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Enrich Phase 2- Final Report

Building the enabling knowledge and technical capacity for multi-purpose forage shrub systems

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Executive summary

Enrich began in 2005 to explore the potential of native perennial shrubs to contribute to the feed base and natural resource management. Our particular interest was to provide new options for low-medium rainfall areas with prolonged dry periods and/or soils that are marginal for other farm enterprises such as cropping. Deep-rooted, woody perennial plants can offer a degree of resilience to difficult environments if they can be incorporated into existing pasture systems. The project has been unique as it has combined the use of Australian plants, previously overlooked for grazing systems, with management approaches that take into account the nutritional behaviours of grazing herbivores.

The highlights of Enrich phase 1 were:

(i) New information on the biomass productivity and nutritive value of over 50 species of shrub species grown at the Monarto site in South Australia

(ii) Bioactivity of shrub species characterised in terms of effects on rumen fermentation, including methane production, and anthelmintic properties

(iii) Development of grazing principles to maximise the use of diverse plant mixtures.

(iv) Bio-economic modelling of mixed farming systems that showed whole-farm profit can increase by around 15-20% with the inclusion of forage shrubs on about 10% of a ‘typical wheatbelt’ farm.

Enrich phase 2 has expanded our knowledge base considerably and, consequently, taken us closer to providing practical options to help producers adapt to a variable and changing climate. In brief, new information and insights include:

(i) Data on productivity and nutritive value over a sequence of years, with and without grazing. A key to the profitable inclusion of shrubs is their contribution to the provision of nutrients over the medium-longer term, and hence their perennial performance needed to be understood.

(ii) Data on productivity and nutritive value at different locations, made possible by the establishment and management of new sites at Merredin in WA and Condobolin in NSW, to compare and contrast with the Monarto site in SA. Shrubs have the potential to be used across different soil types and environments, and producers seek information on the most likely candidate species suited to their conditions.

(iii) The establishment of 16 regional evaluation sites across southern Australia, in partnership with a range of regional groups who have been interested in exploring the potential of new shrub-based grazing systems. This has led to paddock-scale testing at a further six sites, again in partnership with local groups, which are providing proof-of-concept demonstrations of functional and resilient grazing systems.

(iv) Data on the palatability of forage shrubs, and information of importance of learnt behaviour in influencing diet selection. Managing the experiences of livestock is a realistic management tool to improve the utilisation of plants in a diverse mixture, but this does not mean that behavioural management can increase the voluntary selection of all shrub species. In general, preference values for most shrub species under investigation are consistent across locations but, in some cases, we've observed large differences depending on the time and/or location of grazing (for reasons as yet unknown).

(v) Dissemination of 1,800 booklets on 'Perennial forage shrubs providing profitable and sustainable grazing. Key practical findings from the *Enrich* project'. The booklet has been made available online, with the site receiving a high number of 'hits'. http://www.futurefarmonline.com.au/LiteratureRetrieve.aspx?ID=88398

(vi) The establishment of partner projects supported by DAFF to explore the methanogenic properties of shrubs (and other forage species), including detailed *in vitro* testing, rumen microbial metagenomics, and methane production under paddock conditions.

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1 Background

The Enrich project commenced in 2005 as a collaborative effort to provide new options for sustainable grazing systems that incorporate perennial shrubs. The focus was on mixed farms in low-medium rainfall areas where few perennial pasture options existed, particularly summer-active perennials that could remain productive through 'summer droughts'. In contrast to previous investigations of shrubs as a feed source for livestock, the Enrich project has taken a multi-pronged approach to assessing the potential role of forage shrubs by (i) exploring Australian native shrubs more thoroughly (ii) considering shrubs as complementary plants to other pasture species, and (iii) quantifying their potential to improve gut function and health.

From Enrich phase 1, we have learnt that incorporating Australian native forage shrubs into a grazing system on a typical wheatbelt farm can (i) increase whole-farm profit by about one-fifth by reducing the amount of supplementary feed required over summer-autumn and deferment of other pastures on a farm at the break-of-season; (ii) allow more effective use of marginal soils; and (iii) enhance natural resource management (e.g., water use, soil erosion, carbon storage). We have also broken new ground in showing the potential to improve gut function and health of livestock through 'extra-nutritional', or bioactive, properties of some plant species.

The opportunity now exists to begin converting the design principles developed in Enrich phase 1 to paddock scale investigations. 'Enrich principles' – summarised as mixed forage systems built on the interactions between the soil, plant performance, phytochemistry, animal grazing behaviour, animal nutrition and gut health – are attracting interest from landholders and regional authorities who are faced with the need for more resilient farming systems. Combining paddock scale experiments with continued strategic science will ensure that project outcomes are relevant to a wider range of scenarios than those occurring at particular, individual field sites

2 Project Objectives

2.1 Key findings against project objectives

Described animal responses to shrub combinations by assessing
(i) interactions between experience, training by peers and diet selection;
(ii) the role of early-life experiences on feed intake and diet selection;
(iii) the effect of temporal separation of different shrub species on intake, weight gain and rumen fermentation patterns.

- 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.

- Social interactions between animals could offer a practical tool to improve the intake of plants for which animals tend to show a low preference by exploiting the fact that individual animals within the group are likely to eat the plant much more than the average of the group.
- Repeated exposure to forage shrubs can be a practical option to increase preference and intake of such species.
- Diet selection and feed preferences can be influenced by events that occur during pregnancy, and also early in life before and after weaning.
- Exposing animals to novel feeds in early life, such as during pregnancy and/or post-weaning, could offer a practical means to modify grazing behaviour of livestock – a hitherto undervalued management tool.
- Animals can gain weight during autumn when grazing a mixture of shrubs and inter-row, without the cost and labour requirements of supplementary feeding. The shrubs are effectively providing crude protein and mineral supplements.
- This level of productivity can be achieved whilst maintaining ground cover, thus minimising the likelihood of poor natural resource management (i.e. reducing the risk of soil erosion and maintaining high water infiltration due to the presence of organic matter).
- Using supplements to modify diet selection will require management practices that allow animals to actively learn about the benefits rather than relying on innate behaviours or learning by chance.

Quantify the establishment, performance over years, and re-growth after grazing of 50 shrub species across three different environments (WA, SA and NSW).

- There are multiple species which appear both adapted and productive enough that can form part of a successful feedbase to sustain low rainfall grazing systems (this information is expanded in the body of this report)..
- For species that are grazing tolerant (which is the majority of species investigated in Enrich), grazing once or twice a year does not reduce annual biomass production.
- Species are suitable for different forms of grazing management and do not lock producers into a fixed grazing regime.
- In a shrub-based forage system, the bulk of the biomass that fuels animal production will still come from a productive inter-row pasture, or shrub understory.
- Companion pasture can be successfully grown in a shrub stand enabling better utilisation of land area.
- Incorporating shrubs in an annual-based pasture system is a true addition to the forage base, rather than a substitution.

Establish strong and effective collaborations between researchers and regional groups (CMAs,NRM groups, producer groups) to develop and test innovative new systems.

- Partnership with regional groups can disseminate progress and information through established channels at the producer group scale. Linkages between the research team and producer groups are now well established, so there is good potential to capitalise on these partnerships to trigger practice change on farms.
- Three quarters of respondents indicated they would follow-up on the information presented at the 2011 Enrich forums.

- Numerous landholders have already received or have applied for funding to trial shrub-based grazing systems on-farm.

Comprehensive laboratory experiments on the use of plants with bioactive secondary compounds to improve gut health and function completed for 10 shrubs to quantify variation in bioactivity, focussing on rumen fermentation profiles.

- Shrub species can bring different nutritional attributes to the diet than annual grasses and legumes. This reiterates the complementarity between shrubs and the herbaceous inter-row or understorey discussed above.
- There is real potential for shrubs, when in combination with a well-managed pasture, to meet the crude protein and mineral requirements of grazing animals, even when the shrubs may constitute only a modest portion (e.g. 30%) of the diet.
- A number of species offer potential to contribute extra-nutritional benefits to grazing livestock.
- Ongoing studies are required to develop practical ways to capitalise on the traits under commercials grazing conditions, especially considering the variability over time and between plants in bioactivity.
- Given the relative reluctance of sheep to consume *R. preissii*, even with training, this forage shrub may be better suited to a mixed-species forage system, where sheep can meet their nutritional requirements through a diverse diet.
- Additionally, it seems worthwhile to identify and select individual plants for which animals show a higher preference (Kotze et al., 2011), thereby possibly reducing the need to train animals to consume it.

3 (Methodology) - Section

3.1 Field testing of custom-designed plant configurations

We will establish specific combinations of shrub species identified as prospective species from Enrich phase 1, and herbaceous companion plants in paddock-scale plots that will allow grazing studies under 'commercial' conditions. We propose to establish at least 4 sites, each in partnership with at least one regional group. At a general level, these sites will enable us to test the 'Enrich principles' of the benefits associated with plant diversity and managed grazing behaviour, and will be showcases for new grazing systems. The plant species and the combinations used will depend on the locations chosen (soil types etc.) and should be flexible in design to accommodate specific motivations of the participating group/s (e.g., spatial layout, grazing management).

We propose to embark on three paddock scale studies, two in WA, led by Dean Revell, and one in NSW, led by Peter Jessop). The final design and hypotheses will be finalised after consultations between the research team (including co-funders), the advisory group of producers (described later) and regional groups who may be able to add value to the activities by hosting the site and assisting in its delivery.

In all experiments, we will be designing and managing a mixed forage system, and hence we will consider diet selection and grazing behaviours to ensure the plants of interest are consumed. Work in progress in Enrich phase 1 is testing the importance of 'training' animals to components of the forage mixture, and this will inform experimental designs in this next phase of our work. We anticipate that that relatively simple principles can be followed during the first few weeks when animals are moved onto a shrub-based system to manipulate the intake of particular shrubs. (We are currently using Rhagodia preissi as a 'test' plant, because we have recently learnt that plants tend to be avoided by sheep when other options are on offer and when the Rhagodia plants are in flower, which can be from Oct-Feb).

(a) ***Can a mixed forage system incorporating shrubs and complementary pasture species be a 'self-contained' feeding system*** – i.e., standing forage only without hand feeding – to profitably manage livestock from late summer to break-of-season?

The rationale for addressing this question is two-fold. The first issue is that many of the land managers in regions where forage shrubs will have a strategic benefit are predominately crop focussed. In these systems, livestock play a crucial role in stubble management, weed control and enterprise diversity, but from a farm management and labour point-of-view, the livestock are often a distraction from the main enterprise. Therefore, the use of low-input shrub-based system to reduce supplementary feeding over summer-autumn will strike a chord with land managers. The second issue is that economic modelling in Enrich phase 1 has identified the increase in whole-farm profitability associated with a forage shrub system is accrued through a reduction in supplementary feed costs and an increase in annual pasture production elsewhere on the farm.

Research is required to compare different assemblies of plants and spatial configurations, and different grazing management systems to identify the key features for a robust 'self-contained' feeding system.

(b) ***Can specific plants be grazed to control intestinal parasites or can plants with capacity to reduce methane emissions be incorporated into the diet?*** With regard to parasite control, we need to learn what level of intake is required, how does this play out with plant combinations, and whether a continual (trickle) intake of bioactive plants is required to have an effect or if the desired response can occur with animals grazing a bioactive plant for discrete periods of time (medicinal grazing) ?

This pilot scale system would be tested with the view of developing systems with fewer inputs from labour and chemical drenches. The field experiments here will need to be assessed in parallel with more focussed studies on the mechanisms of action of plant bioactivty, which are described in section 4 of the Methodology. Enrich phase 1 has identified at least six shrub species with promising anthelmintic effects, and we propose to use about three of these as the model plants for field testing (actual species depending on characterisitics, such as soil type, of the experimental site).

Enrich phase 1 *in vitro* assays have identified shrub species that, upon fermentaiton by rumen microorganisms, produce less methane than control plant material. About 10 species have shown this effect specific to methane rather than a geernal reduction in gas production, whereas a number of other species reduce methane productiojn but also reduce the 'fermentability' of the plant material. Other species had no effct on methane, and others still increase methane production. The field scale testing of methane emissions is technicially difficult and expensive, but we propose, in the first instance, to determine if plants that Enrich phase 1 have hiughlighted as prospective 'anti-methanogenic' plants can be successfully incorporated in the diet of grazing livestock.

(c) What are the options for managing mixed forage systems over time and space? Biological complexity has been reduced in most modern agricultural systems, with monocultures and external inputs being common. Yet to address the multiple demands of the landscape (soil and water 'health'), the grazing animal (balanced nutrient supply, gut health and function) and the producer (profit, labour, whole-farm systems), there is an inevitable need to embrace biological complexity – but without increasing managerial complexity. Different models of spatial configuration of plant mixes and the temporal use of the forages will be compared. Three options will be explored: (i) different species planted together and used simultaneously; (ii) different plant species spatially separated but grazed simultaneoulsy; and (iii) different plant species spatially separated and grazed at different times. An exciting prospect is the concept of **'grazing circuits' whereby the plant diversity is exploited to stimulate feed intake and animal performance**. This would draw on new research from overseas that shows animals reach satiety on particular foods due to the presence of plant toxins or nutrient imbalance, but that careful switching amongst different types of plants can boost intake. There is also an emerging discipline of investigation that is exploring the animal health and welfare implications associated with providing grazing herbivores with diverse yet balanced forages. Dr Xavier Manteca from the Universistat Autonoma de Bercelona and Professor Fred Provenza from Utah State University are potential collaborators in such studies.

Other opportunities- through partnering with other projects - for paddock scale R, D & E:

The project team is aware of potential opportunties for the activities in Enroch phase 2 to complement other research activities. The funding being sought in this application is insufficient to cover all of these opportunties, but the competencies of the Enrich research team, and their associations with other projects mean that expertise can be shared across projects to add value if additional funding was available. The primary opportunity, given recent political and societal developments, is to focus work on carbon storage under mixed forage systems that include shrubs and to test whether methane emissions from livestock can be reduced by incorporating particular shrub species into the diet ('anti-methanogenic plants').

Can a shrub-based system reduce methane emissions from livestock and increase carbon storage? If new forage shrub systems are incorporated into the emerging carbon trading scheme/s in Australia, it is essential that reliable measures of both carbon sinks and sources are made. The MIDAS economic modelling in Enrich phase 1 showed that a price on carbon could be the single largest driver of profit from a shrub-based system. The profit optimisation modelling showed that the area of a farm allocated to shrubs was considerably greater if carbon was formally valued. With the political and social changes in Australia, this area is of growing significance.

Assessments of above and below ground carbon storage following protocols acceptable to official carbon trading schemes are required. In addition, the possible biological benefits associated with a buildup of soil organic carbon (e.g., water infiltration, microbial activity) in mixed forage systems and innovative grazing are proposed. These benefits should improve the profitability and sustainability of land management, and contribute to regenerative farming practices.

On the carbon emissions side of the ledger, Enrich phase 1 has identified exciting prospects to use specific plants to reduce the methane emission from rumen fermentation. Plants with these properties, identified from *in vitro* studies could be incorporated into the forage mix at a paddock scale. Several methodologies are available for estimating methane emissions from animals in the field, both from individual animals and flocks/herds. FTIR (Fourier Transformed Infra Red) technology is one of the most promising new directions in this field of research. We propose to collaborate with a joint Sheep CRC/Department of Climate Change project entitled "Quantifying methane emissions from Australian sheep systems and options for emissions reduction in preparation for emissions accounting and trading". Our collaboration would be to test emissions from shrub-based systems designed in Enrich phase 2. Dr Vercoe is the project leader for the Sheep CRC component of the project and on the technical committee of the DCC component. When field-scale measurement of methane output is sufficiently developed and affordable (which is the aims of other projects in progress in Australia and overseas), the Enrich team will be will be well-paced to incoporate this technology into our paddock-scale experimental sites.

Other opportunities:

(i) Testing the spatial layout of particular shrub species to provide edible shelter. There is interest from producers to reduce the risk of stock losses due to extreme weather events, especially at lambing time, and this coincides with mounting societal pressure to manage animal welfare risks. Studies or demonstrations could be developed in partnership with the Sheep CRC or regional groups (CMAs).

(ii) Whole-farm implications.. In partnership with other projects, such as EverCrop, there is potential to investigate whole-farm considerations of the spatial variability in soil types (and land capability units). The opportunity exists for case studies that use a combination of remote sensing, yield mapping and local knowledge to design 'appropriate' configurations of shrubs, permanent pastures, rotational pastures and crops.

(iii) NRM implications. In partnership with other groups, the associated NRM impacts could be quantified; eg., water balance, soil health and erosion risk, biodiversity.

3.1.1 The Badgingarra research site

The combinations of plant species (shrubs and herbaceous), grazing intensity, grazing duration, experienced versus naïve animals, parasitised versus clean animals is almost endless, and not possible to cover in the 'showcase' field sites described above. The relative importance of these various factors can be explored rigorously at the Badgingarra field site, which has been set up in Enrich phase 1 specifically to investigate these sorts of questions. The site is designed to test underlying principles that influence the utilisation of forage shrubs that will inform grazing practices in the showcase sites, and greatly improve the advice we can provide to producers who adopt innovative systems based on diverse plant mixtures. The site has a combination of 7 shrub species, annual pasture interrow and sown warm-season perennial grasses. The shrubs were planted in September 2006, and given the long-term nature of establishing shrubs suitable for grazing studies, the site is just beginning to deliver new information on grazing behaviours and shrub utilisation (the first experimental grazing commenced in February 2008). We have recently shown that grazing intensity (stocking rate and duration) influences diet selection from the palette of species on offer, and an experiment scheduled for April-June 2008 will investigate how prior exposure (e.g., with or without supplementation or with 'training') to the most unpalatable shrub species can influence its selection when sheep are offered the full palette. We will also use the experimental site, prior to July 2008, to determine if the *in vitro* anthelmintic effect of one of the shrubs (*Rhagodia preissii*) can translate into beneficial effects under field conditions.

Studies on the Badgingarra site for Enrich phase 2 that we propose are:

(i) ***How persistent are learnt grazing behaviours under mixed forage systems?*** We propose to reintroduce animals that grazed in February 2008 to the plots in spring and again in summer/atumn 2009 to determine how much learnt grazing behaviours (diet selectivity) persist over time and across different seasons and stages of plant maturity. Also, we will address the issue of whether naïve animals can be mixed with animals experienced in utilising a diverse range of shrubs in order to avoid the commonly observed dip in livestock performance over the first week or two after moving on to novel shrub-based systems.

(ii) ***How can plants with anthelmintic properties be effectively used under field conditions?*** We have the capacity to monitor individual plants, and quantify bioactivity over time. Preliminary data from this site has shown us that differences exist in toxicity to parasite larvae, and we need to understand:

   a. How to manage this variability and still achieve the outcome of reduced parasite burdens; e.g., how frequently and how much do animals need to consume particular plants, are there interactions between the number of different plant species on offer and the capacity to use particular plants for medicinal purposes?

   b. What plant traits may be suitable for selecting in future plant improvement activities? Are there phytochemical profiles that can be identified, or other traits associated with preference values ('palatability') by animals?

(iii) ***How can early-life experiences of a wide range of plant species be exploited to improve animal performance and profitability in the longer term?*** Emerging data from a number of research groups (including our own) is clearly showing the importnance of early-life experiences of animals in determining their voluntary selection of different plant species, when offered alone or in combinations. Given the necessary time to run experiments related to early-life experiences (i.e., the time taken to establish a diverse plant mixture and the time to monitor animals over time), the already established Badgingarra research site is ideally suited for this purpose and its use will avoid an otherwise necessary lag between estbalishing the trial site and delivery of research findings.

(iv) ***How might animal performance vary over time with contiued exposure to the shrubs, and how does this relate to the changing profile of nutrients and secondary compounds over time?*** To date, we have not had the opportunity to monitor both the plants and animals over extended periods of time. The Badgingarra field site offers the opportunity to sample all the different plants in the mix over time, test the change in their bioactivity and nutritional value (*in vitro*) and link this to changes in rumen fermentation profiles and animal performance in the field. We will use this information to compare field data with an *in vitro* continuous culture system to develop a rapid way of quantifying the interactions between plants/plant mixes and microbes that represent what happens in the field, to predict best-bet mixes (types and amounts) of novel plants prior to planting.

3.2 Supporting activities to underpin the field testing of innovative systems

3.2.1 Core plant research field sites

Monarto (SA) site:

The research site at Monarto (near Murray Bridge, SA) is unique. It is the only place where such a large number of Australian native shrubs are being examined for their potential to contribute to the feed base for livestock. The site was established successfully in spring 2006 during one of the most difficult spring and summer seasons in the region (a 'decile 1' spring that was both dry and hot).

Research at Monarto falls into three categories: preliminary field evaluation of woody perennial species, the response to grazing of a smaller suite of species and the interaction between shrub and understorey plant species. As mentioned above, the relative long juvenile period of most woody perennials (compared with herbaceous species) means that the species being examined are only now reaching a physiological stage where grazing can commence. It is from this time onwards that the measurements being taken are the most relevant to potential production systems.

Activites based at Monarto proposed during Enrich phase 2:

i) Field evaluation of additional genetic material – In 2007, 18 new lines were planted including 11 species not previously planted were established at Monarto. In 2008 we plan to plant 40 new lines including 14 untested species. This material will need to be assessed for production, morphology and reproductive attributes as well as nutritive value and bioactive properties. The finalisation of the species selection database may suggest new species that warrant investigation and, resources permitting, these could be added at Monarto (it is likely that only a few species will meet this criteria).

ii) Evaluation of woody perennial species – Nearly 70 species comprising 150 lines were established in 2006. Whilst this work has formed the basis for the selection of the 19 species to be tested in collaboration with regional groups (see below), the selections have been made on little data and in the absence of grazing. The full site containing nearly 70 species will be grazed in autumn 2008, allowing us to assess plant re-growth following grazing and also provide some observations on plant preferences. The plants will continue to be assessed for their productivity and suitability for grazing. It is possible that additional species (to the 19 species in our current 'best-bet' list) will be found to have potential and they could be selected for further work. It will also be prudent to monitor the species already shortlisted to see if they continue to perform as we currently anticipate. Additionally, as species from this site have been sampled twice for nutritive value, effects on rumen fermentation and toxicity to parasites, there is an opportunity to examine the changes in these values over a longer period of time for a small subset of species.

iii) Examining the effects of grazing on the growth, production and morphology of 12 shrub species – A replicated experiment consisting of 12 species and three grazing regimes (none, once/year, twice/year) was established during Enrich 1. Due to the time frames involved, re-growth will not be fully assessed in Enrich 1. It is proposed that this experiment continues to fullfill the original aims. It will also be particularly important to assess whether these species regrow to the same extent after repeated grazings (particularly in the more intensive grazing treatment) after the initial soil water (present after years of annual crops) has been exhausted.

There is an opportunity for postgraduate work to complement this experiment if a student and scholarship were secured. The physiological factors that determine the ability of forage shrubs to withstand grazing and regrow are not well understood. The differing roles and levels of photosynthates and stored carbon may explain the varying response of shrubs to defoliation. Understanding temporal variation in carbohydrates, particularly in response to summer drought and defoliation should provide knowledge on the capacity of the shrub base of the system to contribute to the yearly feed base. A better understanding of the physiological limitations of these species will allow prudent management of the grazing system for both short and long term productivity.

iv) The positive and negative interactions of shrubs and understorey pasture species – Complex communities of the type that may appear in Enrich-style grazing systems, where there are different plant types, comprise numerous interactions. An experiment designed to test the plant-plant interaction was established in late 2006. Many interactions, for example competitive effects are not expressed immediately and therefore the full set of results will become available during Enrich 2. Additionally, interactions between two species may be altered when a third species is introduced. In Enrich phase 2, we will superimpose grazing treatments to test the hypothesis that plant-plant interactions are modified following herbivory. It is these interactions that are particularly important to the successful implementation ofcomplex grazing systems.

v) The use of unpalatable nurse shrubs to facilitate the growth of palatable climbing species – In late winter 2007, an experiment was established to examine whether growing a shrub (*Atriplex nummularia*) could act as a biotic refuge for a palatable climber (*Glycine canescens)*. If the shrub can ensure the survival of the palatable species, this species may then contribute positively to the feedbase. Preliminary evidence suggests that climbing (or creeper) plants are unlikely to persist after grazing without the protection of a nurse shrub. Grazing would not occur until late 2008 or more likely 2009.

Additional preliminary evaluation sites – west and east to complement the SA site:

An acknowledged limitation to the accumulation of knowledge about a diverse range of native shrub species is that we have been relying on one location and one soil type. The low-medium rainfall regions of Australia to which a shrub-based system may offer benefits obviously cover a broad range of soil types and environmental conditions. The best-bet species for one location are likely to differ from another. We therefore propose to establish and monitor two additional sites to complement Monarto. The locations of the proposed sites, one in WA (to be managed by DAFWA, Tim Wiley/George Woolston) and and one in NSW (with the current intention to establish this at Condobolin) will be selected to cover soil types that differ from the sandy loam over poorly structured clay at the Monarto site; e.g., include red brown earths or brown solonized soils in NSW and either deep sand (non-wetting) or duplex sand-over-loam in WA. A critical limitation in establishing additional sites (besides funding) has been the availability of germplasm, especially if we are to ensure consistent genetics and propagation methods. To facilitate the establishment of **two new sites, the FFI CRC has invested $30,000 in a Transition Project** to allow the germplasm for the 50 (approx) plant species to be sourced and propagated. Plant material is being grown at a SARDI in SA for distribution and planting in WA and NSW in 2008.

Regional sites

We have already attracted the interest of a number of regional groups across southern Australia who have committed $10,000 per site to establish 11 shrub evaluation sites. These are described in more detail in sections below. They are exciting ventures for co-learning between the research team and producers. It is important to recognise, however, that the 15-20 species that will be planted across these 11 sites were selected as 'best-bets' from the single site at Monarto and with limited data on plant performance, nutritive vlaue and bioactive properties. There is no doubt the establishment of these sites will help considerably in broadening our knowledge on plant performance across different environments, but it is important that we continue to re-evaluate our 'best-bet' list as information builds on a broader range of plants and new systems that use them. This is why evaluation at the three large-scale sites is critical: we do not want to try and pick a 'silver bullet' plant and expect it to work everywhere. On the contrary, the philosophy of this project is to provide more options for landholders across a range of environmental conditions.

Germplasm co-ordination

Coordination of germplasm by Enrich ensures the ongoing availability of quality standardised germplasm of Enrich species. This activity, based at the Waite Institute, has underpinned the establishment of the Monarto site and is currently supporting the establishment of multiple provenances of over 50 species for 2 additional preliminary evaluation sites and 19 'best-bet' species across 11 regional sites. This has ensured appropriate scientific comparisons across sites can occur; i.e., a 'true' genotype x environment evaluation.

In order to meet the ongoing demands for Enrich germplasm it is imperative that there are sufficient quantities of base material (either seed or vegetative cutting material) to allow successful propagation to take place. This will be achieved by maintaining current plantings and undertaking new plantings at a low level as new species are identified. Importantly the current plantings are not sufficient to enable Enrich the capacity to produce enough material to meet demand. In addition to the paddock scale research plantings proposed within this application and anticipated extended regional group collaboration, collaborations with current regional groups are indicating their intent to further partnership and expand on the regional nurseries to test the best shrub options in their locality at the paddock scale. To enable Enrich the capacity to meet future germplasm demands a seed orchard comprised of the 'best-bet' species will be established.

