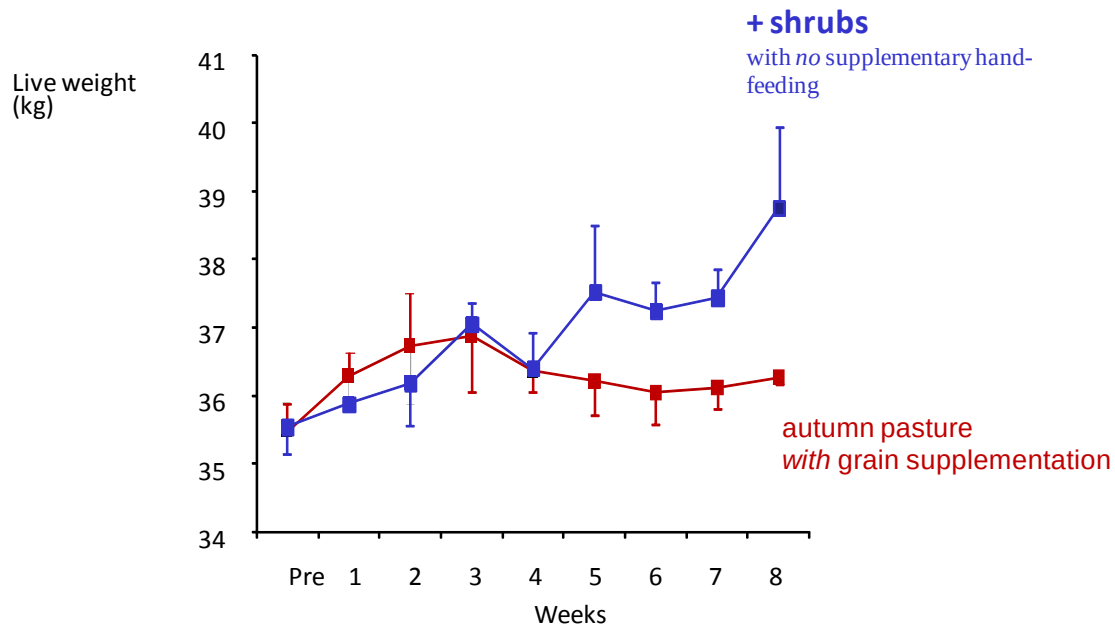

Figure 3: Live weight of sheep in the control group (autumn pasture) and shrub treatment before the experiment commenced ('Pre') and over the 8-week grazing period

4.1.2 Monarto site (SA)

Prior shrub experience

Total shrub biomass in the two shrub experience areas was similar (Table 2). However, in the diversity treatment biomass differed between species. Pasture productivity was also similar across treatments but differed in composition with the diverse treatment containing more perennial herbaceous species (**Figure 4**). About 25% of these species consisted of *Asphodelus fistulosus* (onion weed) which was not grazed.

Table 2: Edible biomass of shrub species in the diverse and monoculture pre-treatments

Pre-treatment	Species	Edible biomass g plant^{-1}	Number of plants	Total biomass (kg)
Diverse	*Acacia ligulata*	211.9	491	104.1
Diverse	*Atriplex amnicola*	24.5	170	4.2
Diverse	*Atriplex nummularia*	605.1	498	300.1
Diverse	*Eremophila glabra*	60.4	1029	61.9
Monoculture	*Atriplex nummularia*	596.6	682	406.9

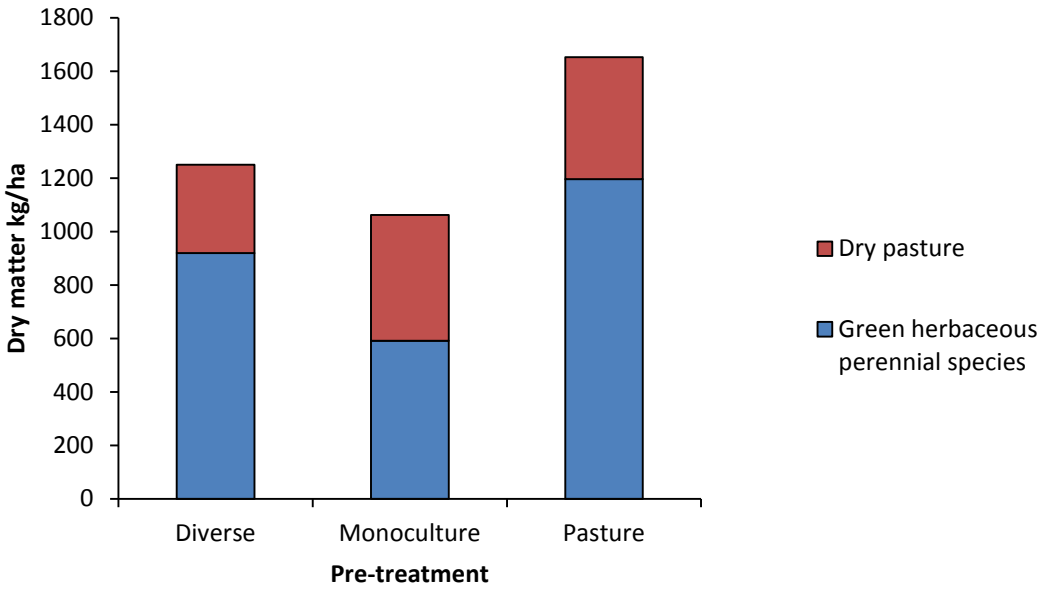

Figure 4: Pasture production in each of the three pre-treatments at the commencement of grazing

Sheep pre-grazed in the diverse shrub area consumed all the *E. glabra* (**Figure 6**), and also showed a difference in grazing preference between the five different accessions of this species (**Figure 6**

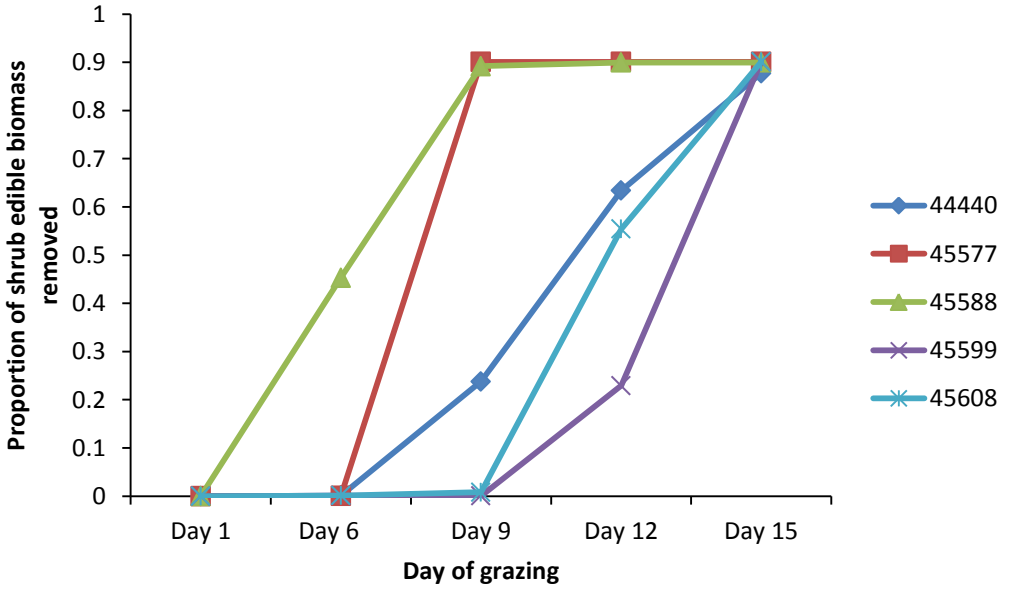

Figure 6). Sheep also consumed all the *A. amnicola* within the first few days although the total biomass of *A. amnicola* was low (Table 2). In the last 4 days of the experience period, sheep started to consume *A. nummularia* at a low level. *A. ligulata* was not grazed.

Sheep that grazed in the monoculture shrub area started to consume *A. nummularia* after about 8 days (Figure 7). Within the last 3 days of the experience regime, sheep

were estimated to be consuming approximately 420 g DM/sheep/day of *A. nummularia*.

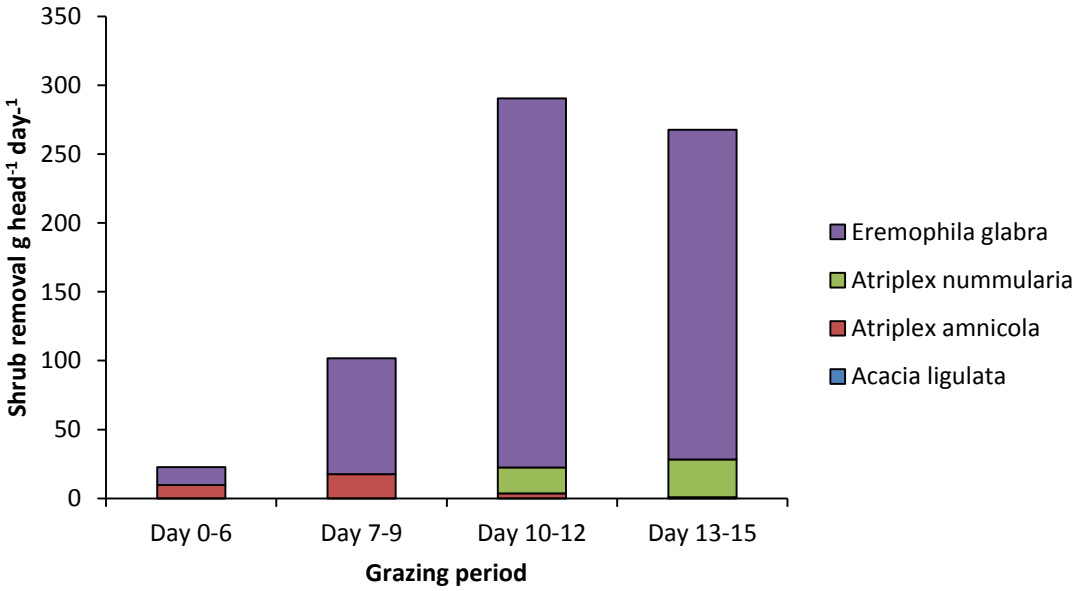

Figure 5: Estimated mean shrub removal per species during the pre-treatment grazing in the diverse shrub area

