



Forage Trees and Shrubs in Australia

**-their current use
and future potential**

**A report for the RIRDC/L& W Australia/FWPRDC
Joint Venture Agroforestry Program**

Supported by the Natural Heritage Trust

By EC Lefroy

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Foreword

Trees and shrubs have long been considered an important source of nutrition for grazing animals in Australia, particularly in the arid and semi-arid areas with a pronounced dry season. Over the last two decades there has been increased interest in planting forage trees and shrubs in the agricultural regions for improved animal production and environmental protection.

In 1999, RIRDC commissioned a study of the commercial prospects for planted woody species in the low rainfall zones of Australia (RIRDC Publication No 99/152). The study examined commercial prospects for wood products, energy, essential oils and fodder. Trees and shrubs for fodder emerged as having promising commercial prospects.

This publication surveys the current extent and use of cultivated forage trees and shrubs in Australia, the state of research and development, and the potential for expansion. It also examines the desirability, feasibility, and scope of a national fodder tree selection R&D program

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This report, a new addition to RIRDC's diverse range of over 700 research publications, forms part of our Agroforestry and Farm Trees R&D program, which aims to integrate sustainable and productive agroforestry within Australian farming systems.

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Peter Core

Managing Director

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Executive Summary

This study found that there are currently some 200 000 ha of cultivated forage trees and shrubs in Australia. The vast majority of this area is planted to three species, Leucaena (*Leucaena leucocephala*), Tagasaste (*Chamaecytisus proliferus*) and Saltbush (*Atriplex* spp.). Of this total, an estimated 100 000 ha is planted to Tagasaste in south western and southern Australia, 50 000 ha to Leucaena in the sub-tropical north east, and 50 000 ha to various *Atriplex* species on salt affected land in Western Australia, South Australia, Victoria and New South Wales. In addition to this, the study identified a small area, estimated to be less than 10 000 ha, planted to other species, predominantly *Acacia saligna*.

The area planted to the three main species was found to have increased six-fold over the ten years since the last national survey. Over that same period, 101 species from 33 genera were advocated in the literature as having potential as forage trees or shrubs, but no new species were found to have achieved commercial levels of adoption.

The potential area suited to cultivation of the three main forage trees and shrubs on the basis of soil type and climate is estimated to be 9.3 million ha. Of this, 1.3 million ha is considered to be suitable for Tagasaste, 4 million ha for Leucaena and 4 million ha for saltbush. Given the fact that these areas are subject to competing land uses and that there are constraints to the adoption of agroforestry systems that generate products solely for on-farm use due to the high initial investment cost, a 20% adoption rate is considered to be a realistic target. This would suggest a potential area of some 2 million hectares of these species, representing a ten-fold increase in the area currently planted.

Due to the small proportion of their total biomass that is edible, their higher establishment costs compared to herbaceous forages, and the delay until they are fully productive, fodder trees and shrubs need to demonstrate a substantial improvement in the quantity, quality and timing of feed supply over conventional sources before they represent commercially viable alternatives. A finding of this study is that researchers proposing the development of new fodder trees have rarely compared their feed value to that of conventional pasture or crop stubbles in order to assess their commercial viability. Such a commercial advantage has only been clearly demonstrated for two species in Australia, Leucaena and Tagasaste.

It is recommended that the most cost effective means of achieving an increase in the use of forage trees and shrubs for animal production in Australia is to invest in further development of Leucaena and Tagasaste, the only species with high forage value to have achieved any significant degree of commercial acceptance. It is suggested that this investment target three areas of R, D & E with respect to these two species:

1. Selection and breeding programs for Leucaena and Tagasaste to overcome the current biological constraints to their wider use, including reducing the levels of anti-nutritive compounds, expanding adaptation to a wider range of soil types, and improving resistance to disease, insects and frost. In the case of Leucaena, promising accessions including the F1 hybrid *L. leucocephala* K636 x *L. pallida* K748 have been identified and warrant further development. In the case of Tagasaste, the industry relies on an extremely narrow genetic base, with all commercial plantings being derived from a few lines introduced over 100 years ago since naturalized.
2. On-farm demonstrations to quantify economic benefits of animal production and demonstrate grazing management systems in established stands of Leucaena and Tagasaste. Such demonstrations need to be regionally targeted, given that the optimum use of these species varies with region, farm and the class of grazing animal.
3. Research into declining soil pH under stands of Leucaena and strategies to ameliorate this problem.
4. Research into alternative financing arrangements. As the commercial lending policy of banks is geared towards annual agricultural production, it is not able to accommodate longer-term agroforestry investment. Share-farming and other partnership investments are also inappropriate as the direct products of forage trees and shrubs have on-farm value only. Alternative forms of financing need to be examined, such as those based on the off-farm value of carbon and salinity credits.

It is further recommended that support for research into the development of new forage trees and shrubs from endemic and naturalized species only be considered where preliminary evidence is presented to demonstrate that they are capable of meeting the basic requirements of cultivated forage species, specifically edible dry matter production in excess of 1t/ha/yr under cultivation with *in vivo* dry matter digestibility greater than 55%. While species are commonly advocated on the basis that they are observed to be browsed by stock, or are regarded as valuable sources of feed during drought, no native tree species has yet met these basic criteria for cultivated forages.

It is also strongly recommended that investment in the introduction, selection and development of new exotic species be avoided due to the high risk of inadvertently adding to Australia's woody weed problem. The history of plant introduction into Australia for the development of new forage plants suggests that the risks posed by woody weeds through invasion of grazing lands and threats to biodiversity are higher than the potential benefits.

1. INTRODUCTION

1.1 Background

In 1999, the Joint Venture Agroforestry Project (JVAP) commissioned a study of the commercial prospects for planted woody species in the low rainfall zones of Australia. The study examined commercial prospects for four broad end uses - wood products, energy, essential oils and fodder (Zorzetto and Chudleigh 1999). Eleven different agroforestry enterprises were identified within these four broad classes and assessed using thirteen technical, commercial and environmental criteria. The three top ranking enterprises were fodder, eucalyptus oil and electricity from by-products and residues, with the study concluding that commercial prospects for these enterprises were reasonably favourable. As a result of the high ranking for fodder production as a commercial use of trees and shrubs in low rainfall zones, JVAP subsequently commissioned this study in February 2000 to review the current status and future R&D needs of forage trees and shrubs in Australia.

1.2 Terms of reference

The terms of reference for the current study were as follows:

1. Provide an update of the 1991 review paper "Trees and shrubs as sources of fodder in Australia" to identify the current status of fodder trees and shrubs compared with the situation in 1991. This review paper was commissioned for the conference "The Role of Trees in Sustainable Agriculture" by the conference convenors RIRDC and the Bureau of Rural Sciences (Lefroy *et al.* 1992).
2. Identify tree and shrub species which can be used for animal fodder and which species require further R&D to determine their full potential.
3. Identify and map key regions of Australia where the integration of fodder trees and shrubs is viable and desirable based on economic and environmental objectives in the context of the viability of other potential tree products.
4. Identify current researchers and determine the desirability, feasibility, scope and cost of a national fodder tree selection R&D program.

1.3 Methods used in carrying out the study

The approach taken to review the current status of forage trees and shrubs in Australia and identify future research needs was as follows:

1. A review of the literature was conducted by searching databases of published scientific information (Biological Abstracts, CAB Abstracts, Agricola, ARRIP), reviewing reports of research commissioned by the rural R&D Corporations (RIRDC, L&WA, MRC, AWC, GRDC) and research undertaken by CSIRO and state agencies. A total of 344 papers and reports published between 1991 and 2001 were identified. Particular emphasis was placed on compiling quantitative data on dry matter production of forage tree and shrub species, edible dry matter production per hectare (EDM/ha), animal response to grazing expressed as liveweight change per animal or per unit area and the profitability of animal production from forage trees and shrubs compared to that from conventional feed sources.
2. Contact was then made by email and/or telephone with individuals in Australia identified through the literature search to be currently engaged in R D&E on forage trees and shrubs. This personal contact was used to identify a wider network of researchers, landholders and extension personnel with experience in the use of forage trees and shrubs. Contact with this wider network was then used to compile additional information on the area of each forage species in commercial use, the potential for further expansion of each species, the technical and economic constraints to wider commercial use, the

perceived environmental benefits such as water use and the protection of soil, crop and livestock and areas that warranted further R D&E investment.

3. The above information was then compiled by species under the broad headings of current extent of commercial use, recent research, estimated potential area and future Research, Development and Extension needs.

4. The desirability, feasibility, scope, cost and likely benefits of a national fodder tree selection R&D program was then determined by examining a) the difference between the current extent of commercial use and the estimated potential range for each species, and b) the constraints to adoption and the future R D &E needs identified in the literature and through informal discussions with researchers, landowners and extension workers.

1.4 Structure of report

The study identified three principle woody plants under commercial cultivation in Australia for forage production – *Leucaena* (*Leucaena leucocephala*), Tagasaste (*Chamaecytisus proliferus*) and Saltbush (*Atriplex* spp.). In addition the study identified 116 endemic, exotic and introduced species which have been either exploited in wild stands, cultivated on an experimental scale or advocated for wider use.

The information gathered during this study is consequently divided into four chapters, one for each of the three main commercial species (Chapters 2-4) and one for the miscellaneous group of less developed species (Chapter 5). Within each chapter, the information collected from the literature review and personal contacts is presented in seven sections:

Background – a history of the introduction and early use of the species for livestock production.

Current use – a brief description of the regions of Australia in which the species is used, the preferred soil types and landscape positions, the enterprises in which it is currently used and an estimate of the current area under cultivation.

Recent research – a summary of the research findings published since the last review of forage trees and shrubs in Australia (Lefroy *et al.* 1992) under the following headings; Plant establishment and management, Edible dry matter production, Forage value, Animal production and grazing management, Profitability, Multipurpose systems, Environmental impact and Adoption.

Annotated bibliography – a list of material published between 1992 and the present indicating the content and scope of the article and the presence of quantitative data on total plant production, edible dry matter production, livestock production and profitability.

Potential area – an estimate of the area of land potentially suited to commercial production of the species based on published data and expert opinion.

Perceived R D&E needs – a summary of the R D&E needs as perceived by researchers, landowners and extension workers

Contacts – a list of the people who have published material on the species in the last decade and those contacted through the course of the study.

2. LEUCAENA

Leucaena (*Leucaena leucocephala* Lam. De Wit) is a tropical tree legume native to Mexico and Central America, now widely used throughout the tropics for animal production. The genus contains 22 species (see below), with the most commonly used being *L. leucocephala* (polyploid, 104 chromosomes). Cultivars of *L. leucocephala* in commercial use include Cunningham, Peru and Tarramba. Several hybrids also exist including *L. leucocephala* x *L. pallida*; *L. diversifolia* x *L. leucocephala*; *L. leucocephala* x *L. diversifolia* and *L. pallida* x *L. leucocephala*.

<i>L. collinsii</i> – white flowers	<i>L. magnifica</i>
<i>L. confertiflora</i>	<i>L. matudae</i>
<i>L. cuspidata</i>	<i>L. multicapitulata</i>
<i>L. diversifolia</i> - polyploid; pink	<i>L. pallida</i> - polyploid; pink flowers
<i>L. esculenta</i> - white flowers	<i>L. pueblana</i>
<i>L. greggii</i> - bright yellow flowers	<i>L. pulverulenta</i> - white flowers
<i>L. involucrate</i> - white flowers	<i>L. retusa</i> - bright yellow flowers
<i>L. lanceolata</i>	<i>L. salvadorensis</i> - white flowers
<i>L. lempirana</i>	<i>L. shannonii</i> - white flowers
<i>L. leucocephala</i>	<i>L. trichandra</i>
<i>L. macrophylla</i> - white flowers	<i>L. trichodes</i> - white flowers

2.1 Background

Leucaena is the most versatile and widely used multi-purpose tree legume in the tropics. In addition to producing high quality livestock forage, fuelwood and construction timber, it is extensively used in Africa, South East Asia and South America for soil stabilization and soil fertility improvement. It was introduced to the Philippines from Mexico in the 16th century by the Spanish colonists and there are now some 2-5 million ha in cultivation in SE Asia, Africa, and the Pacific. It has been the subject of research in Australia for some fifty years. The initial area of interest in Australia was Central Queensland, however adoption was slow during the boom period of development in the 1960's and 1970's as legume-based sown pastures were equally productive, less expensive to establish and easier to manage. An additional early constraint to *Leucaena* adoption was that cattle on high *Leucaena* diets experienced toxic effects of the digestive by-product of mimosine, 3,4 dihydroxypyridine (DHP).

The 1970's saw a slump in beef prices, reduced applications of superphosphate and a subsequent dramatic decline in the legume content and productivity of sown pastures, which presented an opportunity for the wider use of *Leucaena*. A break through came in 1982 when a DHP-degrading rumen bacterium (*Synergistes jonesii*) was introduced into Australian cattle in a rumen sample collected from Hawaiian goats (Jones and Lowry 1984).

Since that time, Australian research has clearly demonstrated the value of this plant for animal production. The highest rates of N fixation in a tropical legume have been recorded from *Leucaena* systems in Queensland with 575 kg/ha of N in edible material (Hutton 1960) and 480 kg/ha in total above ground growth (Ferraris 1979). The highest recorded liveweight gains from a tropical pasture legume (2000 kg liveweight/ha/yr) have been achieved on *Leucaena* in the Ord River Irrigation Area (Pratchett and Petty 1993). Under rainfed conditions in Central Queensland, liveweight gains of up to 1.25 kg/hd/d and 300 kg/hd/yr have been recorded (Jones and Megarritty 1986). Most significantly, growth rates during autumn (March-June) have been achieved at lower cost with *Leucaena* than is possible with alternative supplementary feeds. By 1985 some 3000 ha had been established in Central Queensland. The arrival of the leaf sucking psyllid insect (*Heteropsylla cubana*) in 1986 proved to be

a major set back, and while some degree of balance has since occurred between the insect and its predators, plantings in high rainfall coastal areas have been significantly affected. Selection for psyllid resistance has consequently become an important research objective.

2.2 Current use

Leucaena is currently used for animal production in Queensland and to a lesser extent the Ord River Irrigation Area in northwestern Australia. Plantings in northeastern Australia were originally centered around Rockhampton with smaller areas established since in South Eastern Queensland and more recently on basalt soils south of Townsville. An estimated 50 000 ha are currently in commercial use for beef production on fertile clay soils in the 600-800 mm annual rainfall areas of Central and Northern Queensland, with some 2000 ha in the Ord River Irrigation Area (Shelton 1998). The arrival of the psyllid insect has severely restricted its use within 100-300 km of the coast. The other major biophysical constraints are low rainfall (< 600 mm/yr) and intolerance to frost and low pH soils.

2.3 Recent research (1991-2001)

2.3.1 Plant establishment and management

The most significant recent agronomic research has been to extend knowledge of a wide range of *Leucaena* species. An international screening program of 25 accessions from 7 species at 17 sites in 7 countries (Mullen *et al.* 1998a) and 116 accessions in Australia and The Philippines (Mullen *et al.* 1998b) found large variation in dry matter yield, highlighting the potential of accessions other than the widely used cultivars of *L. leucocephala*. Of particular interest are adaptations to low temperatures, acid soils, low fertility and psyllid resistance. While some accessions showed high yield across all environments, others demonstrated specific adaptations. Mullen and Shelton (1998) found that one group of five interspecific hybrids out-performed all groups in all environments. The outstanding accession was the KX2 F1 hybrid *L. leucocephala* K636 x *L. pallida* K748 which showed broad environmental adaptation, high yield, moderate psyllid resistance and some cold tolerance (Shelton 1998). In 1997, the accession *L. leucocephala* K636 was registered as the cultivar Tarramba (Brewbaker 1997).

These trials also suggested that cold tolerance below 20°C was unlikely within the genus. However differences in tolerance to a 28/23°C diurnal variation indicated that the development of cultivars suited to the highland tropics was possible. No specific adaptations were found to highly acidic soils (pH<4.6; Al saturation >50%) or sites with very low fertility. Of these 116 accessions, Mullen and Shelton (1998) reported that the F1 hybrid *L. pallida* x *L. leucocephala* was the most widely adapted, with a strong correlation occurring between total dry matter and edible dry matter ($R^2=0.97$). In a study involving 25 accessions of 14 species at 19 sites, Mullen *et al.* (1998c) found no adaptation to acid soils and low rainfall, suggesting the need to look outside the genus *Leucaena* for adaptation to these challenging conditions.

Jones (1998) reported that in a study of 26 accessions of 15 *Leucaena* species in NE Queensland, the *L. pallida* x *L. leucocephala* hybrids had the highest yields and the highest psyllid resistance. However, as this hybrid was considered taller than ideal for grazing, was of unknown forage value and presented problems for propagation, Jones concluded that no clear cut replacement for the cultivars Cunningham and Peru had yet emerged.

In a comparison of 22 taxa in the Ord River Irrigation Area, Bolan and Triglone (1998) found that *L. leucocephala* cultivars Cunningham and Tarramba and the hybrids *L. pallida* x *L. leucocephala* and *L. leucocephala* x *L. pallida* ranked highest on the basis of survival, height, edible dry matter and insect damage. They also expressed the view that weak apical dominance was best for direct grazing systems. In a study of relative frost tolerance, Dalziell *et al.* (1998) found that the *L. leucocephala* cultivars Cunningham and Tarramba ranked highest.

Shelton identified the highlights of the international screening program of *Leucaena* accessions as the performance of the F1 hybrids of *L. leucocephala* x *L. pallida*, the cold tolerance of *L. trichandra*,

the variation in psyllid resistance, and the combination of low condensed tannin content and high psyllid resistance in *L. collinsii*.

In terms of improving early growth of *Leucaena* seedlings, Brandon *et al.* (1997) reported that slow colonization by arbuscular mycorrhizal (AM) fungi limited phosphorous nutrition, nitrogen fixation and early growth of seedlings. They conceded however that inoculation or application of phosphorous fertiliser at the rates required to overcome this might not be economically warranted. Brandon and Shelton (1997a) found that the percentage of root length infected with AM fungi was significantly correlated with plant height and weight in the first seven weeks of growth in a pot experiment but not with growth after 60 weeks or in the field, suggesting poor AM infection may not be a major long term limitation. They concluded that well drained soils with bicarbonate extractable P of 8-10 mg/kg and a pH>4.6 (1:5 H₂O) were likely indicators of good *Leucaena* growth. In correcting sub-optimal growing conditions, Brandon and Shelton (1997b) found that post-establishment irrigation and phosphorous applications of between 75 and 1200 kg/ha increased plant weight by 2 to 3 fold while nitrogen applied at 200 kg/ha increased plant weight by 27%. Gilbert *et al.* (1992) describe a rapid approach to predicting the suitability of new plant introductions to varying site conditions, including waterlogging, pH, and levels of phosphorous, magnesium, aluminium and salinity. Meanwhile Mullen *et al.* (1998) found that in a study involving 27 *Leucaena* accessions and 13 strains of rhizobia, only four accessions required specific rhizobium for inoculation and two strains were effective with more than twenty accessions.

