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Perennial pastures for Western Australia

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Compiled by Geoff Moore, Paul Sanford and Tim Wiley
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This book is dedicated to the memory of Ms Carmen Saunders, a pasture research officer with the Department of Agriculture, Western Australia based in Esperance. Carmen helped to renew interest in perennial pastures on the south coast and is especially remembered for looking outside the square at a diverse range of species. She was a major author of 'Perennial pastures for areas receiving less than 800 mm annual rainfall' (DAWA Bulletin 4253). Carmen was tragically killed in a car accident in December 1996.

Foreword

This publication is an important and well executed compilation of knowledge and analysis of the potential for, and use of, perennial pastures in Western Australia. I feel certain that it will become an extremely valuable resource for farmers and their advisers, as well as a point of general reference for researchers and students.

At the same time the Bulletin provides an insight into the continuing evolution of farming systems in the State. A decade ago there was very limited farmer interest in perennial pastures, very little commercial activity and almost no research which might have generated change.

The shift that has taken place in the last ten years is a testimony to many of the things that are good about agricultural innovation in Western Australia. Firstly, there has been a ground swell of farmer interest in perennials, with a range of regional and industry drivers. Farmers have been prepared to develop new ideas and test them on their farms, and many have also been happy to share ideas and initiate groups with a special interest in perennials. Organisations such as the WA Lucerne Growers, Evergreen Farming and the Saltland Pastures Association have been extremely active in creating awareness of opportunities and sharing knowledge.

Individual researchers, their organisations and funders have participated actively in the discovery process, in some cases responding to the opportunities and enthusiasm of farmers and in others developing lateral ideas and approaches that will open up further opportunities.

Partnerships between farmers and researchers have been a feature of the decade of expanded interest in perennial pastures and laid the foundation for future developments.

The willingness of the key research development corporations (Meat and Livestock Australia, Australian Wool Innovation, Grains Research and Development Corporation and Rural Industries Research and Development Corporation) to support research and related technology transfer on perennial pastures has been noteworthy.

Another positive feature is the teamwork between the WA research providers, as evidenced by the representation of authors from DAFWA, CSIRO, UWA and Murdoch University, and the useful linkages to eastern States programs.
The presence of the CRC for Plant-based Management of Dryland Salinity, with its focus on perennial pastures, has assisted with State and national coordination of the research effort.

This Bulletin documents a period of sustained and important research on perennial pastures but it is clear that many questions remain unanswered. The commitment of the collaborators to combine and interpret their results is commendable.
The compilation and editing of this material is a major endeavour and those involved are to be congratulated.

Dr Mike Ewing
Deputy Chief Executive Officer
CRC for Plant-based Management of Dryland Salinity

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Funding from GRDC through the project 'Perennial pastures for cropping systems' (UWA 337) is gratefully acknowledged. The aim of this project was to identify potential new perennial legumes to complement lucerne in phase farming and to identify the role and potential for perennial grasses in WA.

A wide range of field trials with both new germplasm and existing cultivars of both perennial legumes and grasses was conducted across the agricultural region as part of this project. Many thanks to the Technical Officers: John Titterington, Brad Wintle and Kevin Foster who ably assisted with all aspects of the field work. The field trials would not have been possible without the assistance of the following landholders: B. & B. Bunker (Tenterden), K. Shackleton from Carpenter Agriculture, J. & B. Sprigg (Cranbrook), B. & R. Wood (Kendenup), A. Lewis (Narrogin), G. Baker (Baker's Hill), A. Hardie (Crossman), C. Moore (Dandaragan), D. Clarke (Lake Grace) and A. & P. Roberts (Dandaragan). Sue Dodimead provided the administrative support for the project through CLIMA. Many thanks to Dr Mike Ewing who was the project superviser, provided much valuable advice and has contributed the foreword.

The network of perennial grass and legume trials in WA under the auspices of the Salinity CRC-GRDC National field evaluation project (UWA 397) was also invaluable in developing the guidelines for where different species can be grown. More recently, the network of 'quantity and quality' trials (collaborative project between DAFWA and Evergreen-AWI) has provided data on the potential of a range of sub-tropical grasses in different regions. Thanks to Phil Barrett-Lennard, Tony Albertsen, Brianna Peake, George Woolston and Sarah Knight.

A special thank you to the following people. Peter Maloney (DAFWA Image Resource Centre) took many excellent photographs and prepared all of the photographs for publishing. The technical illustrations and figures were prepared by Rod Lewis. Dennis van Gool and Christine Easton (DAFWA) prepared the climate maps and the perennial zones map. Janet Paterson (Sci Scribe) edited the entire manuscript and made many improvements. Georgina Wilson (DAFWA) proof read the final draft. Sue Brierley (DAFWA Document Support Centre) formatted the manuscript. Jacqui Mallard (DAFWA) patiently coordinated the graphic design and printing.

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Geoff Moore
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1.1 Introduction – why perennial pastures?

Geoff Moore

There is a strong interest in perennial pastures due to the growing realisation that farming systems based solely on annual crops and pastures are not sustainable in many regions of south-western Australia. Environmental and management issues facing agriculture include: rising groundwater and the spread of salinity; herbicide resistant weeds; soil acidity and wind erosion. Perennial pastures offer a sustainable and profitable alternative in many areas.

Potential production benefits from perennial species include:

- out-of-season green feed
- increased carrying capacity due to improved seasonal distribution of feed and pasture use
- ability to reduce or replace supplementary feeding in autumn
- ability to increase production from land with a low carrying capacity
- ability to turn-off animals at target liveweights all year-round
- reduced wool faults and maintenance of wool fibre diameter and staple strength
- reduced fodder conservation
- increased winter feed
- opportunity to rest annual pasture paddocks after the break of the season.

Soil conservation benefits include:

- increased water use and reduced deep drainage to groundwater
- maintenance of plant cover in summer to reduce wind erosion
- increased perennial cover for waterways.

Stock grazing green feed all year-round – is this possible or simply a pipedream in Western Australia with its strongly Mediterranean climate? As recently as 5-10 years ago, most people would have thought the latter.

However, innovative producers have led the way in demonstrating that the large scale planting of perennial pastures is a viable alternative. Some producers are even close to achieving the goal of stock grazing green feed all year-round.

While there is still a long way to go, there has been a change in attitude to growing perennial pastures, which in years to come could transform large areas of the rural landscape in WA. Annual pastures are the main component of grazing systems and will continue that way. Most perennial pastures are a mix of annual and perennial species, with the dominant component varying with the season.

Gatton panic with balansa clover. Annual legumes are an important component of perennial grass pastures

Lucerne is a drought tolerant perennial legume suitable for growing animals

In general, perennial pastures are still a minor component of grazing systems but several economic options have been developed for different parts of the landscape. By selecting species that are compatible with the physical environment (soil, climate) and the farming enterprise, some of the least fertile and most fragile soils can be transformed into productive, sustainable areas with an increase in farm profit and reduced land degradation.

- Alleys of tagasaste have transformed some of the poorest, deep-leached sands into productive paddocks. Tagasaste provides out-of-season green feed and increases carrying capacity, while also reducing wind erosion and deep drainage.
- Warm season grasses with companion annual legumes are turning waterlogged land that was previously over-run with reeds into some of the most productive and profitable pasture paddocks in the State.
- Phase farming with lucerne is creating sustainable and profitable rotations with annual crops in medium and low rainfall environments. The area of lucerne increased from ~5,000 ha in 1995 to about 170,000 ha in 2001.
- Alleys of saltbush are being used strategically to keep highly saline groundwater at depth, allowing productive non-halophytic pastures to be grown in the inter-row.
- Perennial pastures are enabling an increase in stocking rates and are reducing land degradation on large areas of sandy soils susceptible to wind erosion on the south coast.

The impetus for increased interest in perennial pastures in WA has largely come from innovative farmers and groups such as Evergreen Farming, the WA Saltland Pastures Association, the Western Australian Lucerne Growers and regional grower groups.

These groups have played a major role in the promotion and the widespread, on-farm testing of perennial pastures. It has been dynamic individuals largely from within these groups who have demonstrated the full potential of perennial pastures. These producers have mastered the practical aspects of successful establishment and management and then captured the benefits of perennials in new farming systems. They have transformed the landscape of their farms and translated the production benefits of perennials into whole-farm benefits by developing more sustainable and profitable farming systems.

Evaluating new lines of lotononis, a promising perennial legume

Tagasaste with kikuyu in the inter-row on the south coast

However while these innovative producers lead the way in the on-farm integration of perennial pastures, they are still a minority.

New farming systems will develop over the next decade which continue to challenge traditional conventions as innovative producers strive to improve their medium- to long-term sustainability. New species and varieties of perennial pastures will be developed to expand the options available to producers.

Potential new species and cultivars that could be available within 5-10 years and which will significantly increase the area sown to perennial pastures include:

- acid-tolerant lucerne varieties
- grazing-tolerant lucerne varieties developed for southern Australia
- perennial herbs like chicory, with new varieties developed specifically for southern Australia
- new perennial legumes like sulla and perennial lotus with desirable attributes such as condensed tannins
- new, warm season grasses specifically developed for southern Australia.

Some producers may have concerns about the potential negative effects from growing perennial pastures. A range of these issues is discussed in Table 1.1.

With this publication, we aim to help producers and farm advisers make well informed decisions about perennial options – where to grow and not to grow different species, how to successfully establish and manage perennial pastures and how to integrate them into the farming system.

All the perennial pasture options both currently available and those being developed are discussed including a few which are not recommended because of the associated environmental weed risk. The weed potential of these species has been flagged.

Table 1.1 Negative effects of perennials – are they perceived or real?

Perceived negative effect	Discussion
Risk of establishment failure or of poor establishment	‘The most expensive pastures are those that fail to establish’. In general, perennial pastures are more difficult to establish than annual crops and pastures. Seedling growth is relatively slow compared with annual species, so good control of annual weeds is essential. However, proven methods of establishment with a high success rate are now available for most perennial pasture types. Ensure all of the steps for successful establishment are undertaken to minimise the risk. Last minute decisions to sow perennial pastures can be expensive if the necessary paddock preparation has not been carried out.
The perennial pasture establishes well, but subsequently fails to survive if there is a dry summer	Well-adapted perennial pastures have proven highly drought-tolerant. Ensure that the most suitable species are selected for the environment (soil, climate) and that all of the factors for successful establishment are undertaken. Perennial plants need to develop a sufficiently large root system in the establishment year to survive the first summer. Excellent weed control during establishment is essential. Even when perennial plants survive weed competition during establishment, the result is smaller plants at the start of summer that will struggle to survive if there is a prolonged summer drought.
Perennial pastures have more management requirements than annual pastures	Most perennial pastures require some form of rotational grazing to persist and be productive in the medium- to long-term. Rotational grazing of annual pasture paddocks can significantly increase pasture production and utilisation. Compared with the set-stocking of annual pastures, there will be additional stock movement required with perennial pastures but this is more than off-set by the reduced need for supplementary feeding in autumn.
Perennial pastures exacerbate problems with worm control in sheep	This is not necessarily the case, as perennial pastures can change the dynamics of the worm population. There is reduced selection pressure for resistant worms as non-resistant worms can survive summer on perennial pastures. As a result, the worm count is sometimes higher on perennial pastures, but the proportion of resistant worms may be lower (Section 2.4).
Perennial pastures become difficult weeds to control in crops	The main perennial pasture species that are likely to be weeds in crops are lucerne, which is often grown in a phase rotation with crops, and kikuyu, which can be spread by stock in dung. Even a low density of lucerne plants in a cereal crop can adversely affect crop yields. Methods for successfully removing lucerne before the cropping phase have been developed (Lucerne – Section 3.4). Most perennial grasses are established as permanent pastures and the risk of spread around the farm is negligible. However, stock movement from kikuyu pastures into paddocks that will subsequently be cropped should be controlled.
Perennial pastures produce less feed than annual pastures	Total dry matter production from well-managed annual and perennial pastures is usually comparable but perennial pastures have a more even seasonal distribution. The term ‘perennial pastures’ is somewhat of a misnomer as most perennial pastures are a mix of perennial and annual species. At certain times of the year, the annual species may be the dominant component of the pasture. Overall production can increase with a perennial-annual pasture, or at the least should be similar to a good annual pasture but with a better seasonal distribution. Spring production from annual pastures is often higher than for many perennial pastures but perennial pastures are more productive in summer, autumn, and/or winter (depending on species and period of active growth) – when feed is often limiting. Consequently, each unit of production is more valuable than the same production in spring when there is a surplus of feed resulting in poor pasture utilisation.
The ‘green bridge’ created by perennial pastures increases the incidence of pests and diseases in annual crops and pastures	Perennial pastures do provide a ‘green bridge’ that can assist viruses and other pathogens to persist over summer. This risk can be reduced by only sowing virus-free seed and manipulating grazing to minimise potential problems. The risk of ‘green bridge’ is reduced for diseases that are carried only on green foliage, as the seasonally dry conditions, which often extend from late spring to mid- to late autumn, ensure a substantial, continuous bridge of green foliage is rarely present away from isolated ‘wet’ areas (Section 2.5).