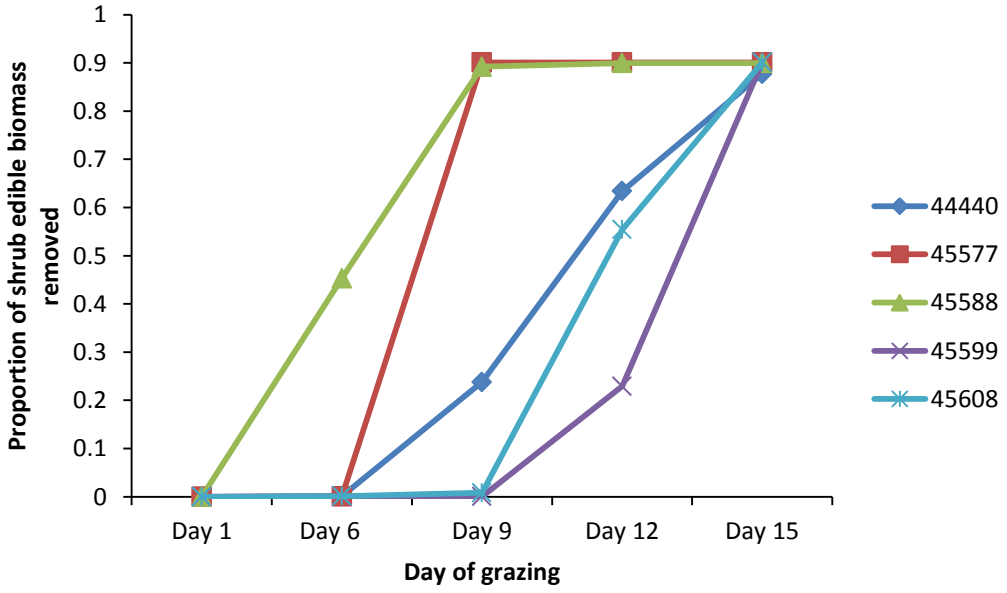

Figure 6: Defoliation of *E. glabra* accessions during the pre-treatment grazing period

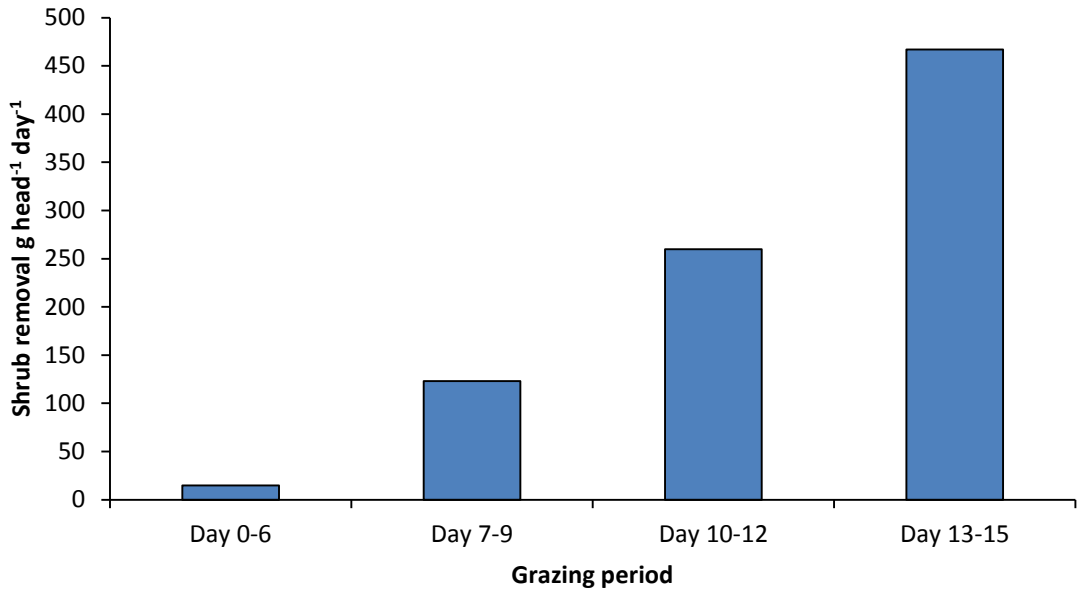

Figure 7: Estimated mean removal by sheep of *A. nummularia* during the pre-treatment grazing in the monoculture shrub area

Main grazing period

At the beginning of grazing, total shrub biomass was greater in the plots containing the diverse mixture of shrubs (Table 3). However, shrub biomass was not limiting in any plot. In these diverse plots, *A. nummularia* cv. Eyres Green comprised an average of 46% of the total shrub feedbase (Table 4). Pasture productivity did not differ between treatments (Table 5). Green pasture growth was estimated at 10.1 kg DM/ha/day over the experimental period.

Table 3: Total shrub biomass (±SE) at the beginning of grazing for the different groups

Main shrub diet	Experience regime	Shrub edible biomass (kg) (SE)
Diverse	Experience	1006.23 (37.09)
Diverse	Naïve	1053.07 (131.09)
Monoculture	Experience	481.19 (9.59)
Monoculture	Naïve	525.26 (0.52)

Table 4: Total edible biomass (kg) of the shrub species in the diverse shrub plots

Experience regime	Experience		Naive	
Plot	1	2	1	2
Acacia iteaphylla	97.3	109.3	125.0	
Acacia ligulata	283.9	16.5	63.4	29.7
Acacia loderi	24.1			
Acacia pendula			1.3	
Acacia pycnantha			39.4	
Acacia saligna				38.2
Atriplex amnicola	12.8	31.4	28.3	43.3
Atriplex cinerea		1.2	15.5	
Atriplex nummularia	387.0	474.3	362.2	678.2
Atriplex paludosa	20.9	26.3	1.4	49.9
Atriplex rhagodioides	83.0			
Atriplex semibaccata				9.2
Atriplex vesicaria	23.5	31.7	2.9	50.7
Chameacytisis prolifer			11.6	
Chenopodium nitrariaceum	4.9	2.9	24.6	5.7
Enchylaena tomentosa	13.2	27.6	17.6	41.6
Eremophila bignoniiflora		21.0	2.4	
Eremophila glabra	27.4	20.6	26.1	22.1
Eremophila longifolia			35.6	2.1
Eremophila maculata		30.7		5.1
Kennedia nigricans	3.2	5.6	1.2	7.4
Kennedia prorepens	0.4		0.1	
Maireana astroticha		17.8		
Maireana brevifolia	4.6	7.3	15.9	3.1
Maireana georgei	3.8			
Maireana pyramidata	3.4	34.1	37.4	46.0
Maireana sedifolia			18.2	
Maireana tomentosa	1.6			40.9
Rhagodia candolleana	18.6	3.3	3.0	1.9
Rhagodia crassifolia		17.2	16.3	29.1
Rhagodia parabolica		36.6	28.8	42.9
Rhagodia preissii	3.7	25.7	19.0	32.8
Rhagodia spinescens	26.1	27.9	24.5	4.6

Table 5: Mean pasture productivity (±SE) at the beginning of grazing for the different groups

Main shrub diet	Experience regime	Pasture DM kg/ha
Diverse	Experience	955.49 (46.72)
Diverse	Naïve	947.06 (29.94)
Monoculture	Experience	1073.3 (28.76)
Monoculture	Naïve	1003.97 (18.71)

Shrub intake was not constant ($P<0.001$) and was much greater ($P<0.001$) in the two diverse treatments until the final grazing period (Figure 8). There was no effect of the experience regime on removal in each main diet treatment. Estimated shrub intake in the diverse treatment was very inconsistent during the grazing period but peaked between 19-21 days. At this time, shrub intake was estimated to be 1158 g

DM/head/day. The shrub species selected in this diverse system was constantly changing during the grazing period as the feedbase changed in response to diet preference and availability. In the monoculture system, shrub removal by both experience groups was generally very low (<150 g/head/day) and did not change until the final ten days of grazing when it increased to more than 500 g DM/head/day. Estimating shrub intake by the methodology used probably resulted in an overestimate of feed intake. We do not have a significant level of understanding of how much of the shrub forage is wasted, particularly with some of the species (e.g. *Rhagodia candolleana*) in the diverse treatment which appeared to lose a lot of leaves during the browsing process.

Removal of pasture decreased from a mean of 1.4 kg DM/head/day during the first 21 days to 0.8kg DM/head/day over the final 21 days (P<0.05) and did not differ between the four treatments.

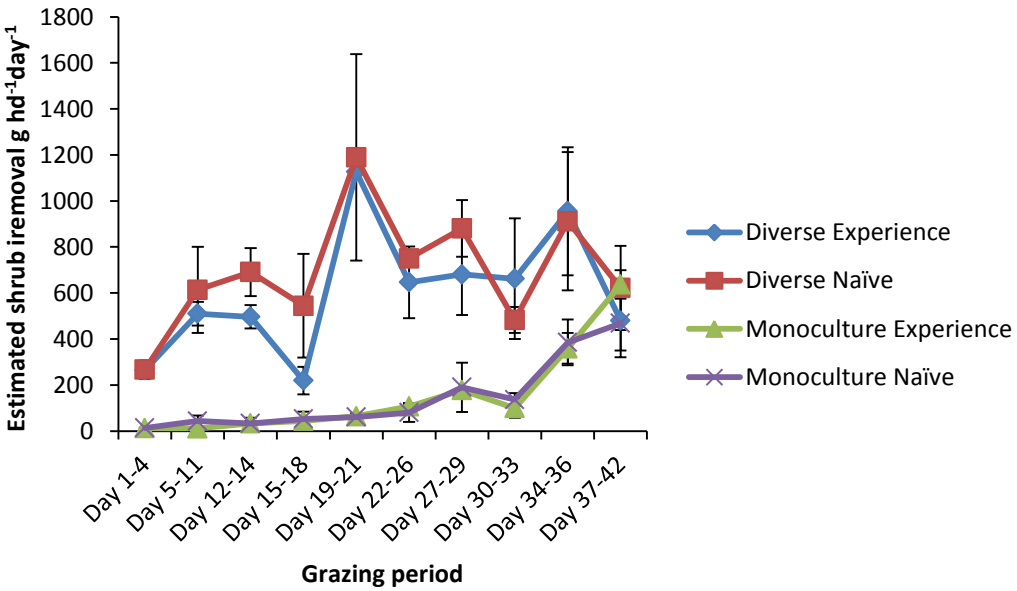

Figure 8: Estimated mean shrub removal by sheep over the main dietary treatment period. Error bards indicate the standard error.