The scale of 'best-bet' plantings will be species specific and will consider prior knowledge of seed production (capacity and timing), propagation success (seed or cuttings) and reliable establishment (direct seed or tubestock). For example, promising direct seeding species like *Atriplex semibacatta* & *Enchylaena tomentosa*, larger scale plantings are proposed. Species difficult to propagate from seed, eg *Eremophila species*, plantings are proposed to ensure sufficient vegetative material is available.

In addition to supporting Enrich research requirements the seed orchard of 'best-bet' species will support the development of a commercial scale industry of seed production or seedling propagation, including approaches for low cost establishment systems.

Selection database for shrub species – 'shrub picker'

An electronic database containing published data of traits of fodder shrub species has been developed as an output from Enrich 1. This database has been used as the primary tool to identify candidate species warranting further investigation.

It is proposed that further development of the 'shrub picker' database be supported to capture trait and performance data generated by the Enrich project team. Capturing Enrich data would greatly add value to the knowledge base and confidence in the data sets. As well as serving as an internal tool to support the development of Enrich species it would provide the backbone for the development of a very useful tool for end users of Enrich outcomes. For example, producers could get ready access to an interactive searchable tool for information on adapting a farm business to Enrich principles. The system would be flexible enough to also suit particular interests, eg catchment management authorities.

3.2.2 Potential uses of bioactive plants

The reason we are screening the shrub species in Enrich phase 1 for bioactive effects is to determine the full potential of these alternative plant species in grazing systems. We know that for most of the shrubs under evaluation they will not be viable propositions for 'fuelling' livestock production if we assess them solely for their annual production of digestible biomass and nutritive value. However, their capacity for survival over extended dry periods and provision of a relatively predictable amount of green (living) plant material out-of-season is atractive to both natural resource management (water use, reduction of soil erosion) and resilient farming systems. So in order to build the case for including shrubs in grazing systems to achive NRM and profit benefits, we needed to think more laterally about what they can offer to livestock (besides limited digestible dry matter). Enrich phase 1 has identified shrub species with bioactive properties that affect rumen fermentation profiles and/or parasite activity *in vitro*. These offer exciting prospects to use forage shrubs to improve rumen function and as medicinal plants, and thus play a role in animal production and health that has not be adequately explored before.

To date, we do not know the plant compounds or underlying mechanisms that confer the bioactivity. The secondary plant metabolites (PSM) that are involved will, almost by definition, vary in their concentration with plant maturity or in response to transient biotic or abiotic stressors. Understanding the variability in bioactivity is necessary to best achieve practical benefits for gut health and function of grazing livestock. Grazing particular plant species will not necessarily lead to improvements in gut health if the correct form of the plant compound is not present or if the animals cannot, or do not, consume the required amount. The 'medicinal' value of secondary compounds depends on the dose. The design of innovative grazing systems must be built on an understanding of the variability in bioactive PSM within plant species (chemotypes) and across time (plant maturity, seasonal conditions etc.) and this needs to be correlated with animal responses if we are to trully benefit from extra-nutritional properties of some plants and thereby increase adoption of perennial shrubs for profit and NRM outcomes.

We propose to focus on two main areas to progress this work, and acknowledge a third area that requires attention but would need funds in excess of what is currently available in Enrich phase 2.

(i) Strengthen our knowledge of how particular shrub species could be used to control intestinal parasites. A staged approach is required to take preliminary *in vitro* data through to practical demonstrations under field conditions. The *in vitro* screening for bioactive effects in Enrich phase 1 was designed to allow a large number of samples to be tested. With our current short-list of promising plant species, additional *in vitro* tests as well as *in vivo* trials will be incorporated into the program. For example, the anthelmintic effects observed to date have been based on the response of free-living nematode larvae, but to be effective in practice, bioactive PSM need to affect the parasitic larval and adult life cycle stages that infect the gastrointestinal tract. While we will continue to use the free-living worm assays to examine new shrub species and to explore plant bioactive variations over time, additional *in vitro* tests, such as inhibition of feeding in adult worms, will be needed to confirm that the activity seen against free living larvae is also present against the parasitic worm stages. These experiments will confirm activity against the ecomomically important life stages as well as deepen our understanding of the underlying mechanism/s of action, and thereby improve the likelihood of developing practical applications. We propose to test the most promising species in small scale *in vivo* trials. Pen trials will be used to assess the intake requirements for significant anthelmintic effects. Field trials will be used in two ways: comparing worm populations in sheep grazing in a shrub system compared to those on traditional pasture systems, and ascertaining whether grazing behaviour is altered towards an increase in intake of a ‘bioactive’ plant by the presence of a worm infection.

(ii) The *in vitro* testing of plants for their effects on ruminal micro-organisms has been based on a relatively simple ‘closed system’ (phase 1), but we will expand the work to include continuous flow systems (Rusitec) and *in vivo* validation studies. Our main focus will be on methane emissions from rumen fermentation for two reasons: first because methane production represents a major inefficiency in the conversion of plant material to animal products, and second because of the mounting pressure to mitigate greenhouse gas emissions from ruminant livestock. Based on Enrich phase 1, we now know there is large variation between shrub species in the methane production during fermentation, with some plant species having lower proportions of methane produced, without affecting other normal fermentation parameters. This offers an exciting prospect of reducing greenhouse gas emissions from livestock. The proportion of the plants in Enrich Phase 1 that have shown reduced methane production upon microbial fermentation is much higher than comparative studies overseas (20% vs <5%). This is an encouraging result as it increases our chances of finding species with suitable combinations of traits (e.g., high nutritive value and water use with potentially less methane). The simple ‘closed’ or batch culture *in vitro* system is also limited in its capacity to provide information about the effects of plant combinations, and proportions of plants in those combinations, on methane production and rumen function. We will extend our preliminary *in vitro* results on plants that reduce methane emissions from Enrich phase 1 to translate preliminary *in vitro* data into practical and reliable approaches for reducing methane emission from grazing systems. We will do this by using the Rusitec system to confirm that the top plants that were identified in Enrich phase 1 reduce methane emissions in a continuous flow system (where end products of fermentation are constantly being removed and new substrate and artificial saliva are constantly being supplied) and then test the top candidates *in vivo* using methane chambers (the most accurate measure of methane production *in vivo* from an individual animal) to measure methane emissions as well as liveweight gain over the experimental period. We will link with the joint Sheep CRC/DCC project to measure methane production from a flock grazing in a shrub system.

The third area of research that is required is the identification and quantification of the plant compounds that confer the bioactivity. Discussions with Dr Steve Colegate, an expert on plant compounds and toxins at CSIRO Geelong have identified the scale of investment that is required. Unfortunately, this exceeds the current capacity of the budget for Enrich phase 2, but we believe this area of research would be extremely valuable in progressing the use of alternative plants species for gut health and function. Additional funds in the order of $200-250,000 would be required.

4 (Results and discussion) - Section

4.1 Experimental activities

4.1.1 Early assessment of the potential of Australian native woody perennials as forage plants

Background

Perennial forages may play a key role in grazing systems by providing year around green feed and mitigating environmental threats such as soil erosion and dryland salinity. Due to a scarcity of herbaceous options available, a focus on finding woody perennial species for incorporation into low rainfall farming systems in southern Australia was attempted.

Australian native species could have particular potential due to their inherent adaptation to the regions under question and they have always been important species in rangeland production systems in inland Australia (Beadle, 1948; Condon and Knowles, 1952; Mitchell and Wilcox, 1994). Woody perennials and in particular forage shrubs, have been the subject of research previously and two species are already of some commercial value in southern Australia (Lefroy, 2002). *Atriplex nummularia* (old man saltbush) and *Chamaecytisus prolifer* (tagasaste) only fulfil niche roles, particularly on saline land and deep sands respectively. Limitations to the use of these forage shrubs have been concluded to be low biomass production, low palatability and the presence of anti-nutritional factors limiting animal production (Masters et al., 2006). The high weed risk of woody species and in particular legumes has also been highlighted by numerous authors as a threat by using these plant types (Lefroy, 2002).

For woody perennial forages to have a productive and economic role in farming systems in southern Australia, a different approach needs to be taken in both their evaluation and their usage. The Enrich research project has aimed to incorporate these species into farming systems by i) systematically assessing a wide range of predominately Australian native species ii) consider woody perennials as part of a mixed grazing system where a sum of the benefits of all plants will be greater than from one species alone and iii) consider novel ways that plant species contribute to the grazing system with a particular emphasis on rumen modulation and animal health benefits.

Aims

A comprehensive species selection process was conducted with the aim to find woody perennial species which have the potential to fit into commercial farming systems. The next step in this process was to evaluate selected woody perennial germplasm in the field for their suitability for inclusion in low rainfall grazing systems. The aim was to build a profile of these plant species on their forage potential, agronomic suitability and their potential for commercial production.

Methods

The species selection process undertaken in Enrich Phase 1 formed the basis for choosing the species in this study. A process was developed for researching potential shrub species based on three main criteria: 1) having a perennial life habit and woody growth form, so as to include growth forms such as trees and creepers, 2) being native to the traditional livestock-cropping zone (temperate) or the southern pastoral zone (semi-arid) and 3) evidence of being palatable. Whilst this resulted in identifying 119 species, an actual total of 87 species were successfully grown in the field with research on another 14 species conducted on plants growing in native locations.

The South Australian Genetic Resource Centre (SAGRC) undertook the process of sourcing seed of these species. Seed was sourced from commercial suppliers or in a number of cases from the SAGRC. Germplasm from the SAGRC which had been collected from the wild had good associated information in terms of collection date, paternal plant details and site details. In an attempt to obtain an accurate representation of the species, three germplasm accessions of each species were sourced. However, this was not always possible and in a number of cases no accessions of a species were found.

Species were germinated using the best available germination stimulating methods described in the literature. After employing the recommended treatment (where available), seeds were pre-germinated in Petri dishes. Germinated seeds were planted when a radicle of over 2cm was present into seedling tubes filled with potting mix. Propagation success was variable due to low seed viability and a lack of knowledge on suitable seed dormancy breaking techniques. This still remains a barrier to the commercial adoption of some species. Seedlings were grown for 2-3 months in a sheltered polyhouse before being placed outside for a further 1-2 months in an attempt to acclimatise to outside conditions. Some species were propagated by vegetative cuttings. Legume species were inoculated with the best available rhizobia after planting where the symbiosis was known.

Monarto

The initial experiment took place at Monarto South, South Australia (S 35.12080 E 139.13763). The soil type was a sandy loam over poorly structured clay with low inherent fertility. The structure of the subsoil, high pH and sodicity below 48cm were apparent barriers to deep root growth. Annual rainfall was below average in the first four years after planting (**Error! Reference source not found.**).

The field experiment employed an unreplicated control plot design to examine as many lines as possible. From the propagation and sourcing process, adequate tube stock of 129 accessions comprising 60 species were advanced for field testing. *Atriplex nummularia* (cv. Eyre's Green) was used as a frequent control plot throughout the experimental area. Plots consisted of 36 plants, using a 6 x 6 layout with 3m (inter-row) x 1.5m (intra-row) spacing for all accessions (2222 plants ha^{-1}). For accessions where 36 plants were not propagated, all available plants were planted. Species were established by planting seedlings in September and October 2006. Shrubs were planted into rows which had been deep ripped to a depth of 30-50cm in June 2006. Weed control was applied before planting. Due to the prevailing dry conditions, drip irrigation was used to establish the experiment. No further irrigation was used after January 2007. The non-selective herbicide Roundup® (glyphosate 450 g L^{-1}) was used for weed control in August 2007 and was applied with a shielded sprayer to avoid off-target damage. In October 2008 the inter-rows were mown to control grass weed seed set. A further 17 accessions were planted in August 2007 and another 36 in July 2008 using the same planting methodology as previously described.

Merredin and Condobolin

In order to avoid the advancement of potential species based on just one soil type and climatic region, two additional contrasting sites were proposed by the Enrich team to complement the existing site at Monarto. The locations of the sites were at Merredin, WA and at Condobolin NSW. The two new sites were selected to cover soil types that differ from the sandy loam over poorly structured clay at the Monarto site.

The site at Merredin was placed on an acidic (pH 6 H_20) duplex loamy sand-over-clay. A total of 52 species, represented by 107 accessions were advanced for field testing at this site. The site was planted in August 2008. At Condobolin the experiment was established on a clay loam soil with a pH of 5.6 (H_20). 108 accessions of 52 species were planted in September 2008. Both sites were planted using the same methodology as described for the Monarto site.

Table 1. Mean and actual annual rainfall (mm) during the experimental period for the three sites

	Long term mean	2006	2007	2008	2009	2010	2011
Condobolin	457			351	398	647	550
Merredin	285			318	290	168	400
Monarto	370	310	327	266	340	512	433

Measurements

Canopy dimensions (height and two diameters) were measured in April and November each year, beginning in the year after planting. Edible biomass, using the shortcut method of Andrew et al. (1979) was estimated during before each grazing event. Only the 24 central shrubs in each plot were measured for these attributes. Plant architecture was classified using the seven categories described by Ismail et al. (1993) with the addition of a climber category. The presence of flowers and fruit, spinescence, volunteer seedlings and pathogenic or environmental damage were also recorded at these times.

Grazing of the experiment took place in the late autumn in the second and third years after planting. At Monarto in 2008, twelve month old White Suffolk hoggets were grazed at a stocking rate of 64 sheep ha^{-1} and in 2009 South African Meat Merino hoggets were used. At Merredin, in both 2010 and 2011 one year old Merino ewe hoggets were grazed initially at 55 DSE ha^{-1} before a short period at 100 DSE ha^{-1} to enable full defoliation of plants. At Condobolin, in both years, 11 month Merino ewe hoggets were grazed initially at 40 DSE ha^{-1} before a short period at 67 DSE ha^{-1}. Grazing was aimed to take place until all plants were defoliated to an estimated level of greater than 80% original leaf area. Defoliation was assessed by using a modified scoring system based on Chippendale (1963).

Main results and discussion

Edible biomass production
The shrubs that are used in grazing systems need to provide sufficient edible biomass for the animal to meet production and health targets. Importantly though, focus should not be on the biomass production of one plant, but on a collection of plants that determine the number of grazing days that are available. Plants that are resilient to the grazing process by surviving and producing new leaf material in preparation for the next grazing event are ideal. Plants that recover well from grazing even under difficult (e.g. dry) seasonal conditions are of particular interest.

There was large variation in edible biomass production for shrubs grown at the three sites with Condobolin being the most productive (Table 2). This partly reflects the amount of rainfall received at this site (**Error! Reference source not found.**). However, the ranking of productivity of the different species is not consistent across sites, so the variation is not simply a reflection of rainfall.

Environment
It is clear environment plays a significant role in shrub productivity. Forage shrubs are generally valued for their reliance in dry periods when there is little other feed. This was clearly shown at Merredin where good re-growth was achieved in very dry conditions. However, at Condobolin exceptional productivity was achieved on the back of above average rainfall. It is apparent that forage shrubs can capitalise on favourable rainfall, especially when it falls ‘out of season’. At both Condobolin and Merredin, mean edible biomass originating from re-growth after grazing was not lower than edible biomass accumulated from 18 months of initial growth. However, this depended on the species, with some species showing substantially lower re-growth indicating less grazing tolerance.

These data suggest that there is a genotype- environment interaction with some species displaying a clear preference for certain environments. However, there are a number of species that are both widely adapted and productive. This is encouraging as there are multiple species to fulfill our original aims of increasing diversity in grazing systems. The process of species exploration has also been worthwhile with a number of promising species identified previously not considered useful in agriculture.

Table 2. Edible biomass production (g/plant) of forage shrub species at three sites at around 18 months from planting ('Before') and 12 months after their first grazing ('After'). An asterisk (*) indicates no surviving plants.

Before or after grazing: Site:	Before Condobolin	After Condobolin	Before Merredin	After Merredin	Before Monarto	After Monarto
Abutilon otocarpum					14	2
Acacia aneura					8	8
Acacia brachybotrya					97	210
Acacia estrophiolata					5	7
Acacia iteaphylla					128	76
Acacia kempeana					13	13
Acacia ligulata	1264	1977	176	235	183	272
Acacia loderi					138	72
Acacia myrtifolia					83	22
Acacia neriifolia	656	876	562	1477	53	8
Acacia oswaldii					7	30
Acacia pendula					20	115
Acacia pycnantha	312	419			100	191
Acacia saligna			679	552	516	395
Acacia victoriae					10	37
Allocasuarina muelleriana					3	6
Allocasuarina verticillata	209	48	142	253	10	29
Atalaya hemiglauca					<1	<1
Atriplex amnicola	2573	2483	590	392	720	755
Atriplex cinerea	362	447	203	284	779	332
Atriplex isatidea	357	291	127	14	585	208
Atriplex leptocarpa					924	778
Atriplex nummularia	2084	5161	365	281	1600	799
Atriplex nummularia (companion for *Glycine canescens*)	1307	3643	410	403		
Atriplex paludosa	911	269	251	164	906	633
Atriplex rhagodioides	1950	2567	332	577	654	1110
Atriplex semibaccata	1521	1332	243	60	561	195
Atriplex vesicaria	1178	882	200	84	849	304
Brachychiton gregorii					<1	<1
Brachychiton populneus					5	13
Brachyscome ciliaris					19	3
Chameacytisus prolifer	86	198	89	122	12	19
Chenopodium auricomum	501	678	24	10	80	145
Chenopodium gaudichaudianum	577		234	92	149	87
Chenopodium nitrariaceum	784	1747	119	74	150	139
Convolvulus angustissismus					1	n/a
Convolvulus remotus	51	*	*	1	66	19
Cullen australasicum	342	108	1	1	4	3
Cullen pallidum					<1	*
Dorycnium hirsutum					48	10

Before or after grazing:	Before	After	Before	After	Before	After
Site:	Condobolin	Condobolin	Merredin	Merredin	Monarto	Monarto
Einadia nutans	790	481			28	201
Enchylaena tomentosa	873	582	183	58	437	366
Eremophila alternifolia					25	67
Eremophila bignoniiflora	256	384	2	<1	32	57
Eremophila glabra	693	452	7	9	108	543
Eremophila longifolia	571	378	3	3	62	263
Eremophila maculata	737	958	<1	1	69	298
Glycine canescens	771	*	<1	2	4	<1
Glycine canescens (companion)	59	2	<1	<1		
Glycine clandestina					3	<1
Glycine tabacina					3	1
Kennedia eximia	*	*	43	38	20	11
Kennedia macrophylla	*	*	48	56	17	15
Kennedia nigricans	425	62	13	54	123	76
Kennedia prorepens	*	*			28	6
Kennedia prostrata	82	19	137	95	11	5
Kennedia rubicunda	*	*	81	35	2	2
Lotus australis	38	*	3	*	15	2
Maireana astrotricha					103	276
Maireana brevifolia	1078	862	147	112	97	162
Maireana convexa	854	325	160	159	64	53
Maireana georgei	1120	474	228	97	127	65
Maireana pyramidata	1187	869	172	168	176	175
Maireana sedifolia	269	266	122	75	41	96
Maireana tomentosa	3180	916	139	48	346	323
Malva preissiana	*	*			7	3
Medicago arborea	63	100	1	2	127	58
Medicago citrina	*	*	<1	*	15	
Medicago sativa cv Sceptre	67	33	<1	1	5	2
Medicago strasseri	64	*	<1	<1	121	42
Myoporum platycarpum					29	65
Pterocaulon sphacelatum	900	*			*	*
Rhagodia candolleana	420	142	136	17	408	454
Rhagodia crassifolia	651	497	87	51	599	323
Rhagodia drummondi	2794	1379	46	29	71	233
Rhagodia eremaea	1512	1185	109	46	68	305
Rhagodia parabolica	1480	2019	241	111	914	659
Rhagodia preissii	1919	2170	234	129	871	631
Rhagodia spinescens	1564	852	55	68	267	325
Rhagodia ulicina					139	n/a
Swainsona greyana	148	98			5	10
Templetonia retusa	*	*	*	*	11	26
Teucrium racemosum					3	47
Viminaria juncea	296	185	385	71	26	17

Key messages

- There are multiple species which appear both adapted and productive enough that can form part of a successful feedbase to sustain low rainfall grazing systems.

4.1.2 The response of forage shrub species to differing frequencies of sheep grazing

Background

As forage plants, the ability of plants to recover and persist after grazing is of paramount importance. Grazing tolerance should be a critical factor in choosing species for inclusion in a grazing system. Forage shrubs in particular, need to be able to recover from heavy grazing which often occurs during the summer-autumn period due to the scarcity of other feed sources. As part of the evaluation of potential shrub species for their inclusion into commercial grazing systems, the species response to grazing was given a high priority in the selection criteria.

Whilst the summer-autumn feed gap is a time when shrub-based systems can make a significant impact to the farm, a feed gap can occur at any time of year depending on the weather, economics or management. Ideally, forage shrub species need to be adapted to more frequent grazing periods or being grazed at different times of the year.

Aims

The aim of this experiment was to test whether 1) a subset of promising shrub species differ in their survival and productivity to heavy short duration grazing with sheep 2) if increasing grazing frequency results in changes in these responses.

Methods

A split plot design was used, comprising 12 species (Table 3) and 3 grazing treatments replicated 4 times. Plots consisted of 36 plants of a single species, using a 6 x 6 layout with 3m (inter-row) x 1.5m (intra-row) spacing. The three grazing treatments were 1) no grazing, 2) grazed in autumn only (most common current practice) and 3) grazed twice a year (autumn and late spring). To obtain a better representation of a species, multiple provenances were used where possible. These were placed randomly within the plot. Species were propagated from seed and were field planted by using established seedlings in August 2006. Shrubs were planted into rows which had been deep ripped to a depth of 30-50cm in June 2006. Seedlings were supplementary watered after planting to ensure survival.

The inter-row area was sprayed with Roundup® (glyphosate 450 g L^{-1}) prior to planting but subsequently weeds were not controlled. The volunteer inter-row pasture contained mainly *Trifolium arvense*, *Trifolium glomeratum* and *Lolium ridigum*.

Table 3. Species used in the experiment.

Species	Number of provenances
Acacia saligna	3
Atriplex amnicola	3
Atriplex cinerea	2
Atriplex nummularia	1
Atriplex semibaccata	2
Atriplex vesicaria	3
Cullen australasicum	3
Enchyleana tomentosa	4
Medicago arborea	1
Rhagodia parabolica	5
Rhagodia preissii	3
Rhagodia spinescens	5

Grazing of the shrub component took place in May 2008, November 2008, May 2009, November 2009, May 2010 and December 2010. White Suffolk hoggets (autumn) or dry ewes (spring) were used for grazing except in May 2009 when South African Meat Merinos hoggets were used. Grazing took place until all species were defoliated to a level of greater than 80% original leaf area. The level of defoliation was assessed using a modified scoring method based on Chippendale (1963) at the completion of grazing.

Growing conditions

The experiment took place at Monarto South, South Australia (S 35.12080 E 139.13763). The soil type was a gradational calcareous loam. The period under study was initially very dry in the first two years before closer to average rainfall was experienced for the remainder of the period. It was also much warmer than average with maximum temperatures being over 1.3°C above average over the whole period (Figure 1).

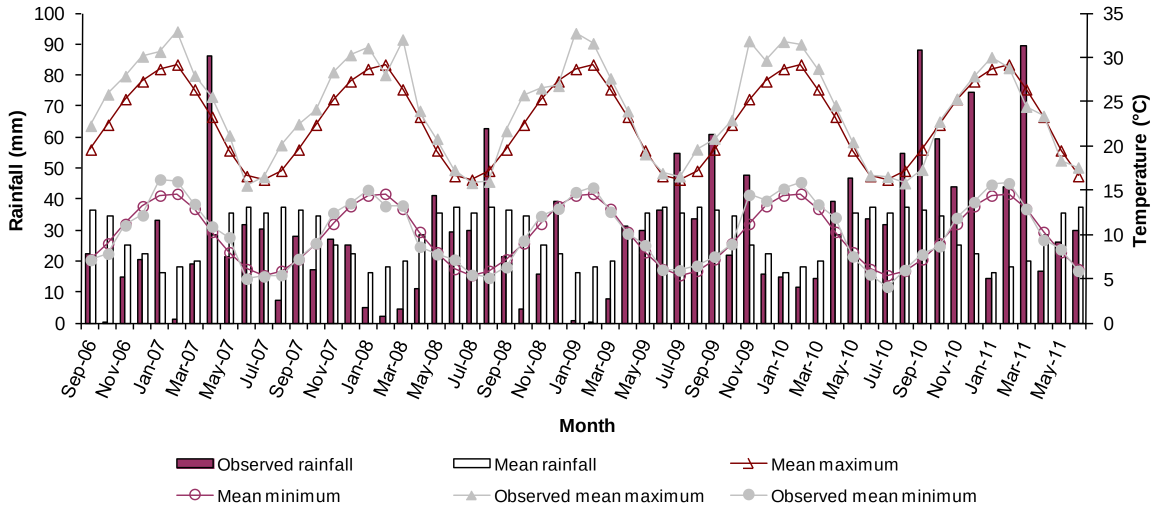


Figure 1. Monthly observed (solid columns) and mean (open columns) rainfall for the experimental period for Murray Bridge, as well as the observed mean maximum (lines with solid triangles) and minimum (lines with solid circles) monthly temperatures. Long term mean

maximum (lines with open triangles) and minimum (lines with open circles) monthly temperatures are also shown.

Measurements

Canopy dimensions (height and two diameters) and edible biomass using the "Adelaide" technique (Andrew et al. 1979) was estimated during May and November of each year beginning in May 2007 and ending in May 2011. Ten reference shrubs of each species were hand stripped to enable a calibration of edible biomass. Only the 24 central shrubs in each plot were measured. Plant architecture (using the categories of Ismail et al. 1993) and the presence of flowering were also recorded at this time.

Main results and discussion

As forage plants, the ability of plants to recover and persist after grazing is of paramount importance. There are clear differences in the potential of forage shrub species to survive and re-grow after heavy grazing. This should be a critical factor in choosing species for inclusion in a grazing system For example, *Atriplex cinerea*, *Atriplex semibaccata*, *Atriplex vesicaria*, and *Medicago arborea* all appear to lack sufficient grazing tolerance to be successful in a multi-species shrub-based system (Figure 2).

Whilst the summer-autumn feed gap is a time when shrub-based systems can make a significant impact to the farm, a feed gap can occur at any time of year depending on the weather, economics or management. Ideally, forage shrub species need to be adapted to more frequent grazing periods or at being grazed at different times of the year. Grazing twice a year (spring and autumn) does not affect shrub species survival compared with annual grazing (Figure 2). The more critical factor appears to be the ability of the species to survive any act of grazing.