1.2 Integrating perennial pastures into the whole farm

Felicity Byrne (nee Flugge)

To receive the benefits possible from integrating perennial pastures into the whole farm, various costs and management requirements need to be considered.

Benefits of perennial pastures include:

- an increase in farm profit
- an increase in the whole farm stocking rate
- shorter feed gaps and a more even feed supply
- reduced need for supplementary feeding
- deferred grazing of annual pastures at the break of season
- improved pasture growth and use due to a higher grazing pressure on annual pastures in late winter and spring
- increased soil water use and reduced soil erosion
- reduced risk of erosion due to lower stocking rates on annual pastures during autumn.

The costs and management considerations of perennial pastures include:

- higher establishment costs for perennial pastures with a time-lag until they can be grazed
- more intensive grazing management to ensure the pastures persist and their quality is maintained
- a possible need to change rotations on other soil types to achieve the best enterprise mix
- recognising that as the focus of the livestock enterprise shifts toward meat production then the value and optimal area of perennial pastures increase
- noting that the area of perennial pastures can often be increased above the optimum with minimal effect on profit.

This section discusses the integration of perennial pastures into a farming system. It outlines some principles that underlie the value and role of perennial pastures in a farming system and uses two case studies as illustrations.

Factors affecting the value of perennial pastures

The characteristics of a farming system will affect the specific role and value of perennial pastures within that system. Farming systems, by their nature, are diverse and variable. The mix of soil types on a farm, the nature of the livestock enterprise, the balance between cropping and grazing all affect where perennial pastures can be grown and used profitably.

Perennial pastures are often a source of green feed at a time when other feed is limited. Carrying stock through periods of feed scarcity is difficult, expensive and limits profit from livestock production in southern Australia. Farmers typically manage this period by feeding supplements or running low stocking rates. As a result, the value of additional pasture during this time is high compared with the value of additional pasture from late winter to the end of spring, when feed is plentiful.[270]

Cattle grazing sub-tropical grasses at Lancelin in autumn. Additional pasture production in summer-autumn when feed is scarce is much more valuable than additional production in spring

Table 1.2 Key questions to consider before growing perennial pastures

Feed supply versus demand
What is the feed supply throughout the year?
What is the feed demand (energy, protein) throughout the year?
Where is the gap between feed demand and feed supply?
Which perennial pastures could help to match feed supply with feed demand?
Alternatively, can the energy demand be changed to better suit the available perennial pasture options, e.g. by changing the time of lambing?
Livestock enterprise
What is the dominant livestock enterprise?
Which perennial pastures would suit this enterprise?
Alternatively, can the focus of the livestock enterprise be changed to better suit the available perennial options?
Area of perennial pastures
What is the size of the niche that perennial pastures are filling?
At what point is the cost of an extra hectare of perennial pasture greater than the benefit?
Are there soil types or areas of the farm which would directly benefit from having perennial pasture cover?
Are there areas of the farm that would indirectly benefit from having perennial pastures elsewhere on the farm?

Growing perennial pastures can increase farm profit because there is an increase in whole-farm stocking rates due to an increase in out-of-season feed supply *plus* changes to grazing on other parts of the farm.[107, 290, 366, 395, 453] Grazing pressure on paddocks with annual pastures can be reduced during summer, autumn and early winter and increased during late winter and spring, leading to improved pasture growth and utilisation.

The key questions to consider before growing perennial pastures are summarised in Table 1.2 and expanded below.

Addressing a seasonal feed gap

A major benefit of perennial pastures is the supply of out-of-season green feed. The timing of the out-of-season feed shortage may vary between regions but the fact remains that many perennial pastures provide green feed at a time when annual pastures have senesced. This can potentially alleviate the major limiting factor in livestock production – the cost of carrying stock through periods of feed scarcity.

Matching feed demand to feed supply

Feed supply fluctuates throughout the year, as does the feed demand (energy, protein). At the farm level, collective feed demand depends on the time of lambing/calving, time and amount of turnoff and the livestock enterprise (e.g. sheep for meat production vs. sheep for wool production). This seasonal feed demand affects the value of perennial pastures.

Livestock enterprise

The value and role of perennial pasture depends on the livestock enterprise.[107, 395, 452, 453] The value of perennials tends to be higher when meat production is the dominant livestock enterprise, however perennial pastures can also increase farm profit when the focus is wool production.

The nature of the livestock enterprise will determine when feed is required (e.g. turning-off stock at target liveweights) and the quality. For example, high quality feed such as lucerne is required to finish prime lambs while lower quality feed such as kikuyu suits fine wool production.

Area of perennial pasture

Incorporating perennial pastures can often increase farm profit, however there is generally an optimum area beyond which profit decreases for every additional hectare of perennials sown. The optimum area depends on several factors, such as the nature of the livestock enterprise (see case study 1), whether a mix of perennials is used (see case study 2), the mix of soil types on the farm and the relative profitability of grazing compared with other enterprises such as cropping.

Perennial pastures are usually more expensive to establish than annual pastures and may have lower growth rates during winter and spring. These costs are traded off against their benefit in supplying out-of-season feed. However, for a given size of livestock enterprise the value

Lucerne is more valuable as the focus of the livestock system shifts towards growing meat rather than wool

of extra out-of-season feed declines as more of this feed is added. At some point the cost of an additional hectare of perennial pasture is greater than its benefit (these costs may be an actual cost such as establishment, or an opportunity cost such as not growing an alternative crop or pasture).

Environmental benefits

Perennial pastures provide environmental benefits such as increased water use, which reduces waterlogging and groundwater recharge. Reducing recharge then helps prevent or delay the onset of dryland salinity.

Perennial pastures can reduce the risk of soil erosion by maintaining plant cover during summer. They can also indirectly reduce soil erosion on annual pasture paddocks by enabling stock to be moved off these paddocks during summer and autumn.

Management considerations

To integrate perennial pastures successfully into the farm there are a number of management issues to consider. Perennial pastures create different management challenges from annual pasture systems.

Grazing management

Farmers who have integrated perennial pastures successfully into their farming systems have found it is important to use some form of rotational grazing to provide adequate recovery periods from grazing.[366] A successful rotational grazing strategy may require subdivision of large paddocks, with additional fencing and water points and regular movement of livestock. This shift towards more intensive grazing management will involve extra costs and time, although the need for hand feeding should be less.

Cash flow

Perennial pastures generally cost more to establish than annual pastures. In the longer term they may reduce the cost of production, but in the short-term farmers need to have the financial capacity to carry the initial debt. Farmers who successfully grow perennial pastures have identified the cost of establishment as a barrier to the rapid conversion from annual to perennial-based pastures.[366]

The impact of the higher establishment costs may be exacerbated by the time-lag until the first grazing. In general, perennial pasture species are slower to establish than annual pastures so it will take longer before they can be grazed, although this time-lag varies widely between species and with seasonal conditions.

There is a higher risk of establishment failure with perennial pastures than with annual pastures because they can be more difficult to establish and farmers have less experience growing perennials than annual crops and pastures. Re-establishment after a failure adds to the cost and the time until first grazing.

The cost of establishment and extra infrastructure along with the longer establishment time, mean it can be several years before the investment breaks even. A study of a number of producers who had adopted lucerne into their grazing systems found that the pay-back period ranged from one to five years.[395]

Rotations

To maintain a desired mix of cropping and grazing, rotations on other soil types may also need to change. The areas which are suited to different enterprises need to be identified and changes made accordingly. The transition from an annual pasture system to a perennial-based system may involve several changes and for financial (and risk) reasons may need to be spread over a number of years.

Case study 1: Growing lucerne in the central wheatbelt

This case study demonstrates some of the issues surrounding perennial pasture establishment, using lucerne as an example. A representative farm in the central wheatbelt is used to examine the profitability of lucerne and to gain insights about its role in the farming system.

The average annual rainfall is 370 mm with 80% falling between April and October. Soil types include deep sands, deep and shallow duplex soils with red and grey medium- to fine-textured soils on the valley floors. Lucerne is assumed to grow on all soil types, albeit at different levels of productivity. In this example, lucerne is established alone, not with a cover crop.

The value of lucerne is analysed for three different livestock systems (Table 1.3): (i) a wool producing flock only (Wool); (ii) a wool-producing, self-replacing flock using surplus ewes for carryover crossbred lambs (SRF XB); and (iii) a specialist crossbred flock with Merino ewes producing crossbred carryover lambs with replacement ewes bought in (XB). For the wool flock, the value of lucerne is compared when lambing either in May and July.

Results

Including lucerne in the farming system increases farm profit for all three livestock systems, however the increase in profit depends on the characteristics of the livestock enterprise. The value and optimal area of lucerne changes with the chosen livestock system (Tables 1.4, 1.5).

Lucerne is more valuable when lambing occurs during July ($16/ha) than in May ($3/ha) (Table 1.4). This occurs because including lucerne with a July lambing gives a better match of feed demand and supply and consequently the optimal area of lucerne is larger, 12% of the total farm area compared with 4% for a May lambing.

Lucerne is more valuable when used for growing meat rather than wool, so the value of lucerne increases as the focus of the livestock system shifts progressively toward meat production (Table 1.5). Lucerne is particularly valuable for finishing prime lambs in summer. The demand for high quality summer feed is greater with a prime lamb enterprise, so a larger area of lucerne can be incorporated profitably into the farming system.

Table 1.3 Livestock systems analysed under a perennial system

System	Description
(i) Specialist Merino wool (Wool)	Emphasis is on wool production. Wethers can be sold as lambs to other graziers or as shippers (18 months or older).
(ii) Self-replacing crossbred lamb (SRF XB)	A self-replacing Merino flock utilising surplus ewes (cast for age or surplus ewe hoggets) for crossbred lamb production. Merino wethers can be sold as Merino prime lamb or as lambs to other graziers or as shippers (18 months or older).
(iii) Specialist crossbred (XB)	Merino ewes producing crossbred carryover lambs. Replacement ewes are bought in.

Table 1.4 Value of lucerne and its optimal area for a May or July lambing with a wool producing flock

Time of lambing	Value of lucerne (extra profit/ha of lucerne grown)	Optimal area of lucerne as % of total farm area
May	$3	4%
July	$16	12%

Table 1.5 Value of lucerne and its optimal area for three livestock systems

Flock type	Value of lucerne (extra profit/ha of lucerne grown)	Optimal area of lucerne as % of farm
Wool	$3	4%
SRF XB	$27	12%
XB	$55	26%

There is a different optimum area of lucerne for three livestock enterprises (Tables 1.4 and 1.5). For all enterprises the value of each additional area of perennial pasture declines gradually as the feed niche is filled. This is illustrated in Figure 1.1, which shows the proportion of the farm under lucerne against profit for the SRF XB livestock system. To maximise profit for this system 12% of the total farm area needs to be under lucerne (Table 1.5), however increasing the area of lucerne to 20% causes only a slight drop in farm profit. Even when lucerne is increased to 30% of the farm's area, profit is still within 90% of the maximum. Hence, if there are reasons to include a larger area of lucerne, e.g. to reduce groundwater recharge or control herbicide resistant weeds this can be achieved with minimal impact on farm profit, provided the required adjustments are made to flock size and enterprise management.