All experience groups except the group grazing the monoculture system had mean increases in live weight over the experience period. During the main experimental period, liveweight of sheep differed over time (P<0.001) and between the four groups (P<0.001). Naïve sheep grazing the diverse system finished on average 1.5kg heavier at the end of the whole experimental period. Greatest weight gain was achieved after 25 days of grazing the shrub system in all groups. The naïve group grazing the diverse system had a mean increase of 3.08kg over the 25 days.

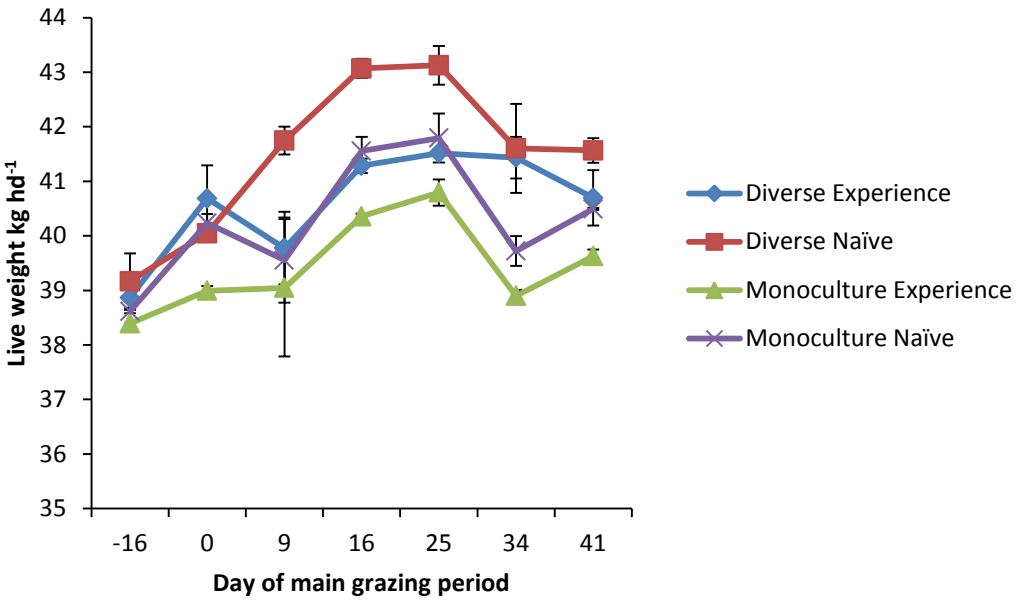

Figure 9: Mean live weight of sheep over the experimental period. Day 0 indicates the start of the main grazing period. Day -16 is the commencement of the experience regime. Error bars indicate the standard error.

Rumen fluid was taken from sheep at the commencement and end of the pre-treatment and then four weeks after grazing the main dietary treatment. VFA concentration differed between groups ($P<0.05$) and over time ($P<0.05$). VFA concentration was higher from experienced sheep grazing the monoculture treatment (**Table 6**). There was a significant interaction between time of sampling and experience-diet group for ammonium concentration in the rumen ($P<0.05$). Both groups grazing the monoculture system had increased ammonium concentration after the four weeks of main grazing period.

Table 6: Total VFA concentration and ammonia (±SE) in rumen fluid collected from sheep grazing different forage systems at Monarto, SA

	Total VFA concentration* (mmol/L)			Ammonia (mg/L)		
	Start	Pre-treatment	During grazing	Start	Pre-treatment	During grazing
Diverse Experience	64.8 (2.7)	51.5 (1.4)	47.8 (6.2)	59.2 (8.4)	46.5 (2.7)	41.5 (2.7)
Diverse Naïve	62.9 (0.07)	43.1 (0.3)	47.3 (7.5)	60.9 (3.5)	57.8 (0.2)	31.4 (5)
Monoculture Experience	68.9 (0.01)	68.0 (3.9)	62.8 (1.7)	62.9 (7.9)	86.3 (1.3)	101.1 (12.9)
Monoculture Naïve	67.6 (0.5)	43.4 (2.5)	61.2 (8.2)	55.9 (4.3)	57.7 (6.5)	70.3 (9.3)

* Total VFAs were calculated as the sum of acetic, propionic, butyric, iso-butyric, iso-valeric, valeric and caproic acids.

4.1.3 Field studies - Discussion

The experiments demonstrated the use of shrub-pasture mixtures to achieve weight gain over autumn, a time in which sheep in many southern Australian grazing systems typically lose weight or require supplementary feeding. At the WA site, sheep grazing the senesced pasture system required 14 kg of supplementary grain just to maintain weight during the same period. Supplementary feeding carries not just the direct cost of the feed but also labour costs.

At the SA field site shrub intake was significantly higher in the diverse treatment and from both sites it is clear that livestock can incorporate a diverse mix of shrub species into their diet relatively quickly. Whilst sheep could have consumed only one species in these diverse systems, they continually consumed a wide array of plant species. In SA, the shrub feedbase comprised 20 species. However, it may be more productive and definitely more practical to plant only a few key species as was used in the WA experiment. Enrich has identified 10 of the most promising shrub species for use in low rainfall zones of southern Australia. The five used in WA were all from this list of 10. The quantity and quality of the inter-row pasture is also critical in generating the most out of grazing shrub-based systems.

Eremophila glabra which, from earlier phases of Enrich and partner projects, shows strong potential in reducing methane emissions (Durmic et al. 2010[14]) was readily consumed at the SA site. This is in contrast to the experiment in WA where it was not eaten. This could possibly be due to the increased diversity present in this species in SA. Five accessions of this species were planted and sheep showed distinct preferences between these. The accession 45599 was the least preferred and this was the genotype planted at Quarading. The more preferred accessions may have allowed the animals to readily experience this species and allow the gut environment to adjust before intake of the least preferred 45599.

Rumen VFA concentrations were (around 50 mmol/L) within expected concentrations and indicative of a moderate quality diet. Published values are: 53-60 mmol/L (pre-feeding) and 74-82 mmol/L (post-feeding) (Males and Purser 1970)[15] for sheep fed a diet consisting of lucerne meal and ground corn; 75 mmol/L at feeding, dropping to 20 mmol/L within an hour for sheep fed dried grass, or 120 to 70 mmol/L for sheep fed concentrate diets (Annison 1954)[16]. Given that sheep were sampled after 1-4 hours off feed, the values obtained are consistent with others reported in the literature and do not seem to indicate any obvious impediment to rumen function.

The values for rumen ammonia concentration obtained with shrub-based diets may indicate that the sheep were able to efficiently use the crude protein supplied by the

[14] Durmic, Z., Hutton, P., Revell, D.K., Emms, J., Hughes, S., and Vercoe, P.E. (2010). In vitro fermentative traits of Australian woody perennial plant species that may be considered as potential sources of feed for grazing ruminants. Animal Feed Science and Technology 160, 98-109.

[15] Males, J.R., and Purser, D.B. (1970). Relationship between rumen ammonia levels and the microbial population and volatile fatty acid proportions in faunated and defaunated sheep. Applied and Environmental Biology 19, 485-490.

[16] Annison E.F. (1954). Some observations on volatile fatty acids in the sheep's rumen. Biochemical Journal 57, 400-405.

shrubs. The ratio of digestible organic matter to nitrogen in shrubs suggests the intake of metabolisable energy would be limiting animal production rather than crude protein supply (Revell et al., 2013[17]).

The sheep in the WA experiment were managed in a way that provided them with a fresh plot of shrubs and inter-row pasture each week. This approach was taken to maximise the learning opportunities of the sheep by regularly providing them with the full mixture of plants. The increase in shrub consumption over the first 4–5 weeks of grazing showed that the animals had strong preferences when the forage shrubs were first offered but that this pattern changed as they adapted to a greater range of shrub species and consumed greater amounts of all species. In particular, the increase in intake of *R. preissii* during the 8 weeks of grazing suggests that the animals showed an adaptive response, via either changes in the population of rumen microbial species or a behavioural adaptation to a novel feed. However previous experience with shrub species did not translate into increased shrub intake or weight gain in SA. The differences between sites could be due to the different way the experience was offered. In WA the sheep were subjected to a fresh plot every week whereas, in SA the sheep were introduced to the same pre-treatment plot only once. It appears grazing management strategies that provide animals with repeated experiences of a diverse mix of shrub species over 4-5 weeks may be a more powerful technique than short duration set stocking.

4.2 Weed risk of prioritised species

The planting of any forage creates a risk of species escaping and becoming a weed, especially of the natural environment. Preventing the spread of weeds is the most effective method of weed control. Appropriate selection of species is the first step in this control. To guard against the introduction or use of new potential weed species, the weed risk of a species can be assessed using a set of questions on climatic preferences, weed history, biological attributes, reproductive and dispersal mechanisms. Many of the inherent biological attributes that make a plant species a successful agricultural plant also make it prone to becoming a weed species. The use of Australian native species does not eliminate the risk of encouraging potential weed species. Australian native species can become weeds when they become established outside of their true indigenous range. There are many examples of Australian species as weeds within Australia.

The Future Farm Industries CRC has an environmental weed risk assessment protocol which contains a scoring system which can assess the relative weed risk of the plant species. This system has been used to assess the weed risk of the potential forage shrubs being prioritised. The project team was responsible for answering the 27 questions in the assessment and providing information to determine the suitable soil types for each species. The potential distribution was then mapped through the FFI CRC weed risk project. Finally, the assessments were reviewed by a number of independent experts outside of the project team.