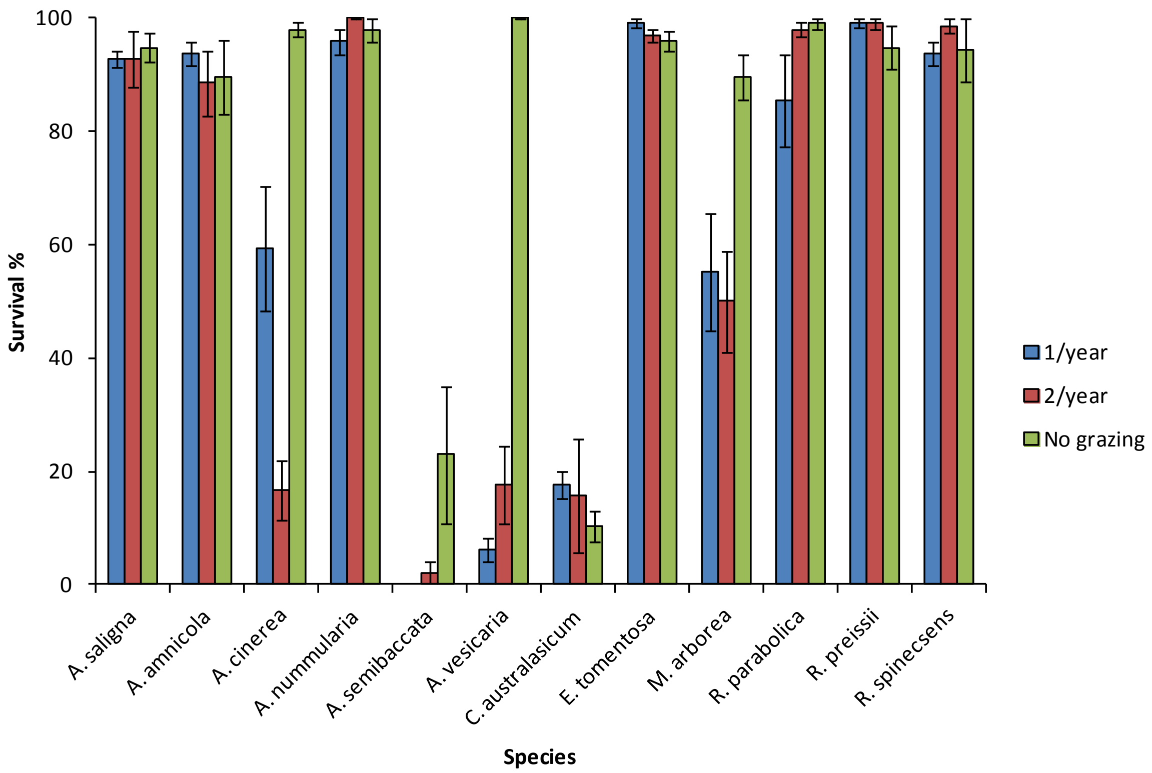


Figure 2. Survival of forage shrub species five years after planting under three different grazing frequencies at Monarto, South Australia. Grazing commenced in May 2008. Error bars indicate the standard error.

For species that are grazing tolerant, it appears that there is little re-growth penalty on plants with the more frequent grazing regime, as similar amounts of annual production were found (

Table **2**). This would indicate that the majority of these species could be adapted to flexible grazing management and may be grazed at other times besides the autumn feed gap depending on the needs of the farm. However, actual half-yearly re-growth biomass can be small so the benefits of twice per year grazing may be questionable.

Table 4. Total annual edible biomass production of species under two grazing frequencies at Monarto, South Australia.

Species	2009		2010		2011	
	once/year	twice/year	once/year	twice/year	once/year	twice/year
Acacia saligna	323	286	323	331	733	612
Atriplex amnicola	381	522	431	409	232	283
Atriplex nummularia	959	859	813	512	816	612
Cullen australasicum	1	9	1	5	17	43
Enchylaena tomentosa	211	184	319	152	275	159
Rhagodia parabolica	364	362	461	284	992	631
Rhagodia preissii	602	521	410	281	821	579
Rhagodia spinescens	123	235	186	182	422	398

Un-grazed forage shrub plants do not keep accumulating edible biomass. They have very low and often negative growth rates compared with annually grazed plants (Figure 3). Un-grazed plants lose biomass through considerable leaf drop, particularly over summer as plants try to reduce demands on transpiration. This was well demonstrated over the relatively wet summer of 2010/2011 where un-grazed plants still could not take advantage of the more favourable conditions and in most species a negative growth rate was seen. Forage shrubs should be regularly (at least annually) used as part of the overall feed base of the farm and not only saved for use in drought periods.

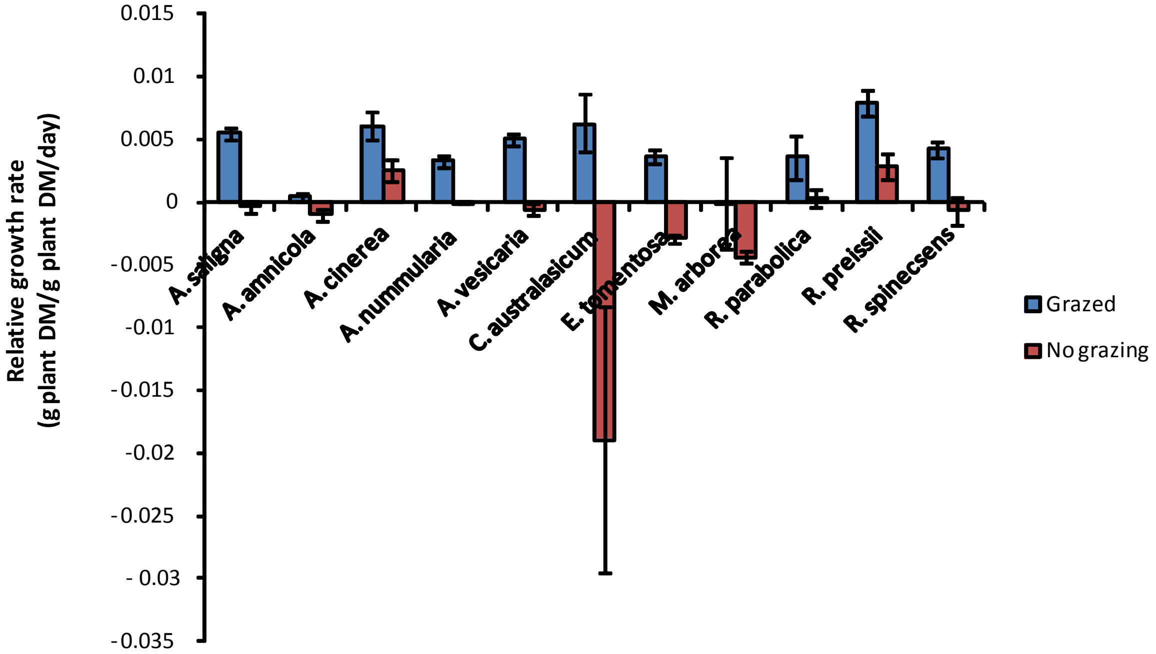


Figure 3. Mean relative growth rate of forage shrub species over the period December 2010-April 2011 when grazed the previous autumn or not grazed. Error bars indicate the standard error.

Grazing also helps to control the height of taller growing species, such as *Atriplex nummularia* and some *Acacia spp*. These species can often grow out of reach of sheep resulting in lower amounts of subsequent available biomass. Whilst un-grazed plants do not always accumulate edible biomass, they do still keep increasing in height (Figure 4). More frequent grazing and early grazing (at around 12 months after planting) is particularly critical in controlling height.

Grazing does not appear to have a large effect on standard nutritive value properties or mineral concentrations of forage shrubs. This makes the provision of nutrients predictable and adds to the potential of species to be flexible in terms of their timing of utilisation.

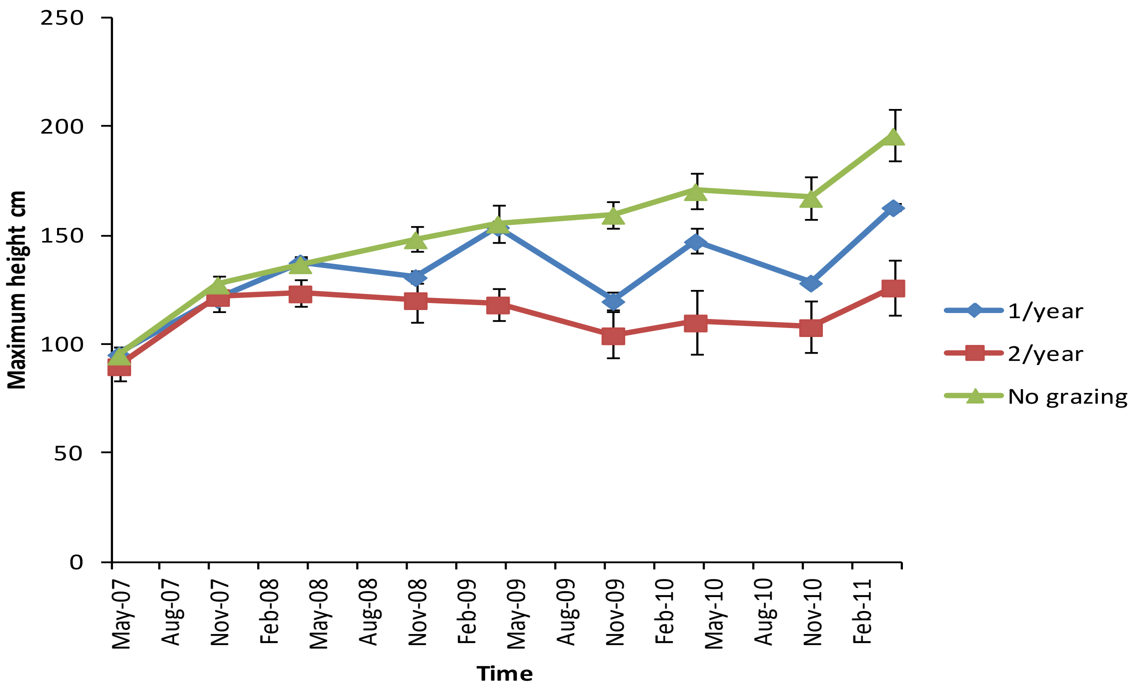


Figure 4. Maximum height of *Atriplex nummularia* under three different grazing frequencies. Grazing commenced in May 2008. Error bars indicate the standard error.

Key messages

- For species that are grazing tolerant (which is the majority of species investigated in Enrich), grazing once or twice a year does not reduce annual biomass production.
- Therefore, these species are suitable for different forms of grazing management and do not lock producers into a fixed grazing regime.

4.1.3 Nutritive value

Background

Forage plants must contribute to the supply of nutrients to livestock, even if they provide other benefits such as reduced risk to wind erosion or control. The most likely scenario in which perennial shrubs will provide the greatest value, but by no means the only one, is the provision of nutrients at a time when other plant types, especially annual species, are unable to provide adequate nutritional quality. In Mediterranean or southern temperate climatic zones of Australia, this is in autumn.

We proposed at the beginning of the Enrich project (Revell and Sweeney 2004) that key design criteria for a mixed forage system in southern Australia would be to:

1. Provide a mixture of plants that animals can use effectively with appropriate grazing management (see later sections of this report);
2. Select a combination of species that complement each other in terms of providing a ‘complete’ diet for animals and inhabiting the full range of microclimates;
3. Broaden the period of plant production beyond the winter and spring period, which means selecting a combination of plants that includes species that can contribute ‘green’ feed growth in summer and autumn.

An underlying principle in our work has been that any given species of forage shrub should provide a valuable component to the profile of nutrients made available to grazing livestock rather than expecting to find one (or more) species that in itself is able provide a complete package of nutrients. To this end, we should consider the nutritive value of the different species with a view of how they can add nutrients that would otherwise be limiting animal performance.

Aims

To show similarities or differences between the different genera of shrub species in terms of their nutritional profiles (crude protein, fibre, minerals, and estimated organic matter digestibility).

Methods

A total of nearly 1,600 plant samples were collected during Enrich phase 1 and 2, as outlined in**Error! Reference source not found.**. The Monarto site, being the first established, contributed most of the samples, but the other two research sites, at Merredin WA and Condobolin NSW contributed about 200 samples since the first collections from these sites in 2010. A similar number of samples were collected from the Badgingarra research site that was used for grazing studies (see section 3.6.2). A small number of samples were collected opportunistically from the regional sites, but these sites were mostly used to provide data on plant productivity and, when a regional group had sufficient resources, to provide information on animal preferences during grazing.

Table 5. A summary of the number and origin of samples collected for analyses of the nutritive value of edible biomass.

Collection Year:	2005	2006		2007		2008				2009				2010			2011			Grand Total
Season:	Summer	Autumn	Winter	Summer	Autumn	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Spring	Autumn	Winter	Spring	
Site:																				
Arboretum (Waite)					10	1														11
Badgingarra								80	40	65					22					207
Condobolin															**56**					**56**
Deniliquin																			2	2
Elbow Hill															1		1			2
Merredin															**138**					**138**
Mingenew															1					1
Monarto				**121**	**116**		**5**	**112**			**111**	**96**	**96**	**28**	**78**	**12**	**15**	**4**		**794**
Morchard															1					1
St Arnaud															1				2	3
Three Springs															1					1
Waite	56	17			6					2	63	80	36	3	10					273
Walpeup															1					1
Non Enrich site	6		52		31	2					13									104
Grand Total	62	17	52	121	163	3	5	192	40	67	187	176	132	31	310	12	16	4	4	1594

Plant samples (leaf plus stems less than 3 mm in diameter) were oven dried at 60°C for 72 hours and ground to pass through a 1 mm screen. Samples were analysed for concentrations of organic matter (OM) and total ash (Faichney and White 1983), neutral detergent fibre (NDF) and acid detergent fibre (ADF) (using an Ankom 200/220 Fibre analyser, Ankom® Tech. Co., Fairport, NY, USA), hemicelluluse (by difference between NDF and ADF), crude protein (nitrogen x 6.25) and mineral content by inductively coupled plasma atomic emission spectrometry following digestion in nitric and hydrochloric acid (Waite Analytical Services, Adelaide; McQuaker et al. 1979). ***In vitro*** OM digestibility (OMD) was estimated from the pepsin–cellulase digestion method followed by calibrations to correct for the effect of salt on digestibility and apparent systematic overestimations of *in vivo* OMD of chenopods and possibly other shrub genera when using the pepsin–cellulase digestion method (Norman et al 2010).

Main results and discussion

There was considerable variation for all nutritive value traits between genera and, in most cases, within genera. The concentration of crude protein and minerals in most of the shrub species examined exceed the dietary requirements of animals, suggesting that the shrubs need only constitute a proportion of the diet to still significantly contribute to the provision of a balanced, nutritious diet. Some caution is required, however, as the bioavailability of the minerals is not known. Calcium bioavailability is of particular concern in plants that contain oxalates as insoluble calcium-oxalate complexes limit the absorption of calcium. Further work is warranted to confirm the bioavailability of minerals from shrub species.

Examples of the nutritive value traits for eight of the shrub genera tested in Enrich are provided in the figures below. (The full data set of nutritive value traits derived from over 200 samples from 33 genera will be made publicly available on the FFI CRC website as part of the delivery phase of Enrich 3.) In the following figures, pale blue shaded bars represent the approximate dietary requirement for livestock. It can be used as a guide to indicate the potential contribution of the different genera and species to a particular nutrient. It can also help show the dietary inclusion rate that a particular plant needs to be in order for it to meet the daily requirements for a particular nutrient. E.g. *Acacia ligulata* at about 5% of the diet would provide half of the dietary sulphur required.

One would generally expect that high fibre plants have lower protein contents, and this was seen to some extent in the Enrich data set. But importantly there was wide variation between and within genera (Figure 5). Beyond some generalisations (e.g. *Rhagodia* spp. having low NDF, *Chenpodium* spp. having high crude protein and low NDF, or *Maireana* spp. having high crude protein and NDF) it will be important for shrub samples grown at different places and used at different times to be analysed for nutritive value, in the same way that any particular feed source for livestock should be tested to confirm its actual nutrient content.

The shrubs tested in Enrich were quite distinct from annual grasses and legumes, in general contributing less NDF and more protein (Figure 5), thus highlighting the complementarity between shrubs and the herbaceous pasture used in combination with shrubs.

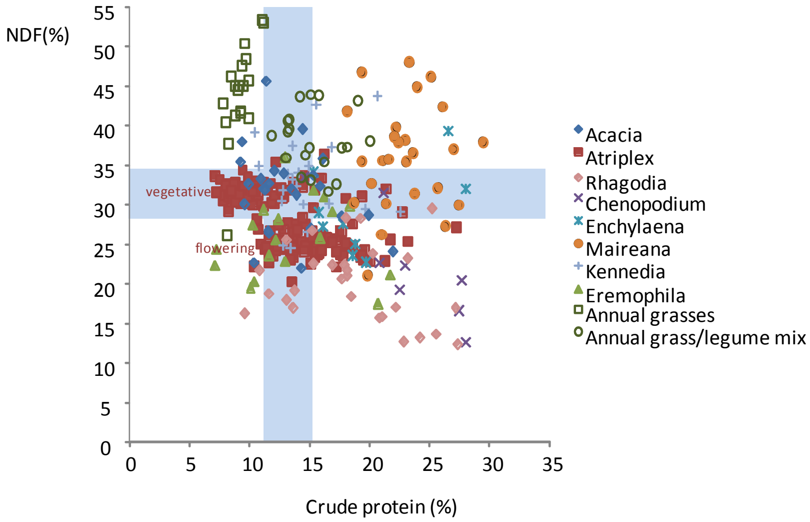


Figure 5. **Crude protein and neutral detergent fibre (NDF) for eight of the genera of shrubs tested in Enrich. Different points refer to different samples collected during the project, including different species, different locations or different stages of plant growth (e.g. vegetative or reproductive stages).values for annual grasses and annual legumes are provided for comparison.**

The sodium (salt) content varied between genera (Figures 6 and 7). As expected, the halophytic species such as the *Atriplex* spp. contained high salt levels. The lower salt content of other genera suggests potential for them to be complementary to saltbush-based pastures. Low Na plants to complement the *Atriplex* spp., in increasing order for Na, are: group 1 – *Acacia* spp., *Eremophila* spp. and *Kennedia* spp.; group 2 – *Chenopodium* spp.; group 3 – *Rhagodia* spp; group 4 – *Maireana* spp. and *Enchylaena*.

Some points of interest are:

(i) There was no relationship between Na and K content within or between genera (Figure 6);
(ii) Most shrubs were high in K, which could interfere with Ca and Mg metabolism –a point worthy of further investigation (Figure 7).
(iii) Clear differences existed between genera in the sulphur content, increasing from *Eremophila* spp., *Enchylaeana*, *Kennedia* spp. (which meet dietary requirements), to *Maireana* spp., then *Rhagodia* spp., *Chenopodium* spp. and *Atriplex* spp. *Acacia* spp. were variable in S content, with *A. ligulata* showing very high values (Figure 8). The sulphur content may be particularly important in influencing palatability (as many sulphur compounds are volatile and therefore having potential to influence the sensory characteristics of the plant.
(iv) Phosphorus content covered a wide range for most genera. Only the *Acacia* spp. were consistently low in P (Figure 8).
(v) *Atriplex* spp. and *Rhagodia* spp. were high in magnesium content. *R. candolleana* was particularly high in Mg content compared to the other *Rhagodia* spp. (Figure 8). Most other genera clustered tightly around values just above dietary requirements.

(vi) *Acacia* spp. covered a wide range in calcium content (Fugure 8). *A. ligulata* was particularly high in Ca. *Acacia ligulata* had much lower OM than all of the *Acacia* spp. tested (reflecting its high Ca and S content) (Figure 8).

(vii) Other data from the literature show halophytic plants such as *Atriplex* spp. tend to accumulate oxalate as the cation content increases, which suggest that in some species, much of the calcium is likely to be bound to oxalates and thereby unavailable to the animal (for example, *Atriplex* and *Acacia* spp., amongst others, may contain oxalates).

(viii) The copper and zinc contents of most shrub genera were close to dietary requirements (Figure 8). Some *Atriplex nummularia* and *Rhagodia* samples were high in copper (for *Rhagodia*, the higher values were not attributable to any particular species). *Enchylaena* tended to be higher than many of the other genera. If these species were consumed in large amounts, then toxicity in sheep or goats could arise (10-20 mg/kg DM), but not in cattle (>100 mg/kg DM).

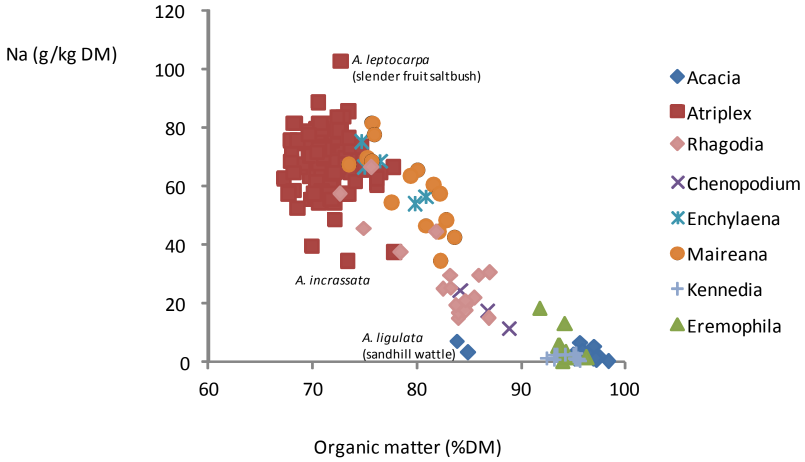


Figure 6. The relationship between organic matter content and sodium (Na) content of eight of the genera of shrubs tested in Enrich. Different points refer to different samples collected during the project, including different species, different locations or different stages of plant growth (e.g. vegetative or reproductive stages).

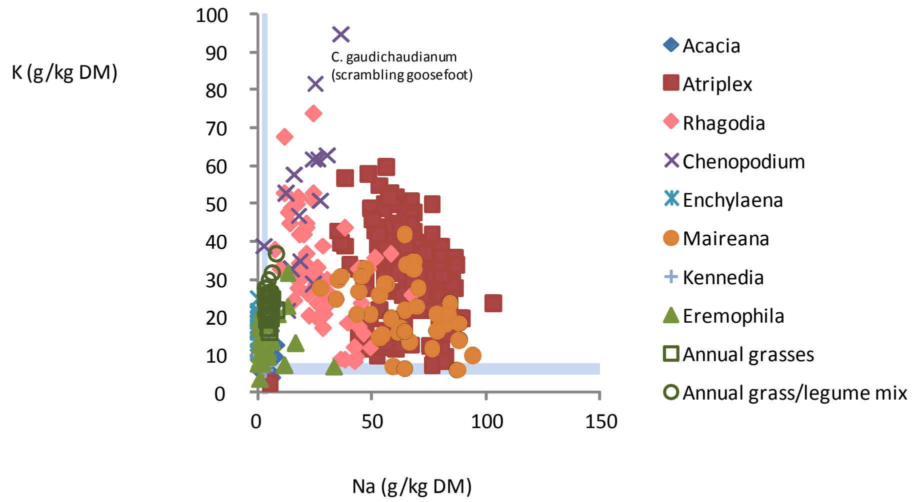


Figure 7. The relationship between organic the sodium (Na) and potassium (K) content of eight of the genera of shrubs tested in Enrich. Different points refer to different samples collected during the project, including different species, different locations or different stages of plant growth (e.g. vegetative or reproductive stages).Values for annual grasses and annual legumes are provided for comparison.

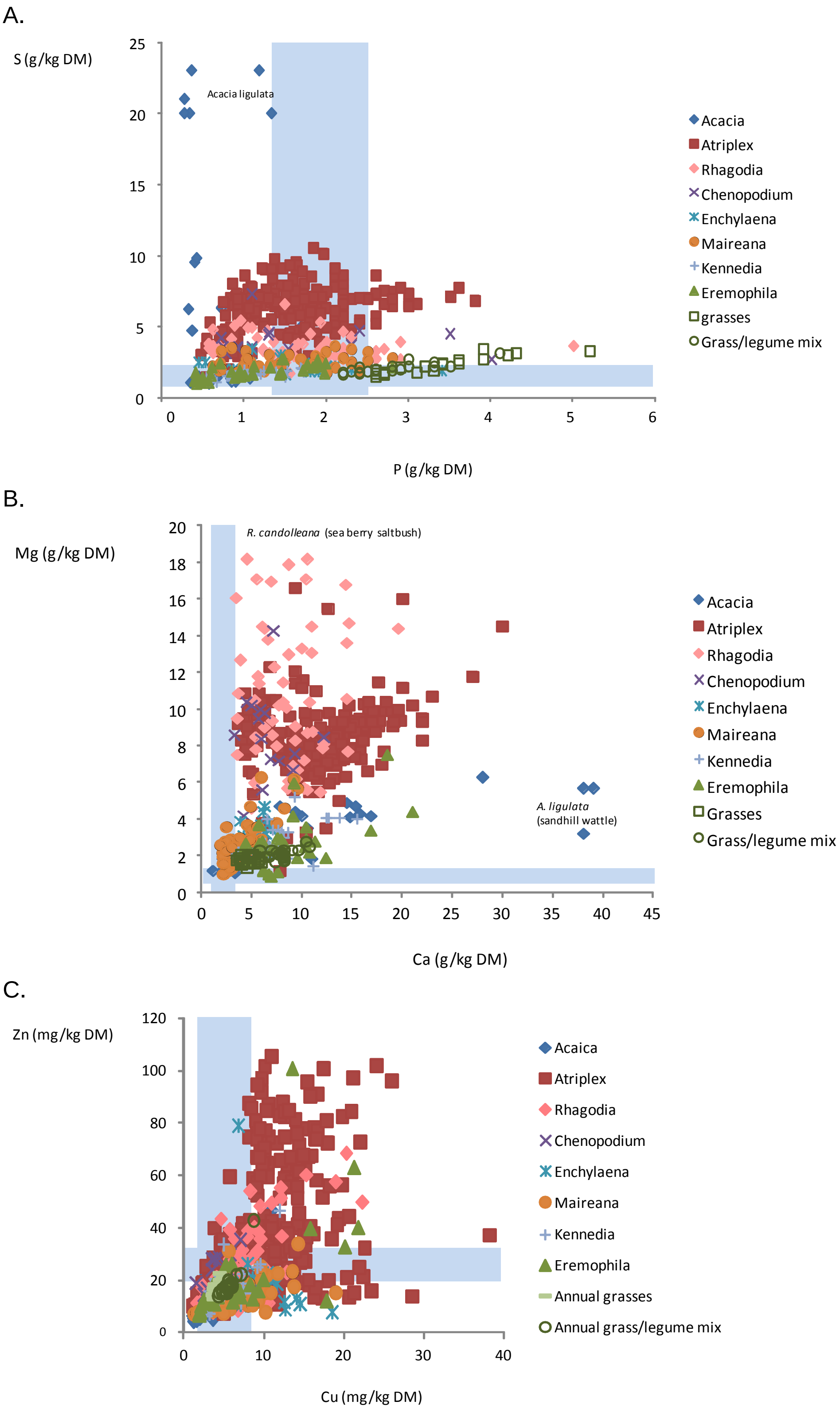


Figure 8. Content of: A. phosphorus (P) and sulphur (S); B. calcium (Ca) and magnesium (Mg); and C. copper (Cu) and zinc (Zn) for eight of the genera of shrubs tested in Enrich. Different points refer to different samples collected during the project, including different species,

different locations or different stages of plant growth (e.g. vegetative or reproductive stages).Values for annual grasses and annual legumes are provided for comparison.

Key messages

- Shrub species can bring different nutritional attributes to the diet than annual grasses and legumes. This reiterates the complementarity between shrubs and the herbaceous inter-row or understorey discussed above.
- There is real potential for shrubs, when in combination with a well-managed pasture, to meet the crude protein and mineral requirements of grazing animals, even when the shrubs may constitute only a modest portion (e.g. 30%) of the diet.

4.1.4 Rumen fermentation

A key part of quantifying the bioactive properties of shrub species has been testing the anti-methanogenic potential of 'Enrich plants'. This work was conducted through 'sister' projects supported by DAFF and MLA (through the Reducing Emissions from Livestock Research Program), with a coordinating role by the Future Farm Industries CRC. The data and their consequences to ongoing research and application to grazing systems have been, and continue to be, reported through the RELRP, but here we provided a summary of the main points and key implications.

Season
Variability in fermentation profiles exists between individual plants and throughout the year. Despite this variability, it is possible to select for individual plants with preferable fermentation profiles (i.e. reduced methane production). Variability between seasons could be used in future research to help to explain mechanisms of these effects as well as assist to develop grazing strategies for optimal effect in the rumen.