On pests and diseases, Mullen *et al.* (1999) examined psyllid resistance in the 116 accessions described above in Australia and The Philippines. They found a complete range of responses from highly resistant to highly susceptible with the latter showing leaf yield decline of 52%. In a study of the psyllid predatory beetle (*Curineus coeruleus*) in the Hawaiian Islands, Follet and Roderick (1996) found that the low rates of gene flow between populations were unrelated to geographic parameters, indicating there are more fundamental obstacles to the rapid spread of this predator other than topography and distance. Shivas *et al.* (1996) reported the first occurrence of the fungal disease *Cerosporella leucaenae* in Australia from the Ord River Irrigation area. It was almost immediately colonized by the endemic parasitic fungi *Dicyma pulvinata*, suggesting natural biological control may limit the impact of the disease.

Clem *et al.* (1993) reviewed *Leucaena* production in Central Queensland and suggested that the key elements to successful establishment were to select well drained, fertile soils with a pH>5.5 (H₂O) and annual rainfall >500 mm and to sow scarified seed using press wheels on a full profile of soil moisture with good weed control until the trees were >2 m tall. Clem and Hall (1994) found that *Leucaena* ranked first for survival and productivity out of 56 accessions of pasture legumes on cracking clay soils in coastal NE Queensland. For the Burnett region, Quirk (1994) suggested the two most critical factors to good establishment were soil depth and fertility. Petty *et al.* (1994) reported that dry matter production from irrigated *Leucaena* was in the range of 12-48 t/ha/yr in the Ord River Irrigation Area and that stands were considered to have a productive life of 15-25 years.

Jeanes *et al.* (1996) examined the possibility of establishing *Leucaena* under a maize covercrop. While the presence of the maize reduced *Leucaena* height and dry matter by over 70% in the first 100 days compared to sole *Leucaena* plots, this competition was reduced to a 14% reduction in growth when two maize rows were forfeited either side of the *Leucaena* row. This had the effect of reducing maize yields in the mixture to 60% of that in sole crop. Wilson (1998) examined competition in four different tree-grass combinations. While there was a positive influence on grass growth near the stem compared to midway between trees in the mixed treatments (attributed to increased availability of soil nitrogen), pasture production in the *Leucaena*-grass mixture was 25% less than in the sole pasture. Mullen and Shelton (1996) suggested Buffalo grass (*Stenotaphrum secundatum*) might prove to be a suitable companion species for *Leucaena* given that it produced a dense stable sward that was shade tolerant and resistant to weed invasion.

In examining potential feed sources for dairying in Northern Australia, Minson *et al.* (1993) observed that the reported edible dry matter production of *Leucaena* were half those of nitrogen fertilized tropical grasses. In addition they note that leguminous shrubs such as *Leucaena* and *Glyricidia* have been found to contain high concentrations of condensed tannins which form complexes with proteins.

2.3.2 Forage value

Dalzell *et al.* (1998) demonstrated that species of *Leucaena* other than *L. leucocephala* rated highly in terms of forage quality. The species *L. collinsii*, *L. lanceolata*, *L. lempirana*, *L. macrophylla*, *L. magnifica*, *L. shannonii* and *L. trichoides* all had high dry matter digestibility (>65%), low levels of non-digestible fibre (<26%) and low concentrations (<1.5%) of condensed tannins. Faint *et al.* (1998) found that the palatability of *L. leucocephala* K636, five accessions of *L. diversifolia* (K156 and four from the Oxford Forestry Institute) and the hybrid *L. pallida* x *L. leucocephala* were similar to *L. leucocephala* Cunningham. They also reported that palatability was not predictable from chemical composition, including condensed tannin concentration, and that the application of NaCl, fructose and polyethylene glycol as foliar sprays did not alter palatability.

Larkin *et al.* (1999) reviewed the prospects for manipulating the concentration of tannins in pasture legumes. They noted that the positive contribution of tannins to animal production at low concentrations (~ 0.2% or less of dry weight) included resistance to plant disease and pests, reduced parasite load in grazing animals and bloat control. At concentrations of >1.0% however they have the effect of binding protein, protecting it from ruminant digestion, and at concentrations of >5.0% they reduce palatability and digestibility. They noted that the low natural variation in tannin content amongst the high-tannin tropical legumes meant a limited ability to manipulate their levels through selection as had been the case in the herbaceous legumes *Lotus*, *Lespedeza* and *Onobrychis*. This implied that transgenics was the most suitable method of manipulating tannin content.

The work of McNeill *et al.* (1998) has highlighted the complexity of the role of condensed tannins in animal nutrition by demonstrating that their tendency to bind protein varies between species, with condensed tannins in *L. pallida* having a higher binding ability than in *L. leucocephala*. They also suggest some level of tannins may be necessary to prevent complete degradation of amino acids in the rumen. As a further complication, Dalzell *et al.* (1998) showed that condensed tannins levels varied seasonally within an accession, being influenced by phosphorous deficiency, soil acidity, water stress and low temperatures. Jackson *et al.* (1996) measured total condensed tannin levels of 9% in *L. diversifolia*, 6% in *L. pallida* and 5% in *L. leucocephala*. They showed that condensed tannins levels varied depending on the analytical method used (bound or extractable) and suggested that low soil fertility may result in higher condensed tannins levels due to a concentration effect. Dalzell and Kervan (1999) reported a new rapid assay for condensed tannin concentration using 70% acetone in 1% (w/v) Na₂S₂O₅.

Castillo *et al.* (1997) examined psyllid resistance in three species of *Leucaena* and found it to be associated with higher condensed tannin concentrations and lower *in vitro* dry matter digestibility. Dalzell and Shelton (1999) assayed 118 accessions of *Leucaena* for condensed tannin content and found a range of 0-15%. Based on observations and assays of *L. collinsii* subsp. *collinsii* they suggested that low condensed tannin content and high psyllid resistance were not incompatible.

In a review of the factors influencing forage quality, Poppi *et al.* (1999) concluded that grazing management and the use of supplements were as effective as high-tech manipulation of lignin and carbohydrate content.

2.3.3 Animal production and grazing management

In a review of experiments in Australia and Latin America where *Leucaena* was used as a supplementary feed in the dry season, Jones (1994b) found that in eight out of 13 cases there was a 70% increase in live weight gain of cattle compared to animals grazing conventional pastures and that expectations of liveweight gains of 310-430 kg/ha/yr were reasonable. Jones *et al.* (1998) found that *L. collinsii* subsp. *collinsii* produced similar liveweight gains in cattle grazing hedgerows of *Leucaena* plus inter row grass as *L. leucocephala*. This is significant given the psyllid resistance of *L. collinsii*.

Quirk (1994) identified two distinct roles for *Leucaena* in a review of its use in the Burnett region. In its role as a protein supplement to native pasture over the cool dry months (April-October), he cites work by Foster and Blight (1982) demonstrating that animals on 25% *Leucaena* and 75% native pasture gained an extra 133 g/d liveweight over a 21 month period compared to those on native pasture alone. In its role of finishing steers (~2½ year old, 500 kg), he indicated liveweight gains of 0.7–1.3 kg/hd/d have been recorded from *Leucaena* pastures for two to three months.

Jones and Bunch (1995) reported on a 22 year comparison between animal production from Leucaena and Safari clover (*Trifolium semipilosum*) at a high rainfall site in SE Queensland (1108 mm/yr). While the clover declined in productivity by 13% over that period, the annual liveweight gain was significantly higher from the clover pasture than the Leucaena (446 kg/ha/yr compared to 399 kg/ha/yr). This serves as a reminder that the value of a forage species to the landholder is determined by its performance relative to the alternatives available for any one site, and not the absolute levels of production, as impressive as they may be.

Esdale and Middleton (1997) demonstrated the nutritional value of Leucaena as a supplement to grass pastures with average daily liveweight gains of 1.26 kg/hd/d in 150 steers grazing Leucaena plus grass pasture over 150 days compared to 0.82 kg/hd/d for steers grazing grass alone.

Petty *et al.* (1994) reported that since the introduction of Leucaena to the Ord River Irrigation Area in 1970, animal production had increased from a maximum of 800 kg/ha to 1700 kg/ha, largely due to the introduction of the DHP-degrading rumen bacteria. Pratchett *et al.* (1992) reported that Brahman-Shorthorn cross steers on irrigated Leucaena-pangola pasture in the Ord River Irrigation Area gained significantly more weight than Africana-Shorthorn cross steers at a stocking rate of 4/ha over a 311 day experiment (0.72 vs. 0.66 kg/hd/d). Ryan *et al.* (1992) used taste panel tests to demonstrate that these two innovations - Brahman cross steers finished on irrigated Leucaena produced beef suitable for the retail trade. Previously it had been thought that cattle from this region would only be capable of producing beef suitable for the manufacturing and hamburger trades. Petty *et al.* (1997) found that supplementing this irrigated Leucaena-pangola pasture with maize at 1.5 kg/hd/d increased liveweight gain in the dry season by 54% (from 0-1.5 to 0.73-1.0 kg/hd/d) but had no influence on weight gain during the wet season. They also reported that total intake varied little with or without supplementation, indicating that liveweight gain was a function of season, supplements and total feed on offer. Petty *et al.* (1998) demonstrated a refinement of this supplementary regime by showing that supplementing with 1.25 kg/d of molasses achieved the same liveweight gain at lower cost as a supplement of 1.5 kg/d of maize.

Jones and Palmer (1999) found that the psyllid resistant Leucaena *L. leucocephala* Tarramba, *L. diversifolia* and *L. pallida* produced lower liveweight gains (400-900 g/d) than *L. leucocephala* Cunningham (1170 g/d). They also found that ranking on the basis of liveweight gain was very similar to that based on in vitro digestibility and fiber, lignin and condensed tannin content.

2.3.4 Profitability

While several authors refer to higher profitability of cattle production from Leucaena-based pastures than conventional herbaceous pastures (eg. Wildin 1994; Middleton *et al.* 1995, Larsen *et al.* 1998), no quantitative data are presented in the literature. Middleton (in Larsen *et al.* 1998) for instance indicates that the marketing implications of the improved weight gains from Leucaena pastures demonstrated by Esdale and Middleton (1997) “are obvious”. However, without comparative data on total costs and returns from each system, growth rates alone are insufficient information for a would-be adopter, particularly given the lead time prior to full production and the amortized cost of the initial investment. Larsen *et al.* (1998) cited high establishment costs as a major disincentive to adoption. Middleton (in Larsen *et al.* 1998) suggests it probably costs 50-100% more to establish Leucaena than conventional buffel grass (*Cenchrus ciliaris*) pasture. This would suggest detailed comparative investment analyses have an important place in any extension program.

Petty *et al.* (1994) reported gross margins of \$1700-2000/ha from cattle production on irrigated Leucaena on the Ord River Irrigation Area although no comparative returns were provided for alternative land uses.

2.3.5 Environmental impact

Two recent studies have reported accelerated soil acidification rates under Leucaena systems (Noble and Jones 1997, Noble *et al.* 1998). In the former study, comparison between a 22 year old Leucaena stand and adjacent grass pasture showed significant acidification and cation depletion down to 70 cm. Cation depletion was estimated to be 2.7 kmol H⁺/ha/yr of which 0.17 was calculated to be due to removal of animal products. This compares with cation depletion rates in the relevant natural ecosystems of 0.5 kmol H⁺/ha/yr. Soil pH (H₂O) under the Leucaena was 5.0 at the surface and 5.4 at

60 cm compared to 6.0 under the grass at the surface and at 60 cm with a low of 5.8 at 30 cm. The authors suggest these significant acidification rates raise questions about the sustainability of Leucaena systems on this site. In the latter study, the impact of Leucaena N-fixation was compared with that of nitrogen-fertilized irrigated pasture. After 36 years under each treatment, the pH_{Ca} at 20cm was lowered from 5.2 to 4.8 under Leucaena compared to 4.3 under pasture. Over the top 90 cm of the soil profile, acidification rates were 1.0 kmol H^+ /ha/year in the Leucaena systems and 5.1 kmol H^+ /ha/yr in the pasture.

2.3.6 Adoption

The rate of adoption of Leucaena is perceived to be low by Gutteridge *et al.* (1999) and moderate by Middleton *et al.* (1995). From a producer's perspective (Larsen in Larsen *et al.* 1998) this is due to the high cost of establishment, the high rate of establishment failure due to weed competition and insect predation, the persistence of 'myths' concerning the hazards associated with Leucaena production and low returns from beef production relative to grain. From an extension workers perspective (Middleton and Chamberlain in Larsen *et al.* 1998), the barriers to adoption are the low level of establishment skills amongst graziers and the failure of extension programs to convince graziers of the benefits of Leucaena, particularly where they perceive their existing grazing practice to be a high production system. Quirk (1998) in a review of Leucaena in Burnett region of Queensland identified five barriers to adoption; low awareness, lack of information, high failure rate (attributed to the use of unscarified seed, lack of rhizobial inoculum and high rates of predation with small plantings), slow and unreliable establishment (due to rainfall variability and weed competition) and the fact that Leucaena has to compete with cropping for the best deep, fertile soils. This latter point suggests this is not a failure on the part of Leucaena but a valid and useful economic indicator of its place in farming systems.

In a review of Leucaena adoption in the Ord River Irrigation Area, Petty *et al.* (1994) reported that since its introduction in 1970, 2000 ha had been planted on seven irrigation farms turning off some 10 000 head each year primarily for the SE Asian store trade. They pointed out that the use of irrigated Leucaena enabled this trade to continue year round, overcoming the problem of mustering station cattle during the wet season, and that Leucaena-fed cattle were also substituting for some of the 25,000 head imported from the south for domestic consumption the North West.

t'Mannetje (1997) identified several conditions that need to be met before improvements in pasture systems are likely to be adopted. Firstly there needs to be a demand for improved levels of animal production reflected in the value of animal products. Secondly producers need to be motivated to meet those demands, and thirdly they must be able to access the resources necessary to implement those improvements, namely information, genetic material and capital. Given the perception amongst research and extension workers that the rate of adoption of Leucaena in northern Australia is low (Middleton *et al.* 1995, Larsen *et al.* 1998, Gutteridge *et al.* 1999) it appears that these pre-conditions are either not widely recognized or not met to the extent that many have anticipated. While R D&E has influence over the availability of genetic material and information, the demand for animal products and the alternative uses for capital are equally important but outside the influence of R D&E and therefore possibly over looked. Gutteridge *et al.* (1999) for instance suggest that low adoption is due to poor perception of the benefits by landholders.

2.4 Annotated bibliography of *Leucaena* in Australia, 1991-2001

Source and scope	Quantitative data			
	Dry matter prod.	Edible dry matter	Live weight gain	\$/ha
Annison and Bryden 1998 <i>Review</i> ruminant nutrition and metabolism				
Bolam and Triglone 1998 22 accessions; NW Aust (Ord River Irrigation Area); 46-1333 g/m row/month; 25-2505 g EDM/m row/month; 61-65% digestible	✓	✓		
Brandon and Shelton 1997a Effects of N, P, lime on yield; 220-1010 g DM/m row, SE Qld	✓			
Brandon and Shelton 1997b Effect of AM fungi on growth of <i>Leucaena</i> , Mt Cotton, Qld	✓			
Brandon <i>et al.</i> 1997 Effects of soil type, AM fungi, grass competition, P application on yield and nodulation Mt Cotton, Qld	✓			
Bray <i>et al.</i> 1997a 2 sites in Aust; N Qld; 10 accessions; 0.05-11.75 t leaf DM/ha after 1 year; 0.1-24.1 t leaf DM/ha after 3 years	✓			
Bray <i>et al.</i> 1997b Complete listing of <i>Leucaena</i> accessions in major collections				
Burrows and Prinsen 1992 South east Qld; performance and palatability (also <i>Acacia</i> , <i>Albizia</i> , <i>Casuarina</i> spp.)				
Buxton <i>et al.</i> 1996 Kimberly; Development of profitable and sustainable strategies with graziers				✓
Castillo <i>et al.</i> 1997 16 accessions of 3 species; Redland Bay 45 km SE Brisbane; 0.25-3.33 kg EDM/tree over 2 years; chemical composition; psyllid scores; digestibility 52-68.3%	✓	✓		
Clem and Hall 1994 3 sites; subcoastal NE Qld; Cunningham; high yielding but only given a productivity rating	✓			
Clem <i>et al.</i> 1993 Establishing <i>Leucaena</i> in Qld				
Dalzell <i>et al.</i> 1998a Frost tolerance; 25 km west of Dalby, SE Qld; 9 accessions				
Dalzell <i>et al.</i> 1998b Chemical composition; 116 accessions; DMD 42-68.9%		✓		
Dalzell and Shelton 1999 Condensed tannins, analytical method				
Dalzell and Kerven 1999 Condensed tannins, genotypic effects				
David 1994 Ord River Irrigation Area; 6-10 t/ha/yr	✓			
Elder <i>et al.</i> 1998				

Source and scope	Quantitative data			
	Dry matter prod.	Edible dry matter	Live weight gain	\$/ha
9 accessions; Raglan, coastal central Qld; infestation ratings				
Faint <i>et al.</i> 1998 Palatability; 3 sites – one in Aust with 24 accessions; Mt Cotton				
Follett and Roderick George 1996 Psyllid; Hawaii				
Gilbert <i>et al.</i> 1992 Townsville; nutritional characteristics; various legumes; cv. Cunningham; 3 soils; $\pm$ N; waterlogging; liming;	✓			
Gutteridge <i>et al.</i> 1999 <i>Review</i> uses, characteristics and limitations; 50 000 ha in N Aust; 22 species; EDM 3-30 t/ha/yr	✓	✓	✓	
Gutteridge 1999 Productivity under grazing		✓	✓	
Hammond 1995 <i>Review</i> Toxicosis				
Jackson <i>et al.</i> 1996 Townsville; <i>L. diversifolia</i> , <i>L. leucocephala</i> , <i>L. pallida</i> ; tannin content; N content; various legumes				
Jeanes <i>et al.</i> 1996 Redland Bay QLD; competition effects between Leucaena and maize; alley cropping system; 0.07-0.24 kg/m (0.9 g/m ² /d)	✓			
Jones and Bunch 1995 Coastal SE Qld; cv. Peru; 13 year trial; mean liveweight gain 157 kg/hd = 399 kg/ha			✓	
Jones <i>et al.</i> 1998 Lansdown Qld & Kununurra WA; animal production; 3 species; 395-814 kg EDM/ha; steer gains 400-723 g/d	✓	✓	✓	
Jones 1994a <i>Review</i> Management of anti-nutritive factors				
Jones 1994b <i>Review</i> Effect of Leucaena on liveweight gain; improving milk production; reproduction in cattle; grazing management; includes table of liveweight gains from 16 experiments 1980-1991			✓✓	
Jones 1998 26 accessions; 15 species (incl 3 hybrids); 50 km S of Townsville; mean of eight harvests 400-3223 kg/ha $\approx$ 1.3-10.4 t/ha/yr; 189-1363 kg EDM/ha	✓	✓		
Jones and Palmer 1999 Weight gains of steers grazing var Cunningham			✓	
Karda <i>et al.</i> 1998 Palatability				
Larkin <i>et al.</i> 1999 Condensed tannins				
Larsen <i>et al.</i> 1998 <i>Review</i> Grazier's view; pasture agronomists view; intensive irrigated production systems; 1.25 kg/steer/d on raingrown Leucaena/grass (Esdale & Middleton)			✓✓	