Of the ten prioritised forage shrub species, weed risk assessment was conducted on nine species. These species were *Acacia ligulata*, *Atriplex amnicola*, *Atriplex nummularia*, *Chenopodium nitrariaceum*, *Enchylaena tomentosa*, *Eremophila glabra*, *Maireana brevifolia, Rhagodia preissii* and *Rhagodia spinescens*. Three of these species (*Atriplex amnicola*, *Atriplex nummularia* and *Rhagodia preissii*) were assessed in the earlier Enrich phases. *Atriplex rhagodioides* was not assessed due to its close taxonomic relationship and biological similarity with *Atriplex nummularia*. The FFI CRC also requested that *Chamaecytisus proliferus* be assessed as it could be continued to be used in certain niche environments with other Enrich species. Other forage shrub species assessed for their weed risk in earlier project phases were *Acacia saligna* and *Atriplex semibaccata*.

Of the prioritised shrub species, none of these were deemed to pose more than a low or negligible weed risk. Full weed risk assessments and scores for all the shrub species mentioned above can be found at http://www.futurefarmonline.com.au/research/biodiversity-water/weed-genetic-risk/assessments.

4.3 Update and integrate existing 'researcher' databases

The Enrich project has an extensive database on plant characteristics from over 100 species of Australian shrubs that relate to the suitability for their use as forage plants. The data includes:

- establishment
- biomass production
- regrowth following herbivory
- nutritive value, including *in vitro* digestibility, crude protein, neutral detergent fibre, acid detergent fibre, and macro- and micro-mineral composition
- *in vitro* anthelmintic effects
- *in vitro* fermentation traits, including methane production, volatile fatty acid composition, and ammonia production

In many cases, data span

- multiple accessions within a species
- age and/or stage of plant maturity
- seasons
- locations

Large amounts of the data have been published in scientific papers (e.g. Kotze et al. 2009[18]; Durmic et al. 2010[19]; Norman et al., 2010[20]; Revell et al. 2013[21]) and in the Enrich booklets (No.'s 1 and 2), but there remains information not fully represented in these publications. For example, we have unpublished data on species not shortlisted for further development, and information on the temporal and spatial variability in traits.

The large database is currently available to Enrich researchers through a Sharepoint site hosted by CSIRO. Once proof-reading the data for entry errors (e.g. repeated information), and removing data that is incomplete, we will migrate the database into the CSIRO-hosted Data Access Portal (DAP). The CSIRO Data Access Portal provides access to data published by CSIRO across a range of disciplines.

The portal is maintained by CSIRO Information Management & Technology to facilitate sharing and reuse of data. Various levels of access to the data can then be set, ranging from fully public to restricted access. The steps associated with depositing data are:

1. Describing the data, including details on who collected the data, how the data were collected, and where it came from.

2. Creating a citation; i.e. providing an attribution statement so the data can be used and appropriately cited by others in the future.

3. Uploading the data files, and additional 'read me' files is required

4. Protecting the data, setting access restrictions and selecting an end-user licence.

Once the files are made accessible to people outside of CSIRO, the files get a 'permalink' (i.e. a permanent web address) and a DOI (digital object identifier) which enables a document or a file to be tracked in perpetuity. If CSIRO ever change from the Data Access Portal, all data would be migrated across to any new system, so it helps overcome the problems of inadequate longevity and lack of ownership of websites.

In addition to the data and supporting documents, we can also add links to other material, including published papers. Once the information is placed in the DAP, the files can be found through a Google Search or other search engines. So once set up

[18] Kotze, A.C., O'Grady, J., Emms, J., Toovey, A.F., Hughes, S., Jessop, P., Bennell, M., Vercoe, P.E., and Revell, D.K. (2009). Exploring the anthelmintic properties of Australian native shrubs with respect to their potential role in livestock grazing systems. Parasitology 136, 1065-1080.

[19] Durmic, Z., Hutton, P., Revell, D.K., Emms, J., Hughes, S., and Vercoe, P.E. (2010). In vitro fermentative traits of Australian woody perennial plant species that may be considered as potential sources of feed for grazing ruminants. Animal Feed Science and Technology 160, 98-109.

[20] Norman, H.C., Wilmot, M.G., Barrett-Lennard, E.G., and Masters D.G. (2010). Sheep production, plant growth and nutritive value of a saltbush-based pasture system subject to rotational grazing or set stocking. Small Ruminant Research 91, 103-109.

[21] Revell D.K., Norman H.C., Vercoe P.E., Phillips N., Toovey A., Bickell S., Hulm E., Hughes S., and Emms J. (2013). Australian perennial shrub species add value to the feedbase of grazing livestock in low-medium rainfall zones. Animal Production Science 53, 1221-1230.

with good key words, people (who are given access, or everyone if the data are made public) can find the data even without knowing the unique web address.

Over the remaining months before Enrich 3 concludes, we will clarify:

1. management of the IP embedded in the database
2. appropriate attribution of the data
3. exactly which data is uploaded (we do not think it useful to upload all data that has been generated, but to be selective in uploading data that others will find useful and be a high-quality legacy).
4. what is to made publically available and what is kept to specified users
5. the form of the data; e.g. Excel files or text files (to ensure the data are always available despite changes in software over the years)

4.4 Development of a case for commercialisaton for Enrich species (excluding old man saltbush)

Feedback from next and end users have led us to feel there is a pressing need to have 'Enrich shrub species' commercially available. From a series of forums in 2011, there was a clear desire from attendees to acquire shrub species that possess desirable traits (78% of respondents). This has been re-enforced through additional landholder enquiries to project members and some nurseries about sourcing species. The number of new sites established with community action type funding is further evidence of a desire to uptake this research.

Enrich has never aimed to develop plant cultivars in the traditional sense. Instead it has focussed on identifying multiple species which have favourable attributes to be used in a grazing system. These species are not currently used or commercially available to agriculture (with the exception of old man saltbush). Whilst we have data on particular genotypes (lines) we have not selected within species for superior lines. At this point we will not be releasing any particular lines (genotypes) of any species. However, we acknowledge there are likely gains to be made from plant improvement in certain species.

Establishment cost and future on-farm adoption

Historically, the most commonly planted (native) forage shrub species is old man saltbush. Old man saltbush propagated in the nursery by seed sells for 30-40 cents per plant. The cost of tubestock which have been propagated by cuttings at the nursery level is likely to be higher (A. Sippel pers comm.). Old man saltbush has been sold commercially in Australia for around 20 years and the techniques used in its propagation have become sophisticated and successful. Further advances in efficiency are unlikely at this level making this a fair indication of the best price expected to be offered by the nursery industry for similar chenopod tubestock.

At a paddock density of 1000 plants/ha, the cost for tubestock alone is at least $300/ha. Further costs for ripping, weed control, planting and possibly companion pasture establishment also need to be added. A survey conducted in 2006, found the establishment cost reported by farmers for shrub plantations established by tubestock to be $328/ha (Revell et al. 2008[22]). Most of these sites were established in the 1990's when the tubestock price was around 20 cents each (Milthorpe et al. 2001)[23] but planting density was much higher than what would be recommended today.. Whilst the payback for shrub-based systems is long term, this upfront cost is a considerable barrier to adoption, especially at scale. Much of the area planted to forage shrubs past and present has been done with the support of various subsidies and incentives. It cannot be expected that these programs will continue and always be available into the future. An alternative method of establishment is needed to achieve low cost future on-farm adoption.

Direct seeding of forage shrubs could be the best opportunity to reduce the establishment cost to levels comparable with other forages such as legume pasture. The cost for direct seeding tagasaste as reported by farmers is around $110/ha (Revell et al. 2008[22]) and Milthorpe et al. (2001)[24] state a cost of $149/ha for establishing old man saltbush. A considerable risk with planting tubestock is that orders must be made with the nursery 6-8 months before planting. If seasonal conditions are not favourable for planting a very large loss to the nursery or landholder occurs. However, if using seed for on-farm sowing, this can be stored for the following season if unfavourable conditions are encountered.

Small amounts of research have occurred in the past on direct seeding woody species (Knight et al. 1998[25]) including native forage shrubs (eg Vlahos 2003[26]) . It is known that seed quality, seeding depth and weed control are important factors (Bulman 2004[27]). There have been some very good results at a local scale (Millsom 2002[28], Barrett-Lennard et al. 2003[29]). However, success has often been variable

[22] Revell, D., Vercoe, P., Bennell, M., Emms, J., Hughes, S., Dumic, Z., Monjardino, M., Byrne, F., Kotze, A., Toovey, A., O'Grady, J., Jessop, P., and Wiley, T. (2008). Enrich – Multi-purpose 'Healthy' Grazing Systems using Perennial Shrubs. Final Report. Future Farm Industries Cooperative Research Centre.

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[24] Milthorpe, P.L., Honeysett, B.M., Patton, D.A., and Wynne, M.J. (2000). Integration of alternative forage sources in drought management. Final report, Program 6, Drought Regional Initiatives Program, New South Wales Agriculture.

[25] Knight, A.J.P., Beale, P.E., and Dalton, G.S. (1998). Direct seeding of native trees and shrubs in low rainfall areas and on non-wetting sands in South Australia. Agroforestry Systems 39, 225–239.

[26] Vlahos, S. (2003). Developing an expert system for the establishment of saltbushes. Final Report Rural Industries Research and Development Corporation.

[27] Bulman, P. (2004). Guidelines for using perennial vegetation in the Murray Mallee. Report prepared for the Murray Mallee Local Action Planning Association Inc.

[28] Millsom, D. A. (2002). Direct seeding of saltbushes: Landholder driven initiatives. 2002. Ecological management and restoration 3, 156-166.

[29] Barrett-Lennard, E.G., Malcolm, C.V. and Bathgate, A. (2003). Saltland Pastures in Australia: a practical guide. Land, Water and Wool

(Milthorpe et al. 2001[24], Azam et al. 2012[30]) and the reasons for the variations in results have not been explored. Consequently, little old man saltbush is directly seeded commercially. Much of the research has been performed in isolation on one aspect of the direct seeding process, or in unique environments where practices have little relevance elsewhere. For example, in saline environments with associated winter water-logging, sowing after the start of August is recommended (Barrett-Lennard et al. 2003[29]). However, in the Murray Mallee, this would be extremely risky (Bulman 2004[27]). In addition, the shrub species which have been recently identified have not always been a part of previous research and are likely to have different seed biology traits. For the seed cost to be reasonable, consideration of the resources required to harvest, process and store seed must also be taken into account.