Grazing
The relative consistency in plant bioactivity before and after grazing suggests that favourable effects on rumen fermentation are not lost by grazing the plants. In some cases grazing may trigger some small changes in the composition of plants that can influence rumen microbial activity. These changes may be beneficial, for example reduction of methane, as seen in *A. nummularia*, or reduction in rumen ammonia production, as observed with *Rhagodia* species.

Site
The current findings confirmed our preliminary results about the variable nature and complexity and of plant bioactivity, probably due to variation in synthesis of plant secondary compounds responsible for these effects. Therefore it is necessary to continue screening of plants grown under variable conditions, but also look into specific plant secondary compounds and how they change under these conditions.

Accessions
Variability in fermentation and methanogenic potential between accessions of *E. glabra* exists. This variability adds a degree of complexity in developing ways to capitalise on bioactive, or 'medicinal', plants for the benefit of livestock health and production. There is a need to continually build our knowledge on the sources of variability in order to understand when anticipated bioactive effects will (or won't) occur.

Potential to capitalise on plant properties to reduce methane production or protein breakdown in the rumen
This is the focus of ongoing 'sister' projects to Enrich. A number of accessions of some species have been identified as having particular potential. The *Eremophila* species were identified as being consistently anti-methanogenic (Figure 9), which is consistent with the literature on the *Eremophila* genera as 'medicinal'. *E. glabra* is being used as a 'model' plant for ongoing studies on the potential to use anti-methanogenic plants.

There was a general pattern across genera of an increase in ammonia produced as fermentation increased (as would be expected), but no such pattern within genera (Figure 10). Most *Eremophila* & *Kennedia* spp. were below average, suggesting that microbial protein breakdown is inhibited in these genera, indicating they may help in providing 'by-pass' protein to grazing animals.

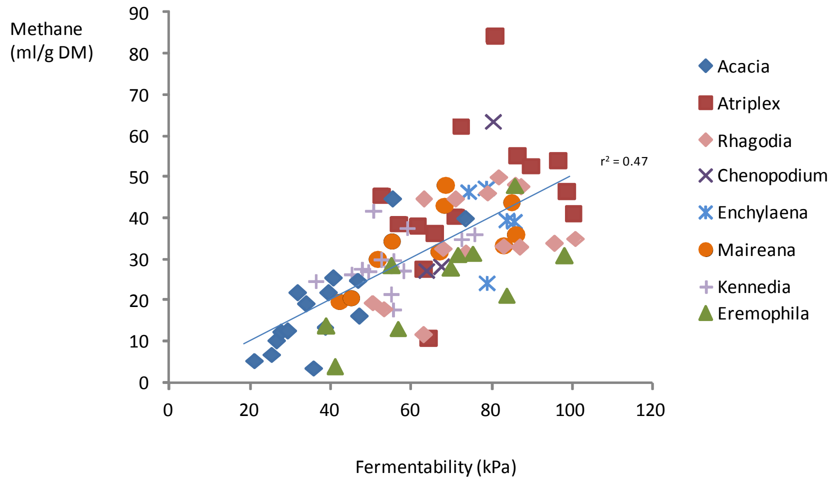


Figure 9. An example of the variability in methane production and total fermentability of the different shrub species tested.

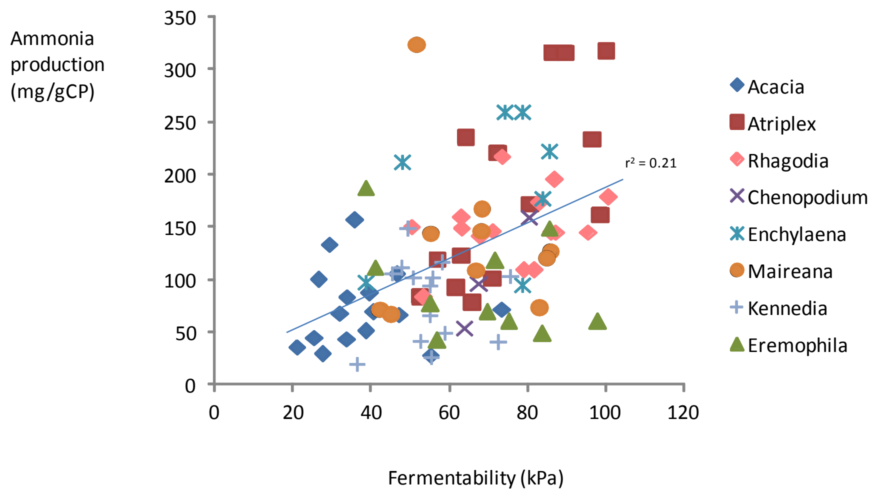


Figure 10. An example of the variability in ammonia production and total fermentability of the different shrub species tested.

Broadening the search?

Screening of several additional native perennial shrubs has not revealed any other plants with attributes exceeding those already described for the Enrich plants. We therefore believe that the opportunity now is to convert the exciting results obtained to date to practical on-farm options, rather than requiring more time and energy on screening additional species of shrubs. However, we encourage the screening of herbaceous pasture species for bioactivity, given the importance of shrub-pasture mixes for productive grazing systems.

Plant mixes and dose

Bioactive plants (e.g. those that appear to have specific inhibitory effects on rumen methanogens) can still be effective when included at a modest part of the diet.

The effect of dose (dietary concentration) has been investigated in detail using *Eremophila glabra* as the 'model' antimethanogenic plant species. A continuous flow *in vitro* system (RUSITEC) was used, which more closely resembles the animal than batch culture *in vitro* systems. *E. glabra* at 15% of the diet reduced methane production by 35% without significantly reducing total gas production or the concentration of VFAs produced (Table 6).

Table 6. Effects of three levels of inclusion of *E. glabra* ('EG') on Rusitec fermentation over the first 7 days of fermentation.

	Control	EG 15 %	EG 25%	EG 40%	s.e.m.
Total gas production, ml/d	1666 [a]	1492 [a]	1234 [b]	1018 [c]	111
CH_4, %	17.9 [a]	13.1 [b]	12.2 [b]	8.8 [c]	1.31
CH_4, ml/d	304 [a]	196 [b]	157 [bc]	104 [c]	26.7
Total VFA, mmol/l	105 [a]	98 [ab]	96 [b]	79 [c]	3.00
Acetate, mmol/l	64.1 [a]	59.1 [b]	56.8 [b]	45.5 [c]	1.80
Propionate, mmol/l	24.1 [b]	24.3 [b]	27.5 [a]	23.3 [b]	0.92
Butyrate, mmol/l	17.5 [a]	15.0 [b]	12.3 [c]	9.8 [d]	0.69
A : P	2.8 [a]	2.4 [b]	2.1 [c]	1.9 [c]	0.06

Mechanisms

It has been proposed that plants (or diets) that yield a low acetate : propionate ratio from rumen fermentation should also yield less methane (due to the propionate synthetic pathway using more hydrogen). The *Eremophila* species did tend to have lower acetate : propionate ratios and lower methane production compared to the other genera, consistent with the expectation that reduced methane would be associated with an increase in propionate production. However, for the other genera examined, no such a relationship was evident (Figure 11), suggesting that other mechanisms of action are occurring. Further research is recommended to explore the underlying plant chemistry in more detail.

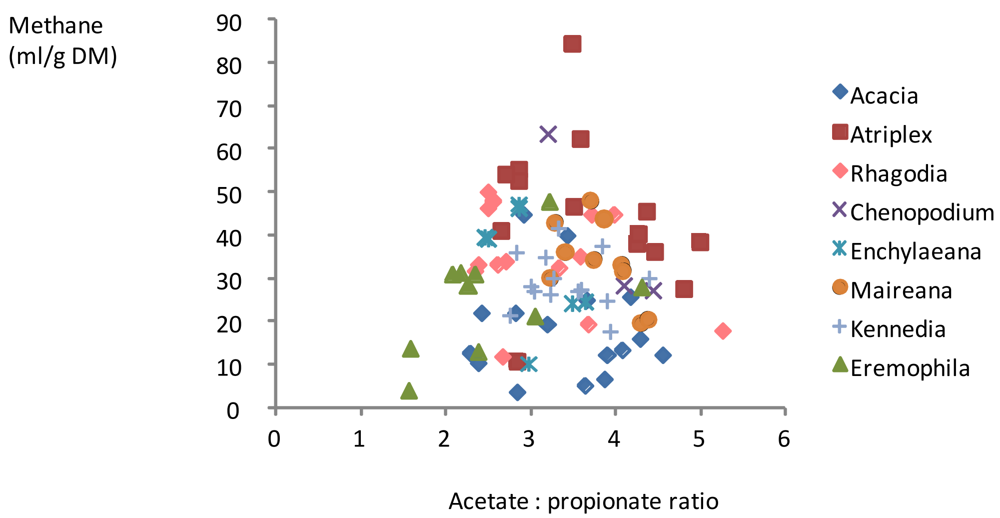


Figure 11. The relationship (or lack of) between the acetate : propionate ratio and methane production of eight of the genera of shrubs tested.

Key messages

- A number of species offer potential to contribute extra-nutritional benefits to grazing livestock.
- Ongoing studies are required to develop practical ways to capitalise on the traits under commercials grazing conditions, especially considering the variability over time and between plants in bioactivity.

4.1.5 THE INTERACTIVE PLANT EFFECTS IN A SHRUB-PASTURE GRAZING SYSTEM

Background

A shrub-based grazing system is comprised of a shrub layer in addition to an understorey of grasses and/or forbs. In southern Australia, forage shrub species are generally not overly productive and produce forage of relatively low quality. However, forage shrubs offer important advantages in their resilience and perenniality creating a more stable feed supply especially during the dry season. Consequently, in a shrub-based system the bulk of the biomass that drives animal production will still come from a productive inter-row pasture, or shrub understorey. Having full ground cover between the shrubs is also an essential strategy in the mitigation of soil erosion, a substantial issue across most of southern Australia.

Cultivating a mixture of different plant types creates a substantial change from conventional agricultural monocultural production and so creates numerous management issues in aspects such as species choice, spatial layout and density. Growing plants together creates various interactions between these differing plant types and in a grazing system these interactions are also influenced by the grazing herbivore. Shrubs by their morphology can create substantial changes in the surrounding micro-climate which may have positive or negative effects on the understorey species. Shrubs may also protect companion species from the grazing animal, especially when they are of differing palatability. Agricultural understorey species are relatively aggressive colonisers and generally productive plants which may compete heavily for water and nutrients, both of which are often limited in southern Australia. However legume species, commonly used as pasture may provide an important source of nitrogen to the shrub component.

Prudent management decisions need to take account of the biology of the system, which in the case of deliberately planted shrub-based systems is not completely understood.

Aim

The aim of this experiment was to determine if growing forage shrubs with grass and/or herbaceous pasture species results in interference (or facilitation) to one or more components of the feedbase.

Methods

This experiment used a split plot design, comprising 4 shrub densities (main plots) and 5 understorey pasture components (sub-plots), replicated 5 times. The 4 shrub densities were 0 plants ha^{-1}, 1111 plants ha^{-1} (3m x 3m spacing), 2066 plants ha^{-1} (2.2m x 2.2m spacing) and 3086 plants ha^{-1} (1.8m x 1.8m spacing). The shrub species that was used was *Atriplex nummularia* (cv. Eyre's Green). The 5 understorey components consisted of 1) annual legumes (a diverse mix of *Medicago truncatula* cv.'s Jester and Caliph, *M. littoralis* cv. Herald, *M.polymorpha* cv. Scimitar, *M. rugosa* cv. Paraponto and *Trifolium glanduliferum* cv. Prima), 2) lucerne (cv. SARDI 7), 3) perennial grass (red leg grass; *Bothriochloa macra*), 4) annual legume/perennial grass mixture and 5) bare (kept plant free as much as possible).

Due to the poor germination of red leg grass over the first year, it was sown again in two replications in October 2007 and irrigated as there was insufficient spring rain for germination. The low success of this procedure resulted in the other replications not being re-seeded. Subsequently, the two treatments containing perennial grass became volunteer grass (both perennial and annual grasses).

Different plot sizes were used for the different shrub density treatments. The area used allowed the same number of measured shrubs per plot (24) across treatments. The 0 plants ha^{-1} treatment had the same plot area as the 1111 plants ha^{-1} treatment. The experiment was located at Monarto South, South Australia (S 35.12080 E 139.13763). The soil type was a gradational loam. Rainfall during the period under study was below average particularly in the first two years. It was also much warmer than average with maximum temperatures being over 1.3°C above average over the whole period (Figure 12).

The understorey components were sown directly into plots in August 2006. The legume species were scarified before sowing but were not inoculated. All seed was tested for germination prior to sowing and the field sowing rate adjusted for viability. The annual legumes were sown at 7 kg ha^{-1}, lucerne at 5 kg ha^{-1} and red leg grass at 8 kg ha^{-1}. The legume grass mixture was sown together at 3.5 and 4 kg ha^{-1} respectively. The shrub component was planted by using established seedlings in November 2006. Shrubs were planted into rows which had been deep ripped to a depth of 30-50cm in June 2006. Due to dry conditions during 2006, irrigation was used to establish plots. Overhead sprinklers were used during October to aid in understorey growth and to ensure seed set of the annual component. Drip irrigation was used to water the shrub seedlings until March 2007.

Selective herbicides - Broadstike (800 g kg^{-1} flumetsulam), Kamba M (340g L^{-1} MCPA 80 g L^{-1} dicamba) Status (240g L^{-1} clethodim) and Verdict 520 (520 g L^{-1} haloxyfop) - were used to modify the annual legume, grass and lucerne understorey components to reflect their desired composition. Herbicides were used in winter 2007, 2008 and 2009. Due to insufficient knowledge of the herbicide tolerance of red leg grass to grass selective herbicides, the annual legume/grass treatment was sprayed with Broadstrike only and the grass treatment was treated with a weed wiper containing Gladiator (glyphosate 360 g L^{-1}) at a height above the red leg grass in winter 2007 only. The bare treatment was kept plant free by the use of the non-selective herbicide Roundup (glyphosate 450 g L^{-1}) in winter of every year.

The experiment was grazed for the first time in March and April 2008. Subsequently, grazing took place in April 2009 and July 2010. Grazing took place until all shrubs were defoliated to a level of greater than 80% original leaf area. A spring grazing of only the pasture components took place in September 2009.

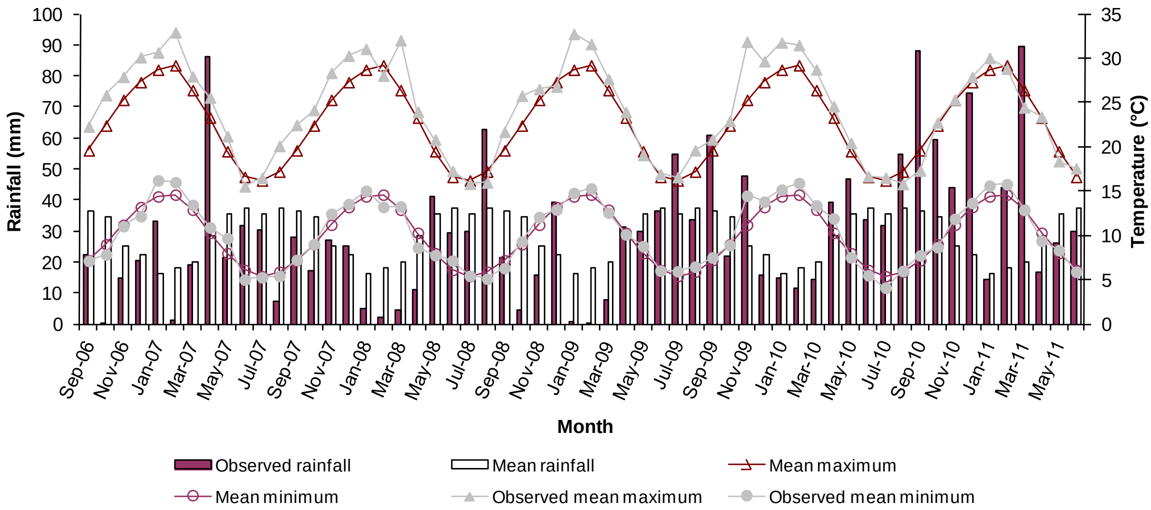


Figure 12.. Monthly observed (solid columns) and mean (open columns) rainfall for the experimental period for Murray Bridge, as well as the observed mean maximum (lines with solid triangles) and minimum (lines with solid circles) monthly temperatures. Long term mean maximum (lines with open triangles) and minimum (lines with open circles) monthly temperatures are also shown.

Measurements

Counts of seedling plant numbers of the understorey component was undertaken after the opening rains of the season and germination had taken place in the years 2007-2010. Ten counts were taken at random in each plot using a 25 cm square quadrat. Plants were divided into annual legumes, annual grass, perennial grass, lucerne and broadleaf weed components. Shrub numbers were counted in June 2007.

The biomass of the understorey components was measured in September and March every year (2007-2011) beginning in September 2007. This was conducted by placing four 33 cm square quadrats per plot and cutting the above ground green herbage to around a 2 cm height. After cutting, samples were sorted into annual legumes, annual grass, perennial grass, lucerne and broadleaf weed components and dried at 60ºC for 72 hours. Shrub biomass was estimated using the “Adelaide” technique described by Andrew et al. (1979) during June and November 2007, and then March and November each year from 2008 until 2011. Ten reference shrubs were stripped to calibrate visual estimation with actual edible biomass. Only the 24 central shrubs in each plot were measured.

Main results and discussion

Forage shrub production appears to be sensitive to competition from both other pasture species and other shrubs. Competition with companion pasture is particularly pronounced in the first year after planting. Perennial pasture such as lucerne causes the most significant reductions in shrub productivity. However, competition with winter growing annuals also reduced shrub biomass. Even though forage shrubs are deep rooted, there must still be a considerable overlap in the rooting zones of annual species. Planting shrubs at too high a density (such as 2000-3000 plants/ha in 375mm average annual rainfall) results in reduced biomass after 1-2 years (Figure 13). This is due to the continual drying of the soil profile and the use of moisture from deep in the soil.

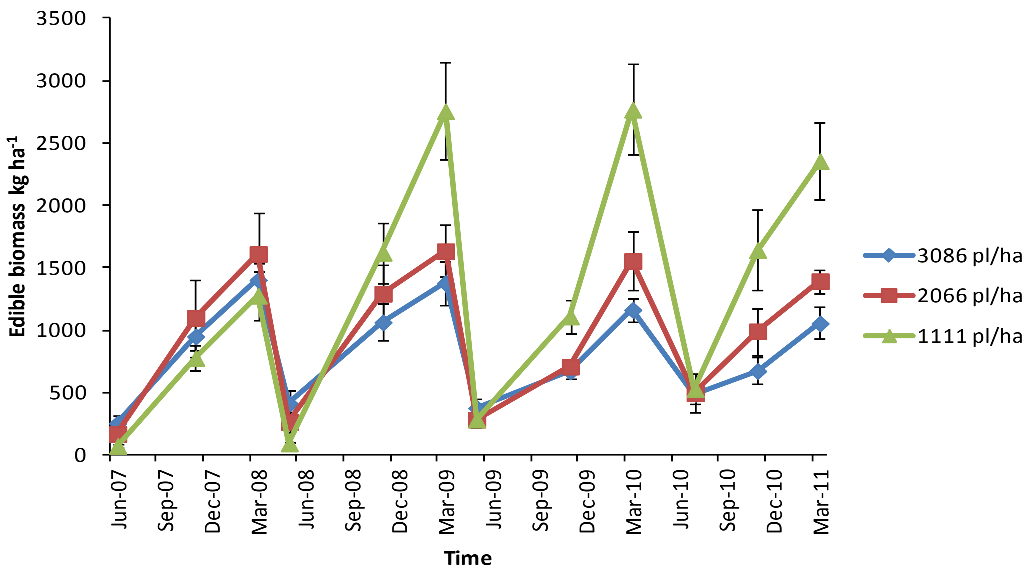
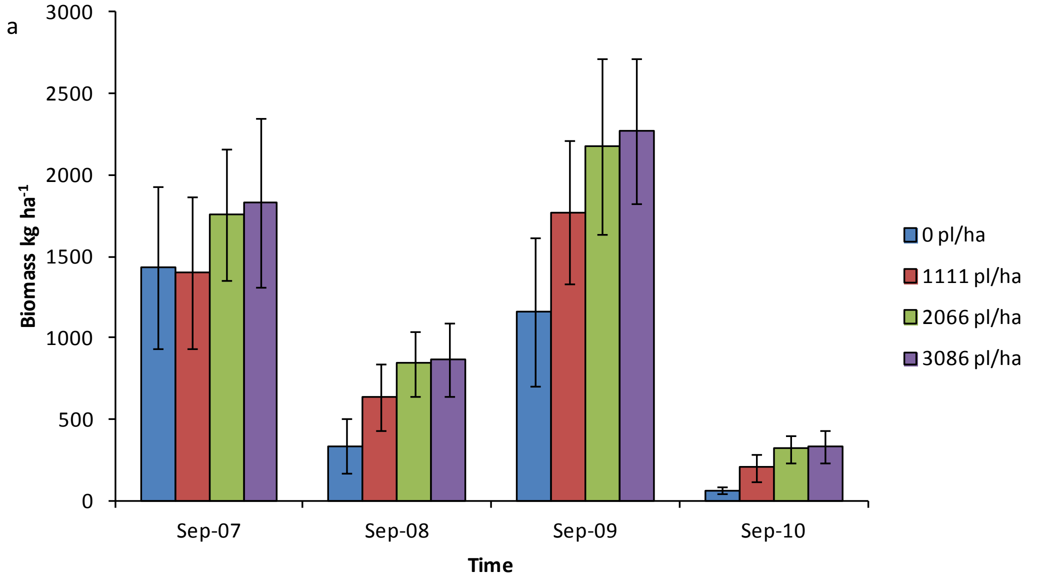


Figure 13. Shrub productivity (kg/ha) when grown at three densities (1,111, 2,066 or 3,086 plants/ha) in companion with a mixed annual legume-grass pasture. Grazing of the shrub component occurred during April 2008 and 2009 and July 2010. Error bars indicate the standard error.

From these results it appears that to maximise shrub production, competition should be minimised. To achieve this it is desirable to plant at a lower density and attempt to capitalise on individual plant potential. Planting fewer shrubs also helps to reduce establishment costs by lowering total seedling costs.

The data gathered here suggests that growing separate blocks of shrubs and perennial herbaceous forages would be the most advantageous. Growing species in separate areas is also advantageous for management and potentially for grazing livestock.

Our research has shown that regenerating seedling numbers and pasture biomass were not affected by growing in close proximity to shrubs (Figure 14). Annual pasture species have been shown to have higher phosphorus and potassium contents when grown as an understory to shrubs (Figure 15). It appears that there may be a positive effect of shrubs on annual medics in particular. The reasons why this occurred are not certain. Possible explanations could be that there are favourable micro-climatic changes within the shrub stand, better nutrition through increased nutrient cycling or possible hydraulic lift processes creating more favorable growing conditions.



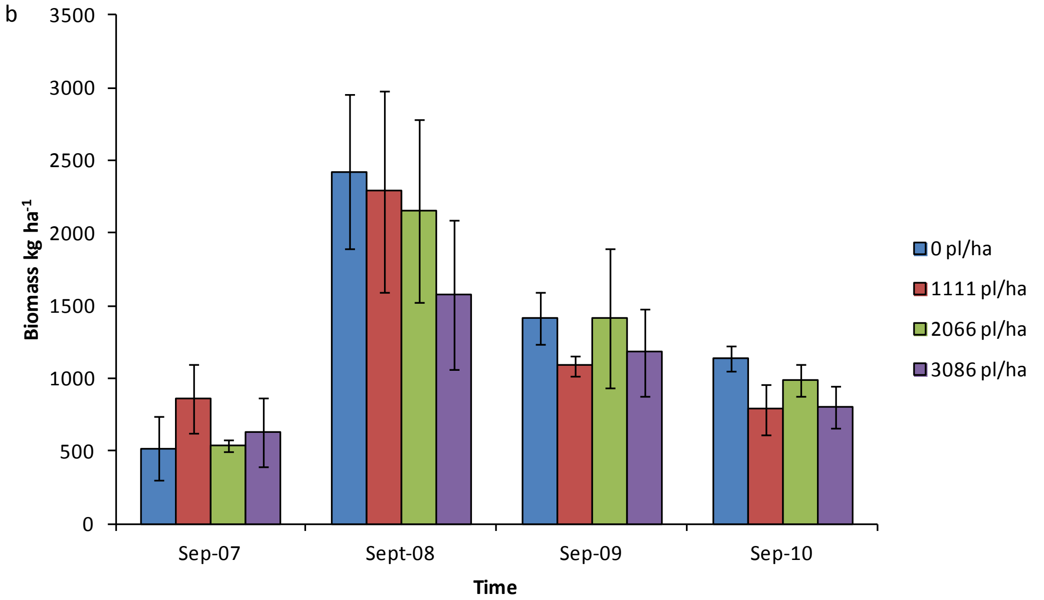
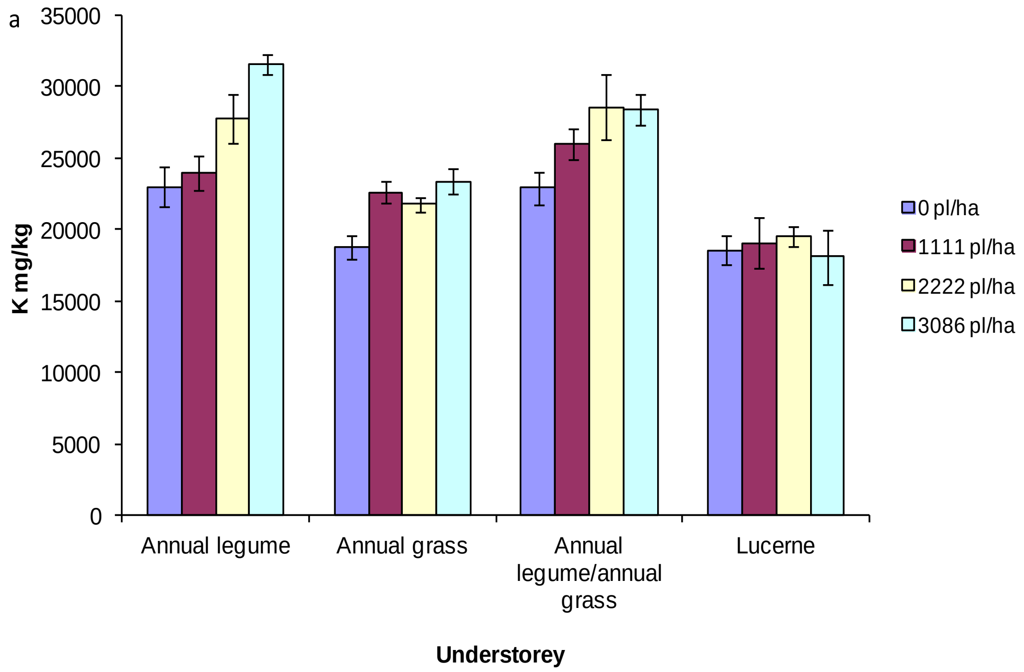


Figure 14. Annual legume (a) and annual grass (b) production over four years grown with shrubs at varying densities at Monarto, South Australia.

Lucerne production has been lower when grown in combination with shrubs planted at high densities. This appears to be directly related to a decline in lucerne density where shrubs are present. This could suggest that both herbaceous and shrub components are compromised in such a high density perennial mixture.