Source and scope	Quantitative data			
	Dry matter prod.	Edible dry matter	Live weight gain	\$/ha
Lowry 1995 Deciduous trees in tropical woodlands				
Ltd 1997 Plant variety 'Tarramba'				
t'Mannetje 1997 <i>Review</i> References to Leucaena N fixation, liveweight gains of 2000 kg/ha/yr (Pratchett & Petty 1993)			✓✓	
Middleton <i>et al.</i> 1995 <i>Review</i> Establishment difficulties; psyllid problem; environmental limitations; forage quality; management limitations; potential for development; non-irrigated 255-330 kg liveweight gain/steer/yr (0.6-1.0 steer/ha) (Wildin 1993); irrigated 1500-1730 kg liveweight/ha/yr (Pratchett & Triglone 1989)			✓✓	
Minson <i>et al.</i> 1993 <i>Review</i> Pasture yield and quality; pasture management; forage consumption; leaf DM up to 22t/ha/yr (Bray <i>et al.</i> 1988)	✓✓			
Mullen <i>et al.</i> 1999b Rhizobium specificity				
Mullen and Shelton 1996 Grazing buffalo grass compared with Leucaena				
Mullen and Shelton 1998 Sub-tropical Australia; 116 accessions (22 species incl. subspecies and hybrids); Brisbane; warm season growth = 8-439 g/m row/ month; cold season growth = 1-223 g/m row/month; highest yielding accessions produced the most EDM	✓	✓		
Mullen and Shelton 1999 Performance of 118 accessions in SE Queensland	✓	✓		
Mullen <i>et al.</i> 1998 25 accessions (14 species, incl. 2 hybrids); 19 sites (5 in Australia) 61 'environments'; 2-568 g/m row/month (9-173 g/m row/month in Australia)	✓			
Mullen <i>et al.</i> 1999a Psyllid resistance				
Noble and Jones 1999 Soil acidity under Leucaena				
Noble <i>et al.</i> 1998 SE Qld; soil acidification effects				
Petty <i>et al.</i> 1994 Ord River Irrigation Area; 12-48 t/ha/yr; growth rates 200-250 kg per animal $\approx$ 1.7 t liveweight/ha/yr; \$1700-\$2000/ha	✓		✓	✓
Petty <i>et al.</i> 1998a Ord River Irrigation Area; liveweight gain 0.73-1.1 kg/d $\approx$ 1575-2112 kg/ha/yr; mean dry season 0.89 kg/d, wet season 0.63 kg/d	✓		✓	
Petty <i>et al.</i> 1998b Ord River Irrigation Area; liveweight gain of cattle rotationally grazing Leucaena/pangola pastures supplemented with four levels of molasses and 2 levels of maize			✓	

Source and scope	Quantitative data			
	Dry matter prod.	Edible dry matter	Live weight gain	\$/ha
Poppi <i>et al.</i> 1999 Forage quality				
Pratchett <i>et al.</i> 1992 Ord River Irrigation Area; 2 steer genotypes; liveweight gain 0.662-0.716 kg/d			✓	
Quirk 1994 <i>Review</i> Burnett Region, Qld; suitable sites; agronomy; grazing systems and cattle production; commercial adoption; liveweight changes from Addison <i>et al.</i> 1984, Quirk <i>et al.</i> 1990; liveweight gain 0.73-1.30 kg/hd/d (Mullaly unpubl data)			✓✓	
Ryan <i>et al.</i> 1992 Ord River Irrigation Area; consumer assessment of beef finished on <i>Leucaena</i>				
Shelton 1998 <i>Review</i> Of workshop on taxonomy; agronomy and environmental adaptation; wood quality and woodiness; forage quality; future opportunities;				
Shivas <i>et al.</i> 1996 Kununurra; infestation of <i>Cercospora</i>				
Siaw <i>et al.</i> 1993 Gas production and rumen degradation of multipurpose trees				
Sparling <i>et al.</i> 1998 <i>Review</i> N cycling				
Wheeler <i>et al.</i> 1996 Dry Matter Digestibility		✓		
Wildin 1994 <i>Review</i> Central Qld; annual liveweight gains of 250-300 kg at 1-1.5 ha/steer, other pers comm. Figures; Prime cattle \$500-800/ha			✓✓	
Wilson 1998 Effect of <i>L. diversifolia</i> on pasture growth; Munduberra, SE Qld	✓			

2.5 Potential area suited to commercial *Leucaena* production

Figure 2.1 illustrates the area of Australia considered potentially suitable to *Leucaena spp.* on the basis of climate and soil type. This was derived from the area of clay soils (Isbell *et al.* 1968) in the 550 to 800 mm rainfall zone. The upper rainfall limit was included to eliminate areas prone to psyllid damage. While the shaded area covers some 22 million ha, Middleton *et al.* (1995) suggested an upper estimate of 3-5 Million ha of land in northern Australia would be suitable for *Leucaena* cultivation based on the criteria of soil fertility, pH and frost incidence.

2.6 Perceived research, development and extension needs

Jones (1994b) explicitly states there is no justification for further formal documentation of the value of *Leucaena* for animal production. He suggests instead that more work is required to demonstrate its value on-farm, particularly as its optimum use varies depending on the country, region and farm under consideration.

Several workers have identified the failure of past extension efforts to clearly articulate the benefits of *Leucaena* to producers. Larsen *et al.* (1998) suggest the best method of increasing adoption rates is to increase the skill level of potential users. In particular they claim misconceptions and myths concerning the expense and difficulty of establishment is a major obstacle. A further obstacle they identified is that *Leucaena* represents a relatively small increase in production compared to the transition from native to sown herbaceous pasture, a point closely related to t'Mannetje's point about producer motivation above. In other words, the perception of producers may be that their current pasture systems are already highly productive and the additional gains from *Leucaena* are not justified given the expense and risk involved in establishment and the changed management regime.

One systematic attempt to identify future R&D needs comes from a survey of participants at a workshop on *Leucaena* farming systems reported by Shelton (1998) shown in Table 2.1. Four of the top ten priorities involved on-farm research (seed increase of the new hybrid cultivars, large scale grazing demonstrations, economic analyses and on-farm testing of new taxa). Two other highly rated priorities were research into improved forage quality and research into seed production techniques for hybrid cultivars.

In contrast with the views of a predominantly research oriented group (Table 2.1), producers (eg. Larsen in Larsen *et al.* 1998) and extension workers (eg. Wildin 1994, Middleton *et al.* 1995 and Middleton and Chamberlain in Larsen *et al.* 1998) highlight the need to overcome establishment failure due to weed competition and the perception that establishment is costly and difficulty.



Figure 2.1. Areas of Australia considered potentially suitable for *Leucaena* production on the basis of climate and soil type. The criteria used were clay soils in the 550 to 800 mm rainfall zone. (Source: Fiona Coates and Max Shelton, University of Queensland).

Table 2.1. The top ten research priorities determined by participants at the workshop “Leucaena - Adaptation, Quality and Farming Systems” held in Hanoi, Vietnam, 9-14 February 1998 (adapted from Shelton (1998)).

Topic	Research area	Ranking
Seed multiplication of the best accessions	Genetic improvement	1
Education on management and use of Leucaena	Farming systems	2
Methods of seed production of KX2 hybrids	Genetic improvement	3
Develop vegetative propagation of KX2 hybrids	Genetic improvement	4
Evaluate Leucaena for dairy production	Forage quality	5
On farm evaluation of other taxa eg. <i>L.collinsii</i>	Agronomy	6
Economics of establishing Leucaena	Farming systems	7
Management of trees to maximize intake	Farming systems	8
On farm evaluation of KX2 hybrids and triploids	Agronomy	9
Studies on protein binding of tannins	Forage quality	10

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3. TAGASASTE

Tagasaste (*Chamaecytisus proliferus* [L. fil.] Link subsp. *proliferus* var. *palmensis* [H. Christ] A Hansen and Sunding) is an evergreen tree legume endemic to the Canary Islands. Reaching 4 to 5 metres under favourable conditions, it is closely allied to the brooms and gorses. Attention was drawn to its economic potential for livestock production by Dr. Victor Perez who described its very localized occurrence at an elevation of 1000 m growing on loose volcanic scoria and ash on the island of La Palma, (Perez 1865 quoted in Anon 1893). Noticing that local farmers had collected seed from these wild populations and were cultivating the trees as a source of fodder for domestic animals, he introduced it into cultivation on the island of Teneriffe and described its merits as a fodder tree.

Francisco-Ortega *et al.* (1990, 1991, 1993) have described seven morphological forms of *C. proliferus* endemic to the Canary Islands, known variously as tagasaste, white tagasaste and escobon ('broom'). Only one of the morphological forms, that described by Perez as originating from La Palma, is readily eaten by stock. Mendez (1993) reported that some 5000 ha of this form were under cultivation throughout the archipelago.

3.1 Background

Tagasaste was introduced to Australia in 1879 when seed was sent from the Royal Botanic Gardens, Kew to the Botanic Gardens in Sydney and Adelaide. It is now reported to be naturalised in Australia, New Zealand, South Africa, Java, Hawaii and California, but only cultivated for stock feed in Australia and New Zealand (Francisco-Ortega *et al.* 1990). It is believed to have been introduced to Western Australia by settlers from South Australia (Snook 1986) and was soon adopted as a reliable source of protein for poultry production during the summer and autumn drought. Long before its broadacre use as fodder for sheep and cattle, tagasaste was a common sight planted around homesteads for this purpose.

Early reports indicated a marked difference of opinion between the Director of the Adelaide Botanic Gardens and a botanist from the New South Wales Department of Agriculture as to value of the tagasaste (Schomburgk in Anon 1891, Turner in Anon 1891):

"The tagasaste has found a most suitable and congenial climate in South Australia, flourishing alike in wet and dry seasons. I have frequently drawn attention to the value of this plant in my reports of previous years, and during that time have distributed seeds for cultivation. It seems to me that in matters of this kind, both the pastorists and agriculturalists have hitherto shown a most remarkable degree of apathy. Considering that the most severe drought does not affect it at all, it would be advisable for every farmer to plant every spare corner of his land with tagasaste."

Dr. Schomburgk, Adelaide Botanic Gardens, 1888

"A Canary Island shrub called tagasaste is now occupying much attention in some quarters...but I can firmly assert that an old man saltbush would at the same age have produced about twice the amount of a superior fodder, and would grow in even more adverse circumstances of drought and heat".

Mr. Frederick Turner, Department of Agriculture NSW, 1889

These accounts remain a fairly accurate reflection of the regard in which this plant is currently held in the western and eastern parts of the continent. These divergent views essentially reflect differences in geology and soil type, as Tagasaste is only suited to very deep well drained soils such as the sandplain regions of Western and South Australia. The early history of tagasaste in Australia featured several enthusiastic champions of its wider use, notably Schomburgk (cited in Anon 1893), Maiden (1915), and Snook (1952, 1961). The lack of sound empirical data and practical difficulties associated with its early use meant that it was not until the late 1980's that large-scale adoption began.

Since that time, interest has developed in the broader integration of tagasaste into dryland farming systems for salinity management, wind erosion control and soil amelioration.

3.2 Current use

In 1986, a 250 ha plantation of tagasaste was established at Newdale, New Norcia, WA by the Martindale Company. This became the site for the first major animal production experiments, conducted by The University of Western Australia. By 1994, five years after the first major field day was held at Newdale demonstrating the high levels of animal production achieved with *in situ* grazing, a postal survey of the West Midlands region (the coastal sandplain between Perth and Geraldton) indicated that some 50 000 ha had been established (Maughan and Wiley 1994). An additional 1000 ha was reported in 1995 in south eastern South Australia and north western Victoria (R Peake pers. comm.). The most recent estimate for Western Australia is 100 000 ha, the majority of which is used for cattle production (G Tudor pers. comm.).

3.3 Recent research (1991-2001)

3.3.1 Edible dry matter production

Early reports of farmer experience in South Australia indicated that the trees grew better in sandy soil than heavier ground, reached their mature height of 4.6 m within three years, and were best established at a density of 2.5 to 3.5 m apart ie. 800-1600 trees/ha (Schomburgk, quoted in Anon 1891). It was also noted that the cut branches were readily eaten by sheep and cattle and that the trees could be cut two to three times over summer after which they rapidly refoliated.

The first measurements of dry matter production were reported by Snook (1952, 1961) from a small experimental plot on deep sands at Perth (annual rainfall 875 mm). Mean edible dry matter (EDM) production from trees cut once a year was 16 kg/tree, although no data on plant density was provided. Snook (1995) later suggested that production of 11.2 t EDM/ha was possible based on an extrapolation from his single-tree studies assuming a density of 700 trees/ha. Analysis of the edible fraction of these trees (leaves plus stems <5 mm) indicated that crude fibre varied from 16 to 25% over a year while crude protein levels in summer ranged from 17 to 21%.

Oldham and Moore (1988) reported yields of 3 t EDM/ha/yr from a plantation of five year old trees at a density of 2000 tree/ha cut once a year, growing on deep infertile sands in a 450 mm rainfall zone. This represented a 4-fold increase over annual pasture DM production on these sands (Oldham *et al.* 1991). Eastham *et al.* (1993) reported above ground biomass yields of 9.2 and 15.9 t/ha/yr from two- and three-year-old trees respectively at a density of 5000 trees/ha growing on deep sands in a 350 mm rainfall zone. Assuming the same edible dry matter fraction of total biomass as reported by Oldham *et al.* (1991), this equates to 1.5 and 2.6 t EDM/ha/yr.

In eastern Australia, tagasaste received very little attention from the scientific community until the mid 1980's despite an enthusiastic review by the NSW Government Botanist (Maiden 1915) and the fact that the tree was widespread in Victoria along roadsides and in gardens (McGowan and Matthews 1992). Prompted by New Zealand studies of tagasaste fodder production (Radcliffe 1983) and the success of the fodder tree *Leucaena* (*Leucaena leucocephala*) in northern Australia (Jones and Jones 1984), experimental plots were established at Ellinbank Research Station in south eastern Victoria in 1986 (annual rainfall 1100 mm). Subsequent studies showed yields of up to 12 t DM/ha/yr and 7.9 t EDM/ha/yr from three-year-old trees cut twice annually (McGowan and Matthews 1992, 1994). The summer active growth pattern of tagasaste was clearly demonstrated in this study with winter, spring, summer and autumn growth amounting to 9, 32, 46 and 13% respectively of total annual production. Trees cut twice a year were found to produce significantly higher annual production than those cut three and four times annually (McGowan and Matthews 1992).

Wheeler and Hill (1990) reported that feed production from tagasaste in New South Wales was 'pedestrian' compared to herbaceous pastures and that its use was limited by its susceptibility to frost. Dann (1991) identified the Western Slopes of the Great Dividing Range as the area of New South Wales most likely to be suited to tagasaste. This region runs parallel to the coast between 200 and 600 km inland, roughly bounded by the 800 mm rainfall isohyets to the east and the 400 mm isohyets to the west. Milthorpe and Dann (1991) reported yields of 3.1 and 5.7 t EDM/ha from three-year-old trees at two sites within this region (annual rainfall of 420 and 640 mm respectively), significantly less

than yields of herbaceous pastures at the same sites. They also found a strong relationship ($r^2=0.72$) between annual rainfall and yield.

Several studies on the influence of plant density on dry matter production have indicated that the yield of mature trees (>3 years old) was insensitive to plant density above about 800 trees/ha at 450 mm/yr (Milthorpe and Dann 1991, Wiley and Maughan 1993), peaked at a density of 8000 trees/ha with an annual rainfall of 640 mm/yr (Milthorpe and Dann 1991), and peaked at 20 000 trees/ha with an annual rainfall of 1100 mm/yr (McGowan and Matthews 1992).

Table 3.1 shows a comparison between tagasaste edible dry matter production and total pasture dry matter production for six locations in southern Australia. This indicates that tagasaste only showed a clear advantage over conventional pastures on deep sandy soils in Western Australia (New Norcia and Wongan Hills). Production from herbaceous pasture was superior to tagasaste on soils with higher clay content at the low rainfall (Condobolin), medium rainfall (Yass) and high rainfall sites (Ellinbank).

Table 3.1. Total and edible dry matter production from Tagasaste compared to total dry matter production of herbaceous pastures measured at sites in southern Australia.

Rain (mm/yr)	Tagasaste DM (t/ha/yr)	Tagasaste EDM (t/ha/yr)	Herbaceous pasture DM (t/ha/yr)	Ratio tag/pasture (EDM/DM)	Source and location
420	3.1	1.1	2.3	0.5	Milthorpe and Dann (1991); Condobolin
440	6.4	2.6	2.0 ^a	1.3	Eastham <i>et al.</i> (1993); Wongan Hills
450	7.0	3.0	0.8	3.8	Oldham <i>et al.</i> (1991); New Norcia
640	5.7	2.0	4.0	0.5	Milthorpe and Dann (1991); Yass
875	11.2	4.5	6.0 ^b	0.8	Snook (1952); Perth
1100	12.0	7.9	10.0	0.8	McGowan and Matthews (1992); Ellinbank

^a based on annual pasture production at Wongan Hills

^b based on perennial rainfed pasture production at Perth

Given the additional cost of establishing trees and the difficulties of grazing management, interest in tagasaste was only seriously maintained on deep infertile sands in the medium rainfall zone of western Australia (Kemp *et al.* 1989). However, even in this region, studies of EDM production and *in vitro* nutritional value carried out in the 1950's and 1960's were insufficient to inspire confidence in Tagasaste as a new forage plant. The impracticality of a cut-and-carry fodder system, poor establishment due to hardseededness, predation by rabbits, ring barking of trees under set stocking and 'lack of courage' on the part of land owners (Snook 1986) limited the rate of adoption until the research by Oldham *et al.* (1992, 1994) clearly demonstrated the benefits through on-farm research.