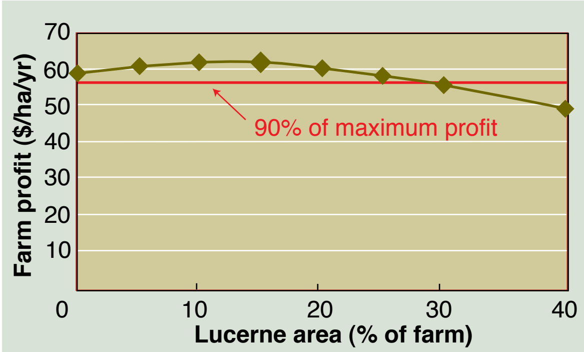

Figure 1.1 The effect of increasing area of lucerne on farm profit for the SRF XB livestock system

Summary

- Lucerne improves farm profitability under all the scenarios examined. However, under some scenarios (e.g. a wool-only flock with May lambing) the small increase in profit is unlikely to warrant the time and risk of establishing lucerne.
- The value and optimal area of lucerne increase as the production focus shifts towards meat production.
- The economic benefits of lucerne can include:
  - reduced need for supplementary feeding
  - higher stocking rate enabling better weed control and pasture use
  - ability to finish a higher proportion of lambs/ha
  - increased water use.
- For each of the scenarios examined there is a range where profit is relatively insensitive to the area of lucerne, which means other objectives (e.g. water management) can be taken into account with little or no penalty.

Case study 2: Growing a mixture of perennials on the south coast

This case study also uses a representative farm model to gain insights about the role of perennial pastures in a farming system.[453] It builds on the previous example by including a number of perennial pastures with different characteristics.

The case study farm is representative of farms on the south coast. Four pasture types are included: annual pasture, lucerne, kikuyu and a (temperate or summer-active) tall fescue. Two livestock systems are considered: a self-replacing Merino flock for wool production only and a self-replacing Merino flock using excess ewes for crossbred lamb production. (Note: These are the same as flock types (i) and (ii) in case study 1, Table 1.3.)

The average annual rainfall is 600 mm with 70% falling between April and October. Soil types include deep sands, duplex soils susceptible to waterlogging and moderately deep sandy duplex soils.

Results

Including perennial pastures increases profit, with the increase in profit higher for the SRF XB flock than the wool-only flock. This indicates that high quality perennial pastures are best used in a livestock system that focuses on meat production rather than on one based mostly on wool production. For both flock types there is an increase in stocking rate, pasture use and pasture growth and a decrease in supplementary feeding as the perennial pasture types included are increased from two to three (Table 1.6).

Perennial pastures enable higher stocking rates by providing higher and more-timely pasture growth (Table 1.6). The total area of perennial pasture can be increased when more perennial pasture types, with different seasonal growth patterns, are included to fill various niches within the farming system (Figure 1.2).

Table 1.6 Profit and production parameters for optimum management with three different pastures

	Annual pasture only	Annual pasture plus lucerne and kikuyu	Annual pasture plus lucerne, kikuyu and tall fescue
Flock type: Self-replacing Merino flock for wool only			
Profit ($/yr)	19,900	79,900	86,200
Stocking rate (DSE/WG* ha)	8.1	10.7	10.1
Supplementary feeding (kg/DSE)	18.5	8.3	6.9
Lambing (%)	87	92	92
Area annual pasture (% of farm)	70	25	19
Area perennial pasture (% of farm)	0	45	51
Pasture growth (t/ha)	6.6	7.0	7.2
Pasture utilisation (%)	35	46	47
Flock type: Self-replacing Merino flock with crossbred lamb production			
Profit ($/yr)	64,300	138,800	164,500
Stocking rate (DSE/WG* ha)	8.5	10.0	12.0
Supplementary feeding (kg/DSE)	33	8.3	8.4
Lambing (%)	89	92	92
Area annual pasture (% of farm)	70	23	3
Area perennial pasture (% of farm)	0	47	67
Pasture growth (t/ha)	7.1	7.6	7.5
Pasture utilisation (%)	37	45	50

* WG = winter-grazed

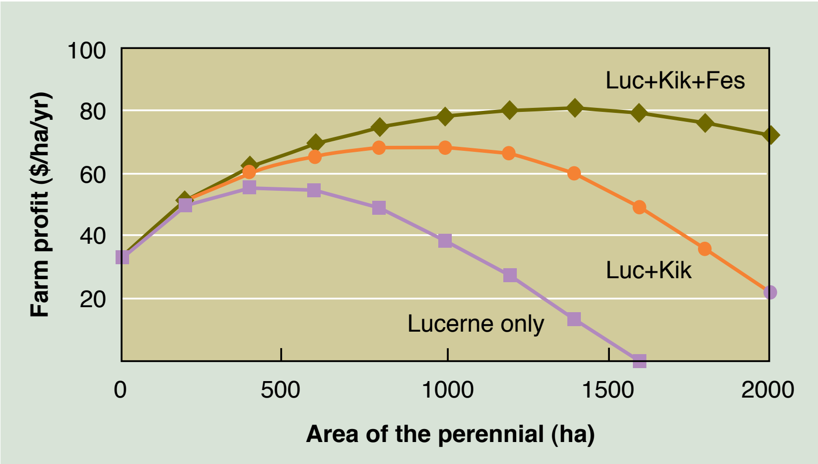

Figure 1.2 The effect of increasing the area of perennial pastures on farm profit for three perennial systems: lucerne only, lucerne and kikuyu (Luc + Kik) and lucerne, kikuyu and tall fescue (Luc + Kik + Fes)

Summary

- The optimal area sown to perennial pastures depends on the livestock enterprise and the mix of perennial pastures.
- There is a wide range (50-90% of total farm area) over which profit is insensitive to the area of perennial pastures.
- A mix of perennial pastures provides a range of feed availability due to their different seasonal growth patterns.
- Perennial pastures help fill the summer/autumn feed gap and so reduce the amount of supplementary feed required per animal.
- Pasture growth and pasture utilisation can be increased through better grazing management.

1.3 Matching perennial pastures to the climate and soils

Geoff Moore, Tim Wiley and Paul Sanford

When planning to grow perennial pastures the aim is to choose an appropriate perennial pasture species to achieve livestock outcomes as well as improve the sustainability of the farming system.

This section outlines the key climatic and soil requirements for the various perennial pasture options. The concept of 'perennial zones' is introduced to provide a spatial framework. This section will help answer the following questions:

(a) What are the perennial pasture options for my area?

- How do I identify the perennial zone (Figure 1.4)?
- How do I identify the species suitable for that zone (Table 1.9)?
- How do I assess the soil and management requirements for those species (Refer to species descriptions – Chapters 3 to 9; Appendix 1)?

(b) What perennial pasture options are available to meet an identified need?

- Identify the key feed gap and/or soil conservation requirements?
- How do I identify the pasture options to meet the needs of the livestock enterprise (e.g. wool, meat, maintain weight) and the critical feed gap (Table 1.7)?
- How do I assess the climatic and soil requirements for the pasture options (species descriptions – Chapters 3 to 9; Appendix 1)?

Climate

South-western Australia has a Mediterranean climate with a strong winter dominant rainfall pattern. In most districts 70-75% of the annual rainfall is received between May and October. The key climatic factors affecting the growth of annual plants are the amount and reliability of the May-October rainfall (i.e. the effective growing season) and the frequency of frosts.

For perennial pastures, the Mediterranean climate presents several challenges. The perennials need to persist through an extended hot, dry period over summer-autumn, which can vary between years from three to seven months. The other challenges depend on whether we are considering a temperate species or a warm season (sub-tropical) species.

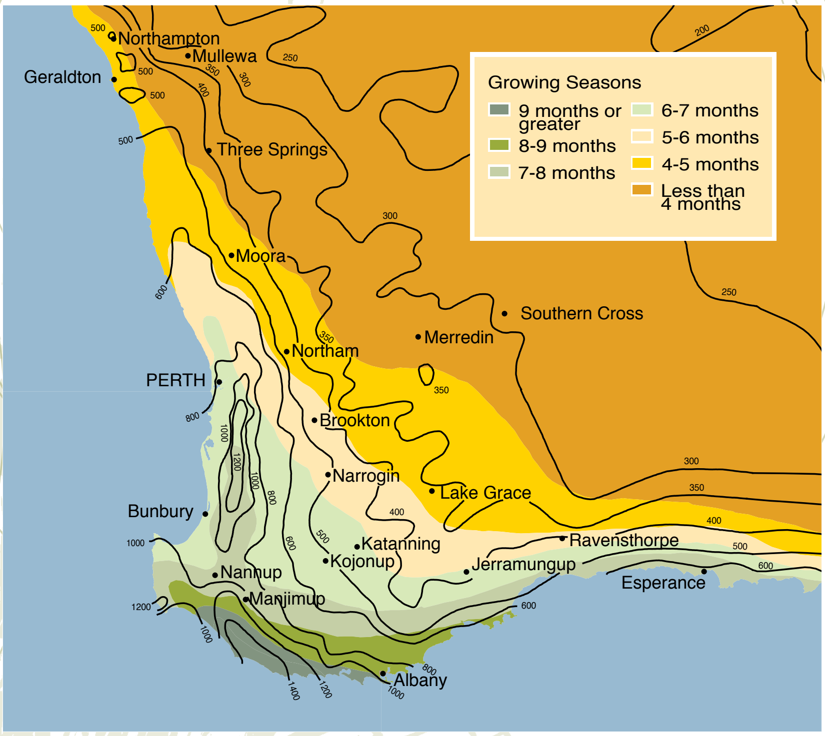

Figure 1.3 Map of growing season length with rainfall isohyets

Table 1.7 A summary of the main perennial pasture types in terms of their seasonal production, suitability for different livestock enterprises and soil conservation (refer to the legend)

Perennial pasture type	Seasonal production				Livestock enterprise					Soil conservation	
	Autumn production	Winter production	Spring production	Summer production	Wool production	Sheep out-of-season liveweight gain	Sheep out–of-season maintenance	Cattle out-of-season liveweight gain	Cattle out-of-season maintenance	Reduce wind erosion	Increase water use
Lucerne	✔✔	✔–✔✔ (depends on WAR*)	✔✔	✔✔	✔	✔✔✔	✔	✔✔✔	✔	✔	✔✔✔
Temperate perennial grasses	✔✔✔	✔✔✔ (depends on species)	✔✔	Nil–✔✔ (depends on species)	✔	Nil–✔✔	✔	Nil–✔✔	✔	✔✔	✔–✔✔
Sub-tropical grasses	✔✔	Nil–✔	✔–✔✔	✔✔✔	✔✔✔	✔	✔✔✔	✔	✔✔✔	✔✔✔ (creeping grasses)	✔✔✔
Halophytic shrubs	✔✔	✔	✔✔	✔✔	✔✔ (with source of energy)	✔✔ (with source of energy)	✔✔ (with source of energy)	✔✔ (with source of energy)	✔✔ (with source of energy)	✔✔	✔✔
Salt-tolerant perennial grasses (tall wheat grass)	✔✔	✔✔	✔✔	✔✔	✔	✔✔	✔	✔✔	✔	✔✔	✔✔
Herbs (chicory)	✔✔	✔	✔✔	✔✔	✔	✔✔✔	✔	✔✔✔	✔	✔	✔✔
Tagasaste	✔	✔✔	✔✔✔	✔✔	✔	✔✔	✔✔	✔✔✔	✔✔	✔✔	✔✔✔

Legend:

✔ low seasonal growth or the least appropriate for the situation, through to

✔✔✔ which equates with very good seasonal production or a species well suited for the situation

NA is not applicable

* WAR is the 'winter-activity rating' (Lucerne – Section 3.4)

For temperate, perennial pastures climatic suitability is related to the length of the growing season (Figure 1.3). In particular, the potential for growing the main temperate perennial grasses: cocksfoot, perennial ryegrass, phalaris and tall fescue is correlated strongly with the length of the growing season (Chapter 4). Lucerne, the main herbaceous temperate perennial legume, is more adaptable as it is highly drought-tolerant due to its deep tap-root.