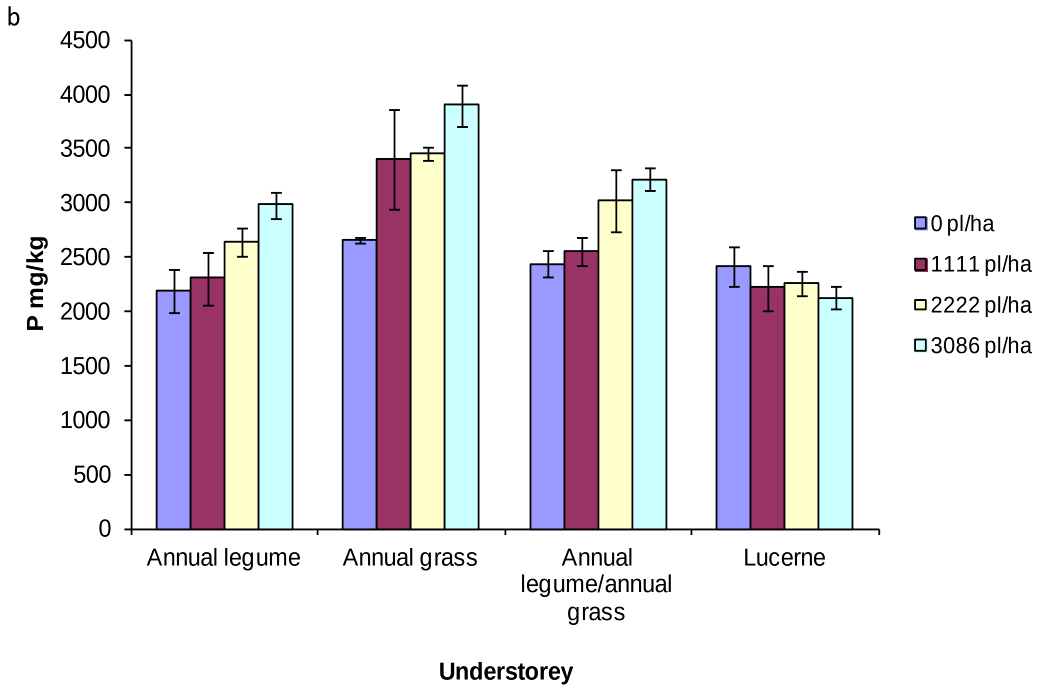


Figure 15. Potassium (a) and phosphorus (b) contents of different understorey pasture grown with shrubs at varying densities at Monarto, South Australia.

When total annual production (autumn shrub plus spring and autumn pasture) is examined, higher productivity is gained from (i) having shrubs (Figure 16) and (ii) a mix of shrubs and annual pasture (Figure 17).

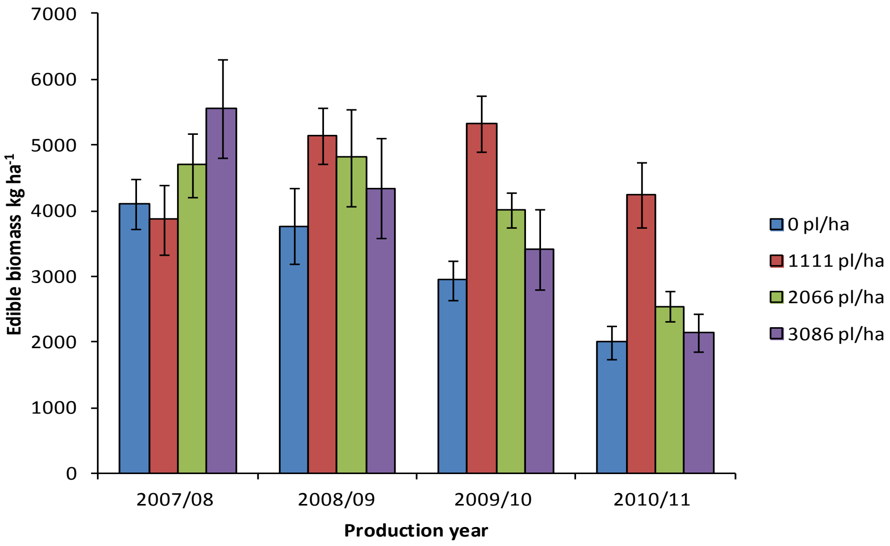


Figure 16. Total annual productivity across four years of an annual legume-grass pasture alone (0 shrub plants/ha) and when in combination with different shrub densities (1,111-3,086 plants/ha). Total annual productivity is classed as autumn shrub production plus spring and autumn pasture production. Error bars indicate the standard error.

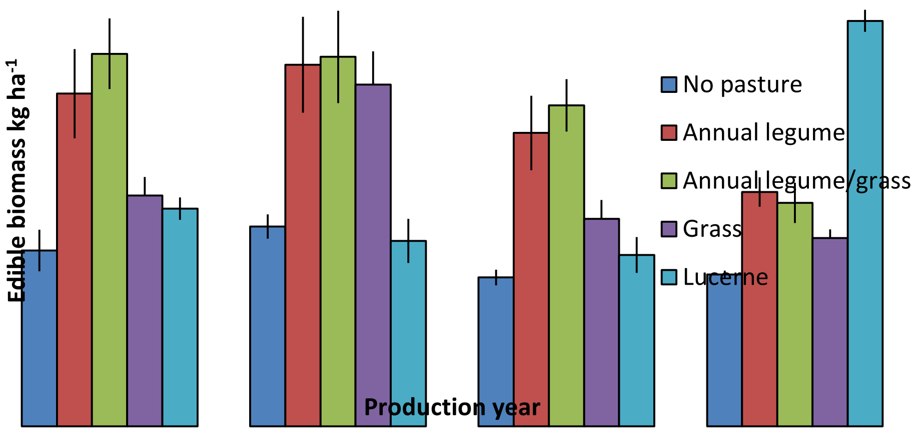


Figure 17. Total annual productivity across four years of shrubs and different pasture mixes. Shrub data are means of three shrub densities. Total annual productivity is classed as autumn shrub production plus spring and autumn pasture production. Error bars indicate the standard error.

Key messages

- In a shrub-based forage system, the bulk of the biomass that fuels animal production will still come from a productive inter-row pasture, or shrub understory.

- Companion pasture can be successfully grown in a shrub stand enabling better utilisation of land area.
- Incorporating shrubs in an annual-based pasture system is a true addition to the forage base, rather than a substitution.

4.1.6 INCREASING EXPOSURE TO SHRUB SPECIES EFFECTS SHEEP PREFERENCE

Background

It has been noted that one of the problems with many of the forage shrub species under consideration is that they are relatively low in palatability and consequently overgrazing of the inter-row pasture results in a high erosion risk and an unbalanced livestock diet. The shrub species themselves also vary in palatability creating a challenge in managing multi-species grazing systems.

Palatability is a complex concept which not only involves odour and taste but also post-ingestive feedback from nutrients and toxins. Herbivores often avoid novel food as an avoidance strategy to unknown adverse effects. Consequently, they do not experience any potential positive effects recognised through the post-ingestive process. Using high stocking pressure is one method to allow the animals to experience species they may not at first consume. Provenza et al. (2003) suggest that making animals to eat a variety of foods, allows them to better mix the components of their diet to avoid negative dietary effects. Repeated experiences can be particularly powerful and lead to much different diet selection patterns than those displayed by naive animals.

Aims

The aim of this experiment was to determine the relative grazing preference by sheep of 15 shrub species and how this is affected by repeated exposures to those same species.

Methods

The experiment took place at Monarto South, South Australia (S 35.12080 E 139.13763). Four adjacent plots (2430m^2) containing 15 shrub species (Table 7) were separately fenced. Shrub species were randomly arranged in sub-plots which consisted of 36 plants of a single species, using a 6 x 6 layout with 3m (inter-row) x 1.5m (intra-row) spacing. Plants were established in winter 2006 and were first grazed in May 2008. The volunteer inter-row pasture contained mainly senesced *Trifolium glomeratum* and *Lolium ridigum*.

Table 7. Species used in the experiment

Species	Number of provenances
Acacia saligna	3
Atriplex amnicola	3
Atriplex cinerea	2
Atriplex nummularia	1
Atriplex semibaccata	2

Atriplex vesicaria	3
Cullen australasicum	3
Enchyleana tomentosa	4
Medicago arborea	1
Rhagodia parabolica	5
Rhagodia preissii	3
Rhagodia spinescens	5

Grazing of this experiment took place in November and December 2009. One mob of 18 White Suffolk dry ewes and one ram were grazed per main plot (78 sheep ha^{-1}). Grazing took place until all species were defoliated to a level of greater than 80% original leaf area. The mob was then immediately introduced into the next ungrazed adjacent plot. This occurred through four plot rotations thereby creating levels of ‘exposure’. The sheep were known to have previously grazed *Atriplex nummularia* but not the other species.

Edible biomass was estimated before grazing using the “Adelaide” technique. Only the 24 central shrubs in each plot were measured. Sheep preference was assessed using a modified scoring method based on Chippendale (1963) every two days during the duration of grazing. This method was used to estimate the biomass on offer during grazing. Pasture biomass was obtained from cutting four random quadrats ($0.1m^2$) per main plot before grazing and then every two days until grazing was completed. Biomass samples were dried at 60ºC for 72 hours before weighing.

Main results and discussion

In the first exposure period, the sheep initially consumed mostly the pasture understorey and the exotic legume shrub, *M. arborea* (Figure 18a). The remaining shrub species were consumed only after the pasture was removed (Figure 19a). As the animal’s exposure to all species increased their preference patterns were modified both for the shrub species and the ratio of shrub to pasture. By the fourth rotation *A. amnicola*, *A. cinerea*, *A. nummularia* and *E. tomentosa* were all preferred to the same extent as *M. arborea*. *R. parabolica* was still relatively un-preferred (Figure 18b) after the four rotations suggesting that previous experience will still not increase the preference and intake of some species. Once experienced, the sheep were choosing to eat a 50:50 pasture: shrub mix (Figure 19b), even when there was enough understory to meet their requirements. This means that animals can be managed so that they graze shrubs routinely (on a daily basis) rather than having inter-row pasture being overgrazed before shrubs are eaten.

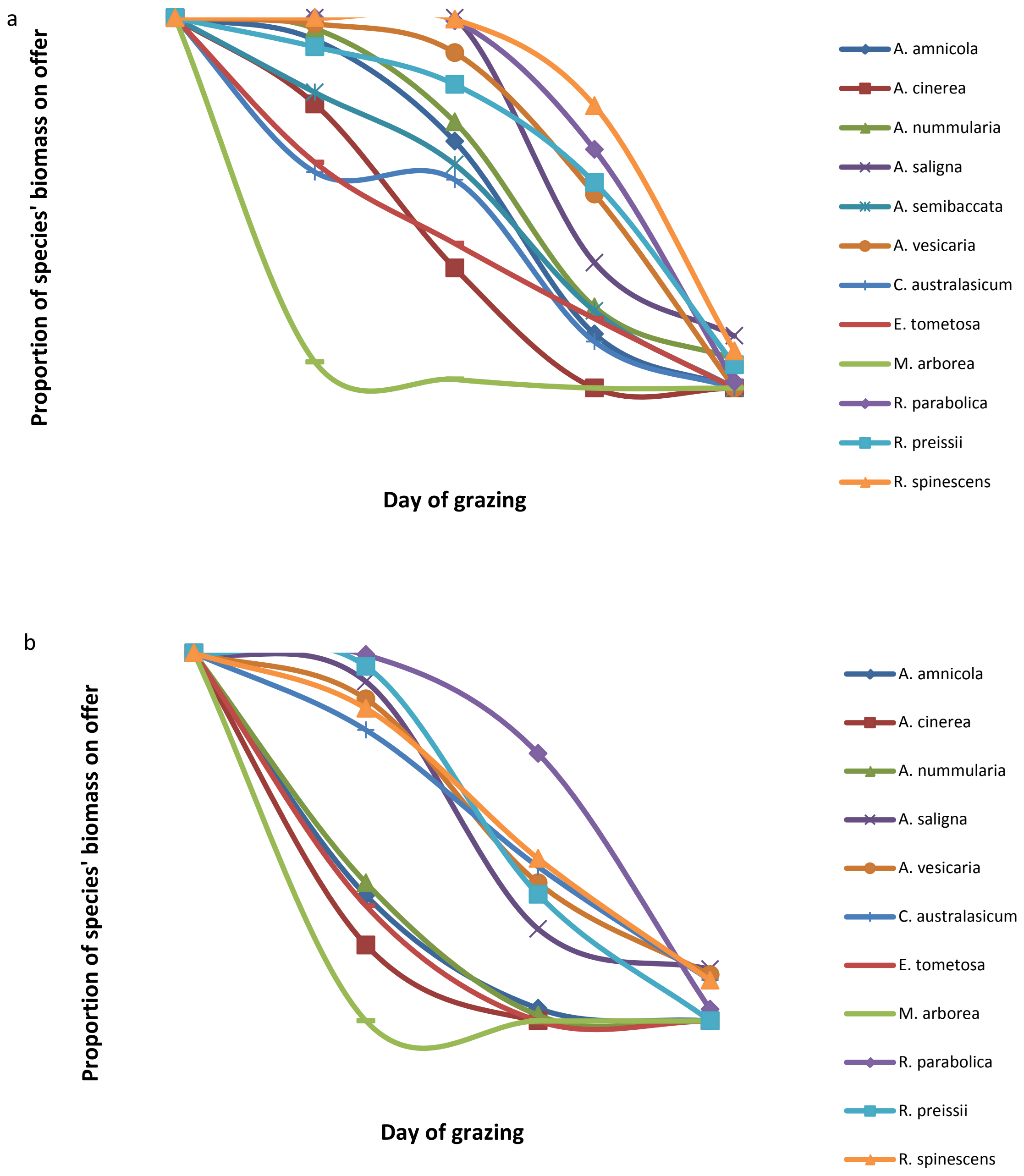
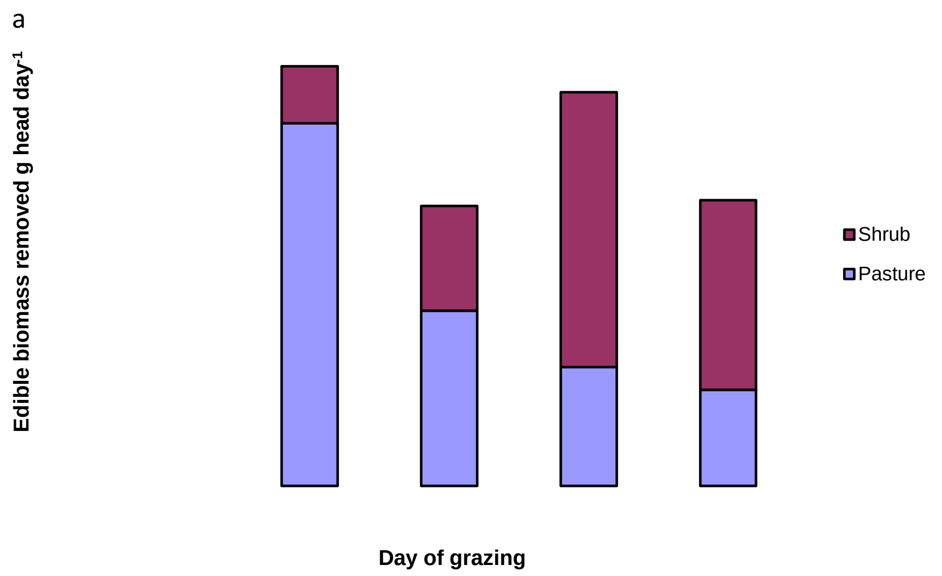


Figure 18. Relative preference over time for 12 shrub species during (a) initial grazing and (b) after the fourth rotation.



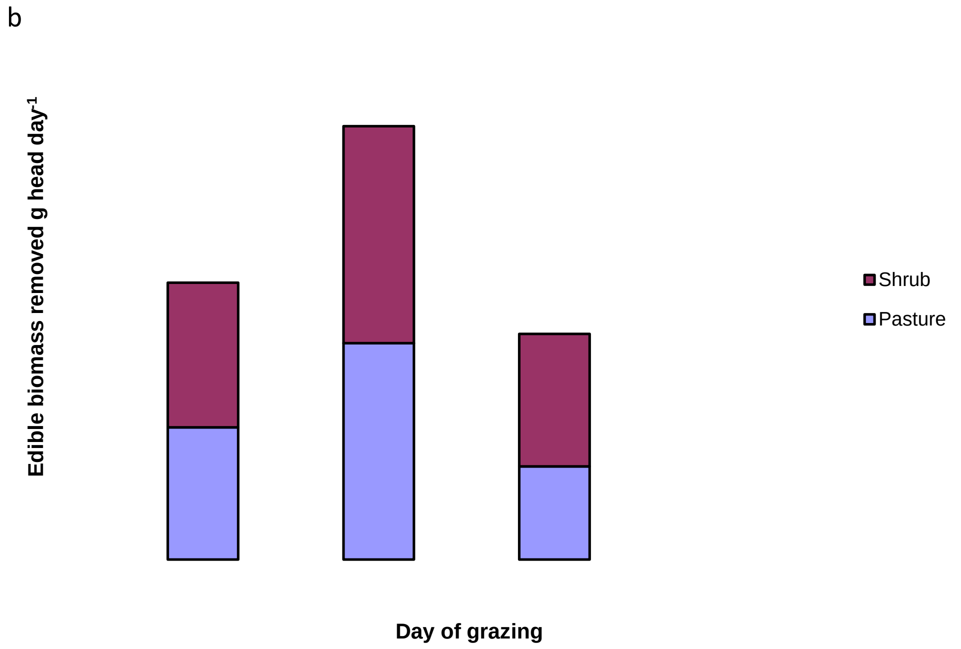


Figure 19. Breakdown of shrub and pasture removal (a) during initial grazing and (b) after the fourth rotation.

Key messages

- Repeated exposure to forage shrubs can be a practical option to increase preference and intake of such species.
- Forage shrubs and senesced pasture can be consumed in similar proportions minimising overgrazing and soil erosion.

4.1.7 HOW BEST TO OFFER MULTIPLE SHRUB SPECIES TO GRAZING ANIMALS

Background

A practical question often asked is whether there are benefits of offering multiple species of forage shrub compared with a single species. Furthermore, if multiple species do offer a broader range of nutrients and secondary compounds, and allow individual animals to best meet their nutritional needs, do the plants have to be offered simultaneously or can animals graze different species in a rotation?

Hypothesis

Providing alternative shrub species in rotation or simultaneously will increase shrub DM intake and live weight of Merino wethers compared to feeding one shrub species alone.

Methods

Four groups of Merino wethers were used, each with two replicates of 8 sheep:

(i) Group 1 grazed tagasaste as the only shrub species

(ii) Group 2 grazed *Rhagodia preissii* as the only shrub species

(iii) Group 3 grazed saltbush (*Atriplex nummularia*) as the only shrub species

(iv) Group 4 grazed *Rhagodia preissii*, saltbush and tagasaste (*Chamaecytisus prolifer*), with all shrub species simultaneously available – “Mixed”

(v) Group 5 grazed *Rhagodia preissii,* saltbush and tagasaste in rotation, moving twice a week. – “Rotation”

The stocking rate was selected with the intention that animals could maintain weight without supplementary feeding. The amount of edible shrub biomass on offer at the start of the experiment is shown below in Table 8. Inter-row pasture averaged 2,491 kg DM/ha, although the inter-row pasture between *Rhagodia* shrubs was less, at 1,465 kg/ha.

Table 8. Edible shrub material on offer for each replicate at start of experiment (average across the two replicates of each treatment).

Treatment group	Tagasaste	*Rhagodia*	Saltbush
Mixed	41 kg	107 kg	34 kg
Tagasaste	47 kg	-	-
Rhagodia	-	140 kg	-

Saltbush	-	-	74 kg
Rotation	62 kg	90 kg	30 kg

Main results and discussion

Moving sheep through the different shrub species in a rotation from one species to the next every 4 days induced the greatest week-by-week variability in live weight (Figure 20). At the end of the grazing period, the animals in the 'Rotation' group had lost about 3 kg. In contrast, sheep grazing either saltbush on its own or the full mixture of three shrub species had gained 2-3 kg. The majority of the increase in weight on the saltbush group occurred during the first week, possibly associated with an increase in body water associated although we did not measure this. Between weeks 2 and 7, there was very little variation in live weight in the 'Saltbush' group. For the sheep in the 'Mixture' group, live weight did not begin to increase until the fourth week of grazing, possibly reflecting the time taken to fully adapt to, and exploit, the diversity of shrubs on offer.

For the sheep that had Rhagodia as the only shrub species on offer, an initial increase in live weight occurred in the first week, most likely reflecting their predominant intake of the inter-row pasture, as very little Rhagodia was consumed. After this first week, the animals lost weight. In a later section of this report, we explore the potential to increase the intake of Rhagodia through behaviour based management. Sheep with tagasaste as the only shrub on offer performed intermediate compared to all other groups, most likely reflecting the slightly lower amount of biomass on offer compared to the 'Saltbush' and 'Mixed' groups. The sheep in the 'Tagasaste' group completed the grazing period at about the same weight that they began it, but they fluctuated during the grazing period by about 4 kg, a pattern that also occurred in the 'Rhagodia' group and, most of all, in the 'Rotation' group, which fluctuated by about 6 kg during the grazing period. The reasons for fluctuating liveweight patterns in some of the groups are not known, but may reflect changeable proportions of shrub:inter-row pasture consumed during the experimental period, or changeable levels of total feed intake.

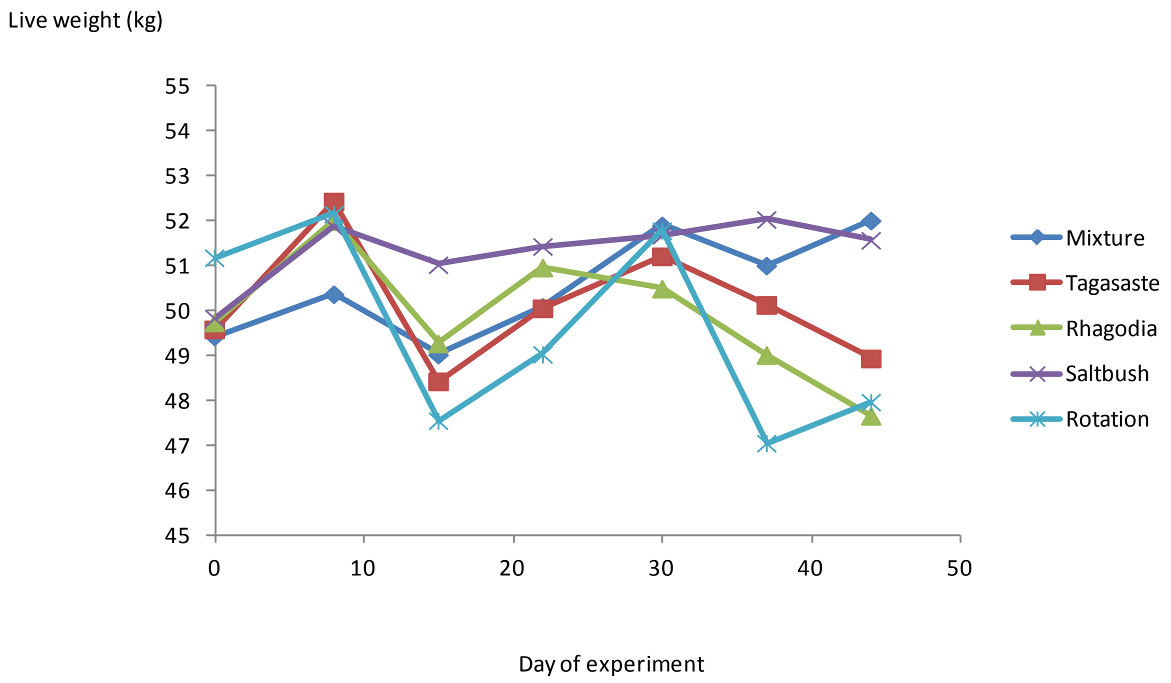


Figure 20. **Live weight of sheep grazing shrubs and inter-row pasture, with either a mixture of shrub species on offer, a single species of shrub on offer (either tagasaste, saltbush or Rhagodia) or offered each of the three shrub species offered in a sequence in a 4-day rotation.**

4.1.8 Can simple management intervention broaden the range of plants selected by livestock offered a mixture of shrubs?

Background

In diverse, shrub-based grazing systems, it is important that the animals select across the breadth of plants on offer to ensure (i) they are more likely to receive a balanced nutritional diet; (ii) can avoid excessive consumption of anti-nutritional factors; (iii) the persistence of a diverse forage base over time; and (iv) the inter-row herbaceous pasture is not overgrazed and become an erosion risk. Previous experiments by us in Enrich phase 1 showed that sheep maintained a diverse selection of shrubs in their diet if they grazed under medium-high pressure (60-330 sheep/ha). Higher grazing pressures require animals to be moved more regularly so they do not run out of feed. Rotating animals through paddocks may be feasible in some practical circumstances but, in other situations, producers may not have the time or motivation to move animals regularly, and will want to 'set-stock' animals for longer periods of time. Our previous experiments have shown that at low stocking rates (10 sheep/ha), the animals show a higher degree of selectivity for their preferred plants, and only move onto other species when they preferred species have been completely eaten. This breaks the four principles we are aiming for. This experiment was designed to test if a short period (4 days) of medium stocking rates (30 sheep/ha) can be used to 'teach' the animals to broaden their selection of shrub species and maintain this breadth when they subsequently graze under lower stocking rates (10 sheep/ha).

A second issue that has arisen from previous experiments is that, of the seven shrub species on offer at the Badgingarra research site, two have been rarely eaten when sheep are offered the full mix of shrubs and pasture: *Acacia saligna* and *Rhagodia preissii*. Factors limiting feed intake of these species is not known, but they may be condensed tannins for the Acacia and oxalate and/or saponins for Rhagodia. All three of these compounds can be bitter, and thereby provide a sensory cue for animals that can influence selection for or against the plants. Strategic supplementation may help overcome the limitations of condensed tannins (with polyethylene glycol, PEG) and oxalates (calcium). Self selection of PEG has been used successfully with other high-tannin feeds (Provenza et al., 2000), and self-selection of calcium supplements has been shown to increase when sheep are fed a high-oxalate food (Provenza et al 2006). The intake of saponin-containing foods can be increased if animals consume condensed tannins (Lyman et al 2009) presumably because of a beneficial interaction between these compounds. If PEG supplementation does increase the consumption of the tannin-containing Acacia, it may affect the intake of saponin-containing Rhagodia. The proposed experiment will include the provision of PEG and calcium (ground limestone) supplements in a factorial design to determine if they alter diet selection.

Hypotheses

(i) Animals that are managed under high grazing pressure for 4 days (i.e. trained to consume a wide range of plant species) will subsequently eat a broader range of shrub species when grazing at lower stocking rates than sheep not 'trained'.
(ii) Providing supplements of PEG and calcium will increase the intake of otherwise low-palatability shrub species.

Methods

All animals grazed the mixed shrub assembly at Badgingarra that was used in experiments in Enrich phase 1. On offer was *Rhagodia preisii* (mallee saltbush), *Atriplex nummularia* (old man saltbush), *Atriplex amnicola* (river saltbush); tagasaste, *Maireana brevifolia* (small-leaved bluebush), *Acacia saligna* (golden wreath wattle), *Allocasuarina huegleii*, mixed perennial grass pasture, and volunteer annual pasture inter-row. The animals in the supplemented groups were provided with calcium (ground limestone) and PEG in feed troughs placed near the water trough in each plot.