3.3.2 Animal production and grazing management

Tagasaste appears to have been initially used in Australia in a cut and carry system in much the same as it has traditionally been used in the Canary Islands. Schomburgk (quoted in Anon 1891) reported that when fed to cattle, each 40 kg of tagasaste fodder produced 1 kg of flesh (*sic*). Assuming 'flesh' refers to the dressed weight of an animal, and tagasaste is expressed in terms of edible fresh weight, this conversion rate is very similar to that reported by Oldham *et al.* (1991, 1993). The latter reported that 3000 kg EDM/ha (approximately 7500 kg/ha of edible fresh weight) could produce 350 kg/ha/yr

live weight (approximately 175 kg/ha dressed weight), giving a conversion rate of 43:1 compared to Schomburgk's 40:1.

While the cut-and-carry system did not suit the extensive nature of animal production, direct grazing was also found to be impractical as trees out-grew the reach of browsing animals and were often killed through bark stripping (Snook 1986). Some research was carried out on cut-and-carry systems (Hemsley *et al.* 1986) but with the development of pruning machinery this was soon abandoned and research concentrated on performance of animals grazing hedgerows mechanically cut once a year. The expectation of the research that followed was that tagasaste could be used in summer and autumn to maintain the rates of body weight and wool growth experienced in other seasons.

Oldham and Moore (1988) demonstrated that production of 3000 kg EDM/ha/yr was sufficient to maintain the body weight of young sheep at a stocking rate of 30 dry sheep equivalent (DSE) per hectare over 100 days, the approximate length of the annual feed shortage in autumn and early winter in south western Australia. This represented an 8-fold increase in year round carrying capacity for these deep sands. This system gave the trees a 9-month period of recovery from cutting and grazing and prevented damage from prolonged exposure to grazing. Based on these levels of production, Oldham *et al.* (1991) suggested that planting 10% of the typical Western Australian sheep/wheat farm to tagasaste would substitute for grain and other supplementary feeds and represent a return to investment of 20%, assuming a 20 year plantation life (Mattinson and Oldham 1989).

Increases in clean fleece weight of 25-30% were also demonstrated in young sheep grazing tagasaste compared to flock mates grazing dry pasture over three consecutive years (Oldham *et al.* 1991). However, associated increases in fibre diameter in tagasaste-fed sheep meant there was no consistent commercial advantage.

Research shifted focus to cattle production following a sharp downturn in wool prices in 1990. Early work suggested that liveweight gains of 0.6 kg/hd/d were possible over summer (Oldham *et al.* 1994). Later work has indicated that cattle continuously grazing tagasaste at 8-10 DSE/ha required grain supplements to maintain these growth rates over summer (Costa *et al.* 1995, Tudor *et al.* 1995).

Continuous grazing of tagasaste with cattle proved to be a breakthrough. The resulting low, compact hedgerows had a high leaf to stem ratio, were subject to far less damage than when grazed with sheep and did not require frequent cutting.

However the growth rates of sheep and cattle grazing tagasaste over summer are considered to be lower than that expected from the nutritional composition of the edible fraction. Several studies indicated lower production levels from tagasaste than alternative feeds in sheep (McGowan and Matthews 1987, Borrens and Poppi 1990) and cattle (Brammar and McGowan 1990). Lower levels of intake and rumen function (Edwards *et al.* 1995) and poor mineral nutrition of animals grazing tagasaste (Costa *et al.* 1994, McGowan *et al.* 1995, Edwards and Allen 1998) lead to research on secondary compounds. The phenolic group of compounds was the initial focus of attention (Fortune and Bailey 1993, Thye 1996) but findings remain inconclusive. Research is also underway examining the feasibility of developing weeping or dwarf cultivars from naturally occurring forms to overcome any requirement for cutting (J Hamblin pers. comm.).

3.3.3 Multi-purpose systems for fodder, shelter and water use

Dann and Trimmer (1986) suggested tagasaste deserved attention as a multipurpose agroforestry species on the basis that it fixes atmospheric nitrogen, re-cycles nutrients from depth and provides shelter for crops, pastures and animals in addition to providing fodder. Snook (1995) and McGowan (1991) allude to its multipurpose use on farms in Western Australia and Victoria in the first half of the century in the form of double-fenced hedgerows that served as paddock boundaries, windbreaks and fodder reserves.

In the early 1990's, landholders in Western Australia and the lower south east of South Australia began experimenting with alley cropping systems (Lefroy and Scott 1994, Stirzaker and Lefroy 1997). This involved cultivating crops between wide spaced rows of trees in the expectation that this would reduce wind erosion, have a beneficial effect on crop yields through microclimatic effects and increase water use and consequently reduce the rate of dryland salinity. Tagasaste, *Acacia saligna* and *Eucalyptus spp* were the most commonly used tree species.

Support for the beneficial effects of alley cropping on crop yield came initially from overseas studies of the effects of windbreaks on crops (Kort 1988) and work indicating improvement in pasture production in the lee of windbreaks in western Victoria (Bird 1991). However, Australian studies have since suggested that in the water-limited and highly variable climate of Australia's cropping zone, the benefits are likely to be minimal. A national study involving a range of crops at four sites over three years suggested a small but insignificant net benefit to crop yield from the presence of shelter belts (Carberry *et al.* in press).

Growing awareness of the scale of the salinity problem has renewed interest in the integration of trees into farming systems over the last decade, particularly in areas where no herbaceous perennial options exist. Two key steps in determining the proportion of a landscape required under perennial vegetation are to establish the recharge reduction target for a particular landscape unit or catchment and the water use of trees. To this end, several studies have attempted to measure the water use of tagasaste trees. Using the ventilated chamber technique, R Engel and PR Scott (pers. comm.) estimated tagasaste water use on a duplex soil in a 500 mm rainfall zone to be 408 mm/yr, (27% of pan evaporation). Eastham *et al.* (1993) used water balance to estimate tree water use at 562 mm/yr in a 350 mm/yr rainfall zone (20% of pan evaporation), and reported that tree biomass declined in subsequent years as soil water reserves that had accumulated under the previous annual cropping regime were depleted.

However, studies that are restricted to measuring total tree water use provide no information on the lateral and vertical extent of the trees' capture zone, or the extent to which trees compete with annual plants for soil water. Such information is necessary if agroforestry systems are to have any influence over water use beyond the area occupied by tree canopies and at the same time minimise disruption to agricultural production. There is also the question of the impact grazing will have in multipurpose systems on leaf area and tree water use.

Multi-purpose agroforestry systems are supported by some hydrologic modeling that suggests vegetation planted diffusely across the landscape is more likely to impact on the large scale processes responsible for rising water tables and salinity than dense, segregated plantings even though the total area under trees may be similar (Raper and de Broekert 1996, Clarke *et al.* 1998). However, these studies involve assumptions about temporal and spatial patterns of tree water uptake and the impact of trees on crops and pastures for which there is no empirical support.

In short there is a lack of sound empirical evidence for the economic and environmental benefits of highly integrated agroforestry systems such as alley cropping. Adoption of Tagasaste for animal production did not take place until its economic advantage over conventional feeds had been well established, despite the presence of enthusiastic advocates for its wider use for almost one hundred years. Similarly landholders are not likely to adopt alley cropping until there is evidence of economic and environmental benefit to the landholder, despite encouragement from government agencies keen to find strategies for salinity management (Western Australian Government 1996).

The assumption that there will be benefits to the landholder and the landscape from the close integration of trees and crops is often based on the assumption that as trees are deeper rooted than crops, competition for resources will be minimal. Some studies of integrated agroforestry systems however have found crops to be deeper rooted than the trees resulting in a high degree of competition (Dupraz *et al.* 1998). Studies of alley cropping in Africa have shown that in water limiting environments, competition between trees and crops for water increases the risk of crop failure compared to monocultures (Ong 1995), particularly when fast growing tree legumes like *Leucaena leucocephala* are used. As a result, the adoption of alley cropping in the semi-arid tropics has been low, despite twenty years of extension effort based on putative benefits to soil fertility and crop yield. The implication is that where trees are closely integrated with crops, advantages over the production of crops in monoculture are only likely to occur if there is complementary use of limiting resources. Ong *et al.* (1996) identify the potential forms of complementarity between trees and crops as stemming from spatial, temporal and functional differences in patterns of resource acquisition. In other words, differences in root architecture, phenology and specialised means of resource uptake such as nitrogen fixation, proteoid roots and hydraulic lift.

Where trees are the only biological option to increase catchment scale water use, the key decisions are what proportion of the landscape requires planting and whether this should be in the form of segregated blocks or integrated agroforestry systems. The basis for this decision will be whether

integrated systems involve a larger gain in production over segregated systems or, as is likely in many cases, a smaller degree of loss. Productive advantages need to be demonstrated in practice, and their underlying biological basis needs to be understood if they are to be repeated across a range of environments through optimal design.

3.4 Annotated bibliography of tagasaste in Australia, 1991-2001

Source and scope	Quantitative information			
	Dry matter prod.	Edible dry matter	Live weight gain	\$/ha
Barton 1995 Comparison of tagasaste, lucerne and pasture; various grazing regimes; gross margin analyses; concluded tagasaste unlikely to carry high stocking rates of cattle			✓	✓
Baxter 1996a Farmer case study, Cook property near Dandaragan				
Baxter 1996b Farmer case study, Parnell property at Tincurren				
Butt 1995 Analysis of the profitability of establishing 600 ha of tagasaste over a 3 year period			✓	✓
Chatfield and Chatfield 1993 Effectiveness of 75 ha of tagasaste in salinity control				
Edwards and Allen 1998 Seasonal variation in mineral status of cattle with continual access to tagasaste				
Edwards <i>et al.</i> 1999a Grazing management of Tagasaste				
Edwards <i>et al.</i> 1999b Phenolic compounds				
Gault <i>et al.</i> 1994 Nodulation studies	✓			
Lefroy and Oldham 1992 Alley farming				
Lefroy 1992 Farm-scale grazing experiment compared to model predictions		✓	✓	✓
Lefroy 1994 Alley farming with tagasaste in Australia compared to alley cropping in Southern Africa				
Lefroy 1996 Influence of farmers on tagasaste research in Western Australia				
Lefroy and Melvin 1996 Yield of lupins in monoculture, biculture with Rhodes grass and alley cropping				
Lefroy <i>et al.</i> 1997 Adoption of tagasaste in Australia, 1879-1995				
Lefroy <i>et al.</i> 1999 Total DM production of trees over fresh water tablekg/ha 1 st , 2 nd and 3 rd years after cutting; water use 2.5 times rainfall mm/yr; shoot:root ratio 2.7:1	✓			
McGowan and Mathews 1992 West Gippsland, Victoria; effect of spacing between plants and	✓	✓		

Source and scope	Quantitative information			
	Dry matter prod.	Edible dry matter	Live weight gain	\$/ha
frequency of cutting on yield; 2116-3833 g DM/plant/yr; 66.7-86% EDM				
McGowan and Mathews 1994 Ellinbank RS, Eastern Victoria; total annual DM yield/plant averaged 3.43 kg with two, 2.24 kg with three and 2.15 kg with four harvests/year; average EDM 66.7, 80.4 and 86.0%, respectively.	✓	✓		
Milthorpe and Dann 1991 EDM/ha 3.1 and 5.7 t/ha from 3 yo trees at 2 sites (rainfall 420 and 640 mm), < herbaceous pastures at the same sites.	✓	✓		
Oldham <i>et al.</i> 1992 Review of Tagasaste research	✓	✓	✓	✓
Oldham 1994 Technical note				
Oldham <i>et al.</i> 1994 Extension bulletin				
Speed <i>et al.</i> 1993 Impact of tagasaste on lowering WT (small perched aquifer)				
Wiley 1995b Area estimation; 1993 - 20 000 ha; 1994 - 40 000 ha; 1995 - 70 000 ha planned; projected area 500 000 ha by 2010			✓	
Wiley 1995a Response of Tagasaste to fertilisers application				
Wilson 1992 <i>Farm Journal</i> article				

3.5 Potential area suited to commercial tagasaste production

An estimate of the area of cleared land in southern Australia suited to animal production from Tagasaste is given in Table 3.2 with its geographical distribution illustrated in Figure 3.1. Three criteria were used to arrive at the estimate of 1.3 million hectares; annual rainfall greater than 350 mm, significant areas of siliceous sands (pH 4.8-8.4 in CaCl₂) with a depth of a metre or more (Stoneman *et al* 1990; Jeffrey 1994; Lanske 1992; Bob Peake PIRSA pers. Comm.) and a pronounced lack of autumn stock feed. This last criterion restricts its role as an economic alternative to other feed sources to deep sands (>1 m) in the 350 to 550 mm rainfall zone. Shallower sands and other well drained soils in the medium to low rainfall areas and deep sands in the higher rainfall areas both support higher production from herbaceous pastures. The estimate by Marsh (cited in Oldham 1993) of 3 million hectares of suitable land in Western Australia reflects its adaptive range rather than its economic range for animal production.

Table 3.2. Estimate of the area of Australia suited to commercial Tagasaste production.

Region	Area of cleared land (million ha)	Area suited to tagasaste (ha)
West Midland Sandplain	2.0	500 000
South West Coast	2.0	250 000
Central Wheatbelt Western Australia	5.0	100 000
Eyre Peninsula	1.3	50 000
Yorke Peninsula, Kangaroo Island, Adelaide Hills and South Coast	1.0	10 000
South Eastern South Australia	1.5	300 000
Western Victoria	1.5	75 000
TOTAL	14.3	1 285 000

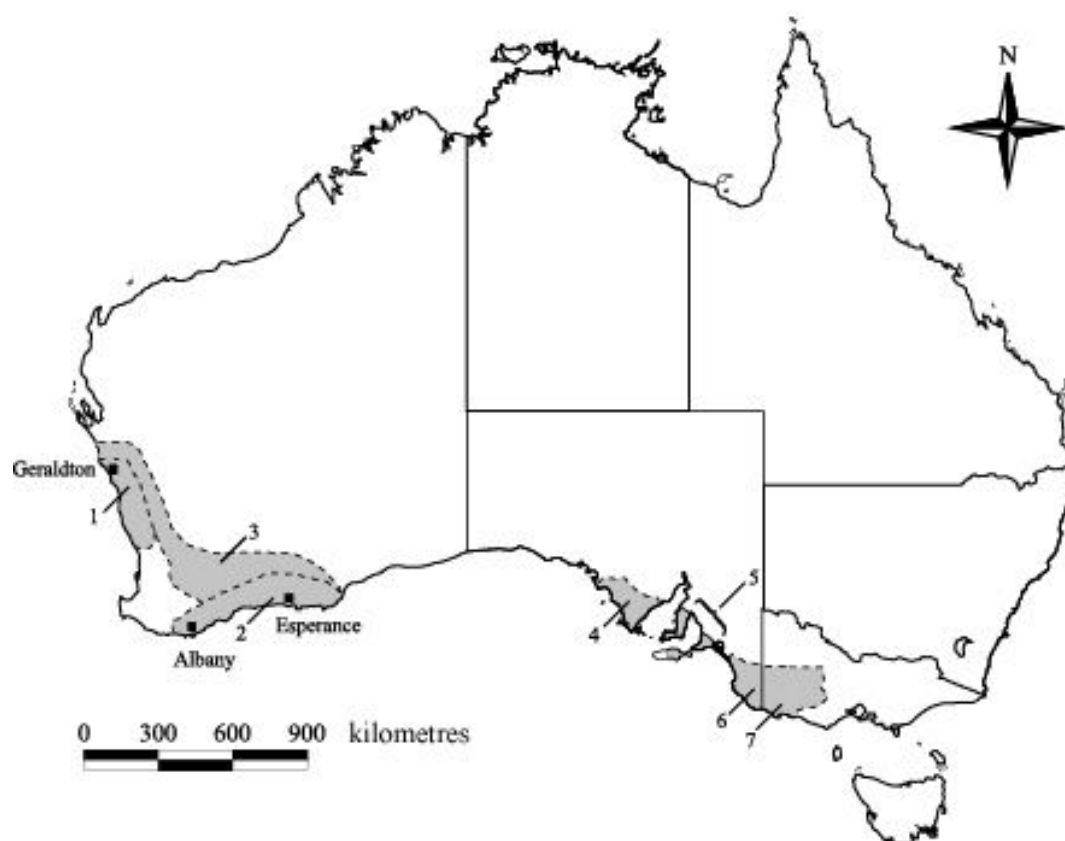


Figure 3.1. Farming areas of southern Australia suited to commercial use of tagasaste on the basis of three criteria: significant areas of deep sandy soils, annual rainfall >350 mm, pronounced lack of autumn stock feed. (1) West Midland sandplain; (2) south west coast; (3) Western Australian wheatbelt; (4) Eyre Peninsula; (5) Yorke Peninsula, Kangaroo Island, Adelaide Hills and south coast; (6) south east of South Australia; (7) western Victoria.

3.6 Summary of perceived R D&E needs

At a series of workshops held to review tagasaste R D&E in 1995 and 2000, the research priorities identified by researchers, extension workers and producers were 1) to overcome the existing constraints to animal production thought to be caused by anti-nutritional factors, 2) genetic improvement, 3) better integration of tagasaste into farming systems and 4) alternative financing arrangements.

Cattle production from Tagasaste in WA is currently characterized by a distinct drop in weight gain during autumn from the expected levels of 0.7 - 1.0 kg/head per day weight gains achievable winter, spring and early summer. Research is currently focused on identifying the cause of this drop and includes the following areas of investigation; i) Monitoring levels of phenolics and their impact on rumen function. ii) Examination of a wide range of secondary compounds including volatiles as possible inhibitors of intake and rumen function. iii) Studies of seasonal variation in animal intake and changes with supplementation. iv) Identifying the effect of energy and protein supplementation. v) using the GRAZFEED model to analyze existing grazing experimental data to develop herbage/mass relationships and relationships of stocking pressure versus weight gain per day and per hectare to optimize the use of this shrub.

The tagasaste population in Australia is derived from a sample of seed sent to Australia from Kew Gardens in 1879. The commercial population has a very narrow genetic base. Problems currently experienced with animal production could well be overcome through a breeding program, critical steps being i) Introduce germplasm and rhizobial collections from IBPGR in Rome and from other institutions who have collections from the Canary Islands. ii) Establish this material at representative sites to examine genotype by environment interactions. iii) Develop skills in clonal propagation and produce clonal ideotypes for palatability and edible biomass production. iii) Define breeding objectives based on current commercial and biological information. v) Study the phenology and reproductive biology of tagasaste.