In contrast, the warm season perennials grow mainly outside the May to October period. The key climatic features affecting the sub-tropical grasses are: spring temperatures, out-of-season rainfall, and the combination of cold, wet soils and frosts which affects persistence over winter (Chapter 5).

Annual pastures and crops are well suited to the Mediterranean climate in WA, but under certain conditions perennial pastures have an advantage:

- Early autumn rain can result in false breaks which significantly reduce the seed bank of annual pastures, while perennial pastures can produce valuable feed from these same rainfall events.
- Frosts in spring when crops are flowering can reduce grain yield significantly but will have minimal impact on temperate perennial pastures and at worst burn the foliage of warm season perennial pastures.
- Late rains in spring or early summer, after annual pastures have senesced, reduce the quality and bulk of dry pastures, while rain at harvest can adversely affect grain quality. However, these late rains enable perennial pastures to grow actively under warm conditions.

Farming systems that include both annual and perennial pastures can benefit from and also reduce the risks from fluctuating seasonal conditions.

Soils

Soil is essentially a medium for plant root growth. The growing plant relies on the soil for support, to exchange gases with the atmosphere and for a supply of water and nutrients. The plant, of course, needs to grow a root system to carry out these functions, so properties that affect root growth also need to be considered. If a soil can supply all of these requirements without degrading then it is non-limiting to plant growth and potential production is determined by the climate. However, most soils in south-western Australia are not in this category as they have physical and/or chemical limitations that require management to minimise their impact on production.[265] The more fertile soils are usually used for intensive crop production, so more than 80% of the soils used for growing perennial pastures have physical and/ or chemical limitations.

Soils with a shallow effective rooting depth are less suitable for perennial pastures

As a result, the best option is to grow a perennial species that has high tolerance of the soil conditions or one which has a growth habit that enables it to overcome the limitation. For example, tagasaste is grown on highly leached, pale deep sands even though they have a very low water-holding capacity and are inherently infertile. Tagasaste grows well on these soils because its deep root system (up to 10 m) enables it to extract water and nutrients from depth.

Some species have specific soil requirements (e.g. bambatsi panic, sulla), while other species can be grown on a wider range of soils (e.g. lucerne). Bambatsi panic is well adapted to fine-textured soils including cracking clays and while it will persist on coarse-textured soils the productivity is usually low. The temperate perennial legume sulla

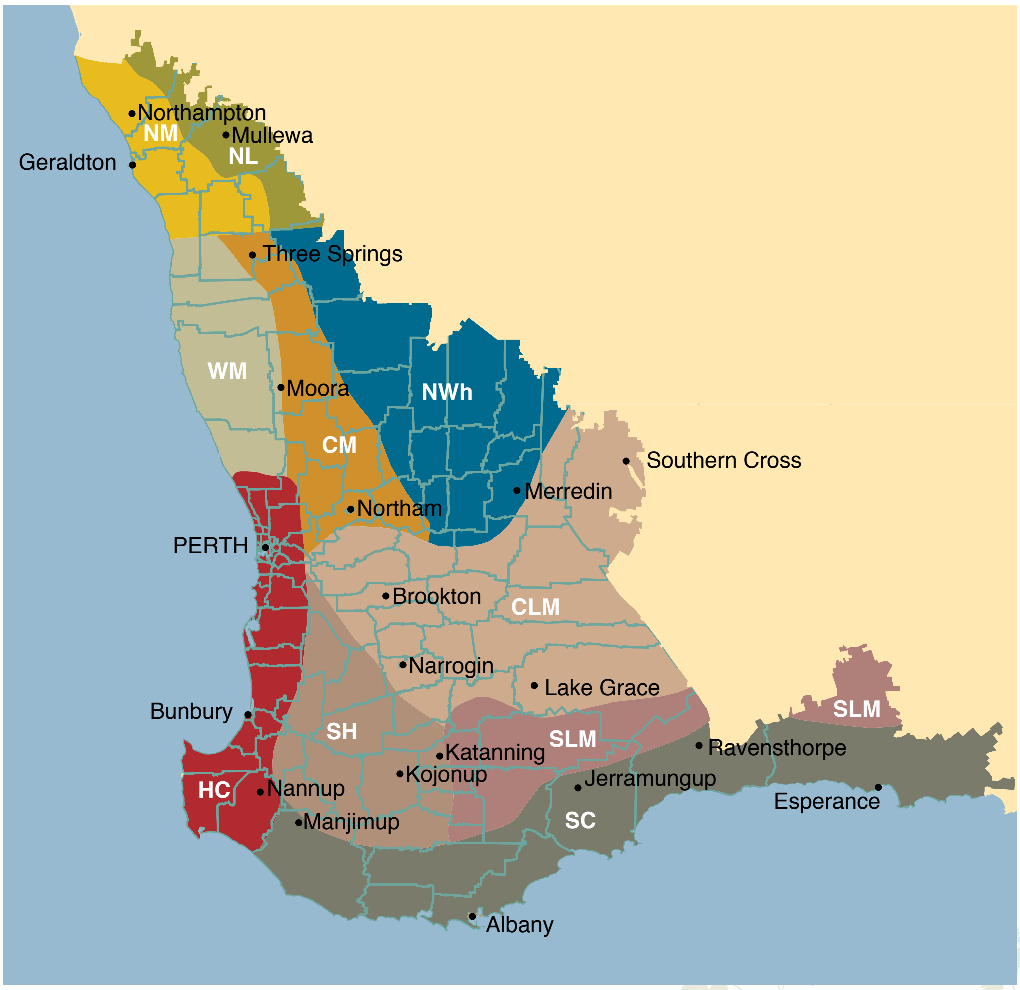

Figure 1.4 Map of 'perennial zones' together with shire boundaries. Refer to Table 1.8 for a description of the zones

requires well drained fertile soils and grows poorly on sandy soils with low fertility. Even though lucerne is best suited to deep, fertile loamy soils it will grow satisfactorily on a range of soils providing they are moderately well to well drained and the soil depth is more than 1.5 m.

In general, perennial pastures are poorly adapted to shallow soils because of the limited soil volume for the roots to explore. The most suitable soils for growing perennial pastures are deep soils and those where the soil moisture extends into late spring to early summer.

Appendices 1.1 to 1.4 summarise the tolerance to soil and climate stresses of perennial legumes, temperate perennial grasses, sub-tropical grasses, pasture shrubs and herbs.

Perennial zones

A map of 'perennial zones' (Figure 1.4) has been developed as a spatial framework for providing perennial pasture options on a regional basis. A new map was developed because the existing maps used for annual crop variety recommendations (e.g. Cereal Variety Trial zones) and annual pasture recommendations were not suitable for perennial pastures. The south-west agricultural area has been subdivided into 10 zones on the basis of a range of factors affecting the growth and persistence of perennial pastures (Table 1.8).

The perennial pasture options for each 'perennial zone' are summarised in Table 1.9. With many species there has been limited field evaluation in the different regions, let alone on the main soils (or land management units) within those areas. As a result, this matrix table remains a work in progress. It will continue to evolve and be updated as more information becomes available to increase our understanding of how the different species perform in the unique environment of WA.

Table 1.8 Description of the 'perennial zones' and their key climatic features

Code	Zone	Boundaries in terms of physical and climatic parameters	Key climatic features
NM	**Northern medium rainfall**	West of 350 mm isohyet, north of line running east-west through southern boundary of Mingenew Shire which is based on sub-tropical grasses continuing to grow slowly in winter (probably due to a combination of mild temperatures and increasing solar radiation).	Nil to low frosts, mild winters, warm springs, short growing season (4-5 months) with hot, dry summers.
NL	**Northern low rainfall**	East of 350 mm, north of line running east-west through southern boundary of Mingenew Shire (see above).	Low incidence of frosts, mild winters, warm springs, very short growing season (<4 months), with hot, dry summers.
WM	**West Midlands**	West of Darling Fault line, north of Gingin (takes in Soil-landscape zones 222 and 224).	Nil to low frosts, cool to mild winters, mild to warm springs, hot, dry summers.
CM	**Central Midlands**	East of Darling Fault line, rainfall >350 mm, southern boundary is 'cold zone' (based on maps of July mean minimum temperature and frequency of frosts in September).	Some frosts, cool winters, short growing season, mild to warm springs, with hot, dry summers.
NWh	**Northern wheatbelt**	<350 mm, southern boundary is 'cold zone' (based on maps of July mean minimum temperature and frequency of frosts in September), northern boundary coincides with the southern boundary of Mingenew Shire.	Some frosts, cool winters, mild to warm springs, very short growing season, with hot, dry summers.
HC	**High rainfall coastal**	Swan Coastal Plain from Gingin south to Busselton, plus the Leeuwin Block between Cape Naturaliste and Cape Leeuwin and the Scott River Coastal Plain. The eastern boundary is the 'cold zone' as defined below.	Nil to low frosts, cool to mild winters, mild to warm springs, medium to long growing season (>6-7 months), warm to hot summers.
CLM	**Central low to medium rainfall**	Growing season <6.5 months, rainfall 300-500 mm, 'cold zone' where many sub-tropical grasses have poor persistence over winter. Defined from maps of July mean minimum temperature and frequency of frosts in September.	Regular frosts, cool to cold winters, cool to mild springs, very short to medium growing season (<6.5 months), with hot, dry summers.
SH	**Southern high rainfall**	Growing season >6.5 months, 'cold zone' where many sub-tropical grasses have poor persistence over winter. Defined from maps of July mean minimum temperature and frequency of frosts in September.	Regular frosts, cool to cold winters, cool to mild springs, medium to long growing season (6.5-8 months), with warm to hot summers.
SLM	**Southern low to medium rainfall**	Defined by 400 mm isohyet to south and 'cold zone' to the north.	Low incidence of frosts, cool winters, mild springs, short growing season with warm to hot summers.
SC	**South coast**	Northern boundary is the 400 mm isohyet, while the southern boundary is the coast. Includes the very high rainfall south-west coastal area (>750 mm) to the west of Albany which is south of the 'cold zone' as defined above.	Nil to low frosts, cool winters, mild springs, medium to long growing season (6-8 months), warm to hot summers with 25-35% out-of-season rainfall.