The experiment was factorial in design (2x2), with two grazing treatments and two supplementation treatments.
Grazing treatments:
1.) low stocking rate (10 sheep/ha) – “L” group
2.) high stocking rate (90 sheep/ha) for 4 days before low stocking rate – “H” group

Supplementation treatments:
1.) no supplements – “-S” group
2.) free-choice access to calcium and polyethylene glycol (PEG) – “+s” group

Main results and discussion

A high grazing pressure for 4 days at the start of a grazing period did not alter the subsequent diet selection of sheep when they grazed the mixture of shrubs and inter-row pasture. This suggests that broadening the range of plants selected by animals exposed to plant diversity may require repeated ‘lessons’; i.e. repeated exposure at moderate-high grazing pressure to the full range of plants on offer, as shown in section 3.6.1. An alternative approach is to use a high grazing pressure throughout a grazing period so animals cannot easily resort to being highly selective in the plants they consume.

The supplements provided in this experiment were not consumed, highlighting the need to actively manage the animals to provide the positive experience of how a supplement can increase the intake of a shrub (or any other feed source). Conditioning animals to the benefits of a supplement is necessary, rather than relying on innate behaviours. Animals can learn the benefits of a supplement themselves given time, either through trial and error or through social facilitation (where ‘trained’ animals ‘teach’ others to modify their eating habits) but, in the current experiment, it appeared that self-learning did not occur, possibly because there was insufficient time for the animals to learn. Consequently, the provision of the supplements did not modify diet selection.

However, by pooling the data across all groups of sheep, we showed that sheep grazing a shrub-based pasture system gained weight at 125 g/head/day and gained 0.5 units of condition score (Figure 21). This was achieved without any supplementary feeding. This occurred a time of year when conventional annual pasture (or crop stubble) is limiting in both quantity and quality, and producers normally expect to be hand feeding (or having animals just maintaining weight or possibly losing condition). At the end of the grazing experiment, there was still adequate ground cover to avoid any erosion risk from wind or heavy rainfall events (Figure 22).

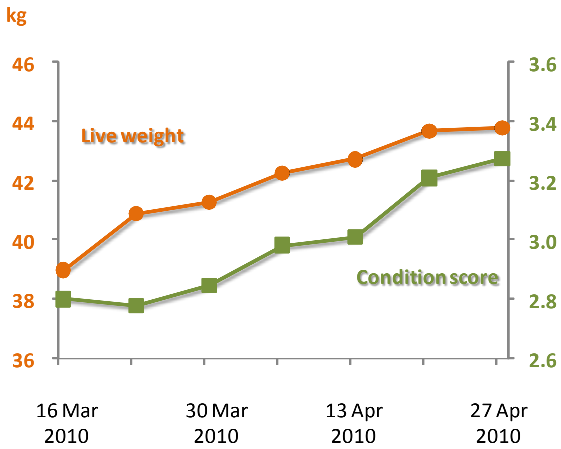


Figure 21. Gains in live weight and condition score of sheep grazing a shrub-based pasture at Badgingarra WA in autumn 2010.

Figure 22. Examples of pasture cover at the end of a 6-week grazing of a shrub-based pasture at Badgingarra WA in autumn 2010.

Key messages

- Animals can gain weight during autumn when grazing a mixture of shrubs and inter-row, without the cost and labour requirements of supplementary feeding.
- This level of productivity can be achieved whilst maintaining ground cover, thus minimising the likelihood of poor natural resource management (i.e. reducing the risk of soil erosion and maintaining high water infiltration due to the presence of organic matter).
- Using supplements to modify diet selection will require management practices that allow animals to actively learn about the benefits rather than relying on innate behaviours or learning by chance.

4.1.9 The effects of early-life exposure to a novel plant on subsequent diet selection

Background

Diet selection by animals is strongly influenced by past circumstances, both in terms of the animals' social and behavioural experiences as well as programming by nutritional physiology (i.e. hormonal and neural factors linking feedstuffs, plant sensory traits, digestive signals from the gastrointestinal and the animal's central nervous system that combine to influence eating behaviours). In this experiment, we examined the potential of foetal programming, maternal training, and diet exposure in the early post-weaning period to reduce aversions and improve utilisation of novel plants. We used saltbush as the model plant. Increasing the intake of novel plants is important to capitalise on 'new' plants, such as shrub species, that add resilience to grazing systems in a climatically-variable environment, and to capitalise on the nutritional or extra-nutritional (bioactive) properties of different plants in a mixture.

This experiment was conducted in partnership with a CSIRO project on 'Genes x Environment x Management', which is ongoing, so further data analysis will occur to fully capture all of the insights from this experiment.

Hypothesis

That early-life exposure to a novel plant increases to selection of that plant later in life.

Methods

On a commercial farm, 280 pregnant, single lamb bearing ewes were selected and managed to produce lambs subject to a factorial design of;

- +/- saltbush exposure *in utero* (during the last 1/3 of pregnancy)
- +/- saltbush exposure as a lamb with its mother (birth to weaning)

After weaning, the lambs were managed as a single flock until a week before experimentation where a further treatment was imposed within the factorial design;

- +/- 'training' - a positive post-weaning experience of saltbush exposure in a small plot with a grain supplement (lupins).

Lamb exposure therefore ranged from individuals that had never encountered the novel plant through to individuals that were exposed *in utero*, pre-weaning and again post-weaning. As a factorial design was used, all possible combinations of exposure (8 treatment groups) to saltbush were included.

Two experiments were then conducted with the lambs; (1) an animal house experiment to quantify short-term feed preferences of the offspring and (2) a field experiment to quantify production of the offspring under the commercial conditions of grazing saltbush with a cereal hay supplement. Although the early-life exposure was to saltbush, two other types of shrubs were included in the cafeteria testing in Experiment 1 (lucerne and Rhagodia) to determine if programmed or learnt behaviours were specific to a particular feedstuff or if they had broader effects.

In the choice feeding experiments with the weaned offspring, two different lines of saltbush (*Atriplex nummularia*) were used that differed in nutritive value, palatability and productivity. These lines were sourced from another project (the FFI CRC-funded Saltbush Improvement

Project, H. Norman *et al*, pers. comm.). Here, the two lines of saltbush are described as 'poor' and 'elite' saltbush.

Main results and discussion

The data provide evidence that early-life exposure to a novel plant (in this case, saltbush) influences dietary preferences later in life (Table 9). In the short-term diet selection experiment (animal house), we found that exposure to saltbush *in utero* or exposure through training (post-weaning exposure) doubled the intake of the elite saltbush. The combination of *in utero* exposure and post-weaning training was additive, with offspring receiving both of these treatments selecting four times the amount of elite saltbush than controls. Interestingly, none of the treatments had any effect on the selection of the poor saltbush. Exposure to saltbush has also led to an increase in the preference for lucerne and a decrease in preference for *Rhagodia preissii* (a plant often found to be of low palatability).

The strong *in utero* impact on saltbush intake suggests metabolic rather than behavioural influences on the factors that determine what an animal chooses to eat when offered a choice. In other words, biochemical signals arising during foetal development appear to have altered the regulation of diet selection in the weaned offspring by altering an (as yet unknown) neural or hormonal pathway. This phenomenon of an animal showing a specific selection behaviour is often termed 'innate' (from within), but an innate response does not mean it is a random occurrence, but rather that the regulation occurs automatically and without obvious reasons. The post-weaning exposure, or training, to saltbush, is more likely to have its effect via behavioural modification by reducing the novelty of the plant – and hence reducing neophobic effects when it was later offered as a choice in the animal house study – and also by allowing the animals to link the sensory characteristics of saltbush (smell and taste) with any nutritional (and possibly extra-nutritional) benefits provided by consuming the plant.

Table 9. The influence of early life exposure on the intake ratio of shrub (compared to wheaten chaff intake) during two cafeteria feeding experiments. The first was a week after housing. The sheep were then provided an opportunity to eat all of the shrubs for a week before the second preference test.

	First preference test				After a week of exposure			
Shrub	Luc	E SB	P SB	R	Luc	E SB	P SB	R
No prior exposure								
In utero	ns	*	ns	*	ns	ns	ns	ns
Pre-weaning ('with mum')	***	ns	ns	ns	ns	ns	ns	ns
Post-weaning exposure ('trained')	ns	ns	ns	ns	^	^	^	ns
In utero x 'with mum'	***	ns	ns	ns	ns	ns	ns	ns
In utero x 'trained'	ns	*	ns	**	*	ns	ns	ns
'With mum' x 'trained'	**	ns	ns	ns	ns	ns	ns	**
In utero x 'with mum' x 'trained'	ns	ns	ns	ns	ns	ns	ns	ns

Intake Ratio = logarithm of the ratio of the shrub intake (+1g) to the chaff intake (+1g).
Cube root weighted analysis to devalue data where animals ate very little.

Shrubs: Luc = lucerne, E SB = elite saltbush, P SB = poor saltbush and R = *Rhagodia*.
ns not significant, ^ P< 0.1; * P<0.05** P<0.01; ***P<0.001.

Practical implications

The link between diet selection and performance on-farm is yet to be defined. Early analysis of the field grazing experiment with the ewe lambs suggests no differences in growth were associated with the early-life treatments. There were also no differences in diet selection (saltbush vs wheaten hay) in the first week of grazing. In the last week of grazing, animals exposed to saltbush during lactation ate significantly less saltbush than those animals that were in an annual pasture paddock during lactation. We think this finding is because animals exposed to saltbush during lactation may have been comparing it with the nutritious alternative of milk, and thus developed an aversion – a conclusion consistent with Catanese et al (2010) who found that early-life exposure to a low-quality feed (where 'quality' is relative to the alternatives being offered) reduces the preference for that particular low-quality feed later in life. However, *in utero* exposure to a novel feed appears to operate quite differently, where the adaptation to a particular feed occurs through physiological programming rather than through behavioural changes. In related studies, we have found that if ewes consume saltbush or a high-salt diet during the last third of pregnancy, it changes the concentrations of hormones involved in salt and water balance and kidney structure in the offspring (Digby et al 2008, 2010a, 2010b; Chadwick 2009a, 2009b,2009c, Tay et al 2011), providing strong support for physiological programming, or adaptation, that is triggered by events during gestation.

Key messages

- Diet selection and feed preferences can be influenced by events that occur during pregnancy, and also early in life before and after weaning.
- This may help explain between-animal differences in feed intake and diet selection.
- Exposing animals to novel feeds in early life, such as during pregnancy and/or post-weaning, could offer a practical means to modify grazing behaviour of livestock – a hitherto undervalued management tool.

4.1.10 CAN THE PREFERENCE FOR A PLANT OF APPARENTLY LOW PALATABILITY BE INCREASED THROUGH BEHAVIOUR-BASED MANAGEMENT?

Background

Rhagodia preissii is one of the native Australian shrub species that has been investigated in some detail as a forage plant for livestock. It has many desirable traits, including its ease of establishment, growth on a range of soil types, resilience to long dry periods (even during its establishment), and its moderate *in vitro* fermentability by rumen microbes relative to other Australian shrub species (Durmic et al., 2010), but there is some uncertainty about its potential because of its low preference and variable intake by sheep (e.g Kotze *et al.* 2011). Initial evidence suggests that sheep may avoid the plant due to its novelty, or due to a deterrent plant compound that might be reduced with drying. A full description of this work has been prepared and submitted for publication. A summary of the experimental approach and results is provided below.

Hypotheses

This study investigated the hypotheses that 1) a low preference for, and intake of, *R. preissii* is due to neophobia (fear of novelty) and can be overcome by training and 2) drying *R. preissii* plant material will increase its preference.

Methods

Thirty six 12-month-old Merino ewe lambs were divided into one of six treatment groups, and each given a different feed training experience which was conducted over 10 days. The treatment groups were; no training or drenching (C), control drenching with an oral dose of water (CD), oral drenching with a diluted extract of *R. preissii* (RD), training either to a variety of novel feeds (NFT) or specifically to both fresh and dried *R. preissii* forage (RT), or undergoing the training regime with a familiar feed (CT). The drenching treatment was incorporated to determine if plant compounds that reach the rumen may trigger an aversive feeding responsive.

The procedure for the RT treatment group was developed, in principle, on the methods described by Voth (2010). Sheep were offered small quantities (200 g air-dry/day) of a series of novel, nutritious commercially-available feeds (either soybean meal, canola meal, millet and a lamb-growing pellet on each day) at 0900 h for four consecutive days. Sheep were offered a base ration of lupins and chaff at an amount equivalent to their energy maintenance requirements at 1500 h. On the fifth day, the novel feed was replaced with *R. preissii* (fresh and dry mixed 50:50) that was combined with the loose-mix base diet of chaff and lupins at an inclusion rate of 10% on a DM basis. During the subsequent 5 days, the inclusion rate of *R. preissii* was progressively increased from 10% to 30%, with a 10% increase every second day. Sheep continued to receive the base diet to maintenance requirements in the afternoon. The same training procedure was applied to the NFT and CT treatment groups, but NFT and CT did not receive any *R. preissii* in their feed. Instead, NFT received the same series of novel feeds they were offered in days 1 – 4 and the CT group was offered 200 g (air-dry) of the base diet each day for the whole training period.

The drenching treatment for the RD and CD groups was administered at the morning feeding time after the sheep had received their daily maintenance (+200 g) diet (approximately 830 g DM/sheep.day). *R. preissii* extract used in the drenching procedure was obtained by putting fresh material collected from CSIRO Floreat each day it was needed through a household fruit juicer. The fresh pulp was immediately mixed with water in a 50:50 ratio to produce a solution suitable for drenching. Drenching started on day 5, so that sheep were receiving the *R. preissii* drench concurrently with sheep offered *R. preissii* in the RT treatment group. The sheep in the RD group were given a 100 ml oral drench, prepared as described above, while the CD group received a 100 ml oral drench of water.

After the training procedure, two short-term preference tests (Experiment 1 and Experiment 2) were conducted. In Experiment 1, paired combinations of *R. preissii* at inclusion rates of either 5 or 20% of dry matter (DM) in lucerne chaff, and *R. preissii* in either fresh or oven-dried forms were offered. Voluntary intakes of both feeds offered in the preference tests were calculated at the end of each feeding interval. Experiment 2 was conducted the day after all sheep had completed Experiment 1. In Experiment 2, all sheep were offered fresh *R. preissii* for one hour, over which time we measured the voluntary intake of *R. preissii* when it was offered on its own.

Main results and discussion

The results of this study provided strong support for the first hypothesis that avoidance of *R. preissii* is at least partially due to neophobia, which can be overcome with a carefully designed training method. The total intake of the feeds offered in the preference tests (Experiment 1) was influenced by training ($P<0.001$;

Figure 23), but was not dependent on the way in which the feed was offered (dry or fresh, or its inclusion rate). Sheep in the RT group, which had previous exposure to *R. preissii*, ate approximately four times more feed during the preference tests than the control group (30 v 8 g DM) and double that of the CT group (15 g DM). Total intake was increased by exposing the sheep to the training procedure even if it occurred without offering novel feedstuffs or *R. preissii* forage; total intake in CT group was approximately twice that of the C and CD groups during preference testing. Form (fresh v dry), inclusion rate (5% v 20%) and feed combination offered did not have an effect on the total intake.

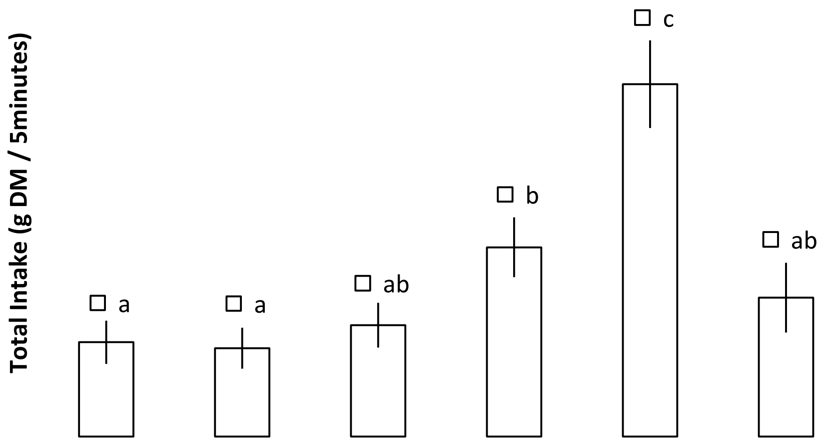


Figure 23. Total intake (g DM) for sheep (n = 6) during each 5 minute preference test across all treatment groups. C = Control, CD = Control Drench, RD = Rhagodia Drench, CT = Training Control, RT = Rhagodia Training and NFT = Novel Feed Training. Error bars represent standard error of the mean, SEM and different letters represent differences at P < 0.05.

The positive response to training is consistent with other studies, where controlled exposure to a feed has helped overcome a fear of novelty (Launchbaugh et al., 1997; Launchbaugh and Provenza, 1991; Provenza et al., 1996; Provenza et al., 2003; Villalba et al., 2009). We found that it was important that the training procedure included *R. preissii* because the Novel

Feed Training (NFT) group, which were offered a series of novel feeds but not *R. preissii*, did not significantly increase their intake of *R. preissii* in the preference testing. This study therefore demonstrates that low acceptance of the forage shrub *R. preissii* by sheep may be improved by providing appropriate experiences for the animals.

The preference of sheep for dried *R. preissii* forage was increased by up to 20%, supporting the second hypothesis that sheep would prefer oven-dried plant material when given a choice. Preference for dried forage might be attributed to the removal of a deterrent odour, associated which a plant compound that decreases in concentration with drying. The response to drying is consistent with other studies, such as with the fodder shrub, tagasaste (*Chamaecytisus prolifer*), where intake increased from 140 g DM/sheep/day of fresh to 348 g DM/sheep/day of sun-dried plant material (Becholie et al., 2005). Becholie et al. (2005) observed that the tagasaste herbage had a strong odour when fresh, which decreased with drying. Plants often contain anti-nutritional factors (toxins), which are compounds that can affect odour and taste, so the issue of toxicity may also be related to the issue of a deterrent odour or taste (Provenza et al., 2000). Animals learn to associate the post-ingestive consequences of eating a food with sensory properties of the feed (Favreau et al., 2010; Pain et al., 2005), and as such the odour or taste of *R. preissii* may be associated with a previous negative experience, possibly associated to a toxin. Arnold et al. (1980) stated that little is known about odour and taste aversions of naturally occurring chemical compounds in herbaceous plants and this is certainly true for *R. preissii*.

Administering an oral dose (drenching) of *R. preissii* pulp to sheep did not alter their intake of *R. preissii* in the preference tests. This may be because the sheep were unable to associate any post-digestive feedback from oral dose with physical or chemical traits that influence their sensory perception of the forage. Consequently, when presented with *R. preissii* in the preference tests, it was an unfamiliar feed, just as it was for the sheep in the control groups. Although the sheep administered *R. preissii* pulp would have experienced its smell and taste, the pairing between post-ingestive consequences and sensory traits of the plant was not strong enough to have influenced feed intake.

The current study also demonstrates that it is possible to increase intake of *R. preissii* through individual learning, as the experimental animals were housed separately in pens during training, so did not have the opportunity to observe or demonstrate the feeding behaviour of their conspecifics during training bouts. Indeed, the training procedure itself (i.e. the Training Control (CT) group) seemed to have a positive effect on the subsequent intake of feed during preference tests, although not as great as when the animal were trained with *R. preissii*. The calm and positive interaction between the sheep and a small number of people who offered food during the training procedure may have reduced animal stress, which made the sheep slightly more willing to consume feed during the test periods. We would expect that the learning experiences that led to an increase in *R. preissii* consumption would have been even more effective if we had allowed for social learning between animals. Animals modify their feeding behaviour based on their observations of other animals (Galef and Laland, 2005) and learning from social models can increase the acceptance of novel feeds (Chapple et al., 1987; Squibb et al., 1990; Thorhallsdottir et al., 1990).

During the training period and the preference testing we found large differences in intake between individual animals. Interestingly, the variability in acceptance of *R. preissii* forage was not reduced after training for familiarity with *R. preissii*. The intake of novel feeds (excluding *R. preissii*) by individuals during the training period was also positively correlated with their intake during the preference tests, suggesting that some sheep are more willing to consume larger quantities of novel feeds. A high degree of variability among individual animals in the intake of forage shrubs has been observed in a number of studies (e.g. Norman et al., 2009). Even within apparently uniform groups of animals, individuals vary morphologically and physiologically and differ in their diet selection (Provenza et al., 2003). In light of this, a more social learning environment could be used to reduce variation between animals.

Key messages

- Behaviour-based management does offer an opportunity to modify the diet selection of livestock. Providing animals with experiences of a particular plant through the managed introduction of the new feed source can boost their intake of that plant.
- However, some plants are likely to remain poorly selected by animals based on interactions between the plant's chemistry and the animal's metabolism.
- Social interactions between animals could offer a practical tool to improve the intake of plants for which animals tend to show a low preference but exploiting the fact that individual animals within the group are likely to eat the plant much more than the average of the group.
- Given the relative reluctance of sheep to consume *R. preissii*, even with training, this forage shrub may be better suited to a mixed-species forage system, where sheep can meet their nutritional requirements through a diverse diet.
- Additionally, it seems worthwhile to identify and select individual plants for which animals show a higher preference (Kotze et al., 2011), thereby possibly reducing the need to train animals to consume it.

4.1.11 Regional field evaluation of potential forage shrub species in partnership with local groups

Background

There was a need in the second phase of the Enrich project to strengthen the knowledge base on the prospective forage shrubs over time (especially important given their perenniality) and space (multiple sites to evaluate their varied traits). Since its inception, Enrich has received considerable interest from local authorities, individual farmers and farmer groups. Landholders have been keen to learn which shrubs species are likely to be suitable performers in their region. Since initial data was generated from one shrub evaluation site, at Monarto, it was not been possible to provide the necessary information to all groups, especially those with very different soils and climatic patterns.

In November and December 2007, Enrich invited regional groups across southern Australia to co-invest in the establishment and evaluation of a shortlist of shrub species in their own localities. Partnerships with nine regional groups were established to set up new shrub evaluation sites in their region under their local conditions. In addition to providing greater confidence in the selection of “best bet” species, new sites provided a direct means of engaging producers and other industry representatives who are more responsive to research, development and education in their region than from elsewhere.

A critical limitation in establishing additional sites has been the availability of germplasm, especially to ensure consistent genetics and propagation methods. The coordination of germplasm was done by the Enrich project (through the South Australia Genetic Resource Centre) which ensured the availability of germplasm of Enrich species, as most species are not available commercially and appropriate comparisons across sites could occur; i.e., a 'true' genotype x environment evaluation.

A standard set of management and measurement protocols was also developed within the project team for use by the partner groups. The sites, among which shrub management and measurements were consistent formed a national evaluation network, which could yield a greater understanding of the adaptive range of these species than that from individual, inconsistent sites. Hence, the protocols were intended to standardise the measures and management of shrub performance, in each replicated evaluation trial, in order that the collected data could be consolidated into a larger consistent set.

Methods

From data gathered during Enrich Phase 1 on species attributes, a shortlist of 23 species was developed for further field evaluation. Partnerships with local groups were formed to enable eleven sites to be established in 2008 across the agricultural zone of southern Australia (Figure 24). Four additional sites were established in 2009 (Minnipa, Streaky Bay, Waikerie, and Wandearah). Sites were highly varied in soil characteristics (

Table 10) and actual annual rainfall (Table 11).

At each site a maximum of 15 species were planted (Table 12). The final site list was chosen based on known soil type preferences, frost tolerance and availability of planting material. Ten species were planted at all of the 15 sites. At some sites, a companion planting of a climber (*Convolvulus remotus* or *Glycine canescens*) in association with *Atriplex nummularia* was also tested. Standard germplasm was used to minimise genetic variation across sites.

Species were propagated using either seed or vegetative cuttings during late summer. Seedlings were grown for 4-5 months in tubes before being ready to plant in the field. Legume species were inoculated with the best available rhizobia whilst still growing in tubes.

The field experiments employed a complete randomised block design. Four replicates of 15 species were tested at each site. Plots consisted 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 July, August and September 2008 or in the case of four sites, June 2009. Shrubs were planted into rows which had previously been deep ripped to a depth of 30-50cm. Weed control was applied before planting. Due to the prevailing dry conditions in some sites, supplementary water was used to establish the experiment. No further water was given after December in the year of planting. In the year following planting the inter-rows were mown or sprayed with Roundup (glyphosate 450 g L^{-1}) to control weeds.

Figure 24. **Locations of regional Enrich plant evaluation sites. The three main evaluation sites (Condobolin, Merredin and Monarto) are also shown.**

Table 10. Regional evaluation sites with their rainfall and soil characteristics.

Site name	State	Mean annual rainfall	Soil pH (H_2O)	Soil texture
Binnu	WA	286mm	7.4	Yellow sand
Broomehill	WA	454mm	6.4	Loamy sand
Deniliquin	NSW	404mm	6	Clay loam
Elbow Hill	SA	280mm	8.8	Clay
Hay	NSW	368mm		Loam
Miling	WA	474mm	6.4	Heavy loam
Mingenew	WA	365mm	8.6	Red loam/ clay
Minnipa	SA	273mm	8.9	Clay
Morchard	SA	325mm	8.75	Clay-loam

St Arnaud	VIC	503mm	5.6	Heavy clay
Streaky Bay	SA	301mm	8.4	Clay loam/sand
Three Springs	WA	387mm	6.5	White sand
Waikerie	SA	254mm	7.9	Sandy loam
Walpeup	VIC	330mm	8.6	Loamy sand
Wandearah	SA	322mm	7.6	Sandy clay-loam

Table 11. Annual rainfall (mm) during the experimental period at all sites.

Site name	2008	2009	2010	2011
Binnu	400.8	299.2	288.4	408.8
Broomehill	475.4	363.5	249.1	470.2
Deniliquin	334.6	224.3	708.6	456.8
Elbow Hill	182.5	203.9	411.7	382.6
Hay	246.4	270.4	739.0	649.8
Miling	306.5	304.2	227.0	403.0
Mingenew	415.8	354.3	267.6	483.2
Minnipa		372.2	326.0	393.2
Morchard	307.8	413.8	444.0	492.8
St Arnaud	304.2	465.6	703.2	558.2
Streaky Bay		461.1	436.4	463.8
Three Springs	347.0	346.4	231.0	458.1
Waikerie		291.4	461.9	374.4
Walpeup	250.0	318.4	546.0	448.0
Wandearah		377.0	413.4	442.9

Survival was assessed in the November after planting. Canopy dimensions (height and two diameters) were measured in April and November each year, beginning in the year after planting. The presence of flowers and fruit, volunteer seedlings and pathogenic or environmental damage were also recorded at these times on all individuals. Edible biomass, using the shortcut method of Andrew et al. (1979) was estimated on five sites. Only the 24 central shrubs in each plot were measured for all these attributes.

Grazing of eleven sites took place in the second autumn or winter after planting. Grazing took place until all plants were defoliated to an estimated level of greater than 80% original leaf area. All grazing took place using Merino sheep but age and class varied across sites due to animal availability.

Main results and discussion

Performance data (canopy volume and plant survival) has been collected from 13 ‘regional group’ sites. This is summarised inTable 13. Edible biomass production was also assessed at a smaller number of sites (Table 12). There is a large amount of variation between sites in both species productivity and survival. Whilst some of this is due to differences in environmental conditions at sites, there also appears to be a significant genotype-environment interaction for some species.

Table 12. Edible biomass production (g plant^{-1}) of species across sites in the second autumn after planting.