At present tagasaste is grown in plantations with a density of about 2000 stems per hectare. Preliminary experimental work and farmer experience suggests it may have a valuable role in when integrated into crop and pasture systems at lower densities to increase water use and lower wind speed as well as provide feed. There is a lack of information on these forms of use which could be overcome through i) Studies of the competitiveness of tagasaste with different crop and pasture species. ii) Studies of its effectiveness in intercepting water and nutrients leaching from the root zone of crops and pastures.

A major constraint to adoption is the cost of setting up animal production systems based on tagasaste given the lead time between expenditure and first returns. Alternative financing arrangements need to be examined as the commercial lending policy of banks is geared towards annual agricultural production and is not able to accommodate longer term investment such as tagasaste. Studies are also needed to establish the optimal life of a plantation before replacement by a new cultivar could be justified.

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4. SALT BUSH (*Atriplex* spp.)

Atriplex is a genus of halophytic (salt tolerant) plants in the family Chenopodiaceae with some 70 species found throughout the world, 24 of which are found in Australia. Approximately 6 million hectares of chenopod shrublands occur in southern Australia stretching from central NSW through South Australia and into eastern Western Australia (Moore 1970). The value of these shrublands for sheep grazing was recognised in the middle of last century and it was from the saltbush plains of the NSW Riverina district dominated by Oldman saltbush (*A. nummularia*) that the Peppin breed of merino sheep originated. The appearance of secondary salinity caused by land clearing prompted interest in the use of *Atriplex* spp. for land rehabilitation in the 1960's and lead to the introduction of several exotic species and the development of sown saltland shrub and pasture systems. The ten species listed below appear in research and extension literature published in the last ten years and include seven endemic and three exotic species.

A. amnicola (River saltbush, WA)

A. bunburyana (WA)

A. canescens (Southern USA)

A. cineria (Grey saltbush, Aust.)

A. lentiformis (Quailbrush, USA)

A. nummularia (Oldman saltbush, Aust.)

A. paludosa (Marsh saltbush, Aust.)

A. semibaccata (Creeping saltbush, Aust.)

A. undulata (Wavyleaf saltbush, Argentina)

A. vesicaria (Bladder saltbush, Aust.)

4.1 Background

Saltbush pastures, and Oldman saltbush (*Atriplex nummularia*) in particular, have been held in high regard from the early development of southeastern Australia's grazing industries. Over much of the Riverina, the pastoral zone of South Australia and the Goldfields, Murchison and Gascoyne districts of Western Australia, saltbush-dominated shrublands are still considered to be among the most productive native plant communities for wool production.

Serious research and development into the establishment and management of sown saltbush stands however did not begin until the 1960's, motivated by interest in rehabilitating land affected by secondary salinity. A research program lead by C.V. Malcolm at the Western Australian Department of Agriculture resulted in the collection of 480 accessions of salt tolerant plants from around the world. These under went initial screening between 1968 and 1970 with 120 accessions being subsequently tested in the field between 1972 and 1982. Of these, 25 species were selected for long term assessment at 14 sites throughout the agricultural zone of south western Australia. The selection criteria were survival, biomass production, environmental tolerance (salinity, drought, frost, water logging and inundation), palatability and recovery after grazing (Malcolm 1996). The three highest ranked species were *A. amnicola* (River saltbush from the Murchison and Gascoyne Basins, WA), *A. undulata* (Wavyleaf saltbush from Argentina), and *A. lentiformis* (Quailbrush from Southern USA). Work in central NSW meanwhile concentrated on improving the reliability of establishing Oldman saltbush (*A. nummularia*) using bare-rooted seedlings (Andrew Sippel pers com.) Experiments at Tatura in Victoria demonstrated that dry matter yields of up to 9 t/ha could be produced from stands of *A. amnicola*, *A. cineria*, *A. nummularia* and *A. undulata* irrigated with saline water (10 000 mg/L; Shultz cited in Barson and Barrett-Lennard 1995).

Early animal production experiments suggested that adult sheep grazing sown saltbush stands in Western Australia made modest liveweight gains for the first 500 sheep grazing days (sgd)/ha over the summer/autumn period and then maintained or slightly lost condition over the next 1200 sgd/ha (Malcolm and Pol 1986). Economic modeling suggested this represented a profitable alternative to the conventional practice of maintaining sheep on dry pasture and grain supplements over the dry season (Salerian *et al.* 1987).

A National Program for the Productive Use and Rehabilitation of Saline Lands (PURSL) was established in the late 1980's with the collaboration of state and commonwealth agencies. The purpose

was to promote saltland revegetation, with the goal of having one million hectares of saline land in Australia revegetated and used for productive purposes by the year 2000 (Barson and Barrett-Lennard 1995). The program has convened six national workshops on research and development of productive uses for saline land since its inception with an emphasis on animal production from saltland pastures (Tatura 1990, Adelaide 1992, Echuca 1994, Albany 1996, Tamworth 1998, Launceston 2000).

Doubt as to the forage value of saltbush followed detailed grazing studies in the mid-1990's which suggested that the initial weight gains observed in earlier animal production experiments were likely to be artifacts of the increased water intake required to compensate for the high salt content (Warren and Casson 1996, 1997). These authors also showed that the saltbush plants rarely contributed more than 0.5–0.75 t/ha of edible dry matter, commonly between a fifth and a quarter of the total feed on offer, and that once the understorey herbaceous feed was consumed, animals lost liveweight. These findings were consistent with earlier rangeland studies examining intake, water consumption and performance of sheep grazing native saltbush stands in the pastoral zones of NSW and South Australia (Wilson 1966, Wilson *et al.* 1969, Squires and Wilson 1971, Wilson 1978, Graetz 1986, Leigh 1986, Squires 1989), research which had been largely overlooked in the new wave of interest in sown saltbush pastures as treatment for secondary salinity in the 1980's.

The work of Warren and Casson (1996, 1997) has challenged the view of saltbush as a valuable fodder plant in its own right and resulted in a change of emphasis for saltland revegetation. Barrett-Lennard and Ewing (1998) suggested that salt tolerant shrubs should now be regarded as providing an improved environment for more valuable understorey herbaceous pasture species through their roles in stabilizing soil and lowering saline water tables. In the most detailed study of water use by saltbush however, Slavich *et al.* (1999) found that transpiration rates in *A. nummularia* were too low to suggest significant hydrological impact.

The value of saltbush as a fodder shrub is therefore under question at a time when the full extent of salt affected land in southern Australia is predicted to reach 12 to 15 million hectares. In the meantime, sown saltbush pastures continue to be used for animal production across the agricultural region of southern Australia and there is a view amongst some producers and researchers that grazing experiments to date have not adequately reflected the way in which saltbush pastures are used and therefore their contribution to year round feed supply.

4.2 Current use

Barson and Barrett-Lennard (1995) estimated that there were 30 000 ha of saltbush pastures established in the winter rainfall region of southwestern Australia. Most of this was believed to be *A. undulata* and *A. lentiformis* established from seed on sandy and duplex soils with electrical conductivities in the range 4-20 dS/m. These authors noted that attempts to establish *Atriplex* spp. from seed on heavier clay soils in higher rainfall areas of the Murray-Darling Basin had been largely unsuccessful, but that *A. nummularia* is reliably established from nursery raised seedlings in lower rainfall areas of NSW. Barson and Barrett-Lennard (1995) also reported that *Atriplex* spp. have been successfully established in South Australia and Queensland on soils with electrical conductivities in the range of 25-50 dS/m. There are however no estimates in the literature of the extent of saltbush planting in eastern Australia but it is believed to be in the order of 5-10 000 hectares (Barrett-Lennard pers. com.).

4.3 Recent research (1991-2001)

4.3.1 Agronomy

In a review of factors influencing the productivity of halophytes, Malcolm (1996b) reported that dry matter yields of 1-2 t/ha have been recorded in the 350-400 mm rainfall zone of Western Australia but did not distinguish between edible and inedible fractions. He also cites work by Lazarescu and Davidson who found that application of 60 kg/ha of nitrogen increased the volume of *A. amnicola* plants by 40%. In addition he reported that ripping prior to planting increased growth by 30-40%, and

that additional ripping parallel to the rows produced a 65-100% improvement in growth while mounds and banks that limit water logging appeared to produce major increases in growth.

While agronomic research in the 1970's and 1980's concentrated on plant selection and growth of saltbush, the emphasis shifted during the 1990's to site selection and characterization to improve the success rate of commercial establishment. In a review of this research, Barrett-Lennard (2000a) described the optimal conditions of low clay content at the surface (ie. having a sand or sandy loam A horizon) and soil electrical conductivities between 5 and 15 dS/m. He also emphasized the importance of controlling Red Legged Earth mites and grass weeds and avoiding sites with low salinity due to weed competition. In the same review he also noted that direct seeding with purpose built niche seeders gave very low establishment rates (18% median) compared to seedlings (90% median establishment) but that the cost of the latter were prohibitively high.

Barrett-Lennard (1999) described three classes of salt affected land in terms of its suitability for productive revegetation. (Table 4.1).

Table 4.1. Potential productivity of salt affected land (after Barrett-Lennard 1999)

Productivity	Groundwater	Soil type	Inundation
Low	Shallow saline	Heavy	Frequent
Medium	Deep saline	Sand over clay	Infrequent
High	Shallow, low salinity	Deep sand	Infrequent

Barson *et al.* (1994) used the PLANTGRO model and the results of field testing of *Atriplex* spp. in WA to predict the likely success of saltbush in the Murray Darling Basin. The outcomes were then compared with data from seven field trials in the Murray-Darling Basin, which confirmed the general prediction that saltbush production would be low to moderate in the Murray-Darling Basin compared to WA due to the higher incidence of clay soils. The negative interactions between low aeration experienced with clay soils and soil salinities >10 dS/m were emphasised.

Davidson *et al.* (1996) reported very low productivity in a detailed study of the growth of *A. amnicola* at a site considered typical of salt affected duplex soil in the Western Australian wheatbelt. The depth of sand over dense clay varied from 10-110 cm with a mean depth of 40 cm. Mean total above ground dry matter was 0.74 t/ha at a density of 1600 plants/ha, and it was concluded that plant growth was limited by salinity, drought, waterlogging and the impenetrable nature of the clay subsoil.

To put these levels of forage production into perspective, Mochrie *et al.* (1981) suggest that the minimal protocols for evaluating new forages for ruminants include edible dry matter production of at least 1 t/ha/yr with a digestibility of at least 55% for maintenance of animals and greater than 65% for growth. Detailed studies to date indicate that saltbush commonly fails both tests, and it is the understorey plants that are of significance as feed.

4.3.2 Forage value

Malcolm (1996c) suggested there is potential to select for high leaf to stem ratio and low ash content when selecting amongst *Atriplex* spp., citing variation in ash contents of 14.6 to 18.3 between *A. amnicola* and *A. lentiformis* growing at the same site. Other studies have suggested that salt contents in the order of 15% can have a limiting effect on intake due to the flushing requirement of 30ml/g salt ingested (Squires 1993). Warren and Casson (1993) suggested that the high salt content of saltland forage plants is likely to be the major determinant of palatability and that dilution of salt content through the availability of other feed sources would be necessary to improve intake and performance. Work by Arieli *et al.* (1989) in Israel demonstrated that the high salt content in a saltbush diet resulted in lower gross energy and lower metabolisable energy available to sheep than from a diet of hay and grain due to the energy requirement of salt excretion.

In discussing the forage value of saltbush, Warren and Casson (1996) note that while *in vitro* dry matter digestibility of leaf can be as high as 72%, *in vivo* measurements (leaf and small stems) have been <55%. This is below the levels required by sheep for maintenance (>55%) and well below those required for growth (>60-65%). They also noted that chenopods typically have high levels of oxalate which can be toxic to ruminants, with concentrations of 10-66 g/kg DM reported in *Atriplex* spp.

A study of the grazing behavior of sheep on saltbush pastures by Atiq-ur-Rehman *et al.* (1999) cast doubt on previous estimates of the grazeable fraction of saltbush feed. They found that sheep only selected stem material of less than 1.5 mm diameter, whereas most studies of edible dry matter in the literature included stem material up to 5 mm diameter, thereby inflating the amount of edible material on offer. They cite a case where for example, pure leaf made up only 760 g/plant out of a total of 1900 g/plant of leaf plus stem <5 mm.

Lange *et al.* (1992) observed that small seedlings of *A. vesicaria* were spared compared to equivalent shoots on adult plants, recording relative survivorship rates of 0.5 and 0.04 respectively. They attributed this to the relative spatial density of the two classes of feed and the increased effort required by the animals to achieve similar intake from the seedlings.

4.3.3 Animal production

The use of revegetated saltbush pastures for animal production was advocated in the 1970's and 1980's largely on the basis that animals were observed to eat the plants. It was not until nearly 20 years after plant introduction and selection began that the first animal production experiments were carried out. Malcolm and Pol (1986) found that adult sheep (40-42 kg/hd) made modest weight gains for the first 500 sheep grazing days (sgd)/ha after being introduced to saltbush pastures over the autumn/early winter period and then maintained or slightly lost weight over the next 1200-1400 sgd/ha.

Warren and Casson (1992) reported a complementary interaction between saltbush and poor quality dry pasture. They found that sheep on tall wheat grass (*Thinopyrum elongatum*) pasture alone lost weight at 80 g/d while those on the same pasture plus a small amount of saltbush or a supplement of 250 g/d of oats lost 30-50 g/d. Warren *et al.* (1994) compared the feed value of five different saltbush stands (*A. amnicola*, *A. cineria*, *A. lentiformis*, *A. undulata* and a mixture of all four) with dry pasture. They found that although feed on offer in the saltbush stands varied significantly (1.6 to 2.2 t/ha total, of which 0.3-0.9 t/ha was saltbush), animal performance was similar in all stands with 7 sheep/ha maintaining weight for nine weeks (440 sheep grazing days/ha). At the end of nine weeks most of the feed had been removed and sheep began to lose weight. Sheep on dry pasture lost weight at 80g/d and were removed after seven weeks.

A more detailed series of grazing experiments conducted over four years challenged the view that saltbush represented a valuable supplement to dry feed. Warren and Casson (1997) and Casson *et al.* (1996) found that the water intake of sheep grazing saltbush was 2-4 times higher than sheep on dry pasture. Using a deuterium dilution technique, Warren and Casson (1996) clearly demonstrated that sheep grazing saltbush (*A. amnicola*, *A. undulata*, *A. lentiformis*) had higher body water content than animals on dry pasture while there was no difference in real tissue mass between the two groups. They also showed that the saltbush plants rarely contributed more than 0.5–0.75 t/ha of edible dry matter, commonly between a fifth and a quarter of the total feed on offer, and that once the understorey herbaceous feed was consumed, animals lost condition and liveweight. They concluded that saltbush had three weaknesses as a forage plant; high salt content (15-27% dry weight), low levels of edible biomass production (0.5-0.75 t/ha/yr) and low digestibility (46-60%).

Morcombe *et al.* (1996) also set out to test the findings of Malcolm and Pol (1986) that saltbush pastures could maintain sheep for 500–1400 sheep grazing days/ha. Their hypothesis was that a saltbush stand with little or no understorey could maintain sheep at stocking rates of 15-30/ha for 60 days over autumn. They found that a saltbush stand with 670 kg/ha of edible dry matter could maintain the liveweight of 15 sheep/ha for about 30 days. At 450 sheep grazing days/ha, this was at the lower end of the earlier estimates. While sheep gained between 0.9–3.7 kg over the first 14 days, they lost weight at 60-100 g/d for the next 14 to 28 days. They concluded that saltbush had limited value as a forage plant due to its low productivity, its effect of reducing staple strength in adult wethers and its unsuitability as a diet for lactating ewes.

The results of the grazing experiments of Warren and Casson (1996), Casson *et al.* (1996) and Morcombe *et al.* (1996) in WA were consistent with earlier work examining intake, water consumption and performance of sheep grazing native saltbush stands in the pastoral zones of NSW and SA (Wilson 1966, Wilson *et al.* 1969, Squires and Wilson 1971, Wilson 1978, Graetz 1986, Leigh 1986, Squires 1989).

In a more recent study, Hopkins and Nicholson (1998) found no deleterious effects of mixed saltbush diets on the liveweight, fat score, or meat quality (aroma, taste and tenderness) of 8 month-old lambs compared to those on a straight lucerne hay diet. However those on the saltbush diets (*A. nummularia* plus *ad libidum* lucerne hay and *A. nummularia* plus grain) had significantly lower carcass weights.

4.3.4 Economics of saltbush

Salerian *et al.* (1987) modeled the economic value of saltbush pastures as autumn feed based on the grazing experiments of Malcolm and Pol (1986). They concluded that with saltbush yielding 1t/ha, the marginal value of each additional hectare declined from \$62 to \$0/ha as the existing area of saltbush on a farm increased from 10 to 80 ha. With a saltbush yield of 3t/ha edible dry matter, the marginal value of each additional hectare under the same conditions ranged from \$238 to \$34/ha.

Krause *et al.* (1994) calculated the Net Present Values of saltbush as a treatment for salt affected cropping land at a wool price of 200 c/kg to be \$9149 for 40 ha and \$45 292 for 270 ha. This was based on assumptions of 1500 sheep grazing days/ha and establishment costs of \$388/ha (including fencing and watering). He estimated that the breakeven wool price would be 389 c/kg for 40 ha and 408 c/kg for a stand of 270 ha. The carrying capacity assumed in this analysis however was three times that found in the grazing studies described above.

Baldwin and Webb (1995) reported a four-fold increase in carrying capacity (from 2.5 dse/ha to 10 dse/ha) following revegetation with saltbush and lucerne-based pasture in the semi-arid plains of Western NSW. This additional carrying capacity was estimated to be worth \$150/ha/year, giving a break-even period of seven years if financed from borrowings. Oldman saltbush (*A. nummularia*) plants were established in double rows two metres apart with the 4 m spacings between double rows sown to a mixture of lucerne (*Medicago sativa*), snail medic (*M. scutellata*) and Makarikari grass (*Panicum coloratum* cv. Bambatsi). The total cost was \$800/ha, of which \$660 was for establishment of saltbush from transplanted seedlings. Saltbush therefore occupied approximately 50% of the area but accounted for 82% of the cost. The relative contribution of the saltbush and inter row pastures to animal performance and profitability was not reported.