To achieve these outcomes, a program which gathers skills and knowledge in the following areas is required:

- Plant biology
- Seed biology
- Machinery
- Extension

A well-resourced, collaborative and co-ordinated approach will be required. At present there is no funding allocated to achieve this, and this is the major constraint to seeking lower-cost and reliable establishment of shrub-based systems.

4.5 Practice change

4.5.1 Awareness raising

Wider communication

Raising awareness of the Enrich project with landholders and land managers has been a major focus during this project phase. During this phase of Enrich, 61 print and web-based articles, seven radio and two television segments were produced (Appendix 1). Nine industry specific end user articles or publications have also been produced (Appendix 2). Four journal and conference papers were produced (Appendix 3).

Project members or associated partners and producers have spoken about Enrich at 59 events during this phase of the project (Appendix 4) reaching a direct audience of 2103 people. Some of these events have utilised Enrich sites, re-enforcing the concept of shrub-based grazing systems.

[30] Azam, G., Grant, C.D., Nuberg, I.K., Murray, R.S., and Misra, R.K. (2012). Establishing woody perennials on hostile soils in arid and semi-arid regions – A review. Plant Soil 360, 55-76.

The Enrich webpage on the FFI CRC webpage has received 1644 views (Figure 10) since April 2013. The webpage has links to numerous farmer case studies produced over the life of the FFI CRC as well as the Enrich booklets. The Enrich webpage on the SARDI site has traffic data available only from August 2013. This site has had less traffic than the FFI CRC page, with 208 views in that time period.

Seven on-line videos have been uploaded during this project phase (Appendix 5), bringing the total to ten available videos on the web about the project. These videos have received 2480 views thus far (Table 7).

The booklet published in 2011: Enrich Perennial forage shrubs providing profitable and sustainable grazing: Key practical findings from the Enrich project, has continued to be very popular and a fourth print run of 2000 copies was printed in 2013. It is still viewed on-line as evidenced by **Figure 10**.

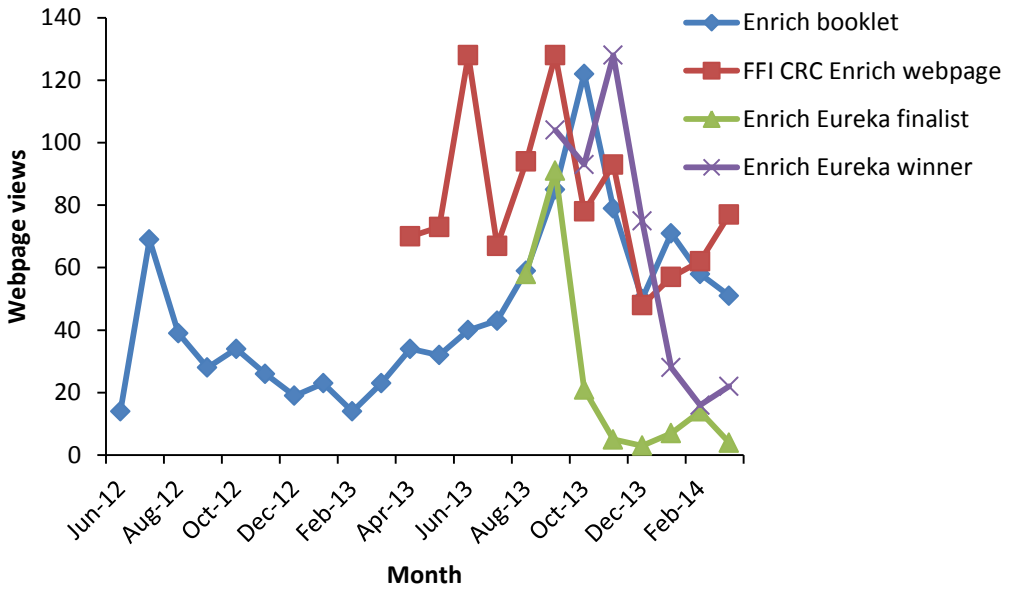

Figure 10: Number of monthly views of the FFI CRC Enrich related webpages

A new booklet, Perennial forage shrubs: from principles to practice for Australian farms: A companion publication to Perennial forage shrubs providing profitable and sustainable grazing: Key findings from the Enrich project, was published in 2014 (**Figure 11**). This new version aims to be an accompaniment to the existing booklet and not an updated version. It is aimed primarily at producers and landholders and aims to answer more of the practical questions about implementing shrubs on farms. The booklet is available on line from http://www.futurefarmonline.com.au/LiteratureRetrieve.aspx?ID=169908.

A brochure targeted to inform nurseries of species identification, project progress and prospects was developed in 2012. A subsequent factsheet focused on species selection was printed in 2013. During all phases of the Enrich project numerous

farmer case studies have been published mainly through Future Farm. Ten of these case studies have been selected and have been printed separately to augment other extension material. Dedicated Enrich document wallets have been printed to house these materials to aid in distribution.

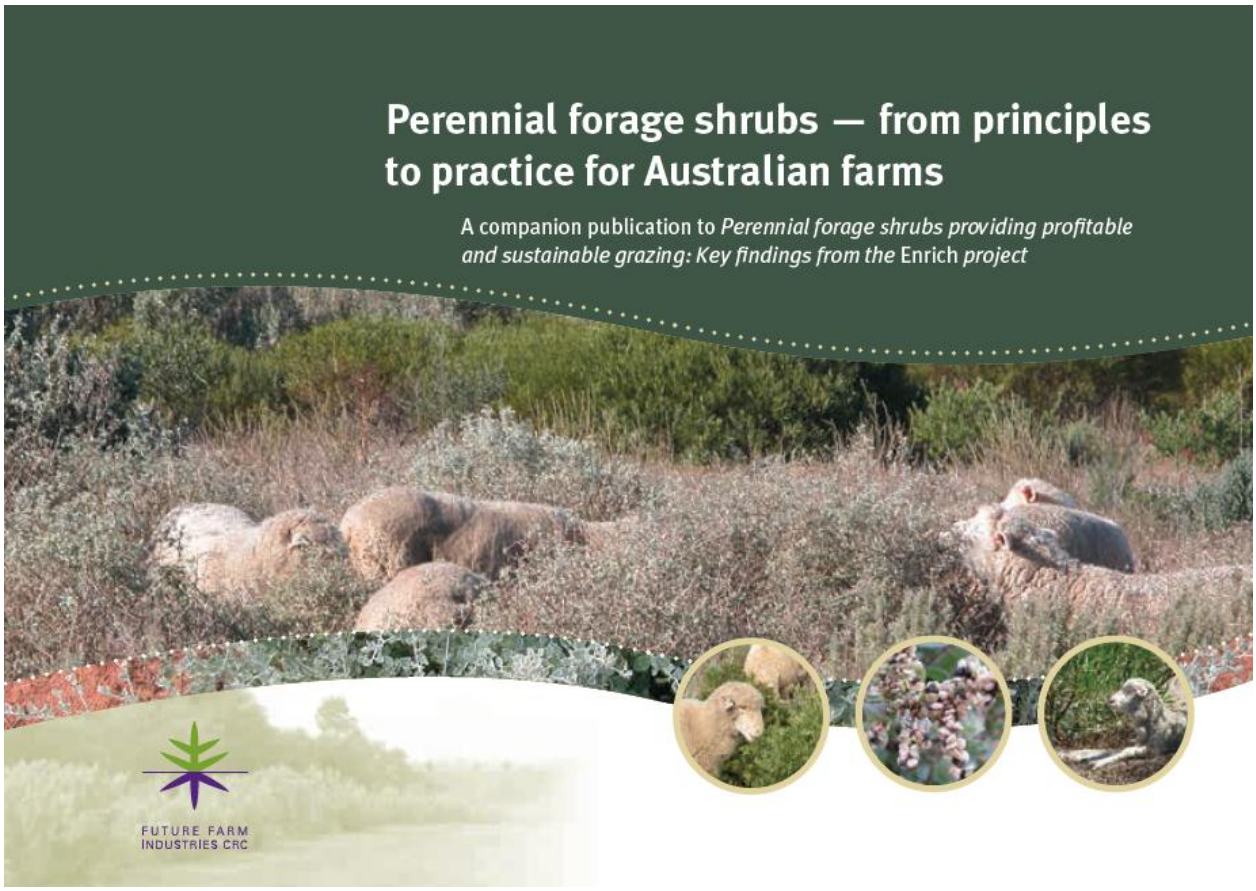

Figure 11: Front cover of new Enrich booklet

Table 7: Summary of awareness raising activities

Activity	Number	Number of attendees/views
Presentations (i.e. field days, workshops, conferences)	50	1951
Field site visits (Enrich sites)	9	152
Print/web articles	61	
Radio segments	7	
Television segments	2	
Journal/conference articles	4	
End-user industry publications/articles	9	
On-line videos	10	2480
FFI CRC Enrich webpage(s) (incl. Eureka releases)	3	1644 (from 1/4/2013 only)
SARDI Enrich webpage	1	208 (from 14/8/2013 only)
Enrich booklet downloads	1	1013 (from 1/6/2012 only)

Eureka Award

A significant achievement was the Enrich project being awarded a Eureka Prize in the inaugural Sustainable Agriculture category. The award was presented at the Australian Museum's Eureka Prize dinner in Sydney in September 2013. The Eureka Award generated a considerable amount of media about the project. A FFI CRC media release was distributed to their media list, plus via distribution network MediaNet. The Australian Museum, who coordinate the Eureka Prizes, contracted 'Science in Public' to manage media for the Eureka Prizes. Their media activity included tweets, webpage updates, letters to stakeholders, a media release, and media interviews for the winners. The Eureka prize generated 33 media stories for the project across print, electronic, radio and television mediums. A specific video available on-line was also produced for the awards (http://www.youtube.com/watch?v=U1kLB59WHNU).

The FFI CRC also participated in an active Twitter conversation on the awards night, and following days. In the week following the Award, the FFI CRC's Twitter account gained 35 per cent of its 69 monthly new followers and 80 per cent of its monthly impressions (opportunity to see) through tweeting activity.

Since the first media release was distributed in August on Enrich being a Eureka finalist and including the subsequent release on 6 September both stories have received a total 669 on-line visits directly. The existing Enrich Booklet posted on the FFI CRC website correspondingly has showed an increase in views since the awards, peaking during September and October with 85 and 122 downloads respectively. In the six month period since September 2013, the Booklet has averaged 79 views per month compared with the previous 12 month period where there were only 32 views per month (Figure 10).