Table 1.9 Pasture options for each perennial zone (see Figure 1.4)

Species	Zone									
	NM	NL	HC	WM	CM	NWh	SH	CLM	SC	SLM
Perennial legumes										
Birdsfoot trefoil			✔✔				✔✔ >600 mm		✔✔ >500 mm	
Greater lotus			✔✔				✔✔ >600 mm		✔✔ >500 mm	
Lotononis	✔ >500 mm		✔✔	✔ >500 mm					✔✔ >475 mm	
Lucerne	✔✔	✔ >325 mm	✔✔	✔✔	✔✔	✔ >325 mm	✔✔✔	✔✔ >325 mm	✔✔✔	✔✔–✔✔✔
Siratro	✔–✔✔		✔–✔✔	✔					✔	
Strawberry clover	Summer moist areas only		✔✔	Summer moist areas only	Summer moist areas only		Summer moist areas only	Summer moist areas only	✔ >500 mm	
Sulla	✔✔ >450 mm		✔✔	✔	✔ >450 mm		✔✔	✔ >450 mm	✔	✔
White clover			niche + Irrigation	niche			✔ >700 mm		✔✔ >700 mm	
Temperate perennial grasses										
Cocksfoot			✔✔		✔ >500 mm		✔✔✔	✔–✔✔ >500 mm	✔✔ >425 mm	
Perennial ryegrass			✔✔ >7 month growing season				✔✔ >7 month growing season		✔–✔✔ >550 mm	
Phalaris			✔✔		✔ >500 mm		✔✔✔ >500 mm	✔ >500 mm	✔✔	
Tall fescue (summer-active)			✔✔✔				✔✔–✔✔✔ >550 mm	✔ >550 mm	✔✔ >450 mm	

Species	Zone									
	NM	NL	HC	WM	CM	NWh	SH	CLM	SC	SLM
Tall fescue (summer-dormant)			✔✔✔		✔ >500 mm		✔✔✔ >500 mm	✔ >500 mm	✔✔ >425 mm	
Veldt grass	✔	✔ >325 mm	✔✔	✔✔	✔✔	✔ >325 mm	✔✔	✔ >325 mm	✔✔	✔ >325 mm
Saltland pastures										
Saltbush	✔✔✔ (Moderately to highly saline soils, 250-450 mm)									
Bluebush	✔✔✔ (Moderately to highly saline soils, 250-450 mm)									
Puccinellia	**niche** (saline)				✔✔ (Moderately to highly saline, waterlogged soils 350-600 mm)					
Tall wheat grass	**niche** (saline)		✔✔	✔	✔✔ (Moderately saline soils >350 mm)					
Sub-tropical grasses										
Bambatsi panic	✔	niche	✔	✔	✔ >375 mm	niche			✔	✔ >375 mm
'Consol' lovegrass	✔✔		✔✔	✔✔	✔✔ >375 mm		✔✔	✔ >375 mm	✔✔	✔ >375 mm
Digit grass	✔ >450 mm	niche	✔	✔–✔✔	✔ >450 mm	niche			✔✔	
Kikuyu	niche		✔✔	✔–✔✔ >500 mm	niche		✔✔ >500 mm		✔✔✔	niche
Panic grasses	✔–✔✔	niche	✔✔	✔✔	✔	niche			✔✔ >425 mm	
Paspalum	Summer moist areas only		✔✔	niche	niche		✔–✔✔ >600 mm		✔ >600 mm	
Rhodes grass	✔✔	✔	✔✔	✔✔	✔	✔	✔?	✔?	✔✔	✔?

Table 1.9 (continued)

Species	Zone									
	NM	NL	HC	WM	CM	NWh	SH	CLM	SC	SLM
Setaria	niche		✔✔	✔✔ >500 mm	niche		✔		✔✔ >475 mm	
Signal grass	✔–✔✔		✔	✔ >500 mm					✔ >450 mm	
Shrubs										
Tagasaste	✔✔	✔	✔✔	✔✔✔	✔	✔ >325 mm	✔–✔✔	✔ >325 mm	✔✔	✔ >325 mm
Herbs										
Chicory	✔		✔✔	✔ >500 mm	✔ >500 mm		✔✔ >500 mm		✔✔ >450 mm	✔ >500 mm

KEY:

(i) Confidence level for particular species.

- Low – limited testing or grower experience
- Moderate – some testing or grower experience
- High – extensively grown or tested

(ii) Adaptation to soils and climate.

- ✔✔✔ Highly suitable for the soils and climate in this zone
- ✔✔ Suitable for the soils and climate in this zone
- ✔ Marginally suitable for the soils and climate in this zone
- niche Only suitable for a specific soil or land management unit in this zone

Chapter 2

Perennial pasture management

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2.1 Grazing method

Paul Sanford

Grazing method is a critical factor in efficient pasture and animal management. For perennial pastures the choice of grazing method is particularly important to ensure plant persistence while maximising pasture utilisation and livestock performance.

With most perennial species some form of rotational grazing is essential to ensure persistence in the medium- to long-term. A number of studies have demonstrated that the density of perennial pastures declines rapidly under set-stocking.[60, 129, 187] Kikuyu is an obvious exception as it persists under set-stocking and can respond to high grazing pressure.[129] There are a number of species including tagasaste and some of the temperate perennial grasses that persist under set-stocking with cattle but not with sheep.

There is considerable interest among livestock producers in using different grazing methods to improve productivity, maintain desirable pasture species and reduce land degradation. Historically set-stocking was the only grazing method used with annual pastures. Under this system, stock were moved from paddock to paddock on an *ad hoc* basis, remaining in each paddock for varying periods and in some cases months. In contrast, rotational grazing involves the frequent movement of large groups of stock through a series of paddocks. The difference between the methods is that set-stocking largely enables the animal to control where, when and which plants it eats where as the higher grazing pressure of rotational grazing, means the animals have less ability to choose. Rotational grazing allows the producer to decide when and for how long a pasture will be grazed and rested.

This section briefly discusses how different grazing methods impact upon the productivity and persistence of perennial pastures, livestock production and land degradation.

Different grazing methods

Grazing method is a procedure or technique of grazing management used to achieve a specific objective. Set-stocking and rotational grazing are examples of grazing methods, but there are many more. Farmers can become confused when confronted with the large range of grazing methods, e.g. set-stocking, rotational grazing, strip grazing and cell grazing, etc. However, all these grazing methods fall on a continuum between the two extremes of (strict) set-stocking and intensive rotational grazing.[237]

Under (strict) set-stocking animals remain in one paddock for the whole year and the pasture receives no rest. However, very few producers use this grazing method in its strictest sense but rather leave stock in the same paddock for long periods, especially during the growing season. Intensive rotational grazing involves moving stock daily and in some cases more than once per day with pastures receiving a long rest between grazings.

With rotational grazing stock are either moved on the basis of time (e.g. four paddock lucerne system with two weeks grazing followed by six weeks rest), or variable recovery time under the 'Savoury' approach, plant growth stage (e.g. three-leaf stage), animal intake (e.g. maintain maximum intake) or feed-on-offer (FOO).

Another key factor in rotational grazing is the number of paddocks in a rotation. As the number of paddocks increases the:

- grazing period for each paddock decreases
- stocking pressure during grazing increases
- rest period for each paddock increases
- animals' ability to graze selectively is reduced
- average stocking rate (i.e. grazing days/ha) stays the same.

Some farmers use an intensive rotational grazing method developed by 'Savoury', the principles of which are to:

- control rest to suit the growth rate of the plant
- adjust stocking rate to match carrying capacity
- plan, monitor and manage the grazing
- use short grazing periods to increase anima performance
- use maximum stock density for the minimum time
- use a diversity of plants and animals to improve ecological health
- use large mob size to encourage herding.[243, 348]

In reality, no single grazing method can meet every animal and pasture objective. The best approach is to use different grazing methods

Cows on setaria pasture on the south coast. All of the sub-tropical grasses except kikuyu require some form of rotational grazing to persist

When FOO is plotted against pasture growth rate for kikuyu (Figure 2.1), it becomes apparent that the fastest growth rate increases occur up to a FOO of about 1400 kg DM/ha, after which pasture growth rates continue to increase but more slowly. Grazing systems that enable a kikuyu pasture to be maintained >1400 kg DM/ha have the potential to increase production.

tactically on the basis of seasonal conditions and livestock and pasture requirements.

For example, in situations of feed deficit rotational grazing allows better control over the regrowth period than set-stocking and can be used to restrict livestock intake.[60, 412] Conversely, in a situation of feed surplus set-stocking at high stocking rates can be used to control FOO and allow animals to select a high quality diet.[346]

Pasture production

Optimising pasture production depends on controlling two variables: the residual FOO following grazing and the length of time pastures are allowed for regrowth.[346] In general, the higher the leaf area the higher the potential growth (FOO provides an estimate of leaf area).

If residual FOO is too low, pasture growth will initially be slow due to the low leaf area available for photosynthesis. If the period of regrowth is short, then pastures will only experience high growth rates for short periods or not at all. Conversely, feed quality declines as plants mature, so there can also be a trade-off between biomass production and quality.

All grazing methods with the objective of maximising production involve monitoring pasture growth and using indicators to maintain the optimum FOO for pasture growth for the longest possible time, e.g. grazing at the three-leaf stage.[119]

An application of this principle is to defer kikuyu pastures at the break of season until they reach ~1400 kg DM/ha then graze and maintain at 1400 kg DM/ha throughout autumn and winter. In spring allow FOO to fluctuate between 2000 and 3000 kg DM/ha to optimise pasture growth and liveweight gain in stock. Another example is rotational grazing systems that maintain the majority of paddocks, cells or strips at ~1400 kg DM/ha or higher.

For other perennial pastures with a more upright growth habit than kikuyu (e.g. lucerne), the minimum levels of FOO are likely to be lower.

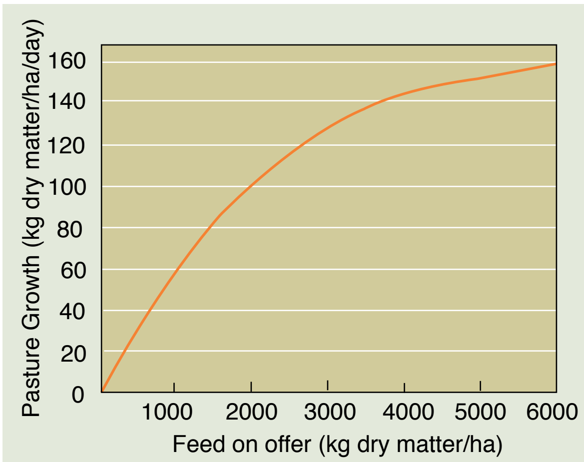

Figure 2.1 Pasture growth rates versus feed-on-offer (FOO) for kikuyu at Manypeaks[129]

Perennial plant persistence

Most perennial species require rest following grazing to allow plants to replenish below-ground reserves and to complete seed set, retain protective sheaths under moisture stress and regenerate from dormant buds.[16, 127, 222, 406]

The key to the long-term persistence of perennial pastures is to manage the carbohydrate reserves. Perennial plants store carbohydrate in their crown, tap-root, stolons and/or rhizomes and use this energy for the initial regrowth following grazing (or defoliation), to persist through periods of stress (e.g. drought, cold) and for regrowth in autumn for summer-dormant species.
If the carbohydrate reserves are continually exhausted and not fully replenished, then the stand density will gradually decline.

The response of perennial pastures to different grazing methods can be considered in terms of their requirements for strategic rest from grazing, the timing of the rest period and grazing pressure. For example, the response of perennial grasses falls into four broad categories:[187]

(a) Some species like cocksfoot require rest during a period of stress (e.g. drought) when growth rates are low. Rest is most likely required during these periods to retain active root systems and buds with low dormancy.[16, 88, 319] A rest in summer also enables sterile tillers to complete their lifecycle.[40]

(b) Some species require a strategic rest during periods of active growth, particularly when regenerating from buds in autumn and during the reproductive phase (e.g. phalaris).[222, 406] These species have limited resources for regrowth if grazed during these periods probably because they have a low density of tiller buds.

(c) Species that respond to additional grazing pressure (e.g. kikuyu). These species exhibit rapid growth following defoliation and have many tiller buds close to the ground. Many possess rhizomes and/or stolons.

(d) Some species show minimal impact from different grazing methods (e.g. wallaby grass). There is some uncertainty regarding these plants as their lack of response may be the result of light grazing pressure.

Research has shown that perennial grasses, when set-stocked, persist better under cattle than sheep, most likely because sheep are more selective and graze more closely than cattle.[129, 441] In summer, selective close grazing by sheep results in a greater loss of perennial plants than cattle at a similar stocking rate (DSE/ha).

The appropriate grazing method(s) for each perennial species are discussed in their respective descriptions (Chapters 4 to 9).

Animal production

It is commonly thought that rotational grazing results in more pasture dry matter production and as a consequence allows higher stocking rates. In recent comparisons between set-stocking and rotational grazing in which production was optimised, the stocking rate was 5-15% higher with rotational grazing.[60, 412, 415] The liveweight gain per head was lower under rotational grazing in the prime lamb studies, but there was little or no difference in wool cut per head in trials involving Merino wethers.

In general, when pasture availability is non-limiting, livestock production per head will be higher with set-stocking as it allows animals to select a high quality diet. However, this may lead to the loss of the most palatable / highest quality species in the pastures so that in the medium- to long-term animal production will decline. The combination of high stocking rates and set-stocking can lead to an increase in the subterranean clover content, which can also improve performance per head. In contrast rotational grazing usually leads to an increase in the grass component, which increases production per hectare.[237]

Most farmers are likely to see similar or smaller increases in stocking rate with rotational grazing than those measured in research trials unless scale is important. Large paddocks often contain areas of pasture that are ungrazed or grazed infrequently. If large paddocks are subdivided and rotationally grazed, pasture that was previously under-utilised will be consumed – leading to an increase in production.[288] A similar result can be obtained by grazing large paddocks with big mobs, thus reducing selective grazing by livestock.