The work of Morcombe *et al.* (1996) suggested that earlier claims of the economics of saltbush pasture establishment (Salerian *et al.* 1987, Bathgate *et al.* 1992) were over optimistic. Based on animal performance from three years of grazing trials they concluded that compared to dry pasture plus a supplement of 0.3–0.4 kg/d of lupins as a maintenance diet for sheep, the value of a hectare of saltbush was between \$35 and \$45. Based on a cost of establishment including fencing and water points of \$300/ha amortized over 10 years, they calculated it would take 8–10 years for a saltbush stand to repay the initial startup costs.

4.3.5 Environmental impact - water use and land rehabilitation

A consequence of the grazing experiments that cast doubt on the forage value of saltbush (Warren and Casson 1996, Casson *et al.* 1996, Morcombe *et al.* 1996) was a change in emphasis for saltland revegetation. Barrett-Lennard and Ewing (1998) suggested that the role of salt tolerant shrubs should now be seen improving a hostile environment to the benefit of more valuable understorey herbaceous pasture species by stabilizing soil and lowering saline water tables.

The water use potential of saltbush however has also been questioned in a study by Slavich *et al.* (1999) who measured transpiration in a grazed stand of Oldman saltbush at Wakool in southern NSW. They concluded that the transpiration rates (<0.3 mm/d) were too low for the stand to be having any significant hydrological impact. Barrett-Lennard and Galloway (1996) reviewed estimates of evapotranspiration by saltbush stands in the central wheatbelt of Western Australia and reported a range of between 0.4 and 0.7 mm/d. The higher estimate however was derived by Greenwood and Beresford (1980) using the ventilated chamber technique, now regarded as over estimating evapotranspiration by plant communities (Raper 1997).

Barrett-Lennard and Malcolm (1999) used salt accumulation in the soil profile beneath a saltbush stand to estimate uptake from the watertable by the saltbush plants to be between 60 and 100 mm over two years. However, Slavich *et al.* (1999) point out that a peak in the chloride profile under a plantation of saltbush cannot simply be interpreted as accumulation arising from groundwater use, as

in their experiment they found a peak at similar depth to that occurring under saltbush in adjacent thinly grassed annual pastures outside the plantation.

4.4 Annotated bibliography of *Atriplex* spp. in Australia, 1991-2001

Source and scope	Quantitative information			
	Dry matter prod.	Edible dry matter	Live weight gain	\$/ha
Baldwin and Webb 1995 Profitability of saltbush, mid-western NSW				✓
Barrett-Lennard and Galloway 1996 Saltbush for water table reduction and land rehabilitation; <i>A. amnicola</i> reduces shallow water tables by 60 cm over summer	✓			
Barrett-Lennard 2000a Argument for the development of saline agricultural systems; <i>A. amnicola</i> , <i>A. cinerea</i> , <i>A. lentiformis</i> , <i>A. nummularia</i> , <i>A. paludosa</i> , <i>A. undulata</i>				
Barrett-Lennard 2000b <i>Review</i> Productive uses for saltland; value of saltbushes as fodder for sheep; value of saltbushes for salt-affected land; <i>A. amnicola</i> , <i>A. undulata</i> , <i>A. lentiformis</i>				
Barson and Barrett-Lennard 1995 Saltbush trials; aims of the National Program for the Productive Use and Rehabilitation of Saline Land				
Barson <i>et al.</i> 1994 Murray-Darling Basin; 30 000 ha planted to saltbush by farmers in WA wheatbelt; PLANTGRO used to predict the success of 6 species on 6 salinised soil types at 6 localities; <i>A. amnicola</i> , <i>A. canescens</i> , <i>A. cineria</i> , <i>A. lentiformis</i> , <i>A. nummularia</i> , <i>A. undulata</i> ;				
Bathgate <i>et al.</i> 1992 Profitability of saltland pastures				✓
Casson <i>et al.</i> 1996 Tambellup, Wickepin; <i>A. lentiformis</i> ; 9-253 kg DM/ha; little change in liveweight	✓		✓	
Davidson <i>et al.</i> 1996 WA wheatbelt; <i>A. amnicola</i> ; average growth rate 0.70 t/ha/yr	✓			
Fanning 1994 Western NSW; erosion rates				
Greiner <i>et al.</i> 1997 Liverpool Plains, NSW				
Hopkins and Nicholson 1999 Meat quality			✓	
Krause 1994 Mid north and Eyre Peninsula, SA; case study of saltbush compared with 2 other options for saline land				✓
Lange <i>et al.</i> 1992 South Australia; <i>A. vesicaria</i> ; forage on offer	✓			
Malcolm 1995a <i>Review</i> Plant adaptation; selection; screening; evaluating; guide to selection of forage plants for saline soils in south west WA				

Source and scope	Quantitative information			
	Dry matter prod.	Edible dry matter	Live weight gain	\$/ha
Malcolm 1995b <i>Review</i> Economic and environmental aspects of halophytic forages; summary of 3 experiments - liveweight gains/losses and DMD 61-85% (see Warren and Casson 1993); \$ from Bathgate <i>et al.</i> 1992; also environmental costs	✓	✓	✓	✓
Malcolm 1995c <i>Review</i> Nutritional factors; growth; water relations and salinity; genetic factors				
Morcombe <i>et al.</i> 1996 Pithara WA; 5 species <i>A. amnicola</i> , <i>A. semibaccata</i> , <i>A. undulata</i> , <i>A. lentiformis</i> , <i>Maireana brevifolia</i> ; 0.01-0.41 t DM/ha; DMD 65.5-80% (leaf); liveweight (sheep) increased in first 14 d then decreased	✓	✓	✓	
Porteners 1993 Natural vegetation of Western NSW				
Rehman <i>et al.</i> 1999a Effects of season and grazing strategy on nutritive value	✓	✓		
Rehman <i>et al.</i> 1999b Katanning; <i>A. amnicola</i> ; DMD 65-72% (leaf); liveweight of sheep changed little		✓	✓	
Robards and Egerton Warburton 1995 WA, NSW				
Slavich <i>et al.</i> 1999 Southern NSW; very low water use suggests <i>Atriplex</i> spp. have little contribution to make to catchment scale water use				
Squires 1993 <i>Review</i> High salinity diets in sheep; distribution map for chenopod shrublands		✓		
Thorburn and Ehleringer 1995 Root water uptake from saline water tables				
Tiver and Andrew 1997 Eastern South Australia; 601 sites; 18 species of trees and shrubs; <i>A. vesicaria</i>				
Walker and Sinclair 1992 North eastern SA; <i>A. vesicaria</i> , <i>A. stipitata</i> , <i>Maireana sedifolia</i> ; soil salinity				
Warren and Casson 1993 Southern WA; <i>A. amnicola</i> , <i>A. cinerea</i> , <i>A. undulata</i> , <i>A. lentiformis</i> , <i>A. nummularia</i> ; DMD 68.9-81.3% (leaf)		✓		
Warren and Casson 1997 WA; DMD (<i>in vitro</i>) 62-80% (leaf) 38-47% (stem)		✓	✓	
Warren <i>et al.</i> 1994 Four species (<i>A. undulata</i> , <i>A. lentiformis</i> , <i>A. amnicola</i> , <i>A. cinerea</i>); DM 408-926 kg/ha	✓		✓	
Warren <i>et al.</i> 1995 4 species; Katanning; 0.2-1.0 t DM/ha; DMD 51-58%	✓	✓	✓	
Warren 1996 Katanning <i>in vitro</i> DMD 62-80% (leaf), 38-47% (stem)	✓	✓	✓	

4.5 Potential area suited to commercial saltbush production

In a rapid appraisal carried out for the Western Australian Salinity Council in 1999, it was estimated that approximately one third of the potential 6 million hectares of saline land in Western Australia would be suited to saltbush and other similar halophytic shrubs (EG Barrett-Lennard pers. comm.). This estimate was based on the observation that approximately one third of the land area currently affected by salinity was subject to levels of inundation and waterlogging beyond the tolerance of these shrubs, and that a further third, while too saline for most annual pastures and crops, was suitable for more productive mildly salt tolerant herbaceous plants such as Balansa clover. Assuming that new areas of salt affected land were distributed in similar proportions, this rule of thirds would suggest that the total area of land suitable for saltbush production would be 2 million hectares in Western Australia and 4 million hectares Australia wide. Mapping based on digital elevation models has been carried out in some parts of the country as part of the National Land and Water Audit to represent where these areas are most likely to occur; however it is not yet possible to represent the expected location of salt affected land with any spatial precision across the entire continent.

4.6 Summary of perceived R D&E needs

The suggestion by Barrett-Lennard and Ewing (1998) that the primary role of salt tolerant shrubs should be improving a hostile environment to the benefit of more valuable understorey pasture species rather than as a source of nutrition in themselves places a different emphasis on research to that which has existed over the past twenty years. The emphasis has now shifted to identifying genera, species and accessions for their ability to grow rapidly under saline conditions and thereby stabilize soil and lower saline water tables to the benefit of understorey pastures. It raises the possibility of even selecting plants on their ability to resist grazing. This fundamental shift in ideotype from a browse plant toward an environmental ameliorant may warrant a re-assessment of existing germplasm collections, particularly the collection of 500 accessions of salt tolerant plants assembled by CV Malcolm in the 1980's and currently held by Agriculture Western Australia. The selection criteria for this re-assessment might include characteristics such as rapid growth, tolerance to salinity and periods of inundation, large leaf area to maximize water use and grazing tolerance.

4.7 Atriplex Contacts

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5. OTHER FODDER TREE AND SHRUB SPECIES

AUSTRALIAN STUDIES

Acacia species including:

A. angustissima
A. aneura
A. estrophiolata
A. georginae
A. holosericea
A. kempeana
A. nilotica (prickly acacia)*
A. pendula
A. plectocarpa
A. saligna
A. salicina
A. shirleyi
A. stenophylla

Albizia lebbbeck

Alphitonia excelsa

Cadariocalyx gyroides

Calliandra calothyrsus

Casuarina species including:

C. cristata
C. cunninghamiana

Ceratonia siliqua (carob)

Eremophila species (16) including:

E. bignoniiflora

Flindersia maculosa

Gleditsia tricanthos (honey locust)*

Gliricidia sepium

Melia azedarach var *australasica*

Mimosa pigra (giant sensitive plant)

Myoporum species including:

M. kermadecense
M. platycarpum

Parkinsonia aculeata (parkinsonia)*

Planchonia careya (cocky apple)

Prosopis species (mesquites)*

Samanea saman

Salix spp. *.

Sesbania species including:

S. formosa
S. sesban cv. Mount Cotton

Tipuana tipu

Ziziphus mauritiana (Indian jujube)*

* see section on Potential weeds

OVERSEAS STUDIES

Acacia species including:

A. aneura
A. cyanophylla
A. nilotica
A. senegal
A. seyal
A. seiberiana
A. tortilis
A. trachycarpa

Albizia species including:

A. lebbbeck
A. chenensis

Cassia sturtii

Cytisus maderiensis

Faidherbia albida

Melia azedarach var *australasica*

Prosopis species including:

P. cineraria
P. juliflora
P. tamarugo

Teline stenopetala

Ziziphus species including:

Z. mauritania
Z. nummularia

ENDEMIC SPECIES ADVOCATED FOR FURTHER STUDY

<i>Acacia</i> species (17 spp.)	<i>Desmodium</i> species
<i>Atriplex nummularia</i>	<i>Glycine</i> species (10 spp.)
<i>Cajanus</i> species	<i>Psoralea</i> species (11 spp.)
<i>Cassia sturtii</i>	<i>Sesbania</i> species (7 spp.)
<i>Cytisus maderiensis</i>	<i>Vigna</i> species (5 spp.)

5.1 Background and current use

The species mentioned in this chapter fall in two broad classes - endemic species that have some history of use in the pastoral zone, and exotic species that have a history of use in other countries. Many of the former group, notably the Acacias, have been advocated for wider use as forage shrubs because of their historical importance as maintenance feed during droughts and periods of seasonal feed shortage in arid and semi-arid zones. Very few of these have been cultivated for their forage value, *Acacia saligna* being the only one to approach commercial significance. An estimated 10 000 ha has been established to this species, mainly in Western Australia and South Australia for multi-purpose use as windbreaks and fodder with an emphasis on the former use. Among the exotic species, *Calliandra calothyrsus*, *Cajanus cajan*, *Ceratonia siliqua* (carob), *Gleditsia tricanthos* (honey locust) and *Prosopis* spp. (mesquite) have all been introduced because of their reported feed value in other parts of the world. These introduced species however pose a very real risk of becoming serious environmental weeds with *Acacia nilotica*, *Gleditsia tricanthos* and *Prosopis* spp. listed as noxious weeds.

5.2 Recent research (1991-2001)

5.2.1 Prospective species

Doran *et al.* (1997) reviewed 164 lesser-known Australian tree and shrub species with known or potential agricultural uses. Of these, 46 were listed as fodder or potential fodder species (including 24 *Acacia* spp.) while 19 had limited value as fodder (13 *Acacia* spp.). Of the potential species, a limited amount of quantitative data was reported for nine species (Table 5.1). A trial in Senegal of *Acacia trachycarpa* planted at 3 x 3 m spacing produced yields 2.03 t/ha foliage after 1½ years (Hamel 1980, cited in Doran *et al.* 1997) while in Malawi a trial planted at 2 x 1.5 m spacing produced yields of 3.3 t/ha foliage after 2.2 yrs (Maghembe and Prins 1994, cited in Doran *et al.* 1997).

Table 5.1. Dry matter digestibility (%DMD) and crude protein content (%) of potential fodder species

Species	%DMD	% crude protein
<i>Acacia aneura</i>	-	11-16
<i>A. plectocarpa</i>	43 <i>in vivo</i>	9
<i>A. shirleyi</i>	53 <i>in vitro</i>	13
<i>A. stenophylla</i>	43 <i>in vivo</i>	11
<i>Alphitonia excelsa</i>	27.6 <i>in vivo</i>	
<i>Eremophila bignoniiflora</i>	67.4 <i>in vitro</i>	
<i>Flindersia maculosa</i>	57.4 <i>in vitro</i>	
<i>Melia azedarach</i> var <i>australasica</i>	77 <i>in vivo</i>	
<i>Sesbania formosa</i>	55-58 <i>in vitro</i>	21-22

Otsinya *et al.* (1999) reviewed arid and semiarid tree and shrub legumes for fodder potential, chemical composition, nutritive and anti-nutritive factors, integration into agricultural systems and agroforestry potential. Some of the data presented in that study are summarized in Tables 5.2 and 5.3.

Table 5.2. Crude protein (g/kg DM) and *in vivo* dry matter digestibility (DMD, g/g) of leaves of 16 forage trees and shrubs (from Otsinya *et al.* 1999).

Species	DMD	Protein
<i>Acacia aneura</i>	0.44-0.63	92-203
<i>A. cyanophylla</i>	0.51-0.53	112-212
<i>A. nilotica</i>	0.69±0.05	112-167
<i>A. senegal</i>	-	141-336
<i>A. seyal</i>	-	111-293
<i>A. seiberiana</i>	-	123-158
<i>A. tortilis</i>	-	103-210
<i>Albizia lebbek</i>	0.43-0.64	181-240
<i>Chamaecytisus palmensis</i>	0.6±0.76	164-264
<i>Faidherbia albida</i>	0.53	171-197
<i>Leucaena leucocephala</i>	0.51-0.68	203-268
<i>Prosopis cineraria</i>	0.39±0.06	119-154
<i>P. juliflora</i>	-	142-222
<i>P. tamarugo</i>	0.32	90-357
<i>Ziziphus mauritania</i>	0.53	111-163
<i>Z. nummularia</i>	0.41	141

Table 5.3. Feeding value of four forage trees (100% browse diet).

Browse species	Animal	Dry Matter Intake g/d	Dry Matter Digestibility g/kg	Liveweight change g/d
<i>Acacia aneura</i>	sheep	21	0.47	-
<i>Prosopis cineraria</i>	sheep	539	-	-28
	goats	672	-	46
<i>Leucaena leucocephala</i>	goats	27	0.62	46
<i>Ziziphus nummularia</i>	sheep	16	0.63	0.41
	goats	33	-	0.46

Several reviews have identified the potential fodder value of endemic trees and shrubs. Thomson *et al.* (1994) suggested that 17 species of *Acacia* from the dry subtropics could be useful stock fodder and listed a further 28 species as of limited use. Bastin (1998) described some of the important forage trees and shrubs of the Alice Springs district. Fox (1995) reviewed the ecological characteristics of *Acacia saligna*, reporting a range in digestibility of 50-58.5%, and crude protein from 12-16%. Richmond and Ghisalberti (1994) reviewed of the medical, cultural (traditional aboriginal), horticultural and phytochemical uses of *Eremophila* spp., listing 16 as having potential value for fodder. A review of *Myoporum* spp. noted that many species are toxic to stock (Richmond and Ghisalberti 1995). A study by Hacker (1993) identifying some of the more significant genera of perennial herbaceous and shrub legumes from Queensland and their significance as pasture or forage species. The most promising genera for fodder were considered to be *Glycine* (10 species), *Psoralea* (11 species; some high yielding and palatable), *Sesbania* (7 species) and *Vigna* (5 species).

5.2.2 Experimental work

Bray *et al.* (1997) studied the effects of fertiliser addition on leaf and stem production of 21 shrub legumes growing on infertile soils in the tropics (2 sites in each of Australia and Indonesia). Harvesting occurred repeatedly for up to 3 years. Overall, *Calliandra calothyrsus*, *Acacia angustissima*, *Gliricidia sepium*, *Leucaena diversifolia*, *L. pallida* produced the highest yields. *C. calothyrsus* produced more than 10 t leaf dry matter per year and *A. angustissima* more than 14 t. The authors suggest *A. angustissima* not be used in future programs because of its weed potential. Gutteridge and Shelton (1995) described *Sesbania sesban* cv Mount Cotton as having a crude protein content of 28%, DMD *in sacco* of 86%. They also reported liveweight gains of 0.7 kg/hd when *Sesbania* was grazed with signal grass compared with 0.4 kg/hd on fertilised signal grass alone

Ahn *et al.* (1997) found that oven drying leaves of *Calliandra calothyrsus* and *Gliricidia sepium* improved their nutritional value when used as a feed supplement for sheep. The DMD (g/g) of *Calliandra* was 0.363 (fresh), 0.59 (dried) and *Gliricidia* was 0.423 (fresh), 0.605 (dried). Karda *et al.* (1998) reported that oven-dried leaves of *Gliricidia sepium* were unpalatable to sheep and goats compared with *Calliandra calothyrsus*, *Albizia chinensis* and *Leucaena leucocephala*. Both sheep and goats preferred *Leucaena*, having the highest rate of intake of the leaves (Table 5.4).