Facilitation of community or producer groups in the application of new grants for forage shrub planting

A significant strategy in trying to raise awareness and achieve practice change has been to facilitate community or producer groups (e.g. Landcare, farming systems groups or NRM organisations) in the application of new grants for forage shrub planting and demonstrations. At least 13 groups over four states have applied for their own funding to establishing forage shrub plantings with some producing multiple proposals. At the time of writing we know nine of these groups have been successful in obtaining funding. It is also possible other groups have applied for funding without contacting anyone in the project team.

Exclusive old man saltbush improvement communication activities

Numerous wider communication and awareness raising activities involving next and end users have occurred in this part of the project (Appendix 6). This project has had significant producer interest as evidenced by media interviews and stories (Appendix

7), requests for information and the fact that the research release of 250 000 plants sold out within a month. Demand has been much greater than available shrubs. Seven referred publications were also produced (Appendix 8).

4.5.2 Assessment of practice change

Given the Enrich project was an amalgamation of at least two previous projects, the data that is available as part of calculating the extent of practice change is diverse and variable in detail. In the absence of any specific, consistently collected whole-of-project practice change data, this calculation required analysis across a range of different data sources. The outcome of this analysis revealed that there were over 6,600 industry interactions with Enrich/old man saltbush delivery events. This included producers (farmers), researchers, advisers and other associated coordinators participating in industry events, the majority of which were based in South Australia and Western Australia. There is inevitably duplication amongst this data, with some producers able to be captured as attending, for instance, either more than one field day, or a field day and training event. Nevertheless, at least 201 unique delivery events were conducted throughout the life of the project including South Australia (72), Victoria (31), NSW (22) and Western Australia (76), as well as numerous associated events through which the program and associated information was promoted. Additionally, several nurseries were involved in promotion, sales and distribution of Enrich related species across the four states.

Analysis across the range of data sets reveals evidence of several practice change achievements.

1. A minimum of 583 landholders changing farm practice, including:

    - Direct sales of Enrich relevant forage shrub species to at least 243 unique landholders by nurseries
    - Evidence of Enrich relevant forage shrub species practice change by a further 340 landholders as collected from evaluation and other survey instruments at Enrich related events, or through direct correspondence with landholders, advisers or NRM / other Boards where specific individuals can be identified. This includes SA (128), WA (142), Victoria (53) and NSW (17).

Taking account of the remaining approximately 6000 participants involved in Enrich related events, and discounting 33 percent to account for duplicate participation, this figure conservatively estimates that approximately ten percent of those attending these events have changed farm practice as outlined above. Most of the events for which this data refers have little or no evaluation / survey data captured in relation to actual change. However, several captured ‘intention to change’ information and for those instances where this intention data was collected, over 95 percent of respondents indicated a desire to change in response to what they had learnt.

While the data over and above the confirmed practice change figures is inconclusive, the responses received through formal evaluation measures, from interviews conducted, and from associated nursery and other industry information, all collectively indicate that the project practice change achievement is likely to exceed 1000 and possibly much higher.

4.6 Student involvement

During 2013, a Masters student working alongside the project, has submitted their thesis titled, 'Saltbush (*Atriplex nummularia*) can increase soil organic carbon in salt-affected land in south Western Australia, but the magnitude of increase depends on site characteristics'. It was concluded an *A. nummularia* shrub system can increase soil organic carbon (SOC) in saline land, but site characteristics such as soil texture have an important effect on the magnitude of increase. Therefore, site characteristics are important in identifying opportunities to use shrubs as an approach to regenerate saline lands and increase SOC. The abstract can be seen in Appendix 9.

Additionally, a Honours student has recently submitted her thesis titled 'Investigation of the allelopathic potential of four native perennial shrub species on several pasture species'. The results demonstrated that some native shrubs (e.g. *Rhagodia preissii*) have a stronger negative allelopathic potential and may therefore reduce the germination and growth of companion pasture plants. The abstract can be seen in Appendix 9.

A PhD student has also worked closely with the Enrich project and due to part time status is expected to complete in 2016. Their project is titled 'A Study of Unique Secondary Metabolites in Australian Perennial Pasture Plants'. A subset of species researched in Enrich show promise in terms of antimicrobial and anthelmintic functions, and methane and acidosis reduction. The specific plant secondary metabolites (PSMs) that cause these effects are not well known but they can be identified through analysis by GC/MS. This project will aim to isolate volatile compounds of interest and test them for their relationship to sheep preference and beneficial physiological effects. Further studies will explore the relationship between PSMs to the plants' survival and defence behaviour.

An undergraduate student from The Fenner School of Environment & Society at The Australian National University conducted their field research for their Independent Research Project at the Monarto Enrich site during 2013. The study sought to determine if plantations of *Atriplex nummularia* (old man saltbush) alter the physical, chemical and biological properties of soil directly underneath their canopies as compared with soil only a few metres away in open inter-row spaces. The results found whilst some properties were affected by the presence of shrubs, the overall effect is less pronounced than in natural systems. This work is being developed for submission to a journal of publication.

5. Acknowledgments

This project was funded by the Future Farm Industries CRC and Meat and Livestock Australia. The project would like to acknowledge the input of the following people:

Nick Edwards, Geoff Gale, Craig Tilley, Rick Llewellyn, Bill Daveron, Tim Herrmann, Dale Stevenson, Jess Crettenden, Neil Ackland, Christian Preuss, Paul Erkelenz, Scott Williams, Allen Buckley, Ian Ellery, Tim Hollitt, Glenice Batchelor, Tanya Kilminster, Georgie Troup, Jane Bradley, Donna Rayner, Sam Bickell, Jill Griffiths, Jean Burton, Meg Hele, Cat Nicholls, Greg Richards, Tony York, Craig Forsyth, Narelle Beattie, Karen Nalder, John Arentz, Scott Glyde, Bruce Maynard.

6. Appendices

Appendix 1: Media on Enrich during the project period

Date	Title	Organisation/Forum	Medium
7/07/2011	Van Rooy a winner (incl. My Take)	Stock Journal pg 51	Print
25/08/2011	Natives may hold solutions	Countryman pg 11	Print
9/09/2011	Native grasses field day	Northern Times (Kerang) pg 5	Print
19/09/2011	Improve land for grazing on limited rainfall	The Advertiser pg 32	Print
20/09/2011	Diverse productivity discussions	Northern Times (Kerang) pg 8	Print
27/10/2011	Farmers urged to reduce livestock emissions	Farm Weekly pg 15 (WA)	Print
10/11/2011	On-farm solutions may come out of Africa	Farm Weekly pg 18-19	Print
1/12/2011	Enrichment for the triple bottom line	GRDC Ground Cover	Print
1/12/2011	Forage shrubs thrive in tough times	Future Farm (December 2011 issue)	Print
1/12/2011	Forage shrubs fill grazing gaps	Farming Ahead pg 62	Print
19/01/2012	Shrub trials hold feed key (incl. My Take)	Stock Journal pg 29	Print
21/04/2012		ABC Ballarat	Radio
14/06/2012	Emu bush lowers methane	The Land pg 65	Print
21/06/2012	RELRP Forages	DAFF media archives	Video
27/07/2012	Changing the Livestock Menu	Elders Farm Weekly	Print
1/10/2012	A shrub solution	MLA Feedback	Print
1/10/2012	Enriching the on-farm offerings	MLA Feedback	Print
29/10/2012	Enriching on farm grazing systems	Get Farming	Web
31/10/2012	Enriching on farm grazing	The Land	Web
31/10/2012	Enriching on farm grazing	Farm Weekly	Web
7/02/2013	Future Farm	ABC Catalyst	TV
21/02/2013		ABC South Western Victoria	Radio
21/02/2013		ABC Western Victoria	Radio
21/02/2013		ABC South East SA	Radio
21/02/2013		ABC North & West Country Hour	Radio
7/03/2013	Fodder shrubs cut down on risks	Stock Journal p 38	Print
14/03/2013	Incentive to add native plants to grazing menu	Smart Farmer p4	Print
1/04/2013	New options increase forage shrub potential	Future Farm	Print

Date	Title	Organisation/Forum	Medium
1/04/2013	Saltbush fills gaps in mixed-farming system	Future Farm	Print
1/08/2013	Forage shrubs - no silver bullets but many possibilities	Future Farm	Print
1/08/2013	Perennials support cattle backgrounding enterprise	Future Farm	Print
19/08/2013	Shrubs sought to provide sustainable grazing	Farming Ahead Online	Web
19/08/2013	Shrubs sought to provide sustainable grazing	ABC	Web
19/08/2013	Native shrubs could provide sustainable grazing solution	ABC Rural	Radio
4/09/2013	Eureka! Australian scientists celebrated at awards night	The Conversation	Web
5/09/2013	2013 Eureka Prize winners	Australian Life Scientist	Web
5/09/2013	Grazing sheep show appetite for native plants	The Australian, p 2	Print
5/09/2013	Enrich project nets prize	The Australian Dairy Farmer	Print/Web
5/09/2013	Enrich project nets prize	WEB Farm Weekly	Web
5/09/2013	Enrich project nets prize	WEB Queensland Country Life	Web
5/09/2013	Enrich project nets prize	WEB Queensland Register	Web
5/09/2013	Eureka prize science awards:	Getting to Sustainability	Web
5/09/2013	Eureka sustainable agriculture prize	WEB Efficient Farming	Web
5/09/2013	Eureka Prize - Dean Revell interview	Qld Country Hour, ABC Southern Qld	Radio
5/09/2013	Eureka Prize for old man saltbush project	WEB ABC Online	Web
5/09/2013	Eureka! We've done It again.	WhySci	Web
5/09/2013	The 2013 Eureka Prizes	AgriTapestry	Web
5/09/2013	Wrap-up of all winners – Eureka	Biotech Daily	Print
5/09/2013	Enrich project nets prize	The Land	Web
5/09/2013	Enrich project nets prize	Stock & Land	Web
5/09/2013	Enrich project nets prize	Stock Journal	Web
5/09/2013	Enrich project nets prize	Weekly Times	Web
5/09/2013	Eureka! We've done It again.	News @ Csiro	Web
5/09/2013	Enrich perennial farming system a Eureka winner	Get Farming	Web
6/09/2013	Sheep show appetite for native plants	WEB West Australian	Web
6/09/2013	Sheep show appetite for native plants	Seven News	Web
6/09/2013	Sustainable agriculture project wins Eureka award	UWA - WEB University News	Web
9/09/2013	Native plants the perfect food to keep stock alive, reduce gas	Wangaratta Chronicle	Print
9/09/2013	Eureka award for sustainable grazing project	SARDI News	Web