During lambing most producers prefer to set-stock to reduce mis-mothering particularly with Merino ewes. However some farmers successfully rotate lambing ewes by allowing them to 'drift' between paddocks (i.e. gates are left open so the ewes that have just lambed can catch up to the mob when ready). Set-stocking is also preferred during joining and birth by producers who are single sire mating and who need to identify progeny carefully.

Rotational grazing can be used as a tool to assist in the control of internal parasites, either by using cattle to clean up a pasture for sheep or ensuring that livestock are not exposed to heavy worm larvae pick-up. This requires planning and an understanding of larval survival patterns. In set-stocked situations clean paddocks can be prepared (Section 2.4 Internal parasites).

Large mobs associated with rotational grazing can increase the spread of certain diseases (e.g. footrot) or make control difficult.[237] On the other hand, rotational grazing with large mobs can reduce a farmer's work-load as there are fewer mobs to check and manage compared to set-stocking.

Land degradation

Deep-rooted summer-active perennials reduce groundwater recharge and subsequent salinisation and can also reduce soil erosion. Most perennial pastures reduce soil erosion to some extent as they increase the surface cover. However, when lucerne is grazed hard in summer or autumn there is insufficient groundcover (~250 kg DM/ha) to control either wind or water erosion.

Rotational grazing can result in more groundcover than set-stocking and therefore less soil erosion. Set-stocking was compared with an eight-paddock rotation at Walebing in the northern agricultural region. The rotationally grazed paddocks had 2 t/ha more groundcover at the start of summer than those that were set-stocked at the same stocking rate (8 DSE/ha).[91]

Saltbush requires rotational grazing for long-term persistence and productivity

2.2 Animal production from extensive grazing systems

Hayley Norman and David Masters

A large component of the productivity of extensive grazing systems is determined by plant herbage production (both quantity grown and time of production) and the feeding value of this herbage. Feeding value is defined as 'the animal production response to grazing a forage under unrestricted conditions' and is a function of voluntary feed intake and nutritive value.[399] Grazing ruminants require a high feed intake because:

- the gross energy of herbage is generally low
- 15-60% of ingested energy is lost via faeces
- up to 18% of the energy released through ruminal fermentation is lost through heat and gas production
- the process of grazing and ruminating can incur a high energy cost.[426]

To achieve maximum **profitability** from extensive grazing systems, livestock production (value of meat, wool or milk) must be considered in relation to efficiency of production per unit of feed versus a number of costs. Direct costs include livestock health and processing, pasture establishment and maintenance and feed conservation costs. Indirect costs are environmental outcomes and opportunity costs.

This section discusses the factors influencing the productivity of ruminants from extensive grazing systems including the time of feed availability, quantity of herbage production, voluntary feed intake and nutritive value of herbage. It concludes with a discussion about some of the opportunities perennial pastures offer to livestock production systems.

Figure 2.2 Dry matter digestibility, crude protein, and herbage biomass of a typical subterranean clover pasture set-stocked at 10 DSE/ha from September in Bakers Hill, WA[287]

Factors influencing the value and productivity of pastures

Time of feed availability

The cost of carrying stock through periods of feed shortage is a major limitation to the profitability of mixed farming systems in southern Australia. In Mediterranean-type environments this scarcity occurs during the late summer/autumn/early winter period. Figure 2.2 shows the herbage available from a subterranean clover-based annual pasture set-stocked at 10 DSE/ha from September until March. At the start of September only 1 t DM/ha of herbage had been produced. Two months later the pasture contained over 5 t DM/ha despite continuous grazing by 10 sheep/ha. By March only 1 t/ha of dry, low quality pasture remained. As a result of this autumn/winter feed gap, producers must conserve excess spring herbage, reduce stock numbers, feed costly supplements or fail to fully use the spring biomass production.

Pasture available in autumn or early winter therefore has a higher marginal value than herbage produced in the spring, i.e. a small change in pasture availability in autumn has a higher impact on whole farm economics.

Saltbush is a high protein forage available to meet the autumn feed gap and provides a source of vitamin E

Economic modelling indicates that an additional kilogram of pasture produced in the wheatbelt in May has 10 times the value of a kilogram of equivalent quality feed in October.[270] Therefore, perennial pasture species that provide a relatively small quantity of biomass when the marginal value of pasture is high could be more profitable than annual species that provide a larger number of total grazing days but with most of the production in spring when there is a surplus of feed.

Quantity of herbage production

Herbage production depends on the genetic potential of the pasture plants in that environment, competition between plants, rainfall amount and distribution, temperature, soil type, soil fertility, disease and the grazing intensity.

In contrast to annual pasture systems, some of the biomass produced by perennial plants is not available to livestock. For instance, some may be inedible, such as woody stems (stems >2-5 mm in diameter are usually considered inedible for sheep), while some may be out of reach of animals without cutting.

Voluntary feed intake

Variation in voluntary feed intake accounts for at least 50% of the variation that is observed in feeding value of forages.[399] Voluntary feed intake is not easy to predict. Characteristics that influence voluntary feed intake include: gut fill;[425] clearance rate of digesta from the rumen (influenced by digestibility); energy; protein content; palatability; feeding behaviour and species; and class and physiological state of the animal. Other related factors include the amount of time the animal grazes and ease of grazing reflected by bite mass and bite frequency. Plant morphology also plays a role, for example, browsing from sparse shrubs is more time consuming than eating from a dense sward.

Physical and metabolic control mechanisms

A conceptual model for the regulation of pasture intake by the grazing animal based on a combination of physical and metabolic signals has been developed.[425, 426]

Digestibility of herbage has a large influence on voluntary feed intake as it determines the rate that plant material can be cleared through the rumen. Put simply, animals can only eat as fast as the rumen clearance rate will allow. Low clearance rates are associated with increases in the generation of satiety signals from the rumen to the central nervous system. This limitation represents a physical constraint to intake that is particularly important for feed sources with a low digestibility. There are also metabolic signals, for example, an energy deficit generates hunger signals, relative to the size of the deficit. Conversely, high levels of energy within the animal causes the generation of satiety signals. These metabolic signals are more significant for animals consuming highly digestible feeds. Intake by the animal is regulated through the central nervous system based on a combination of hunger and satiety signals generated by physical and metabolic responses to the feed.

With very low quality feeds, grazing animals can reach a stage where the rate of digestion is so slow that they are simply unable to consume enough feed to grow. Under these conditions, the physical signals override the hunger signals generated through low energy levels within the animal.

The predicted relationship between digestibility and voluntary feed intake for a three year old, 50 kg dry Merino ewe is illustrated in Figure 2.3, using the ruminant nutrition model GrazFeed. Assuming that all diets contained 15% crude protein, an average ewe of this size, condition and age requires the digestibility of the feed to be above 60% for growth. Generally crude protein is lower in feeds of low digestibility, in which case the line in Figure 2.3 would be steeper.

Palatability

Palatability (or feed preference) depends on any characteristic of the feed that increases or inhibits intake of forage whether the forage is offered alone or as a mixed sward. If an animal rejects forage then clearly that forage will be of reduced feeding value even if its nutritive value is high. Palatability is also likely to be regulated by the central nervous system through a combination of pre- and post-ingestive feedback signals. The physical and metabolic signals described above fit within this framework, but so do others such as taste, odour, texture, where the learned behaviour has often been developed in response to either nutrients or toxins.[96]

Evidence for nutrient signals has been reported in experiments under a range of environmental conditions. Under normal circumstances, ruminants prefer foods with high digestibility and avoid those with low digestibility and high fibre.[95, 303] Growing lambs will select from a range of different crude protein levels to obtain a mixture of feeds that meet their crude protein requirement, but will avoid the excessive intake of degradable protein.[192, 303]

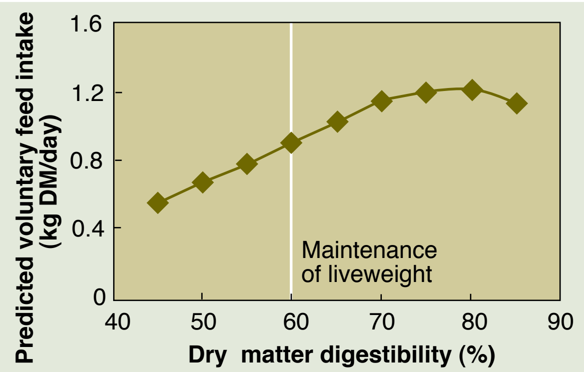

Figure 2.3 Predicted relationship between voluntary feed intake and dry matter digestibility for a 50 kg mature dry ewe fed ad lib hay of varying digestibility. Predictions were generated from the ruminant nutrition model Grazfeed[117] assuming the crude protein of all diets was 15%

However, there is also clear evidence that these nutritional signals may be overridden by others related to the presence of toxins and other anti-nutritional factors. For example, compounds such as tannins, oxalates, coumarins and nitrates, which are all commonly found in grazed plants can depress feed intake and alter dietary selection. Many perennial plants generate a range of compounds as a deterrent to grazing and to improve persistence in their environment. Annual plants tend to focus resources on the production of seed as a persistence mechanism.

Nutritive value

Nutritive value refers to the responses in animal production per unit of voluntary feed intake and is a function of the digestibility of nutrients and the efficiency with which the nutrients are used for maintenance or growth. It is influenced by plant maturity, genetic variation, environment and management.[69]

Metabolisable energy

Metabolisable energy (ME) is the amount of energy available for absorption by the animal after digestion and fermentation of the feed consumed. The energy value of feeds can be characterised as the megajoules (MJ) of ME/kg of DM at the maintenance level of feeding (M/D).

The dry matter digestibility of a feed (DMD) is often used to predict the ME. DMD is simply the difference between the quantity of feed eaten and the quantity that is excreted as faeces, expressed as a percentage of total DM eaten. Insoluble minerals (ash) and acid detergent fibre (ADF) represent the bulk of the indigestible material excreted.

Minerals that are soluble and absorbed by the animal have no energy value, however, they may contribute to the DMD. If feeds have a high ash content (e.g. saltbush), digestible organic matter in the dry matter (DOMD) is the most appropriate method for comparison with other feeds. Figure 2.4 illustrates the relationship between DMD, DOMD and metabolisable energy for feeds within the normal ash range (90-120 g ash/kg DM).[369]

Measurements of *in vivo* DMD are time consuming and expensive as they involve studies with penned animals. A number of laboratory (*in vitro*)

Lucerne is a high quality pasture for finishing prime lambs out-of-season

techniques have been developed to predict DMD by determining modified ADF or by measuring DM disappearance in a rumen fluid or pepsin/cellulase digestion system. More recently, techniques have been developed to predict *in vitro* and *in vivo* DMD using Near Infrared Reflectance Spectroscopy (NIRS). It is important to note that laboratory-based predictions have been developed for a narrow range of 'typical' forage species. Predictions of DMD or ME for novel forages may be unreliable until there has been more extensive animal house *in vivo* calibration.

Figure 2.5 illustrates how the digestibility or energy value of herbage impacts on liveweight changes. The data were generated using the ruminant nutrition model GrazFeed by 'offering' *ad lib* roughage with 45-85% DMD and 15% crude protein. The classes of stock were:

- three-year old, dry Merino ewe weighing 50 kg (same as Figure 2.3)
- 50 kg pregnant ewe carrying twin lambs, 100 days after mating
- 50 kg lactating ewe with twin lambs, 25 days after lambing
- three-year old, dry Merino ewe weighing 50 kg subject to cold temperatures (0-15°C) and 5 mm of rainfall.