Table 5.4. Intake rates (g DM/min) of *Albizia*, *Calliandra*, *Gliricidia* and *Leucaena* leaves when fed to sheep and goats (from Karda *et al.* 1998).

Species	Intake rate (g DM/min)	
	Sheep	Goats
<i>Albizia</i>	6.35	7.78
<i>Calliandra</i>	4.86	7.41
<i>Gliricidia</i>	-1.17	1.21
<i>Leucaena</i>	12.13	13.37

Burrows and Prinsen (1992) compared the growth and palatability to cattle of *Leucaena leucocephala* cv. Peru with 8 Australian trees and shrubs (*Acacia aneura*, *A. holosericea*, *A. pendula*, *A. salicina*, *A. saligna*, *Albizia lebbbeck*, *Casuarina cristata*, *C. cunninghamiana*). The most palatable species was *Leucaena leucocephala*, closely followed by *Albizia lebbbeck*, *A. pendula* and *A. holosericea* were not touched.

Gutteridge (1997) reported on the productivity of *Tipuana tipu* under three cutting regimes in Redland Bay, southeast Queensland. The 12 weekly cutting regime produced a higher total leaf yield (4.02 t/ha/yr) than the 6 weekly (2.44 t/ha/yr) or 8 weekly (2.97 t/ha/yr) cuttings. Nitrogen content ranged from 4.0-4.8%. Gutteridge (1999) studied the productivity of three tree legumes (*Albizia chinensis*, *Leucaena leucocephala* K636, *Tipuana tipu*) grazed by cattle, and grown on poorly-drained acid soils in south east Queensland. *Albizia* had the highest yield of edible dry matter, a high survival rate and moderate liveweight gains of 0.45kg/hd/d compared with *Leucaena leucocephala* with low productivity but the highest liveweight gains in first 280 days. *Tipuana tipu* had a low survival rate, the lowest liveweight gains and the lowest palatability (Table 5.5).

Table 5.5. Edible yield (kg/ha) of three tree legumes and liveweight gain (kg/hd/d) of steers grazing tree legumes in southeast Queensland (from Gutteridge 1999).

Species	Edible Dry Matter Yield (kg/ha)			Liveweight gain (kg/hd/d)		
	May 1994	May 1995	Feb 1996	May-Nov 1994	Jan-May 1995	May-Nov 1996
				(160 d)	(120 d)	(167 d)
<i>Albizia chinensis</i>	885	802	1220	0.51	0.54	0.30
<i>Tipuana tipu</i>	295	121	529	0.42	0.35	0.19
<i>Leucaena leucocephala</i>	610	63	370	0.44	0.6	0.17

Lindeque *et al.* (1999) evaluated 11 fodder trees and shrubs for adaptation to South African conditions, and potential production of protein rich forage and fuelwood. *Atriplex nummularia*, *Cassia sturtii*, *Chamaecytisus proliferus*, *Cytisus maderiensis*, *Leucaena esculenta-paniculata*, *L. leucocephala*, *L. pulverulenta*, *Teline stenopetala* showed potential as forage species and were considered to warrant further investigation. Yield potential and nutritive value of these species is shown in Table 5.6.

Table 5.6. Fodder yield (t DM/ha) and average nutritive value of leaf material over the growing season.

Species	DM Yield t/ha	DMD <i>in vitro</i>	CP	ADF	NDF	Lignin
<i>Atriplex nummularia</i>	3.4-9.8	71.5	20	20.5	41.2	15
<i>Cassia sturtii</i>	3.7					
<i>Chamaecytisus proliferus</i>	11.7-23	64.9	19.6	23.7	39.9	10.5
<i>Cytisus maderiensis</i>	6.8-29.7	68.1	19.3	23.3	38.3	9.2
<i>Leucaena esculenta-paniculata</i>	22-42.3	42.4	18	29.8	42.1	15.3
<i>L. leucocephala</i>	8-34.9	49.1	21.6	35.5	40.8	15.3
<i>L. pulverulenta</i>	9.3-28.1	38.9	16.7	31.5	47.1	17.7
<i>Teline stenopetala</i>	7.7-8.0	55.1	20.2	24	39.9	13.1

Lowry (1992) studied flowers from the cocky apple tree (*Planchonia careya*), found in subcoastal woodlands in the Kimberleys, Northern Territory and Queensland. Flower fall occurs in the early morning for about 6 weeks in the dry season (October-November) and is highly palatable and sought after by cattle. Lowry (1995) also examined the feed quality of natural leaf fall from 27 deciduous tree species in Australian tropical woodlands as a potential source of dry season roughage. Some leaves were of higher quality than grass available at the time of leaf fall. The dry matter digestibility of leaf material in the rumen of the trees ranged from 29.2% to 89% compared with the grasses, ranging from 24.8% to 39.7%.

Miller *et al.* (1997) found that Polyethylene glycol (PEG) enhanced digestion and liveweight gain in sheep fed mulga (*Acacia aneura*). They reported that sheep consuming a predominantly mulga diet under paddock conditions showed significant improvements in liveweight gain (100%) and clean wool growth (9%) when fed PEG at a rate of 12g/day compared to unsupplemented flock mates.

Owino (1996) observed variability in biomass production between half-sib progeny of *Calliandra calothyrsus* in response to different cutting regimes in an alley cropping system. He concluded that there are good potential gains from selection at the family level for response to that management regime, but only after 6 cutting cycles. The range in leaf and wood biomass yield at each harvest are shown in Table 5.7.

Table 5.7 Variation in biomass production of 12 half-sib families of *Calliandra calothyrsus* (from Owino 1996).

Plant fraction	Biomass yield per harvest (kg)						
	April 1993	August 1993	November 1993	March 1994	July 1994	November 1994	March 1995
Leaf	22-42	28-72	37-55	28-60	28-47	40-75	59-107
Wood	10-30	35-70	18-38	17-40	19-41	26-61	49-100

Peoples *et al.* (1996) evaluated the ability of *Calliandra calothyrsus* to fix N, using several alternative measurement techniques, and compared its N₂-fixing ability with a widely grown multipurpose shrub legume, *Gliricidia sepium*, and a fast growing shorter lived species, *Cadariocalyx gyroides*. *Calliandra calothyrsus* had a reduced reliance upon N₂-fixation for the first 65 weeks after establishment which appeared related to an efficient capacity to scavenge soil mineral N. Subsequent measurements (weeks 65 and 117) indicated that *Calliandra* achieved similar levels of N₂ fixation to the other shrub legumes.

5.2.3 Potential weed species

The honey locust tree (*Gleditsia triacanthos*), originally promoted as a garden ornamental and high protein fodder tree (14.3-17.3%), is now a serious weed (Csurhes and Kriticos 1994). It was declared a noxious weed in Queensland in 1993 and it has the potential to spread over much of southeast Australia. Past, present and future research of invasive shrubs in Australian tropical rangelands has recently been reviewed (Grice and Brown 1999). They identified the following species as serious threats in northern Australia: rubber vine (*Cryptostegia grandiflora*), prickly acacia (*Acacia nilotica*), mesquites (*Prosopis* spp.), Indian jujube (*Ziziphus mauritiana*), giant sensitive plant (*Mimosa pigra*) and parkinsonia (*Parkinsonia aculeata*).

Low (1997) documented cases where exotic tropical grasses and legumes introduced for sown pastures have become serious environmental weeds. He cautions against introduction of new exotic species and suggests research should be directed towards developing native plants as a grazing resource. "At least with native species, there is little risk of releasing a new weed, a potential concern with exotic species once they become widespread, eg. *Eragrostis curvula*, *Stylosanthes scabra* and *Leucaena*." (Silcock and Johnston 1993, cited in Low 1997).

5.3 Annotated bibliography, miscellaneous fodder species in Australia, 1991-2001

Source and scope
Ahn <i>et al.</i> 1997 <i>Calliandra calothyrsus</i> ; <i>Gliricidia sepium</i> ; ex-central America; anti-nutritional factors; DMD <i>Calliandra</i> 36.3% (fresh) 59% (dried); <i>Gliricidia</i> 42.3% (fresh), 60.5% (dried).
Bastin 1998 Important forages of the Alice Springs District
Bird 1998 <i>Review</i> Effects of windbreaks on pastures
Cowan <i>et al.</i> 1993 Qld; milk production from various species
Csurhes and Kriticos 1994 <i>Gleditsia triacanthos</i> ; exotic fodder tree gone wild in SE Qld, NSW; declared noxious in Qld in 1993
Doran and Turnbull 1997 Australian tree and shrub species with potential value for fodder; 47 species are used or have the potential to be used for fodder; 20 species has limited value for fodder

Source and scope
Fox 1995 <i>Review</i> <i>Acacia saligna</i>
Grice and Brown 1999 <i>Review</i> Effective control measures for exotic weeds in Australian rangelands
Gutteridge and Shelton 1995 <i>Sesbania sesban</i> ; shrub or small tree to 6 m in height; widely used as a forage in ‘cut and carry’ livestock feeding systems in south Asia and Africa; DM yield > <i>Leucaena leucocephala</i> cv. Cunningham (Gutteridge & Shelton 1991); <i>in sacco</i> DMD 86% (Ahn <i>et al.</i> 1989); Liveweight gains of 0.7 kg/hd/d for young growing cattle (Gutteridge & Shelton 1991)
Gutteridge 1997 <i>Tipuana tipu</i> ; productivity under 3 cutting regimes in Redland Bay, SE Qld
Gutteridge 1999 <i>Albizia chinensis</i> , <i>Leucaena leucocephala</i> , <i>Tipuana tipu</i> EDM
Hacker 1993 Queensland; potential of <i>Cajanus</i> , <i>Desmodium</i> , <i>Glycine</i> , <i>Psoralea</i> , <i>Sesbania</i> , <i>Vigna</i> and others as forage species
Hawley and Lowe 1994 SE Queensland
Henschke 1997 Kangaroo Island; management options for saline areas; <i>Acacia saligna</i> , <i>Melaleuca uncinata</i> , <i>Phalaris</i> , cocksfoot, Lucerne, pucinellia, salt bush
Jackson and Ash 1998 Queensland; tree-grass relationships; <i>Eucalyptus</i> spp. and <i>Corymbia erythrophloia</i> ; perennial grasses; pasture yield and quality
Jones and Jones 1999 Grazing management in the tropics
Knight <i>et al.</i> 1997 Murray-Darling Basin; alley farming guide
Lake 1997 Dual purpose trees in agroforestry
Lindeque <i>et al.</i> 1999 Evaluating fodder shrubs in South Africa
Low 1997 Weeds; <i>Acacia nilotica</i> (prickly acacia); <i>Prosopis</i> spp (mesquite)
Lowry 1992 <i>Planchonia careya</i> ; cocky apple; common small tree of open tropical woodland; possible valuable supplement for cattle grazing some native pastures; rate of disappearance of DM <i>in sacco</i> ~54% in 24 h; distribution map;
Lowry 1995 27 tree species; DMD 29-89%
Milthorpe <i>et al.</i> 2001 Report evaluating the existing and potential use of 15 chenopod shrubs as forage supplements during drought
Miller <i>et al.</i> 1997 <i>Acacia aneura</i>
Otsyina <i>et al.</i> 1999 Evaluation of 16 semi-arid forage trees and shrubs
Owino 1996 <i>Calliandra calothyrsus</i> ; differential adaptedness to frequent cutting after 6 cutting cycles over 2 years (Kenya)
Peoples <i>et al.</i> 1996 <i>Calliandra calothyrsus</i> , <i>Codariocalyx gyroides</i> , <i>Gliricidia sepium</i> ; N ₂ fixation;
Race <i>et al.</i> 1999 Potential viability of a carob agroforestry industry in the Murray Valley region; whole pods useful as a fodder supplement
Richmond and Ghisalberti Emilio 1994 <i>Review</i> <i>Eremophila</i> species (83); cultural, food, medicinal uses and potential applications; 16 species identified as either currently used or potential for fodder; common names/locations

Source and scope
Richmond and Ghisalberti 1995 <i>Review</i> <i>Myoporum</i> species (31); cultural, food, medicinal uses and potential applications; some useful as fodder plants (<i>M. platycarpum</i> , <i>M. kermadecense</i>); many others toxic to animals
Thomson <i>et al.</i> 1994 <i>Acacia</i> ; 125 species; subtropical dry zone; summary of potentially suitable <i>Acacias</i> for fodder eg. <i>A. aneura</i> , <i>A. estrophiolata</i> , <i>A. pendula</i> , <i>A. georginae</i> , <i>A. kempeana</i> etc

5.4 Summary of perceived R D&E needs

Two features of new or prospective species that deserve attention are the weed potential of exotics and the forage value of endemics. The first is important as many of the fast growing exotic trees and shrubs introduced for their potential commercial value as animal feed have since become serious environmental weeds. The invasive woody weed Scotch Broom (*Cytisus scoparius*) in southeastern Australia is an example. This is difficult if not impossible to avoid, given that the key selection criteria for a successful forage plant and invasive weeds are very similar – rapid early growth and adaptation to a wide variety of environments. The history of escapes from forage selection programs presents a strong argument for not importing any more exotic trees and shrubs (Low 1997).

If the search for new species is to shift to endemics, more attention needs to be paid to the edible dry matter production and *in vivo* digestibility of candidate species than has occurred in the past. Ever since Maiden's 1915 review of the commercial prospects of endemic plants there has been a tendency to assume that evidence that a tree or shrub is eaten in the wild is adequate proof of its commercial potential under cultivation. The fact that no endemic species has achieved any significant level of adoption as a cultivated forage species despite the fact that many promising candidates have been put forward, particularly amongst the genus *Acacia*, emphasizes the importance of protocols for evaluating new forage species (Mochrie 1981). No Australian endemic species has yet been shown to meet the basic requirements of producing in excess of 1t/ha/yr of edible dry matter with a dry matter digestibility of greater than 55% under cultivation.

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6. CONCLUSIONS

This study found that there are currently some 200 000 ha of cultivated forage trees and shrubs in Australia, occupying some 0.2% of the countries arable land. Virtually all of this area is planted to three species, *Leucaena* (*Leucaena leucocephala*), *Tagasaste* (*Chamaecytisus proliferus*) and *Saltbush* (*Atriplex* spp.). Of this total area, an estimated 100 000 ha is planted to *Tagasaste* in south western and southern Australia, 50 000 ha to *Leucaena* in the sub-tropical north east, and 50 000 ha to various *Atriplex* species on salt affected land in Western Australia, South Australia, Victoria and New South Wales. In addition to this, the study identified a small area, estimated to be less than 10 000 ha, planted to other species, predominantly *Acacia saligna*.

The area planted to the three main forage shrubs, *Leucaena*, *Tagasaste* and *Saltbush*, was found to have increased six-fold since the previous national survey in 1991. While the review found that 101 tree species from 33 genera were identified in the literature as having potential for forage production in Australia over the last ten years, no new species achieved commercial levels of adoption during that period.

This section reviews the changes that have occurred in the use of forage trees and shrubs over the last ten years, the R D&E needs as perceived by the industry, and the desirability and scope of a national forage tree R&D program.

6.1 Changes in the use of forage trees in Australia, 1991-2001

The six-fold increase in the area planted to the three major forage trees and shrubs ranged from a ten-fold increase in areas planted to *Tagasaste*, an eight-fold increase in the area of *Saltbush* to a three-fold increase in the area planted to *Leucaena*. The area of *Tagasaste* is estimated to have risen from 10 000 ha to 100 000 ha, the area established to *Saltbush* from 6000 ha to 40 000 ha and the area planted to *Leucaena* from 17 000 to 50 000. Figure 6.1 shows these changes in area compared to their predicted potential commercial extent. The predicted potential area is an estimate based on 20% of the total area of land identified as suitable on the basis of soil type and climate. This proportion of one fifth of the total area of suitable land has been used to reflect the proportion of suitable soils that are arable, and realistic adoption rates given the existence of more profitable alternate land uses such as herbaceous pastures, and the capital costs involved in the transition to an agroforestry system.

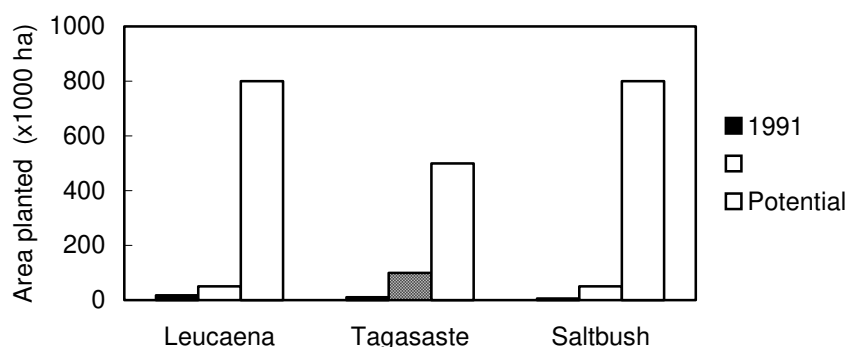


Figure 6.1. The estimated area planted to *Leucaena*, *Tagasaste* and *Saltbush* in Australia in 1991 and 2001 and their predicted commercial potential.

It must be emphasized that the areas illustrated in Figure 6.1 are estimates, with the potential area of each species being at best an educated guess given that the constraints to adoption and economic competitiveness of alternative land uses are poorly understood.

The estimate of the area currently planted to *Leucaena* is taken from Shelton (1998). The increase from 3000 ha in 1985 to 17 000 ha in 1991 and 50 000 ha at present follows over 50 years of research by state and commonwealth organizations, representing an investment of several million dollars.

Commercial plantings began in earnest following a significant break through in the early 1980's with the introduction of rumen bacteria capable of breaking down a toxic by-product of *Leucaena* digestion in cattle. The subsequent arrival of the psyllid beetle then saw a retraction from high rainfall coastal areas, but a steady increase in plantings in central and northern Queensland. The current level of adoption is considered low by researchers and extension workers. This is attributed to a combination of the following factors; a low level of establishment skills amongst graziers, a high rate of establishment failure due to weeds and insects, low recognition by landholders of the economic benefits, the high cost of establishment, the belief that there are still hazards associated with grazing *Leucaena* and low returns from beef production relative to grain

The estimate of the area currently planted to tagasaste is based partly on a postal survey conducted in 1994 of landholders in the West Midlands region. This coastal region, lying between Perth and Geraldton and consisting predominantly of sand plain soils, is where the rapid expansion of tagasaste occurred in the early 1990's. That survey indicated that 50 000 ha had been planted and this has since been estimated to have doubled on the basis of seed sales and producer inquiries to Agriculture WA (Geoff Tudor pers. comm.).