Date	Title	Organisation/Forum	Medium
10/09/2013	CSIRO wins award across science spectrum	Sustainable Family Life	Web
10/09/2013	CSIRO wins awards across science spectrum	ECOS Science for Sustainability (CSIRO Publishing)	Web
11/09/2013	WA research excels at Eureka science awards	ScienceNetwork Western Australia	Web
12/09/2013	Australian Museum Eureka Prizes	ABC Catalyst	TV/Web
12/09/2013	Eureka! Native shrubs lift profit	Stock & Land (Vic)	Print
12/09/2013	Team awarded for work on sustainable grazing systems	Countryman (WA)	Print
13/09/2013	2013 Australian Museum Eureka Prizes	WEB - labonline.com.au	Web
16/09/2013	Congratulations to the Eureka Prize Winners	Inspiring Australia (Qld)	Web
1/12/2013	Winds of change	KnowHow Magazine	Print
1/12/2013	Recovery time key to optimal saltbush utilisation	Future Farm	Print
1/4/2014	Enrich forage shrubs – removing 'marginal' from farming language	Future Farm	Print
1/4/2014	Shrubs provide profitable option on marginal land	Future Farm	Print

Appendix 2: Enrich end user publications during the project period

Date	Title	Publication	Medium
2012	Enrich – Incorporating a perennial shrub feedbase into mixed farming systems on Eyre Peninsula	2011 Eyre Peninsula Farming Systems Summary pp 135-138	Print
2012	Forage shrubs trial results	North Central Catchment Management Authority's (CMA's) Innovative Farming Program newsletter	Print
2012	Establishing perennial shrubs for mixed farming systems on Eyre Peninsula	2012 Eyre Peninsula Farming Systems Summary pp 143-145	Print
2013	Forage shrub options for Mallee mixed farming	Mallee Sustainable Farming 2012 Results Compendium	Print
2013	Enrich forage shrubs: Grazing systems with less risk	Future Farm Industries CRC Fact Sheet	Print
2013	Saltbush thrives under short-sharp grazing regime	Coorong Tatiara Local Action Planning (LAP) website	Web
2013	Recovery time key to optimal saltbush utilisation	Coorong Tatiara Local Action Planning (LAP) website	Web
2014	Forage shrub systems for the Mallee	Mallee Sustainable Farming 2013 Results Compendium	Print
2014	Enriching upper EP forage options	2012 Eyre Peninsula Farming Systems Summary	Print

Appendix 3: Journal and conference publications related to the Enrich project

Provenza F.D., Pringle H., Revell D.K., Hinds C., Bray N., Maynard B., and Teague R. (2012). Complex Adaptive Systems: Principles, Processes, and Practices Proceedings of Strategic Grazing Management for Complex Adaptive Systems. Fort Collins, Colorado, USA (29-30 November 2012).

Provenza F.D., Pringle H., Revell D.K., Bray N., Hinds C., Teague R., Steffens T., Barnes M., and Rittenhouse L. (2013). Complex creative systems: Principles, processes, and practices of transformation. *Rangelands* 35, 6-13.

Emms J., Vercoe P.E., Hughes S., Jessop P., Norman H.C., Kilminster T., Kotze A., Durmic Z., Phillips N., and Revell D.K. (2013). Making decisions to identify forage shrub species for versatile grazing systems. Proceedings of the 22nd International Grasslands Congress (Sydney, 15-19 September 2013) pp. 1372-1373.

Revell D.K., Norman H. C., Vercoe P.E., Phillips N., Toovey A., Bickell S., Hulm E., Hughes S., and Emms J. (2013). Australian perennial shrub species add value to the feedbase of grazing livestock in low-medium rainfall zones. *Animal Production Science* 53, 1221-1230.

Appendix 4: Enrich Presentations to next and end users during the project period

Date	Group/Event	Venue	Number of people
6/07/2011	Evercrop Local Adaptation Group	Allen Buckley's Farm/Waikerie Enrich site	11
17/08/2011	Moulamein Farm Efficiency Day	Moulamein Bowling Club	55
6/08/2011	Stress Free Stockmanship for Healthy Landscapes	Poltalloch Station	8
14/09/2011	Minnipa field day	Minnipa Agricultural Research Centre	120
14/09/2011	Native grasses and forage shrubs in farming systems	Lake Charm Hall	50
15/09/2011	Native grasses and forage shrubs in farming systems	Marnoo Public Hall/visit to Enrich St Arnaud site	30
18/10/2011	Drought-hardy and carbon conscious grazing systems	Ridgefield UWA Farm: whole-farm carbon emissions open day	145
27/10/2011	Adaptation options for livestock systems	CSIRO: WA 21st Century Climate Change Challenges Forum	90
9/11/2011	Animal nutritional wisdom and feeding behaviour - think of the small things when developing your big picture	7th National Native Grasslands Conference (Stipa) Holbrook NSW	90
10/11/2011	Streaky Bay/Wirrulla sticky beak day	Streaky Bay Enrich regional field site	29

Date	Group/Event	Venue	Number of people
5/03/2012	Central Eyre Peninsula Agricultural Bureau	Kyancutta Sports Club	22
6/03/2012	Minnipa/Mount Damper Agricultural Bureau	Minnipa Sports Club	14
6/03/2012	Charra/ Goode/ Nundroo Agricultural Bureau	Charra Sports Club	12
7/03/2012	Wirrulla/Muddy/Nunjikompita Agricultural Bureau	Wirrulla Sports Club	15
7/03/2012	Streaky Bay Agricultural Bureau	Piednippie Hall	12
8/03/2012	Elliston Agricultural Bureau	Elliston Hotel	15
8/03/2012	Port Kenny/ Mt Cooper Agricultural Bureau	Pt Kenny Golf Club	12
13/03/2012	Darke Peak/ Tuckey/ Rudall/ Waddikee Agricultural Bureau	Darke Peak Hotel	20
13/03/2012	Lock/Murdinga Agricultural Bureau	Lock Sports Club	22
14/03/2012	Crossville Agricultural Bureau	Simms Farm	14
14/03/2012	Franklin Harbour Agricultural Bureau	Cowell Sports Club	12
15/03/2012	Arno Bay/ Wharminda Agricultural Bureau	Wharminda Hall	12
15/03/2012	Buckleboo Agricultural Bureau	Buckleboo Sports Club	20
3/04/2012	Pasture Update Series. Pastures and Green Feed Options for Northern Victoria	Boort Memorial Hall	70
10/05/2012	Forage Shrubs for The Future	Condobolin Agricultural Research Centre	16
24-26/7/12	ANCCART conference - "Animals adapting to change"	Perth	100
26/07/2012	Productive and profitable grazing systems for mixed farms in the Mallee	Manangatang Enrich Field Site (John Arentz's Property)	56
31/07/2012	Upper North Farming Systems Perennial Shrubs Sticky Beak Day	Kevin O'Dea's, Ian Ellery's, Neil Sleep's farms	16
14/08/2012	Integrating conservation and production through revegetation using native plant options - Native forage systems: purpose, options and management	Gillamii Centre, Gnowangerup and Cranbrook	20
15/08/2012	Mt Marshall - Native perennial forage shrubs: Benefits of native perennial forage shrubs to North Eastern wheatbelt farmers	DAFWA Merredin and Bencubbin field sites	18
27/08/2012	Balliang Branch of Victorian Farmers Federation	Balliang	15
27-31/08/12	Behavioural Education for Humans, Animals and Vegetation in Ecosystems – workshop	Dubbo TAFE	32
3/09/2012	Moore Catchment Management Group	Binbi Bindi	10
4/09/2012	Yarra Yarra Catchment Management Group	Perenjori	20
4/09/2012	Minnipa Agricultural Centre Women's Field Day	Minnipa Agricultural Research Centre	60
12/09/2012	Minnipa Agricultural Centre field day	Minnipa Agricultural Research Centre	180
4/02/2013	Crop & Livestock consultants meeting	Waite Campus	29

Date	Group/Event	Venue	Number of people
5/02/2013	Livestock Grazing Management	Echuca	25
6/02/2013	Livestock Grazing Management	Kerang	25
7/02/2013	Livestock Grazing Management	Ouyen	15
8/02/2013	Livestock Grazing Management	Horsham	10
20/03/2013	Value Adding Salty Soil	Quairading CRC	20
21/03/2013	Value Adding Salty Soil	Cunderdin CRC	10
26/03/2013	EverCrop Research Workshop	Waite Campus	25
5/04/2013	Big Tree Day Out (WEROC, SEAVROC, NEROC) (hosted by Stephen Fry)	Bruce Rock	40
11/08/2013	Kaniva Landcare Group	Monarto field site	10
6/09/2013	UWA Ridgefield Future Farm-DAFF Demonstration Farm Open Day	Ridgefield UWA Farm	150
11/09/2013	Evertrain Salinity Concepts and Management Workshop	Murray Bridge	10
11/09/2013	International Grasslands Congress pre-congress satellite tour on Forages in Mediterranean Systems	Albany WA	50
5/10/2013	Shire of Perenjori-Bush Heritage Open - 'Food for thought on managing land for food production'	Charles Darwin Reserve	40
8/10/2013	Mallee Sustainable Farming Ouyen Trial Site & Research Forum	Walpeup	30
25/10/2013	Recent Advances in Animal Nutrition conference: 'How can Aust perennial shrub species add value to grazing systems in the low- to medium-rainfall zones?'	UNE, Armidale	60
6/11/2013	SA State Landcare Conference Delegate visit to Waite Campus	Waite Campus	20
11/02/2014	‘Feed for thought’ New options for filling Mallee pasture feed gaps	Waikerie (incl. Enrich site visit)	12
12/02/2014	‘Feed for thought’ New options for filling Mallee pasture feed gaps	Murray Bridge	12
13/02/2014	‘Feed for thought’ New options for filling Mallee pasture feed gaps	Sea Lake	16
5/03/2014	Grazable Shrubs ‘SERCS’ Project Field Day	Warrenbayne	30
21/03/2014	SERCS WA study tour - visit to UWA Ridgefield Future Farm	Ridgefield UWA Farm	11
29/03/2014	Kaniva Landcare Group	Manangatang Enrich Field Site (John Arentz's Property)	10