Figure 2.5 illustrates that the feed quality required for maintenance of liveweight for a 50 kg ewe depends on the ewe's physiological state and on the climate. A dry ewe is predicted to maintain bodyweight on hay of 60% DMD (8.6 MJ/kg DM), however a lactating ewe with twin lambs is unable to maintain bodyweight even with a diet of 85% DMD (12.7 MJ/kg DM) because she cannot

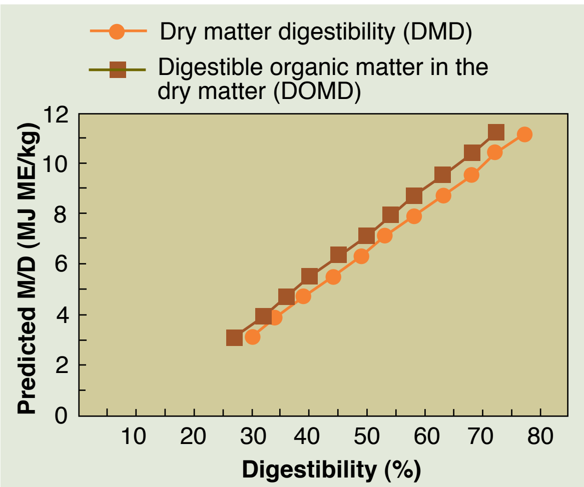

Figure 2.4 The predicted relationship between DMD, DOMD and metabolisable energy for feeds within the normal ash range of 90-120 g ash/kg DM[369]

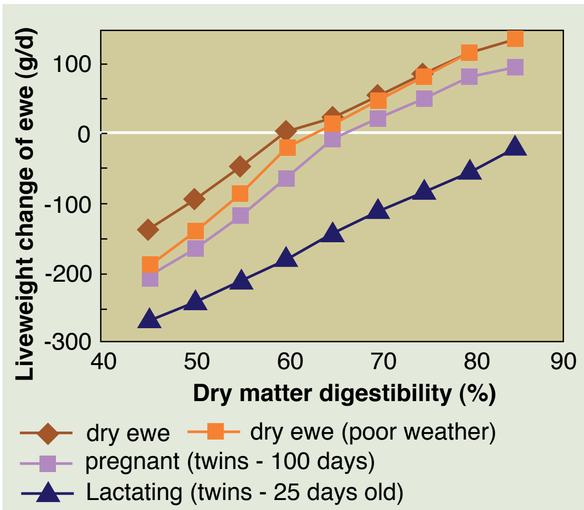

Figure 2.5 Predicted relationship between DMD of herbage and liveweight changes for four classes of ewes

eat enough to meet her energy requirements. When these requirements are compared to the DMD of subterranean clover (Figure 2.2), it becomes apparent that annual pasture residues in summer and autumn contain insufficient energy for maintenance of liveweight for any of the ewes. Sheep will only maintain weight through selection of the highest energy components of the feed or through supplementation. Table 2.1 presents DMD values of a range of annual and perennial pasture species in spring and autumn. Most, but not all of the pastures would provide enough energy for the dry and pregnant ewes in spring, however few species provide enough energy in the autumn. Table 2.2 is an estimate of the quantity of dry matter in autumn required to provide the same energy as 1 tonne of lupins.

Protein

Ruminants have a minimum protein requirement for maintenance, growth and reproduction. The figure of 7-9% crude protein (CP) is often used as the minimum requirement for an adult animal that is not reproducing or growing. For growing ruminants, dietary requirements are 14-16%. Protein requirements are often presented as a range for different classes of ruminant livestock, due to the unique relationship between the ruminant, the microbes within the rumen and the diet which makes defining more specific requirements impossible. A proportion of all protein consumed is degraded by the microbes in the rumen (rumen degradable protein). Depending on the amount of energy supplied by the diet, some of this degraded protein is converted back to microbial protein by the microbes and then passes down the digestive tract for absorption as amino acids. Within most diets, a component of the protein is resistant to microbial breakdown (undegraded dietary protein). This passes through the rumen and is either absorbed lower down the gastrointestinal tract or excreted in the faeces. Therefore the amount of protein available for absorption depends on the type of protein consumed, the energy available for microbial protein synthesis and the protein content of the diet.

Protein deficiency has been associated with grazing sub-tropical perennial grasses during the dry season and with grazing dry annual pastures in summer. Table 2.1 demonstrates the low protein

Table 2.1 Dry matter digestibility (DMD) and crude protein (CP) of a range of annual and perennial pasture species sampled in spring and autumn

Lifecycle	Species	Spring		Autumn	
		In vitro DMD (%)	CP (%)	In vitro DMD (%)	CP (%)
Annual	Annual ryegrass	67 (48-78)	10 (4-18)	58 (49-63)	5 (3-6)
	Subterranean clover	72 (69-75)	23 (20-29)	50 (44-54)	9 (7-11)
Biennial	*Melilotus alba*	74 (70-77)	16 (13-20)	65 (51-81)	12 (4-24)
	Sulla	60 (52-71)	17 (17-18)		
Perennial	Lucerne			63 (61-66)	14 (13-15)
	Dorycnium hirsutum	52 (45-55)	12 (11-14)	45 (45-46)	12 (11-12)
	Lotus corniculatus	69 (55-75)	16 (12-19)		
	Setaria	65 (60-72)		60 (52-72)	
	Puccinellia	59 (56-61)	6 (4-8)	56 (51-63)	4 (3-6)
	Tall wheat grass	61 (58-64)	8 (6-10)	58 (53-63)	8 (5-13)
	Paspalum	74 (67-80)			
	Rhodes grass	65 (50-71)		54 (50-57)	
	Veldt grass	56 (50-60)			

Data from CSIRO Livestock Industries laboratory database (unpublished, E. Hulm, D. Henry, L. Bell and H. Norman).

content of perennial grasses (in autumn and spring) and annual ryegrass (in autumn). Introduction of annual or perennial legumes or improved nitrogen nutrition would alleviate the protein deficiency in a perennial grass system. Alternatively protein could be provided through grain legume supplements (such as lupins) or a protein lick.

Crude protein is estimated by analysing a pasture sample for nitrogen content and multiplying the resulting figure by 6.25 (as protein generally contains 16% nitrogen). However, this crude calculation may over-estimate the true protein in feeds due to the presence of some non-protein nitrogen compounds (e.g. nitrates, betaines). These non-protein compounds may be converted into microbial protein in the rumen, but the extent to which this occurs depends on the availability of energy from the diet. In the absence of sufficient energy, the compounds are converted to ammonia in the rumen, which is absorbed by the animal, converted to urea and excreted in the urine.

Sulphur is primarily used along with nitrogen for the production of microbial crude protein in the rumen. The recommended dietary N:S ratio for sheep is 12.5:1.[369] Perennial pastures such as saltbush provide high levels of sulphur.

Table 2.2 Quantity of feed in autumn required to provide the same energy as 1 tonne of lupins

Feed source	Dry matter (kg)
Wheat grain	964
Lucerne	1415
Typical dry annual pasture	1800
Cereal straw	2509

Vitamins and minerals

Livestock also have minimum requirements for a range of minerals and vitamins.[186] In summary, naturally occurring deficiencies of copper, selenium and cobalt (vitamin B12) will occur in some regions if supplements are not provided or pastures have not been fertilised with the appropriate trace elements. For selenium and cobalt, deficiencies are most likely in the medium to high rainfall areas in spring. Deficiencies will result in reduced growth and wool production and in extreme conditions incapacitation and death. Deficiencies of calcium can also result if livestock are fed high levels of grain supplements. Responses to zinc supplements have been reported in grazing sheep.[238]

Of the essential vitamins, only vitamin E deficiency is consistently of commercial importance. Vitamin E (α-tocopherol) is a powerful antioxidant present in green plants. Deficiency can cause nutritional myopathy in weaner sheep,[371] especially when they have grazed dry feed for an extended period. Sub-clinical nutritional myopathy is not detrimental to liveweight gain or wool production and can often go unnoticed,[118] but clinical deficiency may cause the death of the animal. Perennial pastures offer significant opportunities to supply young animals with vitamin E when they remain green over the summer and autumn. Weaner sheep grazing saltbush have been found to have significantly higher vitamin E levels in their muscle and liver tissues than sheep grazing stubbles.[298]

Additional secondary compounds that impact on intake and nutritive value

Increasing sodium chloride (salt) in the diet decreases feed intake, digestibility, liveweight gain and wool growth significantly.[240] This is particularly relevant to plants growing in saline soils where the salt content of the leaves of halophytes can be up to 35% of DM.

Condensed tannins (CTs) are a large and diverse group of compounds, present in a number of species including tagasaste, sulla, *Lotus* and *Acacia* spp. They may have a positive contribution to animal production at low concentrations (0.2% or less of dry weight) through resistance to plant disease and pests and bloat control. They are also thought to assist in the control of internal parasites in lambs, but this is yet to be demonstrated under Australian conditions.[282, 283]

However, at concentrations of more than 1% CTs bind protein – protecting it from ruminant digestion. At concentrations more than 5% CTs reduce the voluntary feed intake and digestibility of the herbage.[87, 411] Tannin concentrations in herbage vary with plant genotype, season, soil fertility, soil acidity, water stress and temperature.[208]

Principles of feed budgeting and grazing management

Feed budgeting at its most complex takes into account all of the factors that influence pasture intake and use. Feed budgeting is the process of matching feed supply with the demand of the grazing animal. In practice, estimates of feed-on-offer, pasture growth rates and dry matter digestibility provide the information required to calculate stocking rate and the length of the grazing period. This information needs to be adjusted to take account of the required pasture cover at the end of grazing and the proportion of pasture that is used. Pasture utilisation is never 100% due to losses from trampling, selective grazing and natural decay. Feed budgeting can be used tactically to improve pasture utilisation and meet livestock production targets in the short-term (e.g. strip grazing) [89] or strategically to assess the ability of the feed base to meet livestock requirements over a full year.[259]

There is now a range of tools and options available to improve the efficiency of production from grazing systems. Extension programs such as PROGRAZE focus on tactical grazing management to meet livestock targets.[36] Satellite images can be used to provide real time information on feed-on-offer and pasture growth rates at the paddock scale.[99] Computer programs such as GrassGro[116] can be used for longer term strategic planning to simulate pasture and livestock production under different grazing regimes, while optimisation models such as MIDAS can be used to evaluate options for changes in whole-farm enterprise structures.[271]

Opportunities offered by perennial plants in extensive grazing systems

Significant opportunities exist to improve the profitability of extensive animal production systems through strategic use of perennial plants within a farming system. In this context the perennial plants may have a higher value when considered as a contribution to total farm feed resources than when considered on their own.

Opportunities for perennial plants include:

- Summer-active perennial plants have the capacity to fill the autumn feed gap by producing biomass and responding to summer rainfall when annual plants have died. The biomass produced usually has higher ME and CP than dry crop and pasture residues. Increased feed availability outside of the winter/spring growing season provides the opportunity to develop novel animal production systems that reduce the impact of seasonality of annual pastures on meat and wool production and quality.
- Perennial plants could also provide components of the diet that are lacking in dry autumn feed, such as crude protein and vitamin E.
- Tannins and other secondary compounds could help to reduce parasite burdens and reliance on chemicals.
- Small amounts of high quality feed in summer and autumn could improve the use of dry crop and pasture stubbles. For example, the high crude protein and low fibre in saltbush complements the high fibre and low protein content of crop stubbles, which can improve the use of the total feed resource.
- Selective plantings of perennials could be used to meet special animal nutrition needs such as high energy for colostrum production to improve lamb survival or to increase ovulation rate in breeding ewes.
- At lambing time the tussock growth habit of some perennial grasses (e.g. tall wheat grass) or the hedge formation of some shrubs will provide shelter and nutrition. This will protect the newborn lambs from wind and rain. At the same time, a close supply of feed allows the mother to graze close by and decreases the likelihood of mis-mothering.
- Mixed annual and perennial pastures provide animals with the capacity to manage their diet, offering both increases in profitability and environmental sustainability.[318]

2.3 Animal toxicity

Jeremy Allen

Rhodes grass has a low oxalate content and is safe for horses

Most herbaceous perennial pastures and shrubs used for livestock production provide a valuable and good quality food source. However, occasionally some of these plants can poison livestock. Even though you may never encounter such a situation, it is worthwhile to be aware of the possibility. This will enable prompt action and minimise losses should poisoning occur.