The rapid increase in the area of tagasaste followed a concerted eight year research effort (1986-1994) which involved a total investment of some two million dollars. It was initiated by a private company with interests in the finance and banking sector and landholdings that included a 250 ha experimental planting of tagasaste. The partnership between this company, Martindale Pty. Ltd., and The University of WA was stimulated by the 150% tax rebate on R&D investment existing at the time. While research had been conducted into the value of tagasaste since the 1950's by the state Department of Agriculture, there was no significant adoption until the large scale, on-farm cattle grazing experiments set up as part of the Martindale Research Project quantified the economic benefits and demonstrated a practical management system. Despite the dramatic improvements in long term productivity demonstrated by that research (up to eight times the carrying capacity of annual pastures on deep infertile sands) the cost of transition to a tree-based grazing system with its high infrastructure investment in fencing, watering points, pruning and management are seen by landholders, researchers, and extension workers as the main constraints to adoption.

The area currently planted to saltbush is based on the estimate by Barton and Barrett-Lennard (1995), in which the authors estimated that 30 000 ha had been planted in Western Australia and up to 10 000 in eastern Australia. The area of land suitable for saltbush is expected to grow significantly over the next few decades and the potential area shown in Figure 6.1 is based on the total area of salt affected land in Australia reaching 12 million ha, with one third of that being suited to saltbush. The estimate of one third of all salt affected land being suited to saltbush is based on an estimate prepared for the Western Australian Sate Salinity Council (Barrett-Lennard pers. com.). This concluded that one third of the total area would be unsuitable due to frequent inundation and waterlogging while a further third would be only mildly salt affected and therefore likely to be more productive under less salt-tolerant herbaceous pasture plants.

6.2 The industry perceptions of R D&E needs

Given the significant potential for expansion in the area of cultivated forage trees and shrubs identified above, this section reviews the R D&E needs for each of the three main species as a guide to future R&D investment.

Leucaena: Jones (1994b) that there is no justification for further research to document the value of *Leucaena* for animal production. He suggests instead that more work is required to demonstrate its value on-farm, particularly as its optimum use varies depending on the country, region and farm under consideration. In other words, the present need is for site-specific on-farm demonstration.

One systematic attempt to identify future R&D needs was a survey by Shelton (1998) of participants at a workshop on *Leucaena* farming systems (see Table 2.1). Three of the top four priorities involved genetic improvement, while four of the top ten involved on-farm research, including large scale demonstration of grazing management, economic analyses of *Leucaena* grazing systems and on-farm testing of new taxa.

In contrast with the views of this predominantly research oriented group, producers (eg. Larsen in Larsen *et al.* 1998) and extension workers (eg. Wildin 1994, Middleton *et al.* 1995 and Middleton and Chamberlain in Larsen *et al.* 1998) considered the highest priority was to overcome the perception that establishment is costly and difficult by improving the quality and delivery of information. Several workers have identified the failure of past extension efforts to clearly articulate the benefits of *Leucaena* to producers. Larsen *et al.* (1998) suggest the best method of increasing adoption rates is to increase the skill level of potential users. A further obstacle they identified is that *Leucaena* represents a relatively small increase in production compared to the transition from native to sown herbaceous pasture, a point closely related to the argument put forward by t'Mannetje (1997) that the perception of producers may be that their current pasture systems are already highly productive, and the additional gains from *Leucaena* are not justified given the expense and risk involved in establishment and the changed management regime.

Tagasaste: At workshops held to review tagasaste R D&E in 1995 and 2000, the R D&E priorities identified by researchers, extension workers and producers were to overcome the constraints to animal production believed to be due to anti-nutritive factors, genetic improvement, better integration of tagasaste into farming systems and alternative financing arrangements.

Cattle production from tagasaste in WA is currently characterized by a distinct drop in weight gain during autumn from the weight gains achievable during winter, spring and early summer. Despite the eight fold increase in carrying capacity achieved with tagasaste compared to annual pastures, animal production researchers have identified the elimination of anti-nutritive factors as a high priority and focused on identifying the compounds responsible. This has involved examination of a wide range of secondary compounds including volatiles as possible inhibitors of intake and rumen function, monitoring levels of phenolics and their impact on rumen function, studying seasonal variation in animal intake and changes with supplementation and identifying the effect of energy and protein supplementation.

In terms of genetic improvement, the tagasaste population in WA is derived from a sample of seed sent to Australia from Kew Gardens in 1879. The population therefore has a very narrow genetic base. Leakey (1996) in a review of Tagasaste research suggested that the problems currently experienced with animal production could well be overcome through a breeding program, with the critical steps being to introduce germplasm and rhizobia from overseas collections, establish this material at representative sites to examine genotype by environment interactions, develop skills in clonal propagation and produce clonal types with high edible biomass production and palatability, define breeding objectives based on current commercial and biological information and study the reproductive biology of Tagasaste to achieve the most cost effective means of genetic improvement.

There may also be value in developing a 'competition ideotype' for use in integrated systems where Tagasaste may have a valuable role at lower densities to increase water use and lower wind speed as well as provide feed.

A major constraint to adoption that has been identified by the industry is the start up cost of tree-based grazing systems and the lead time between expenditure and first returns. One recommendation is that alternative financing arrangements need to be examined as the commercial lending policy of banks is geared towards annual agricultural production and is not able to accommodate longer term investment such as forage shrubs. Studies are also needed to establish the optimum plantation phase before replacement by a new cultivar could be justified.

Saltbush: Research in the last decade has seen the emphasis switch from saltbush as a valuable forage species to one that has a primary role of improving a hostile environment to the benefit of more valuable understorey pasture species (Barrett-Lennard and Ewing 1998). This places the emphasis on identifying new genera, species and accessions of shrubs on the basis of their ability to grow in very saline soils, to lower saline water tables and even to resist grazing, rather than selecting plants for their high forage qualities. This fundamental shift in ideotype from a browse plant toward an environmental ameliorant warrants a re-assessment of existing germplasm collections. Of particular value in this regard is the collection of some 500 accessions of salt tolerant plants assembled by CV Malcolm in the 1980's, currently held by Agriculture Western Australia. The selection criteria for this re-assessment might include characteristics such as rapid growth, tolerance to salinity and periods of inundation, large leaf area to maximize water use and grazing tolerance.

6.3 The potential role of a national forage tree R&D selection program

The final term of reference for this study was to assess the desirability, feasibility, scope and cost of a national fodder tree selection R&D program. Three broad scenarios exist for the wider use of forage trees and shrubs in Australia. These are:

1. Development of new exotic species to the point of commercial adoption.
2. Development of new endemic species to the point of commercial adoption.
3. Further development and adoption of species currently in commercial use.

6.3.1 Development of new exotic species

Of these three scenarios, the introduction of new exotic species is rapidly becoming the least acceptable option due to the increasing awareness of the cost and environmental impact of woody weeds in Australia. Silcock and Johnston (1993) argue that “At least with native species, there is little risk of releasing a new weed, a potential concern with exotic species once they become widespread.” The history of plant introductions into Australia indicates that one serious or noxious weed has been introduced for every year since European settlement (Low 1999). Fast growing exotic legumes such as *Prosopis* spp., *Acacia nilotica*, *Cytisus scoparia* and *Gleditsia tricanthos* have become some of the most serious environmental weeds. *Leucaena* and *Tagasaste* are already regarded as serious environmental weeds in some environments and conflict is likely to arise between biological control programs for woody weeds closely related to these commercial species (eg, *Cytisus scoparia* (Scotch Broom) and *Tagasaste*). While the commercial value of *Leucaena* and *Tagasaste* can be well argued, it would be difficult to put a case for further introductions of woody forage plants given our current understanding of the long term environmental costs.

The inadvertent introduction of a new woody weed would be difficult if not impossible to avoid in any plant introduction program, given that some of the key selection criteria for a successful forage plant - rapid early growth and adaptation to a wide variety of environments - are essentially the same as the characteristics of an invasive weeds. It has also been shown that it is extremely difficult to predict whether a species is likely to become invasive, as some have remained relatively dormant for up to one hundred years before posing any serious threat (Low 1999). The history of escapes from forage selection programs in the past presents a strong argument for discouraging the introduction of any more exotic trees and shrubs (Low 1997, 1999).

6.3.2 Development of new endemic species

Ever since Maiden's (1915) review of the commercial prospects of Australia's endemic plants, many species have been advocated for development as forage plants, particularly among the *Acacia* and *Atriplex* genera. This advocacy has been largely based on the observation that native trees and shrubs of the arid zone are valuable sources of feed for sheep and cattle during drought periods. However, evidence that a tree or shrub is eaten in the wild is not adequate proof of its commercial potential under cultivation. If the search for new species is to shift to endemics rather than exotics, more attention needs to be paid to the edible dry matter production and *in vivo* digestibility of candidate species than has occurred in the past. The fact that no endemic species has achieved any significant level of adoption as a cultivated forage plant despite the fact that many promising candidates have been put forward emphasizes the importance of protocols for evaluating new forage species (Mochrie 1981). No Australian endemic species has yet been shown to meet the basic requirements of a commercial forage plant of producing in excess of 1t/ha/yr of edible dry matter under cultivation with a dry matter digestibility of greater than 55%. For this reason, investment in the development of endemic species should only be made where there is preliminary quantitative data to demonstrate they reach these thresholds before investment is made in plant selection, breeding and grazing experiments.

6.3.3 Further development and adoption of existing species

The above constraints to developing new commercial forage species from wild plants suggest the third option, expansion in the area planted to the current commercial species, as the most cost effective and

least environmentally risky means of increasing the use of forage trees and shrubs in Australia. The potential area suited to cultivation of the three main forage trees and shrubs on the basis of soil type and climate alone is estimated to be 9.3 million ha, 1.3 million ha for Tagasaste, 4 million ha for Leucaena and 4 million ha for saltbush. Given the fact that these areas will be subject to competing land uses and that there are constraints to the adoption of agroforestry systems that generate products solely for on-farm use, a 20% adoption rate is considered to be an optimistic target. This provides an upper estimate of some 2 million hectares of these forage trees and shrubs, representing a ten-fold increase in the area currently planted.

Three areas of research need that emerged from the review of main commercial species were genetic improvement, on-farm demonstration of benefits and alternative financing arrangements.

Genetic improvement

Significant improvements are likely to result from the establishment of dedicated breeding programs for Tagasaste and Leucaena. A feature of the history of these two forage species in Australia has been that development has been largely driven by the disciplines of agronomy and animal husbandry, with genetics arriving much later on the scene. In the case of Tagasaste, the industry relies on an extremely narrow genetic base, with all commercial plantings being derived from a few naturalized lines introduced over 100 years ago. Given that germplasm strategies were very poor in the 1870's, it is not possible to know what subset of the variation within Tagasaste exists in Australia without targeted research. For Leucaena the situation is somewhat better, with a concerted effort to examine genetic variation within the genus underway, albeit with a limited number of accessions as the starting point. There are good prospects for improvement through breeding programs given that both species have a very short generation time compared with most commercial tree crops, they are prolific seeders, exhibit a high degree of phenotypic variation and are capable of selfing and therefore high levels of heritability.

In a review of the potential for further development of the Tagasaste industry, Barbour (1996) observed that forestry breeding programs had produced far superior results to naturalized lines wherever they had been introduced throughout the world. Examples are *Eucalyptus grandis* in South Africa, Maritime Pine (*Pinus pinaster*) and Monterey Pine (*Pinus radiata*) in Australia and *E. globulus* in Portugal and Australia. Breeding programs also represent the best insurance against diseases and pests which are likely to be a constant threat to these industries as has been seen in the case of the Leucaena psyllid.

Barbour (1996) also emphasized the importance of having a high level of initial diversity and clear breeding objectives. Experience in forestry breeding programs suggests in the order of 300 breeding selections from 1000 accessions is the level of diversity required for a successful breeding program. A wide variety of seedling material taken from different sources and randomized as single tree plots is likely to give a significant improvement through out-crossing alone without selection. Barbour (1996) cited the example of *E. globulus* where a 40% improvement resulted from the first cross, with a further 12% improvement from subsequent selection.

While breeding objectives for forage trees will obviously differ from those of forestry species, similar principles will apply, such as selection for optimal growth rate, root architecture, dry matter production, ease of harvest and ease of processing (forage quality and digestibility). An important component of clear breeding objectives will be the ability to attribute economic weightings to each desirable characteristic, so that the value in \$/ha of each unit of improvement in each objective can be determined, and the return on investment for improvement in each characteristic is known to the breeders.

Leakey (1996) suggested that tree improvement for agroforestry may require defining several ideotypes, depending on the land use systems involved. He suggested the concept of a crop ideotype for plantation species where resource use efficiency, harvest index and quality would be the primary objectives, and a competition ideotype for more closely integrated agroforestry systems where growth rate, coppicing ability, time to high leaf area index, phenology and canopy morphology become increasingly important.

Leakey (1996) also advocated the use of the simple 'poly-propagator' clonal technique pioneered by the Institute of Terrestrial Ecology for use in Africa that uses readily available materials to construct a high humidity environment for striking cuttings. He suggested that improvement in

desirable characteristics of up to 100% are possible with clonal methods compared to 30-40% from breeding approaches given that in out-breeding trees, there can be up to an 8-9 fold variation between clones.

To date the diversity used in selection of superior lines of both *Tagasaste* and *Leucaena* has been low relative to that advocated by Barbour (1966) and commonly used in forestry and horticulture. Investment in dedicated breeding programs for both species is recommended as the most cost effective way of overcoming the biological constraints to their wider use, including reduced levels of anti-nutritive compounds, adaptation to a wider range of soil types, and resistance to disease, insects and frost.

On-farm demonstration of economic benefits

A consistent theme that runs through the comments of extension workers and researchers is that landholders do not fully appreciate the well established commercial benefits of both *Leucaena* and *Tagasaste* (eg, Larsen *et al.* 1998, Middleton 1995, Wiley 1994).

A key message from this study is the need for researchers and landowners to compare the amount of feed forage trees and shrubs provide with the amount available from pasture or stubble. Because of the small proportion of their total growth that is edible, the relatively high cost of establishment, and the delay until they are fully productive, fodder trees need to demonstrate a substantial increase over conventional feed sources before they represent commercially viable alternatives to conventional feed sources.

The majority of the research effort to date has gone into animal production experiments that have established the nutritional value of the plants to grazing animals. The next logical step in the sequence to adoption is to establish in the mind of landholders the economic benefits to them. This has only rarely been done effectively. One means of overcoming this would be to support on-farm demonstrations specifically aimed at quantifying the economic benefits to the landholder of animal production from established stands of forage trees and shrubs. These would need to be regionally specific, given that optimum use varies with the country, region, farm and class of grazing animal.

Alternative financing arrangements

The major non-biological constraint to the adoption of forage trees and shrubs are the establishment cost (seeding, pest control, fencing, provision of watering points, pruning and management) and the lead time between expenditure and first returns. Alternative financing arrangements need to be examined as the commercial lending policy of banks is geared towards annual agricultural production, and is therefore not able to accommodate longer term agroforestry investment. Share-farming and other partnership investments are not attractive as the direct products have on-farm value only. Areas that warrant investigation are financing based on the prospective markets in carbon and salinity credits.

6.4 Recommendations

Forage tree development R&D program: It is recommended that the most cost effective means of achieving an increase in the use of forage trees and shrubs for animal production in Australia would be to invest in further development of the two species that have demonstrated their commercial acceptance (*Leucaena* and *Tagasaste*, Recommendations 1-4) rather than establishing a national fodder tree selection program as suggested in the terms of reference. It is further recommended that support for research into the development of other forage trees be restricted to endemic species where there are preliminary data to indicate their potential as cultivated forages (Recommendation 5), and that investment in selection and development of new exotic species be specifically avoided due to the high risks associated with the introduction of woody weeds (Recommendation 6).

Recommendation 1. Genetic improvement of *Leucaena* and *Tagasaste*: It is recommended that JVAP invest in breeding programs for *Leucaena* and *Tagasaste* to address levels of anti-nutritive compounds, expanding their adaptation to a wider range of soil types, and improving resistance to

disease, insects and frost. This is seen as the most cost effective way of overcoming the current biological constraints to their wider use.

Recommendation 2. On-farm demonstration of economic benefits: It is recommended that JVAP support on-farm demonstrations specifically aimed at quantifying the economic benefits to the landholder of animal production from established stands of *Leucaena* and *Tagasaste*. These would need to be regionally specific, given that optimum use varies with the region, farm and class of grazing animal.

Recommendation 3. Exploring alternative financing arrangements: It is recommended that JVAP support research into alternative financing arrangements given that the commercial lending policy of banks is geared towards annual agricultural production, and is therefore not able to accommodate longer-term agroforestry investment. As the direct products have on-farm value only, alternatives to share-farming and other partnership investments need to be developed, such as the applicability of financing based on proposed carbon, salinity and biodiversity credits to forage trees.

Recommendation 4. Managing declining soil pH under stands of forage tree legumes. Research to determine the extent of declining soil pH under stands of *Leucaena* and *Tagasaste* and the development of strategies to ameliorate this problem where appropriate.

Recommendation 5. Development of endemic forage tree and shrub species: It is strongly recommended that JVAP only invest in the development of endemic or naturalized trees and shrubs as new forage plants where there is preliminary evidence that a) the candidate tree or shrub species are capable of producing in excess of 1t/ha/yr of edible dry matter under cultivation with a dry matter digestibility of greater than 55% or b) the grazing system as a whole (i.e. woody overstorey plus herbaceous understorey) is capable of producing in excess of 1t/ha/yr of edible dry matter under cultivation with a dry matter digestibility of greater than 55% and this exceeds the forage production available from conventional sources in times of seasonal feed shortage. These conditions are based on evidence that while endemic forage trees and shrub species can be important sources of drought feed under extensive grazing conditions and are frequently observed to be consumed by stock, evidence from forage evaluation and grazing studies suggests that where they do not satisfy these minimum conditions they are very unlikely to be of sufficient value for animal production to warrant investment in their broad acre commercial cultivation.

Recommendation 6. Discourage the introduction of new exotic woody forage species: The history of plant introduction into Australia for the development of new forage plants suggests the risks of inadvertently introducing new woody weeds are higher than the possible benefits to society through invasion of grazing lands and threats to biodiversity

For the purposes of funding priorities, these recommendations are presented in three distinct groups; recommendation 6 represents a policy recommendation across the JVAP program and is aimed at avoiding support for this particular area of research; recommendations 1 to 4 pertain to *Leucaena* and *Tagasaste* and are presented in their perceived order of priority based on surveys and assessments of producers, researchers and extension workers carried out within those industries; recommendation 5 relates to endemic species with commercial potential and where the specified conditions are met, is considered to rank equally with recommendation 1.

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