Appendix 5: On-line videos posted to the web during the project period

Date uploaded	Title	URL	Hits (as of 12/4/2014)
18/07/2012	Perennial Shrubs in Mixed Farming	http://www.youtube.com/watch?v=278Twm8MpUo	193
7/02/2013	Future Farm	http://www.abc.net.au/catalyst/stories/3685323.htm	
3/03/2013	Establishing Perennial Shrubs for Pasture	http://www.youtube.com/watch?v=tpsoyD8UQXU	108
17/03/2013	Perennial Shrubs for Low Rainfall Farming	http://www.youtube.com/watch?v=AqpuLVKjjks	129
11/06/2013	Perennial shrubs -- an option for problem soils	http://www.youtube.com/watch?v=NOp4KVWift0	105
23/08/2013	2013 Eureka Prize for Sustainable Agriculture finalist Enrich Project	http://www.youtube.com/watch?v=U1kLB59WHNU	453
8/4/2014	Enrich	www.youtube.com/watch?v=4Y_IpEwBw4o	20

Appendix 6: Media articles regarding the old man saltbush improvement project in the project period

Date	Title	Location	Medium
August 2012	Saltbush supports system flexibility and productivity	Future Farm	Print
August 2012	Saltbush development narrows the field	Future Farm	Print
March 2013	Woolgrowing challenging in dry conditions	AWI Beyond the Bale	Print
May 2013	Sheep and saltbush thrive in the dry	Farming Ahead,	Print
June 2013	Saltbush on show	The Land	Online
20 August 2013	Shared salinity challenge unites WA and Iraqi	ScienceNetwork	Online
September 2013	Serving up tastier saltbush	MLA Producer Case Study	Online
13 Feb 14	Cranbrook salt forum	Countryman newspaper	Print
18 Feb 2014	Farmers, land carers to learn salt combat	Albany Advertiser	Print
20 Feb 2014	Workshop set to tackle salinity challenge	Great Southern Herald	Print
March 2014	Release of elite saltbush	AWI Beyond the Bale	Print
April 2014	Elite saltbush lines offer	Future Farm Magazine	Print
In press	Saltbush – from problem to opportunity	MLA Producer Case Study	Online

Appendix 7: Old man saltbush extension events during the project period

Date	Event	Location	Attendees (#)
26-27/7/2012	Saltland Evertrain workshop OMSB Improvement	Cranbrook	20
28/08/2012	Scientific seminar at CSIRO Sustainable Agriculture Flagship		80
4/09/2012	Moore Catchment Management Group	Bindi Bindi	10
5/09/2012	Yarra Yarra Catchment Management Group	Perenjori	20
12/09/2012	Corrigin Pasture Improvement Group	Yealering	25
3/10/2012	Western Flat Ag Bureau	Western Flat	6
4/10/2012	Sheep Connect SA field day	Lameroo	10
6/10/2012	Pathways to Productivity NRM Workshop	Keith	30
11/10/2012	Bordertown Annual show	Bordertown	12
20/10/2012	Coonalpyn Show	Coonalpyn	
14/11/2012	Program Leader AWI	Tammin	
21/11/2012	Iraqi agriculture delegation to Australia	Brisbane	55
12/12/2012	MLA Program Leaders	Tammin	
5/02/2013	Livestock Grazing Management	Echuca	25
6/02/2013	Livestock Grazing Management	Kerang	24
7/02/2013	Livestock Grazing Management	Ouyen	15
8/02/2013	Livestock Grazing Management	Horsham	10
20/03/2013	Value Adding Salty Soil	Quairading CRC	20
21/03/2013	Value Adding Salty Soil	Cunderdin CRC	10
21-22/3/13	Saltland Evertrain workshop & OMSB Improvement	Wagin	15
26/03/2013	Talking soil health conference	York	170

26/03/2013	EverCrop Research Workshop	Waite Campus	25
23/04/2013	Field Walk	West Arthur	12
24/04/2013	Field walk	Broomehill	10
6/06/2013	Field day at research site	Tammin, WA	35
12/08/2013	CRC FFI board visit to a research site	West Arthur, WA	14
29/08/2013	Dowerin field day display (Enrich & OMSB)	Dowerin , WA	? Hundreds
11/09/2013	International Grasslands Congress visit to Cranbrook research site	Cranbrook, WA	40
13/09/2013	International Grasslands Congress presentation	Albany, WA	50
13/03/2014	Scientific tour, Pakistani Scientists	Tammin, WA	30
24/03/2014	Evertrain workshop & site visit	Cranbrook, WA	12

Appendix 8: Journal and conference publications related to the old man saltbush improvement project

Norman HC, Masters DG, Barrett-Lennard EG (2013). Halophytes as forages in saline landscapes: interactions between plant genotype and their environment change their feeding value to ruminants. *Journal Experimental and Environmental Botany* 92, 96-109.

Revell DK, Norman HC, Vercoe PE, Phillips N, Toovey A, Bickell S, Hulm E, Hughes S, Emms J (2013) Australian perennial shrub species add value to the feedbase of grazing livestock in low- to medium-rainfall zones. *Animal Production Science* 53, 1221-1230.

Al Daini H, Norman HC, Young P, Barrett-Lennard EG (2013). The source of nitrogen (NH4+ or NO2–) affects the concentration of oxalate in the shoots and the growth of *Atriplex nummularia* (old man saltbush). *Functional Plant Biology*, 40, 1057 - 1064.

Fancote CR, Vercoe PE, Pearce KL, Williams IH, Norman HC (2013). Backgrounding lambs on saltbush provides an effective source of Vitamin E that can prevent Vitamin E deficiency and reduce the incidence of subclinical nutritional myopathy during summer and autumn. *Animal Production Science* 53, 247–255.

Lymbery AJ, Kay GD, Doupé RG, Partridge GJ, Norman HC (2013). The potential of a salt-tolerant plant (*Distichlis spicata* cv. NyPa Forage) to treat effluent from inland saline aquaculture and provide livestock feed on salt-affected farmland. *Science of The Total Environment* 445-446, 192-201.

Norman HC, Jessop PJ, Sweeney G, Wilmot MG, Mazanec R, Nair RM, Bennell

M, McKenna D and York A (2013). Adapting grazing systems to capitalise on local plants; domesticating old man saltbush for arid and saline grazing systems. *Proceedings of the International Grasslands Congress Mediterranean Satellite Workshop*, Albany, Australia, 8-13 September 2013

Mitchell ML,.Whalley RDB and Norman HC (2013) The use of functional traits to identify grasses and fodder shrubs for domestication to suit a changing climate. Keynote paper, Proceedings of the International Grasslands Congress (Sydney, September 2013)

Appendix 9: Student projects connected to Enrich

Saltbush (*Atriplex nummularia*) can increase soil organic carbon in salt-affected land in south Western Australia, but the magnitude of increase depends on site characteristics

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Dean Revell (CSIRO)

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Abstract

The aim of this study was to assess the potential contribution of *Atriplex nummularia* shrubs in regenerating soil organic carbon (SOC) in saline lands of the low-medium rainfall zone of the Western Australian wheatbelt. In two sites with 10-year old shrub stands, mainly differing in soil texture (clayey vs. sandy), soil samples were collected under shrubs and in adjacent areas with no shrubs in order to test the hypothesis that the SOC content under shrubs is higher than in areas with no shrubs. Additional measurements on SOC and pasture properties where collected in the sandier site within the inter-row space to assess whether SOC near to shrubs was also higher, with a progressive decline as distance from shrubs increased. At the clayey site, SOC under shrubs was 29% higher than in the area with no shrubs, while only a trend for higher SOC under shrubs was obtained in the sandy site. Within the sandier site, the ability of shrubs to contribute higher SOC may be associated with watertable depth, which varied across the site. SOC did not show the expected decline with increasing distance from shrubs. Interestingly SOC in the inter-row space was not correlated with pasture biomass or soil cover, but was positively correlated to salinity (EC1:5). An *A. nummularia* shrub system can increase SOC in saline land, but site characteristics such as soil texture have an important effect on the magnitude of increase. Therefore, site characteristics are important in identifying opportunities to use shrubs as an approach to regenerate saline lands and increase SOC.

Investigation of the allelopathic potential of four native perennial shrub species on several pasture species

Nadia Meakin

Supervisors:

Petra Marschner (UA)

Jason Emms (SARDI)

The incorporation of perennial species such as Australian shrubs into annual pasture systems is a strategy to mitigate livestock feed shortages over the summer months. However the allelopathic potential of leaves from Australian native shrubs may reduce the essential understory pasture biomass in mixed forage systems of semi-arid southern Australia. Aqueous leaf extracts of the native shrubs *Rhagodia preissii*, *Atriplex nummularia*, *Rhagodia spinescens* and *Acacia saligna* were assayed to a 1:10 stock solution and dilution to 5, 7.5, 15 and 20 %. These extracts were tested in Petri dishes on the germination of the pasture species *Medicago polymorpha*, *Trifolium glomeratum* and *Lolium rigidum*. Extracts of *Rhagodia spinescens* and *Rhagodia preissii* were diluted to 3, 6 and 9 % and tested for their effect on hydroponic seedling growth of *L. rigidum*. In the field pasture biomass growing in association with the above four shrub species was assessed using the dry-weight-rank method. *R. preissii* and *A. nummularia* extracts reduced the germination percentage of all pasture species to < 40% at the high concentrations. The seedling root length of ryegrass was significantly reduced and the root diameter was increased by *R. spinescens* and *R. preissii* shrub extracts. Total pasture biomass was sound to be lower under only *R. preissii* canopies compared to the adjacent inter-row. However, annual pasture grass biomass was lower under both *R. preissii* and *A. nummularia* canopies. These results demonstrate that some native shrubs (e.g. *Rhagodia preissii*) have a stronger negative allelopathic potential and may therefore reduce the germination and growth of companion pasture plants.