	Broomehill	Walpeup	Waikerie	Minnipa	Streaky Bay

	Broomehill	Walpeup	Waikerie	Minnipa	Streaky Bay
Atriplex amnicola	267	1180	1718	901	1355
Atriplex cinerea	342	942	2107		776
Atriplex nummularia	312	1909	2584	2399	2831
Atriplex paludosa					2050
Atriplex rhagodioides	499	1362	3239	2606	1582
Atriplex semibaccata	145	980	2760	797	2208
Atriplex vesicaria		698			
Chamaecytisus prolifer	183	77	23	15	50
Chenopodium nitrariaceum	90		400	177	45
Convolvulus remotus			38		
Cullen australasicum		85			
Enchylaena tomentosa	152	512	1383	1217	1211
Eremophila glabra	45	285	623	382	571
Eremophila maculata				76	
Medicago strasseri	4	71	18	40	103
Rhagodia crassifolia	168	804	1484	669	676
Rhagodia parabolica	451	1022	1639	2058	1415
Rhagodia preissii	129	890	978	931	1860
Rhagodia spinescens	149	429	892	1313	590

Table 13. Mean canopy volume (m^3 $plant^{-1}$) of forage shrub species across sites in the spring around 14 months after planting. Data from the three larger evaluation sites are also included for comparison. Values for individual sites expressed as a percentage of the species mean across all sites. Mean site survival is displayed in parentheses.

	Binnu	Broomehill	Condo-bolin	Elbow Hill	Merredin	Miling	Mingenew	Minnipa	Monarto	Morchard	St Arnaud	Streaky Bay	Three Springs	Waikerie	Walpeup	Wandearah
Acacia saligna	183 (45)				35 (85)	56 (79)			168 (100)				121 (79)			
Atriplex amnicola	51 (23)	45 (66)	314 (92)	21 (78)	95 (82)	63 (74)	29 (41)	74 (93)	549 (99)	25 (89)	14 (96)	51 (85)	6 (29)	174 (93)	160 (99)	27 (92)
Atriplex cinerea	(0)	113 (44)	60 (50)	18 (75)	43 (23)				561 (97)	10 (93)	1 (28)	77 (79)	6 (8)	237 (60)	168 (93)	6 (34)
Atriplex nummularia	36 (46)	82 (73)	220 (91)	24 (78)	41 (91)	36 (91)	32 (53)	185 (98)	505 (98)	30 (96)	12 (96)	121 (100)	4 (81)	169 (96)	182 (97)	17 (99)
Atriplex nummularia (companion)	16 (23)	196 (85)	361 (92)	44 (99)	94 (63)	62 (82)	45 (63)			51 (94)	20 (93)		15 (80)		294 (97)	
Atriplex paludosa			99 (86)		18 (67)		11 (46)		501 (100)			54 (97)				17 (91)
Atriplex rhagodioides	51(59)	163 (98)	180 (96)	32 (96)	51 (83)	43 (88)	22 (80)	194 (100)	474 (98)	22 (96)	20 (99)	57 (100)	2 (86)	201 (100)	144 (100)	40 (97)
Atriplex semibaccata	103 (50)	95 (96)	153 (72)	36 (76)	71 (65)	87 (81)	106 (99)	85 (43)	282 (99)	56 (99)	104 (100)	129 (76)	8 (46)	219 (90)	120 (99)	37 (84)
Atriplex vesicaria			138 (78)		22 (78)				308 (98)		15 (68)				117 (100)	
Chamaecytisus prolifer	293 (26)	126 (86)	135 (92)		191 (58)	35 (82)	10 (26)	24 (31)	273 (92)			52 (16)		14 (88)	21 (92)	
Chenopodium auricomum			200 (98)		94 (79)				191 (79)							16 (63)
Chenopodium nitrariaceum	39 (36)	158 (90)	253 (99)	7 (75)	100 (80)	73 (85)	22 (73)	75 (78)	548 (100)	32 (90)	8 (85)	8 (36)	2 (21)	247 (88)		26 (53)
Convolvulus remotus			63 (35)		27 (15)	102 (65)	228 (2)		310 (100)	45 (7)	3 (9)			122 (80)		
Convolvulus remotus (companion)	12 (20)	26 (71)						527 (3)		8 (18)					24 (77)	
Cullen australasicum			317 (64)		8 (33)				142 (69)						32 (83)	
Enchylaena tomentosa	71 (54)	106 (94)	153 (97)	19 (98)	50 (83)	62 (91)	46 (99)	89 (82)	723 (99)	32 (98)	24 (97)	48 (91)	19 (81)	135 (93)	95 (99)	23 (90)
Eremophila glabra		97 (73)	278 (82)	15 (80)	20 (58)			61 (52)	348 (89)	27 (43)		79 (66)		94 (56)	165 (96)	15 (6)
Eremophila maculate			289 (96)		3 (67)			15 (4)	193 (92)							
Glycine canescens			278 (17)		39 (17)				83 (95)							

	Binnu	Broomehill	Condo-bolin	Elbow Hill	Merredin	Miling	Mingenew	Minnipa	Monarto	Morchard	St Arnaud	Streaky Bay	Three Springs	Waikerie	Walpeup	Wandearah
Glycine canescens (companion)			346 (54)	(0)	(0)	52 (14)	(0)				(0)		3 (1)			
Medicago strasseri	8 (15)	50 (41)	55 (67)	4 (57)	5 (58)	14 (15)	(0)	110 (71)	927 (92)	25 (82)	24 (65)	154 (74)	7 (1)	58 (73)	59 (91)	(0)
Rhagodia candolleana			112 (75)	12 (80)	31 (83)				345 (100)							
Rhagodia crassifolia	89 (44)	126 (77)	215 (78)	13 (73)	37 (83)	67 (64)	(0)	100 (56)	460 (100)	34 (91)	6 (60)	63 (53)	40 (31)	153 (44)	175 (98)	17 (25)
Rhagodia parabolica	84 (65)	141 (98)	257 (93)	9 (96)	94 (85)	32 (64)	28 (92)	163 (85)	344 (98)	21 (88)	6 (79)	41 (93)	23 (85)	268 (91)	163 (99)	21 (78)
Rhagodia preissii	1.50 (75)	50 (59)	241 (81)	6 (79)	78 (89)	52 (79)	26 (68)	138 (72)	338 (99)	32 (90)	2 (16)	128 (88)	34 (49)	188 (89)	147 (98)	13 (46)
Rhagodia spinescens	0.16 (33)	180 (96)	177 (89)	10 (63)	44 (67)	94 (82)	23 (61)	166 (96)	462 (98)	19 (91)	25 (82)	48 (94)	7 (52)	260 (98)	124 (97)	25 (77)

4.1.12 CHOOSING THE RIGHT SHRUB SPECIES

Background

Whilst many of the 101 species which undertook testing have at least one good attribute it is practical (for both further research and adoption) to narrow down the list of species to a sub-set which have the most potential. Once again, it is not envisaged that a grazing system will be based on one superior plant but a mixture of plants which all contribute to the overall success of the system.

This process was done with the aim of narrowing down the large list of species to aid both further research and landholders. However, landholders may have the other (not prioritised) species on their land naturally or have other reasons for wanting to plant other species. This is to be supported and is a key reason information on all species was included in the published booklet "Perennial forage shrubs providing profitable and sustainable grazing: Key findings from the Enrich project". Further information is planned to be published on a dedicated Enrich website.

Methods

This process was attempted by the use of a decision tree (Figure 25). A particular attribute of this method is that species can take various pathways to prioritisation and so do not need to have every desirable trait. However, there are a number of critical attributes a species must have, which are being long lived, being moderately palatable, grazing tolerant and must have a low or negligible weed risk.

To further guide which species are more suited to particular conditions, another simple decision tool was developed using questions primarily based on soil characteristics (Figure 26). A tool of this type would be most suitable for landholders.

Main results and discussion

Using the decision tree resulted in 17 species being shortlisted (Table 14), three of which have undergone a weed risk assessment (*Atriplex amnicola*, *Atriplex nummularia*, and *Rhagodia preissii*) but the others still require this assessment. About half of the 17 species were in the short-list of 23 taxa which were involved in regional site evaluation. It must be remembered that the regional group species list was derived on very early data during Enrich Phase 1.

Table 14. The list of species generated from the species section decision tree process

Acacia ligulata
Acacia neriifolia
Atriplex amnicola
Atriplex nummularia
Atriplex rhagodioides
Chamaecytisus prolifer
Chenopodium nitrariaceum
Eremophila glabra
Eremophila longifolia
Enchyleana tomentosa
Maireana astroticha

Maireana brevifolia
Maireana pyramidata
Maireana sedifolia
Rhagodia eremea
Rhagodia preissii
Rhagodia spinescens

This number of species is still too large for most landholders to practically plant on-farm and does not take into account the finer details of environment suitability. However, by using the second decision tree a smaller number of the shortlisted species can be found for particular conditions. To illustrate this process, the 17 species from the short-list derived from the species decision tree were used in this step (Figure 26). It is hoped to develop 'fact sheet' style cultural information for the short-listed species in the next phase of Enrich to further aid landholder decision making.

Key messages

- A 'decision-tree' can be used to provide a short-list of species from our initial screening. Further research under commercial conditions, and the development of partnerships with the nursery industry, should be undertaken in phase 3 of Enrich.

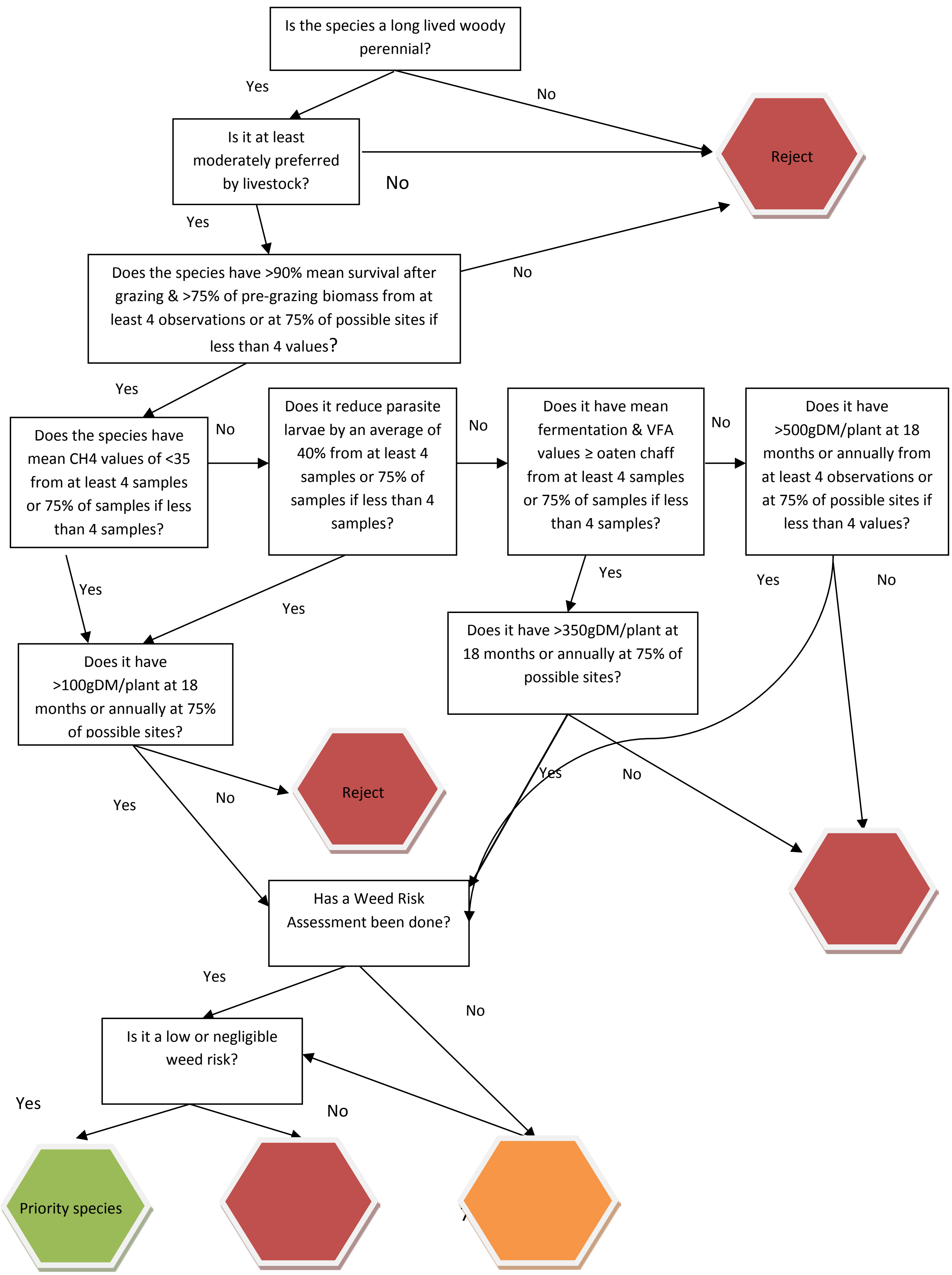


Figure 25. A decision tree to assist in identifying a short-list of shrub species with particular attributes.

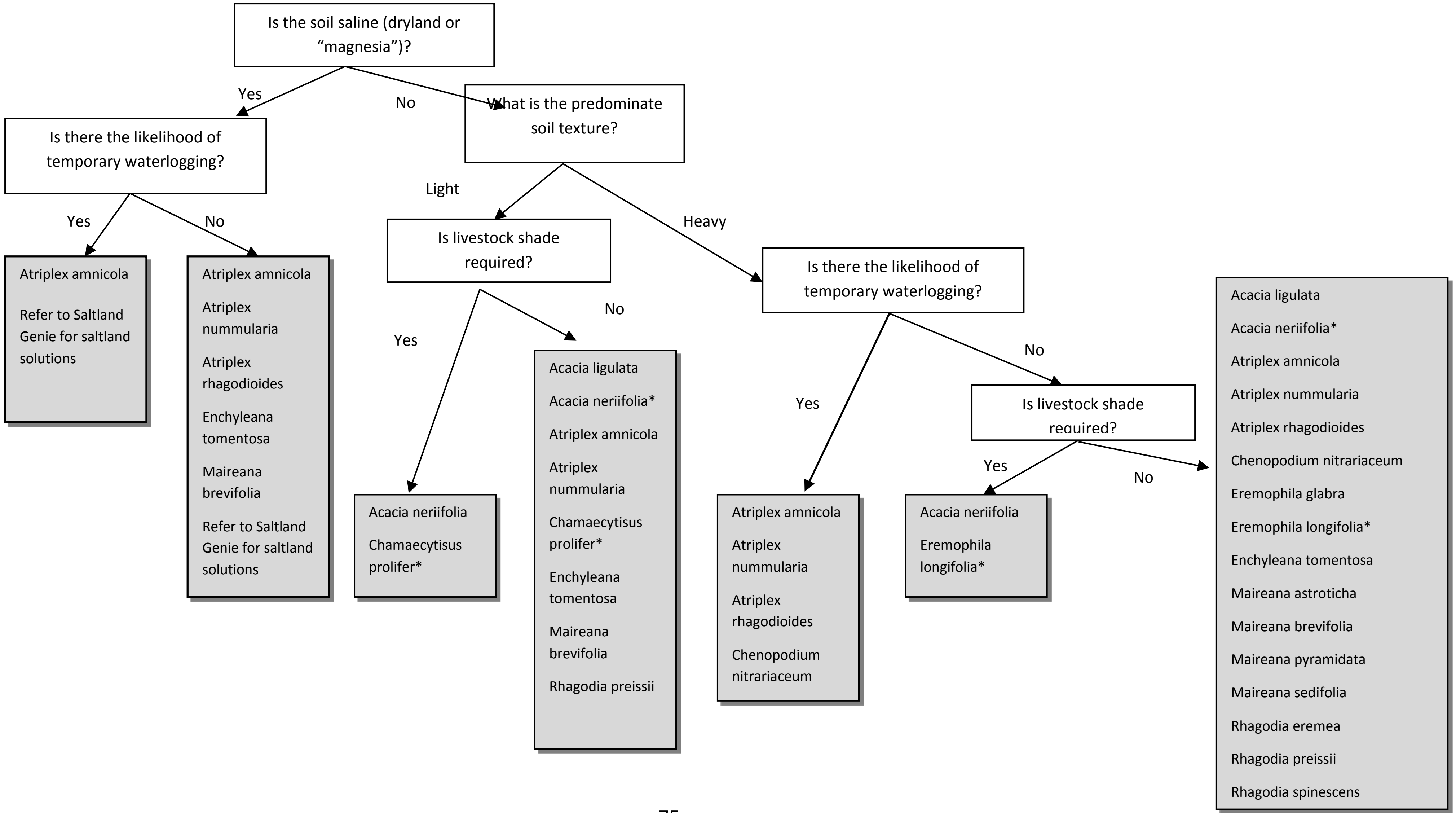


Figure 26. A decision tree to assist with shrub selection based on practical issues that are likely to influence decisions by producers (and nurseries). An asterisk (*) next to a species indicates it is likely to grow above 2m.

4.2 ENRICH DELIVERY AND ADOPTION

Raising awareness of the Enrich project with landholders and land managers has been a major focus during this project phase. This has been seen as an essential component in the adoption strategy. Awareness raising activities have included conducting deliberate Enrich forums, wider communication through the media and presentations at field days and similar events. Partnering with regional groups to conduct local scale research has also been an integral strategy to engage with next and end users.

4.2.1 Enrich Forums 2011

Background

The Enrich project held a series of forums to share knowledge and ideas amongst producers and researchers and to promote the 'big picture' concepts of managing diverse landscapes for economic and environmental benefits. Additional funding for these forums was provided through the project P1 FP03e FFI CRC Grain &Graze II Delivery.

The aims of the forums were to:

- Promote the aims of Enrich
- Update regional participants on Enrich progress
- Receive feedback on research directions and progress
- Be a catalyst for participants to be involved with future research delivery in their region
- Contribute to the knowledge base of both researchers and regional participants

As many of the partner regional groups have had a high staff turnover and sites have shifted between 'owners', we believed the forums would be a fantastic opportunity to ensure there is a clear and consistent message about Enrich. Regular communication with the regional group contacts has led us to believe that there is a real need to keep reminding partners about all of the Enrich objectives. As partner regional group activities are based around small plot species evaluation sites, there is a tendency for partners to focus solely on the research being about a new plant.

The forums were also an effective way to launch the new Enrich booklet – Perennial forage shrubs providing profitable and sustainable grazing: Key practical findings from the Enrich project. From monitoring feedback of regional groups partners and participants at extension activities (i.e. field days) we were confident the booklet was tailored to meet the demands of the target audience.

Methods

The ‘Enrich forums’ were successfully held at six regional centres across southern Australia (Merredin and Mingenew in WA, Minnipa and Waikerie in SA; Walpeup in Vic; and Condobolin in NSW) in March and April 2011 (

Table 15). Autumn 2011 was targeted as it would showcase the potential value of ‘Enrich principles’ at a time of year where the benefits are most obvious (e.g. addressing an autumn feed gap), and would allow us (the researchers) to present a near-complete set of information from Enrich 1 and 2.

Table 15. Dates and locations of Enrich forums

Town	Location	Date
Merredin	Merredin Research Station	8 March 2011
Mingenew	Mingenew Irwin Group Offices	10 March 2011
Condobolin	Condobolin Agricultural Research Centre	23 March 2011
Minnipa	Minnipa Agricultural Research Centre	5 April 2011
Waikerie	Waikerie RSL	7 April 2011
Walpeup	Mallee Agricultural Research Station	8 April 2011

Speakers included researchers from the Enrich project, plus contributions from the EverCrop and old man saltbush improvement projects. Two producers – Cameron Tubby and Bruce Maynard - with practical experience about perennial forage systems also agreed to present at the forums. An example of the program is presented in Table 16.

Numerous press articles appeared before the forums in a number of regional newspapers and at least one radio station to advertise the event. Additionally, the use of several established networks (e.g. Sheepconnect, MLA website) was also used to raise awareness of the forums.

Attendees were asked to fill out a tailored evaluation sheet at each forum (Appendix). Responses were averaged and tabulated.

Table 16. Forum agenda (some minor variation occurred between locations)

Topic	Speaker
Introductions and overview of the day	Local representative
New options on the horizon to build your feedbase and increase profit: Forage shrubs in resilient grazing systems – an overview of R&D in the Enrich project and their application	Dean Revell (CSIRO)

Lessons and experiences from a Nuffield study tour: drought-proofing for low-rainfall zones	Cameron Tubby (producer from Morawa, WA)
Integrating shrubs into the forage base and farm system – shrubs with pastures	Jason Emms (SARDI)
Plants provide more than energy – nutrients and bioactivity for production and health	Phil Vercoe (UWA)
How animals cope with diversity	Dean Revell (CSIRO)
Field site visit/s– see shrub growth at the local research site, and begin to discuss practical issues of shrub selection and their management	Local site manager
Finding the most profitable fit in mixed farming systems - findings from EverCrop	Rick Llewellyn (CSIRO)
Old man saltbush improvement – What new old man saltbushes are in the pipeline and what will they offer?	Peter Jessop (NSW DPI)
Practical issues in establishing and successfully using forage shrubs, including layout, paddock size, fencing, water points and managing the animals	Bruce Maynard (producer from Narromine, NSW)
What shrub species might work?	Jason Emms (SARDI)

Results

A total of 127 people attended the forums with the highest attendance at Merredin and Walpeup (Table 17). The majority (67%) of attendees were producers (Table 18). Other attendees included researchers, advisors and NRM/CMA representatives. The overall mean response rate to the evaluation sheets was 63.7% (Table 17).

Table 17. Attendance and response rate to the evaluation forms

	Attendees	Respondents	% response
Merredin	38	22	57.9
Mingenew	8	4	50.0
Condobolin	11	10	90.9
Minnipa	14	9	64.3
Waikerie	21	16	76.2
Walpeup	35	15	42.9
Total	81	50	63.7

Table 18. Breakdown of how respondents classified their role

	Producer	Adviser	Researcher	Other
Merredin	13	3	1	5
Mingenew	3	1	0	0
Condobolin	8	1	1	0
Minnipa	5	1	3	0
Waikerie	9	0	3	4
Walpeup	13	1	0	1
Total	51	7	8	10

Feedback from attendees was very positive (Table 20), with respondents rating the day highly beneficial (mean - 5.3 on a 1-6 scale). Producers rated the day slightly higher than the other attendee groups (Table 20). Of the forum topics, attendees indicated that they gained less new knowledge about the economics of shrub-based systems than other topics. About three quarters of the respondents indicated they would follow-up on the information presented (Table 21). Five subsequent media articles were published as a direct result of holding the forums with some local journalists attending the entire day.

The forums proved to be an important delivery activity for the Enrich project and were the first of such activities to be run through the project. Through their full day length and focussed agenda, they were attractive to audiences who were already positive about shrub-based grazing systems, native plants and/or greater diversity within the feedbase. Hence they did not appear to have engaged landholders who were unfamiliar or not supportive of the concept. It is important to continue to participate in wider communication activities such as rural press stories and attendance at general field days to try and capture this audience.

The forum attendees and particularly those who responded to the evaluation forms comprise an important element of the target audience for the Enrich project. They are likely to be the first adopters of the technology emanating from the project. They also represent a likely audience for future survey work needed for monitoring practice change resulting from

Enrich knowledge. The forums have provided critical information in the recent development of a delivery and adoption strategy for the next phase of the Enrich project. Further forums would be worthwhile once some outstanding issues have been resolved. In particular, there is a need to further define the benefits to livestock at a field scale, reach agreements with partner nurseries which will be able to supply species to landholders and the development of a comprehensive information package including a revised and updated booklet.

Table 19. Average score across venues on the level of new knowledge gained on forum topics and the perceived benefits to rural industries in that region (1-6 scale)

Venue	Overall	Enrich project	Forage shrub options	Grazing behaviour	Bioactivity	Economics	Benefits to region	Respondents (#)
Merredin	5.1	4.4	4.7	4.8	4.7	3.9	5.3	22
Mingenew	5.8	4.5	5.0	5.3	5.8	5.3	5.5	4
Condobolin	5.3	4.7	4.9	4.8	5.1	4.9	5.0	10
Minnipa	5.0	4.1	4.6	4.3	4.2	3.8	4.6	9
Waikerie	5.3	4.1	4.7	4.6	5.3	4.2	5.2	16
Walpeup	5.6	4.7	4.9	4.6	4.7	4.1	5.3	15
Grand Average	5.3	4.4	4.7	4.7	4.9	4.2	5.2	

Table 20. Average score for respondent groups on the level of new knowledge gained on forum topics and the perceived benefits to rural industries in that region (1-6 scale)

	Overall	Enrich project	Forage shrub options	Grazing behaviour	Bioactivity	Economics	Benefits to region	Respondents (#)
Adviser	5.1	4.1	4.6	4.4	4.7	3.7	5.1	7
Other	4.9	3.9	4.6	4.8	4.8	3.5	5.3	10
Producer	5.4	4.5	4.8	4.6	4.9	4.3	5.2	51
Researcher	5.3	4.4	4.8	5.0	5.3	4.4	4.6	8

Table 21. Intentions of forum respondents to follow up on topics as a result of the forum

	Follow up- Shrub options	Follow up -Grazing behaviour	Follow up - Bioactivity
Yes	59 (78%)	51 (67%)	49 (64%)
No	2 (3%)	3 (4%)	1 (1%)
Unsure	9 (12%)	14 (18%)	19 (25%)

4.2.2 Wider communications

During this phase of Enrich, 53 print and web-based articles, six radio and seven television segments were produced (Appendix 2). Due to the number of follow-up phone and email communications which the project team received from landholders who stated to have seen or heard about Enrich from various media, the wider communication activities are reaching a large audience.

Project members or associated partners and producers have spoken about Enrich at 71 events during phase 2 (Appendix). Some of these events have utilised Enrich sites, aiding to re-enforce the concept of shrub-based grazing systems.

A significant achievement during this project phase was the publishing of the booklet: Enrich "Perennial forage shrubs providing profitable and sustainable grazing: Key practical findings from the Enrich project". Many of the principles and guidelines emerging from the Enrich project are presented in the booklet in a style suitable for a wide audience. These booklets have proved very popular with two additional print runs being completed. At present about 1,800 copies have been distributed, and a PDF version is available online at http://www.futurefarmonline.com.au/LiteratureRetrieve.aspx?ID=88398.

4.2.3 Regional group engagement

Enrich has established partnerships with regional groups interested in exploring the potential of new shrub-based grazing systems. Originally, this involved 16 small-scale sites across four states testing shrub productivity, and now, through extended partnerships with some groups or other projects, we also have six paddock-scale sites suitable for testing and demonstrating livestock performance. All of these sites have been initiated through the regional groups themselves. In addition, two producers in the Mallee Sustainable Farming Group (based around the Waikerie site) will each host a new larger scale site in 2012. At the time of writing the Mingenew Irwin Group has submitted a proposal to DAFF's Action of the Ground program to allow landholders to be directly involved in testing shrub-based systems for their application on farm. There has already been an established commitment from a number of landholders to be involved. Landholders will be situated in WA, SA, NSW and Victoria.

Most of the regional based groups we have worked with contain both next and end users. Enrich has aimed at linking with local group partners to disseminate progress and information through established channels at the producer group scale. Contributions from the project team have included presentations at group events such as field days along with contributions to publications.

Success with linking to the regional group partners has been variable. Some groups are clearly more experienced and/or resourced to undertake field research. Similarly, there was variation between the linkages that the sites had with producer or similar groups. Since the beginning of the 2009/2010 financial year, five sites have undergone a change in group “ownership”. All of these instances have been due to financial constraints on the original groups. Another two groups have had significant changes in personnel (in one case, three times) associated with managing the sites. This has severely impacted the level of engagement producers have had around these regional sites.

Given the challenges faced by the regional groups, it is difficult to quantify exact levels of engagement around each Enrich regional site. A limited budget within the project has also made direct survey and analysis not possible. However, using regional group field days or site visits attendance where Enrich has been focussed, 650 people have been engaged around these sites (not including forum attendees) during Enrich Phase 2. More would have been reached through regular group communication channels such as newsletters and research updates.

Implications of delivery & adoption

From evidence of producer feedback and inquiry as well as continued interest from regional groups and organisations, the amount of media and presentations completed during the project has reached a wide audience. Whilst the regional group engagement-research model has had limitations, it has still been an integral part of continued engagement with producers. Linkages between the research team and producer groups are now well established, so there is good potential to capitalise on these partnerships to trigger practice change on farms.

The use of more targeted forums gave a better reflection of the number of producers who are actually enthusiastic and confident enough to trial forage shrubs. 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 technology.

The current major barrier to adoption is that these species are not currently used or commercially available to agriculture (with the exception of old man saltbush). The first step in rectifying this is the need to have ‘Enrich shrub species’ commercially available by working with nurseries to propagate sufficient quantities for new plantings on farms. It is likely the nursery industry will need some time to test and develop techniques which will allow effective propagation strategies for commercial quantities of species to become available. Having plant material available (seedling tubestock, as direct seeding technology is beyond the scope of the core Enrich project - but is a major focus of other components of P1 FP03e) will lead to adoption by early adopters and innovators to test the benefits under their own production systems and environments. There is also a need for an encompassing information package to accompany any new shrub species release.

4.3 Assessment of profitability and sustainability of potential production systems in a whole-farm context

The impact on whole-farm profitability of incorporating forage shrubs into grazing systems was investigated in detail in Enrich phase 1. A peer-reviewed paper encapsulating this work was published during phase 2: 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. The Abstract from this paper is presented below. The forthcoming issue of the Farm Journal is presenting these findings in a form suitable for a more lay audience (see Appendix A for reference details).

> ABSTRACT. In face of climate change and other environmental challenges, one strategy for incremental improvement within existing farming systems is the inclusion of perennial forage shrubs. In Australian agricultural systems, this has the potential to deliver multiple benefits: increased whole-farm profitability and improved natural resource management. The profitability of shrubs was investigated using Model of an Integrated Dryland Agricultural System (MIDAS), a bio-economic model of a mixed crop/livestock farming system. The modelling indicated that including forage shrubs had the potential to increase farm profitability by an average of 24% for an optimal 10% of farm area used for shrubs under standard assumptions. The impact of shrubs on whole-farm profit accrues primarily through the provision of a predictable supply of 'out-of-season' feed, thereby reducing supplementary feed costs, and through deferment of use of other feed sources on the farm, allowing a higher stocking rate and improved animal production. The benefits for natural resource management and the environment include improved water use through summer-active, deep-rooted plants, and carbon storage. Forage shrubs also allow for the productive use of marginal soils. Finally, we discuss other, less obvious, benefits of shrubs such as potential benefits on livestock health. The principles revealed by the MIDAS modelling have wide application beyond the region, although these need to be adapted on farm and widely disseminated before potential contribution to Australian agriculture can be realized.

A summary of the whole-farm benefits arising through the addition of perennial forage shrubs to the feedbase of mixed farms (measured, modeled or anticipated) that have arisen from Enrioch 1 and 2 is presented below in **Error! Reference source not found.**.

Table 22. An outline of the benefits arising to whole-farm systems through the incorporation of perennial shrubs.

Broad benefit	Specific benefit	Explanations and comments
Animal nutrition	Improved timing of feed supply; i.e. filling a summer-autumn (or early winter) feed gap.	Plant growth data collected over 3+ years at three large research sites (Merredin WA, Monarto SA, and Condobolin NSW), with support from 16 regional sites, has shown the capacity of many species to provide edible biomass at a time of year where few other options for green feed exist. Whole farm modelling (MIDAS) highlighted the value of autumn grazing by (i) reducing the cost of supplementary feeding and (ii) deferring the grazing of annual pastures at the break-of-season which improves performance on other

		parts of a farm (e.g. translates to an increase in carrying capacity of about 1 DSE/ha).
	Provision of digestible energy	All shrubs have been tested for their effects on rumen fermentation (the process that liberates energy from plants for use by animals). This information can be used in designing forage mixes (e.g. plants with lower rumen fermentation should be provided at only a modest proportion of the feedbase, but possibly included for other benefits such as providing bioactives (see below) or NRM benefits. A key to the provision of digestible energy is the management of an herbaceous understory or inter-row. The pasture layer will provide the majority of energy to grazing animals, with the shrubs acting as 'standing supplements'.
	Provision of crude protein	Most of the shrub species tested in Enrich have considerable potential in providing crude protein – which can be lacking in grass-dominant pastures, especially in summer and autumn (in Mediterranean and temperate climatic zones). It is important that a readily-available energy source be provided with shrubs in order for the crude protein to be 'captured' by the microbial population and provided to the animal as microbial protein. This could be in the form of companion pastures, cereal stubble with grain, or supplementary feeds.
	Minerals	Most of the shrub species tested in Enrich have considerable potential in providing minerals to grazing animals. The concentration of many minerals are often well above dietary requirements, which indicates that they need only constitute a modest proportion of the whole diet to still make a considerable contribution to mineral requirements. Further work is required to test the bioavailability of minerals from shrubs, especially the possibility of calcium binding to oxalates and being unavailable.
	Economic impact	In an assessment of the impact of technologies developed in the Future Farm Industries CRC, the predicted footprint of 'Enrich farming systems' was about 600,000 ha, which was based on the assumption that 10% of the farm area in the 250-350 mm rainfall zone is the optimal area to be used for perennial shrubs. This is likely to be a conservative estimate because there has been considerable interest in the use of perennial shrubs in medium rainfall areas (350-650 mm) and, indeed, we have had enquiries from producers in high rainfall areas as well. Impacts on whole-farm budgets: • 60% reduction in cost of supplementary feeding from $13 to $5/ha • 15% increase in livestock receipts up from $102/ha to $117/ha • 21% increase in whole-farm profit from $84/ha/yr to $102/ha/yr

		• Profitable use of marginal and poor land, reducing the opportunity cost of growing less crops and pasture in those soils.
Animal gut function and health	Improved profile of rumen fermentation	All Enrich shrub species have been tested *in vitro* for fermentability (i.e. gas production) by rumen microbes, methane production, ammonia production, volatile fatty acid production, acetate:propionate ratio and pH. These analyses have shown wide variability between genera, and between species within genera. A cohort of species was tested more thoroughly for variation over time (season and stage of plant maturity) and growing location, and variation due to grazing. Beneficial effects of 'bioactive' forage shrubs are expected even when the plants constitute a modest portion (say 10-15%) of the diet. This has been confirmed with the anti-methanogenic properties *of Eremophila glabra* using a continuous flow *in vitro* system. An *in vivo* (i.e. whole animal) experiment is currently in progress in a sister project to further validate this conclusion.
	Anthelmintic properties	Although this was not part of the funded Enrich project, evidence has been provided that a number of the Enrich species under investigation possess anthelmintic properties. The plant chemistry underlying these responses was not investigated in detail, but we know that for some species it is related to the tannin content whereas as for others it is a non-tannin effect. This is encouraging, because it suggests that a mixed planting can provide multiple mechanisms to help combat gastrointestinal parasites, potentially increasing efficacy and minimising the risks of developing resistance to the plant compounds. More work is required with whole-animal and paddock grazing studies.
Natural resource management	Carbon sequestration	The direct economic value of carbon sequestration depends on the carbon price and carbon trading schemes. However, a typical analysis using MIDAS showed a farm with 7-9% of the area allocated to forage shrubs could achieve a net carbon balance (i.e. sequestered carbon minus emissions) of about 230 t CO_2-e/year. Building soil carbon is a beneficial regardless of a market price for carbon. Of all the variables tested in the MIDAS modelling (e.g. soil type, commodity prices), carbon price had the largest influence on the area of a farm planted with shrubs to maximize whole-farm profit. Opportunities should be explored in ongoing work to collect in-field measurements of above- and below-ground carbon in shrub-based forage systems from established field sites.
	Groundwater recharge	MIDAS modelling showed an average 20% reduction in groundwater recharge from 20 ml/ha to 16 ml/ha.
	Ground cover	Implied by year-round growth and supported by anecdotal evidence from producers who report that well-managed

		shrub-inter-row systems have significantly reduced wind and water erosion risks.
	Shade and shelter	Implied based on shrub growth and physical characteristics (height and form) and supported by anecdotal evidence from producers. There is a considerable amount of literature (from others outside of the Enrich project) on the effects of shade and shelter for livestock (and pasture productivity).
Labour	Reduced hand-feeding of livestock	Anecdotal evidence from producers of having more flexibility with their time due to a reduced requirement for hand-feeding supplements over late summer-autumn, and for having a feed source for livestock to graze at the break-of-season when mixed farmers are focused on sowing crops. Some extra labour may be required for moving animals in a rotational grazing system that would be required with perennial plants including shrubs.

5 (Conclusions and recommendations) - Section

5.1 Scoping for next phase of Enrich

The Enrich phase 2 project was reviewed at the Future Farm Industries CRC Office, University of Western Australia on March 11, 2011. The review team included; David Masters (Independent Chair); John McGrath (Future Farm Industries CRC) and; Stephen McMaugh (DAFF – by video conference). The project team was represented by Dean Revell (CSIRO – Project Leader), Phil Vercoe (University of WA) and Jason Emms (SARDI). Primary producers Bruce Maynard, (NSW) and Craig Forsyth, (WA – by phone conference) also contributed independently to the review.

The main recommendations of the review, in terms of progressing Enrich into phase 3 are provided below. Our responses to each recommendation are provided in italics.

1. The project should continue to focus on the use of a diverse set of shrubs as the basis to a multi-purpose grazing system in the low/medium mixed farming zone. It is our interpretation that:

- The project has sufficient shrub species to achieve its aims and further incorporation of new species is not required and would be difficult to deliver during the life of the CRC;
- Further selection within the current set of shrubs is not justified. Enrich is based on selection by animals within a diverse feed resource. Diversity currently exists within and across species and this diversity would be decreased through selection for limited characteristics.

This recommendation has been generally accepted. Other related work is – or is proposing to – identify superior lines of particular shrubs species. For example, work is progressing with identifying elite lines of old man saltbush, and there is growing interest in identifying lines of plants that lead to reduced methane production.

2. The livestock components of the project should be re-focussed within this next phase. A clear definition of research hypotheses and researchable questions are required. In particular the research should focus on:

- Defining the benefits to livestock (production and health) at a field scale;
- Laboratory/animal house quantification of both the potential benefits of bioactive compounds and the animal's ability to detect and select plants with beneficial nutritional characteristics and bioactive compounds;
- Field quantification of selection behaviour and bioactive effects.

The project team agrees with this recommendation. The degree to which these activities can be achieved in phase 3 will depend, to some extent, on likely budgetary constraints. The intention is to look for opportunities to add value to the core Enrich project through partnering with other programs and groups.

The review team considered that outcomes from research on training and learning were appropriate for incorporation into the Enrich package further research on this topic was not justified.

3. NRM outcomes be given a higher priority. These outcomes should be defined through a combination of measurement, calculation (inference) and modelling. It is likely this will require expertise from outside the current project team.

The project team agrees with this recommendation. As for recommendation 2, the intention is to look for opportunities to add value to the core Enrich project through partnering with other programs and groups to ensure appropriate assessments of the broad NRM benefits are achieved.

4. Additional resources/support be provided to the research team to facilitate the communication and M & E plans. Interaction with the RDC Communications programs is advocated. It was apparent the team were not confident that they had the skills and resources to implement the plans.

The project team agrees with this recommendation.

5. The Enrich team should prepare an Enrich package prior to the end of the year. Package should communicate: the rational for using a diverse group of shrubs; demonstrated grazing principles; production and health outcomes and; NRM benefits. The preparation of this package would benefit from expert assistance in design and presentation.

The Enrich booklet, which encapsulates the broad principles and provides information on different shrub species, has been completed and very well received. The first print run of 500 copies was quickly distributed, so a second print run of 2,000 copies was undertaken with support from Australian Wool Innovation. To date, about 1,300 of these have been distributed, totalling 1,800 booklets in circulation.

6. The project team should be strongly encouraged to prepare all relevant project information for peer-reviewed publication. This facilitates project support from other agricultural professionals, improves support from partner organisations and ensures a long-term Enrich legacy.

The project team agrees with this recommendation. A number of papers are still in preparation, and we accept that some of these are behind schedule. Completing this work is a current priority.

7. Modelling should focus on risk management in a variable and changing climate.

The project team agrees with this recommendation. Additional support (financial and technical) will be required to meet this recommendation.

The proposal for Enrich phase 3 has approved by the FFI CRC Board and MLA have approved baseline funding for Enrich in the 'delivery phase' of the FFI CRC. Additional proposals have been submitted, or are in preparation, to various calls for R&D projects.

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7 Appendices

7.1 Appendix 1- An example of participant feedback form distributed to Enrich forum attendees

Enrich forum - Waikerie 7th April, 2011

Participant feedback form

Contact details: ....

Name.. ....

1. Which group best describes your role: □ Producer □ Researcher □ Adviser □ Other

2. Overall, how beneficial did you find the forum?

Not all beneficial □ 1 □ 2 □ 3 □4 □ 5 □ 6 Highly beneficial

Comment

3. What could have made the forum (even) more beneficial to you?

Comment

4. During the visit, what level of new knowledge or understanding did you gain about:

	No new knowledge					A significant amount
4.1 The Enrich project:	□ 1	□ 2	□ 3	□4	□ 5	□ 6
4.2 Forage shrub options:	□ 1	□ 2	□ 3	□4	□ 5	□ 6
4.3 Grazing behaviour:	□ 1	□ 2	□ 3	□4	□ 5	□ 6
4.4 Bioactivity in forages:	□ 1	□ 2	□ 3	□4	□ 5	□ 6
4.5 Economics of shrub based systems:	□ 1	□ 2	□ 3	□4	□ 5	□ 6

5. How would you rate the potential benefits of the Enrich project that were presented to rural industries in the region? Little benefit □ 1 □ 2 □ 3 □4 □ 5 □ 6 Significant benefit

6. What is a key message that you are taking away from the forum?

Comment

7. As a result of what you have heard at the forum, do you intend to follow-up or act on the information in relation to:

6.1 Forage shrub options	□ Yes	□ No	□ Unsure
6.2 Grazing behaviour	□ Yes	□ No	□ Unsure
6.3 Bioactivity in forages	□ Yes	□ No	□ Unsure

8. Please make any other comments or suggestions about the forum, topics or the Enrich project.

Comment

Thank you for your feedback

7.2 Appendix 2- Enrich media during phase 2 of the project

Date	Title	Publication	Medium
1/09/2008	Plant-animal dynamics short course reveals grazing secrets	Focus on Perennials	Print
1/09/2008	Forage shrubs benefit more than the bottom line	Focus on Perennials	Print
18/10/2008	La zona árida, con todo el potencial ganadero	La Nacion	Print
24/10/2008	Jason Emms, destacado investigador Australiano especialista en manejo de Recursos Forrajeros de Zonas Áridas, visito la Estación Experimental Agropecuaria INTA La Rioja	INTA	Web
1/12/2008	Risk protocol proves its worth with researchers	Focus on Perennials	Print
1/12/2008	Bring on the revolution and the tree crops	Focus on Perennials	Print
1/12/2008	Enrich update	Focus on Perennials	Print
1/12/2008	Enriching Cowell Flats	Future Farm	Print
19/01/2009	Old man saltbush takes root in Argentina	The Land	Web
20/01/2009		ABC North & West Country Hour	Radio
28/01/2009	Saltbush flavours Argentine	The Advertiser	Print
28/01/2009	Saltbush prospects on the rise	Murray Pioneer	Print
29/01/2009	Old man saltbush in desert feed demand	Stock Journal	Print
19/02/2009		Network 10 News	TV
1/03/2009	Argentina submits to the saltbush spell	Focus on Perennials	Print
22/04/2009	Monarto research triggers trial on native scrubs being used for livestock grazing to take place in the Riverland	ABC Riverland & Mallee	Radio
1/06/2009	Local approach lifts awareness and caoxes continued collaboration	Focus on Perennials	Print
30/07/2009	My Take	Stock Journal	Print
29/09/2009	Forage shrubs under microscope	ABC Central West (NSW) Central West Rural Report	Radio
Nov/Dec-09	Grazing shrubs offer options	MLA Feedback magazine	Print
1/12/2009	Bird-proof cage keeps	Focus on Perennials	Print

	research under wraps		
26/11/2009	Research delves into perennials potential	Stock Journal	Print
4/03/2010	Drought aid extended	Countryman	Print
8/08/2010	Enrich project	ABC TV Landline	TV
	Taking trials to the troops - an interactive approach	Focus on Perennials	Print
28/09/2010		WIN Mildura News	TV
28/09/2010		WIN Bendigo News	TV
28/09/2010		WIN Ballarat News	TV
29/09/2010		WIN Shepparton News	TV
29/09/2010		WIN Riverland News	TV
29/09/2010	Native shrubs the latest weapon in worm control	ABC Radio Country Hour	Radio
18/10/2010	Native shrubs could form basis of better fodder	ScienceNetwork. Western Australia	Web
1/12/2010	Perennial shrubs support productive pastures	Focus on Perennials	Print
1/12/2010	Perennial shrubs prove palatable option	Future Farm	Print
1/01/2011	Perennial shrubs support productive pastures	Farming Ahead	Print
10/02/2011	Grazing land develops from 'Enrich' trial	Stock Journal	Print
3/03/2011	Forage shrubs in the mix	Countryman Vol. 126 No. 6290, pg 14	Print
24/02/2011	Sheep, shrubs	Forbes Advocate, pg 11	Print
3/03/2011	Craig has high hopes	Countryman Vol. 126 No. 6290, pg 14	Print
10/03/2011	Farmers encouraged to Enrich their valuable properties	Stock Journal (SA), pg 19	Print
16/03/2011	Forage shrubs; a valuable part of the feed-base puzzle	The Condobolin Argus	Print, Web
15/03/2011	Forage shrubs; a valuable part of the feed-base puzzle	Lachlander (Condobolin)	Print
18/03/2011	Forage shrub forum to boost farms	Cowra Guardian pg 43	Print
18/03/2011	Forage shrub forum to boost farms	Champion Post pg 15	Print
18/03/2011	Forage shrub forum to boost farms	Young Witness pg 30	Print
16/03/2011	Forage shrubs vital part of the feedbase	Lake News (Cargelligo)	Print
19/03/2011	Forage shrub forum to boost farms	Forbes Advocate, pg 22	Print
22/03/2011	Enrich forums - Richard MacCallum	ABC regional radio - Condo	Radio
24/03/2011	Enrich your farm with forage shrubs	Eyre Peninsula Tribune pg 21	Print
26/03/2011	Sticking up for shrubs on farm	The Land	Web

30/03/2011	Ag Station holds seminar on advantage of perennial forage shrubs	The Condobolin Argus pg 11	Print
31/03/2011	Sharing sheep and shrub stories	Farming Ahead, March 2011, pg 44	Print
31/03/2011	Alternative Fodder Forum at Walpeup	North West Express (Ouyen), pg5	Print
31/03/2011	Walpeup to host forum on alternative fodder options	Hopetoun Courier and Mallee Pioneer, pg2	Print
31/03/2011	Deciphering the true value of shrubs	Farm Weekly, pg24	Print
31/03/2011	Shrubs natural fit for grazing	Stock Journal pg 40	Print
5/04/2011		ABC Riverland SA	Radio
6/04/2011	Benefits of planting perennials	River News	Print
14/04/2011	Shrub mix enriches feed outcomes	Stock Journal pg 35	Print
18/04/2011	Shrub mix enriches feed outcomes	Stock Journal	Web
28/04/2011	Don't shrug off shrubs	Countryman pg 52	Print
4/05/2011	Livestock diet change	Border Times (Pinaroo) p 6	Print
1/04/2011	A tale of two sites – Enrich shrubs prove their value	MLA Feedback magazine p 10	Print
11/05/2011	Of drought and flooding rain...	Future Farm (April 2011 issue)	Print
11/05/2011	Science behind the story for 'Scholarship highlights perennial opportunities'	Future Farm (April 2011 issue)	Print
15/06/2011	Sheep like to mix it up	The Weekly Times pg 72	Print
17/06/2011	Sheep can learn to mix diet	Tasmanian Country pg 12	Print

7.3 Appendix 3- Enrich presentations to next and end users during phase 2.

Date	Group/Event	Venue	Number of people
15/08/2008	EPNRM and Rural Solutions SA	Elbow Hill regional field site	
1/09/2008	Eyre Peninsula farmers	Morchard regional field site	10
2/09/2008	Cowell Flats Group	Monarto field site	8
19/09/2008	Upper North Farming Systems Field Day	Morchard regional field site	53
24/09/2008	Western Eyre Pen. farmers organised by Rural Solutions SA	Morchard field site	15
26/09/2008	Coorong Perennial Forages Project Field Day	Monarto field site	25
26/09/2008	Franklin Harbour Agricultural Bureau - Annual farmer crop	Elbow Hill regional field site	

	walk/field day		
7/10/2008	NSW Ag teachers annual conference	Deniliquin regional field site	
14/10/2008	DAFWA - Badgingarra Research Station Spring Field Day	Badgingarra RS - Enrich grazing site	94
15/10/2008	DAFWA - Badgingarra Research Station Spring Field Day	Badgingarra RS - Enrich grazing site	94
16/10/2008	31st Argentine Animal Production Congress	Potrero de los Funes, San Luis, Argentina	40
29/10/2008	NCCMA - Natural resouce management committee - visit as part of Asset Protection Tour.	St Arnaud regional field site	
5/02/2009	Advisory Board of Agriculture. Responding to Climate Variability at a Local Level Workshop	Monarto Town Hall	15
24/02/2009	Future Farm Industries CRC Briefing for the SA Murray Darling Basin NRM Region	Murray Bridge Racecourse	33
3/03/2009	Future Farm Industries CRC Briefing for the Eyre Peninsula NRM Region	Cleve Golf Club	12
31/03/2009	Multiple benefits from forage systems; embracing complexity whilst trying to keep it simple	Narrogin Pastures for Profit (MLA, Evergreen and Facey group)	30
2/04/2009	Multiple benefits from forage systems; embracing complexity whilst trying to keep it simple	Kellerberin, Buntine Catchment Group	10
17/04/2009	Evercrop Local Adaptation Group	Monarto field site	12
14/05/2009	Using animal metabolism & plant chemistry in designing healthy grazing systems	CSIRO Perth, International delegation	10
20/05/2009	native shrubs and grazing systems: quantifying biodivertsirt-production tradeoffs	CSIRO Program meeting, CSE Brisbane	25
2/06/2009	Kellerberrin District High School	DAFWA Merredin field site	17
25/06/2009	Evergreen Northern field day	Binnu field site	~90
11/07/2009	Dawsley Creek Landcare Group	Monarto field site	12
30/07/2009	Rural Solution Land	Waite seed orchard	30

	management team		
4/08/2009	Visiting scientists from Libya	DAFWA Merredin field site	18
7/08/2009	50th Annual Conference of the Grasslands Society of Southern Australia	Geelong	50
25/08/2009	IHD Pasture Link Agronomy Forum	Monarto field site	20
1/09/2009	MSF Field Day	MSF Field Site	12
1/09/2009	MSF Waikerie Field Day - Site visited as part of the Waikerie MSF filed day	Waikerie regional field site	
4/09/2009	EP Climate Change Forum	Clapham	42
10/09/2009	Profit from Saltland - Annual Field Day	Hyden Telecentre	
10/09/2009	Livestock, grazing and saltbush – What can I do to boost productivity	Hyden, Saltland Pastures Association seminar day	25
16/09/2009	Minnipa field day	Minnipa regional field site	140
16/09/2009	MMPIG Spring field day	Miling field site	45
18/09/2009	UNFS Field Day	Morchard Hall & Morchard Enrich site	35
24/09/2009	DAFWA - Merredin Research Station Field Day	Merredin filed site	64
28/09/2009	Franklin Harbour Agricultural Bureau - Annual farmer crop walk/field day	Elbow Hill regional field site	17
30/09/2009	Condobolin Research & Advisory Station Annual Field Day	Condobolin Research & Advisory Station	50
1/10/2009	FFI CRC Workshop for Industry Participants	Bairnsdale RSL	15
2/10/2009	Grazing Perennial Shrubs for Livestock Productivity, Animal Health and Twin Lamb Surivial	Bengworden EverGraze supporting site (Rick Robinson's Farm)	15
2/10/2009	Streaky Bay Agriculture Bureau	Streaky Bay regional field site	20
12/10/2009	Monarto Ag Bureau	Monarto field site	18
1/12/2009	Tagasaste Improvement workshop	CRC Board room, UWA	
24/02/2010	Are shrubs the answer? A workshop on perennial forage shrubs for low rainfall grazing systems	Morchard Hall & Morchard Enrich site	23
9/03/2010	Landline interview	DAFWA Merredin field site	
12/03/2010	MMPIG - "Successful	Miling field site	32

	Saltland Pasture Workshop"		
17/03/2010	Diet diversity, animal behaviour and remote sensing	Northern Australia Beef Research Council meeting, Perth	40
1/06/2010	North Central CMA Board field tour	St Arnaud Field Site	
7/06/2010	FFI CRC Directors	Monarto field site	13
8/06/2010	Interactions between plants and animals in healthy landscapes	Dryland Research Institute, DAFWA, Merredin	12
22/06/2010	FFI CRC SA Symposium	Monarto field site	8
9/07/2010	Grazing Pastures, Cereals and Saltbush Field Day	Gavin Rehn's property, Arno Bay	20
5/08/2010	LambEx - Don Nairn	Burswood International Resort	500
7/09/2010	MSF Field Day	MSF Field Site	20
10/09/2010	West Midlands Group Pasture and Livestock Field Walk	Badgingarra RS - Enrich grazing site	21
22/09/2010	Condobolin Research & Advisory Station Annual Field Day	Condobolin Research & Advisory Station	60
23/09/2010	Mount Marshall Farmers SA field tour	Monarto field site	15
23/09/2010	Merredin Research Station field day	Merredin dryland research station	70
28/09/2010	MRS Field day	Walpeup field site	22
30/09/2010	Farming with perennial native grasses and fodder shrubs workshop	Coorow (hosted by Coorow LCDC, funded by NACC and Caring for our Country)	25
1/10/2010	UWA Ridgefield Future Farm-DAFF Demonstration Farm Open Day	Ridgefield Farm, Pingelly	75
8/03/2011	Enrich forum - Merredin	Dryland Research Institute, DAFWA, Merredin	38
10/03/2011	Enrich forum - Mingenew	Mingenew-Irwin Group conference room - Mingenew	8
23/03/2011	Enrich forum - Condobolin	Condobolin Agricultural Research Centre	11
30/03/2011	NEWROC Nungarin Field walk	Nungarin WEROC/NEROC field site	8
5/04/2011	Enrich forum - Minnipa	Minnipa Agricultural Research Centre	14
7/04/2011	Enrich forum - Waikerie	Waikerie RSL	21
8/04/2011	Enrich forum - Walpeup	Walpeup Agricultural Research Station	35
14/04/2011	WEROC Quairading field day	WEROC Quairading field site	20
10/05/2011	Condobolin Enrich site	Condobolin	30

7/06/2011	- follow-up visit following Enrich forum Northern and Yorke Natural Resources Management Board upper north tour	Agricultural Research Centre Morchard Enrich site	16

7.4 Appendix 4- References cited

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