For many of these plants there are reasonably well known predisposing factors involved in the development of toxicity. These will vary with the particular plant and type of toxin involved. However, with most plants, the risk of poisoning is increased if the plant is the dominant pasture species available.

Several clinical syndromes are involved in the poisoning of livestock following consumption of herbaceous perennial pastures and shrubs.

Photosensitisation

Photosensitisation occurs after exposure to sunlight and is essentially an inflammation of the skin (dermatitis) and sometimes an inflammation of the conjunctiva and cornea of the eye (conjunctivitis/keratitis).

Photosensitisation is caused when light sensitive molecules, usually derived from plants, are deposited in the skin and cornea. These are activated by exposure to sunlight to cause considerable local damage. Access of sunlight to these molecules is blocked or diminished by pigmentation in the skin or long hair or wool. For this reason, the physical changes of photosensitisation are most apparent in areas with white hair or wool and those least covered by hair or wool, such as eyes, eyelids, ears, lips, face and coronets. Photosensitisation is not the same as sunburn. It is caused by exposure to visible light and does not require prolonged exposure. Sunburn is caused by ultraviolet light and requires prolonged exposure.

Animals showing clinical signs of photosensitisation might:

- appear restless
- seek out shade
- shake their heads, or
- rub against other objects.

Affected parts become swollen due to fluid accumulation under the skin (oedema) and this might cause the ears to droop. This will progress to weeping of the oedema fluid though the skin, death of the skin, formation of hard scabs and sloughing of the dead skin to leave raw wounds. It is likely there will also be discharges from the eyes and the cornea may become opaque. In many cases animals may appear lame because the coronets become inflamed. If animals are removed from the source of the problem and into shade as soon as the early behavioural changes or signs of oedema are noticed, they will recover well.

However if removal is delayed, extensive damage may occur and some animals may die.

There are two types of photosensitisation:

(a) Primary photosensitisation occurs when plants contain light sensitive molecules and these are absorbed unaltered by the animal eating the plant. This is very rare in perennial pastures but has been reported in lucerne and birdsfoot trefoil.

(b) Secondary photosensitisation occurs when ruminants and occasionally horses suffer damage to their liver and then graze green pasture. A plant toxin is the most common cause of the liver damage. Chlorophyll from green pasture is metabolised by bacteria in the alimentary tract to phylloerythrin, a very potent light sensitive molecule. When this is absorbed it is normally extracted from the blood by the healthy liver and excreted, however a damaged liver is unable to remove all the phylloerythrin from the blood and its concentration increases, causing photosensitisation. A number of sub-tropical grasses can cause secondary photosensitisation including signal grass, bambatsi panic and panic grass.

Acute oxalate poisoning

Plants containing more than 2% soluble oxalate (DM) have the potential to cause acute oxalate poisoning in ruminants, however poisoning is normally associated with much higher concentrations (e.g. >10%). The effect on stock depends on 'pre-conditioning', i.e. whether stock have had previous exposure to plants containing oxalate, and whether the stock are hungry or not when given access to the plant.

The soluble oxalate is absorbed and combines readily with calcium to form insoluble calcium oxalate crystals within the body. Death is usually due to hypocalcaemia but can also result from damage caused by the calcium oxalate crystals in the kidneys, rumen wall and lungs. Clinical signs include difficulty in breathing, staggering, collapse and a quiet death. Perennial pastures and shrubs reported to occasionally cause acute oxalate poisoning include saltbush, small leaf bluebush, setaria, buffel grass and panic grasses. Ensuring these species are not the sole feed source and that pasture with a low oxalate content is also available to stock will minimise the risk.

Big head in horses

If most of the calcium in plants is in the form of insoluble calcium oxalate, then horses grazing such plants will be at risk of developing calcium deficiency. This does not occur with ruminants as the rumen bacteria breakdown the calcium oxalate, releasing the calcium for absorption. As a result, pasture that may be excellent for ruminants can be dangerous for horses. Plants that have a calcium to total oxalate ratio less than 0.5 and more than 0.5% total oxalate content (DM) are considered hazardous. Clinical signs include weight loss, lameness, fracturing of long bones and swelling of the bones of the face and jaw; hence the term 'big head'. Perennial pastures and shrubs reported to cause big head in horses include: buffel grass, setaria, panic grass, kikuyu, signal grass, small leaf bluebush and saltbush.

Cyanide (hydrogen cyanide or prussic acid) poisoning

Many plants contain cyanogenic glycosides that act as deterrents to snails and insects. Within the plant the cyanide-containing compound is linked to a sugar and is harmless. When the plant is damaged (e.g. by chewing), hydrogen cyanide is released by hydrolysis. In the body the cyanide blocks cellular respiration and in most situations results in sudden death. Affected animals may be seen to stagger for a short time before they collapse. Perennial pastures that occasionally produce cyanogenic glucosides include birdsfoot trefoil, white clover, couch grass and greater lotus, but it is a very rare condition.

In WA an extremely unusual situation occurred where goats fed branches of *Acacia saligna* died from cyanide poisoning. This fodder tree is normally considered safe and not to contain cyanogenic glycosides. However, the branches fed had been pruned because of gross malformations due to a heavy thrip and virus infection and these processes had induced the infected branches to produce cyanogenic glycosides. The normal (uncut) branches contained no cyanogenic glycosides.

Stagger syndromes

There are a number of stagger syndromes involving different plants. In all cases, clinical signs are brought on or exacerbated by exercise. The conditions 'perennial ryegrass staggers', 'phalaris staggers', 'paspalum staggers' and 'tagasaste staggers' are specific to these species and are described under livestock disorders in the relevant species description (Chapters 3 to 9).

Poisoning by ergot alkaloids (ergotism)

Ergot alkaloids are produced in the ergots of the fungus *Claviceps purpurea*, which can be found in the seed heads of some of the perennial grasses (couch, *Paspalum dilatatum*), or by the endophytic fungi *Neotyphodium coenophialum* in tall fescue and *N. lolii* in perennial ryegrass. Ingestion of these alkaloids results in three prominent clinical syndromes – hyperthermia (pathologically high body temperatures), gangrenous ergotism (affecting peripheral parts of the body such as ears, tip of tail and hooves) and agalactia (substantially reduced or non-secretion of milk)/extended gestation/abortion. Generally, hyperthermia occurs in association with warmer temperatures and gangrenous ergotism with cooler temperatures.

Nitrate poisoning

As a general rule, any plant containing greater than 1.5% potassium nitrate equivalent (DM) is considered at risk of causing nitrate poisoning, however the concentrations associated with clinical disease are frequently more than 5%.

Nitrate is converted in the rumen to nitrite, which when absorbed oxidises the iron in haemoglobin, rendering it ineffective in carrying oxygen around the body. This results in rapid and deep breathing, muscle weakness, coma and rapid death. Nitrate poisoning appears similar to cyanide poisoning. Pregnant ruminants that survive a clinical episode of nitrate poisoning will often abort. Long-term intake of nitrate at levels just below those likely to cause clinical nitrate poisoning have been associated with, but not proven to cause, abortion, congenital abnormalities, reduced production and goitre. Perennial pastures that have the potential to cause nitrate poisoning include lucerne, perennial ryegrass, kikuyu, small leaf bluebush and saltbush.

Specific plant associated conditions

There are several conditions associated with specific pasture species: phalaris sudden death syndromes; kikuyu poisoning; 'red gut' (twisted intestine) in sheep grazing lucerne; and bloat in cattle grazing lucerne, strawberry clover and white clover. These conditions are discussed under livestock disorders in the relevant species descriptions (Chapters 3 to 9).

2.4 Internal parasites of livestock and perennial pastures

Brown Besier

Internal parasites (nematodes or worms) are a major cost to the grazing industries and effective worm management is an essential part of profitable livestock production. The continual presence of worm burdens in most grazing animals causes reduced animal production, outbreaks of parasitic disease and occasional deaths. In addition to the effects of worm infections and the necessary control costs, increasing levels of resistance by worms to drenches further threatens the effectiveness of chemical-based worm control.

Pasture management is an important aspect of worm control programs, as the egg and larval stages of the common worm species spend some time in the external environment. The microclimatic conditions within the pasture have a major influence on the worm numbers and types present at a particular time and location.

Worm lifecycles

Moisture at ground level is essential for the worm lifecycle. Adult worms produce eggs that are excreted onto the ground in the faeces. Providing that suitable environmental conditions are present – adequate moisture and mild temperatures – the eggs develop to larvae within the faecal mass. The larvae migrate onto pasture – again, providing sufficient moisture is present – where they may be ingested by grazing animals and over a few weeks, develop into adult worms, which then complete the lifecycle (Figure 2.6).

The effects of pasture on worm populations

Worm eggs and larvae are highly vulnerable to extremes of climatic conditions while on the pasture. During very hot and dry periods, such as in summer in WA, most eggs die quickly after deposition onto the ground, and larvae which have developed on the pasture also die as conditions become more extreme. However, where there is sufficient moisture at ground level, both eggs in faeces and larvae on the herbage can survive, unless temperatures reach very high levels.

The state of the pasture is a good way to gauge the likelihood of worm larvae being present to infect grazing livestock. Green pasture – indicating moisture or at least higher humidity at ground level – is highly correlated with the ability of worm eggs to develop and the larvae to survive. On irrigated pastures and in tropical situations, worm larval development can continue year-round, and is only affected by extremes of temperature. In more seasonal environments, the worm risk to livestock is mostly restricted to the green-pasture period. However, in these environments, areas of perennial pasture such as kikuyu have been shown to support worm larvae when none were present on dry annual pastures.

Perennial pastures and worm burdens

The good relationship between green pasture and worm larval survival increases the risk of worm infections in grazing animals. The likely effects of an expansion of perennial pastures into environments where annual species are presently dominant include:

- An increase in the length of the ‘worm season’, as worm pick-up by livestock will continue outside the traditional risk period.
- The risk of greater worm problems and the need for more complex management, due to the continual presence of worms.
- Introduction of the highly pathogenic barbers pole worm (*Haemonchus contortus*) into areas where it does not exist at present. This worm is a major cause of sheep and goat deaths in summer rainfall regions, as it requires warm and moist conditions, but does not presently occur in inland WA.

Management of worms on perennial pastures

The increased risk of damaging worm burdens in young (worm-susceptible) animals and greater production loss in all classes of stock due to continual worm burdens complicates worm management strategies. In particular:

- Traditional programs based on removing worms during the summer period are less effective on perennial pastures. More drenching is usually necessary to keep burdens at acceptable levels, especially in young stock.
- More frequent monitoring of faecal worm egg counts is necessary, to detect impending worm problems.

- Pasture rotations can play a major role in ensuring that livestock are not exposed to heavy worm larval pick-up. This requires forward planning and knowledge of larval survival patterns, but can be highly effective in avoiding parasitic loss.

Worm control benefits of perennial pastures

Although there is a higher worm risk on perennial pastures, they can also have some benefits over pastures based on annual species:

- Animals in good nutritional condition are better able to resist the effects of worms. The higher levels of protein nutrition provided by perennial pastures during the summer-autumn periods of winter rainfall regions are likely to help offset the effects of greater worm burdens.
- The development of drench resistance by worms is lower on green pasture. The highest levels of drench resistance occur where worms which survive summer drenching are not diluted by further worm pick-up. Even though more frequent drenching is typically necessary in green-pasture systems, the continual larval intake reduces the dominance of resistant worms. This may be a significant benefit in developing sustainable worm management strategies which maintain the effectiveness of drenches.

Changes to worm control strategies will be necessary where large areas of perennial pastures are grown in regions previously dominated by annual species. In particular, worm egg count monitoring will be an essential basis for ensuring that excessive burdens do not develop. In the longer term, research into parasite ecology will produce systems to deliver the nutritional and environmental sustainability benefits of perennial pastures while providing effective worm management.

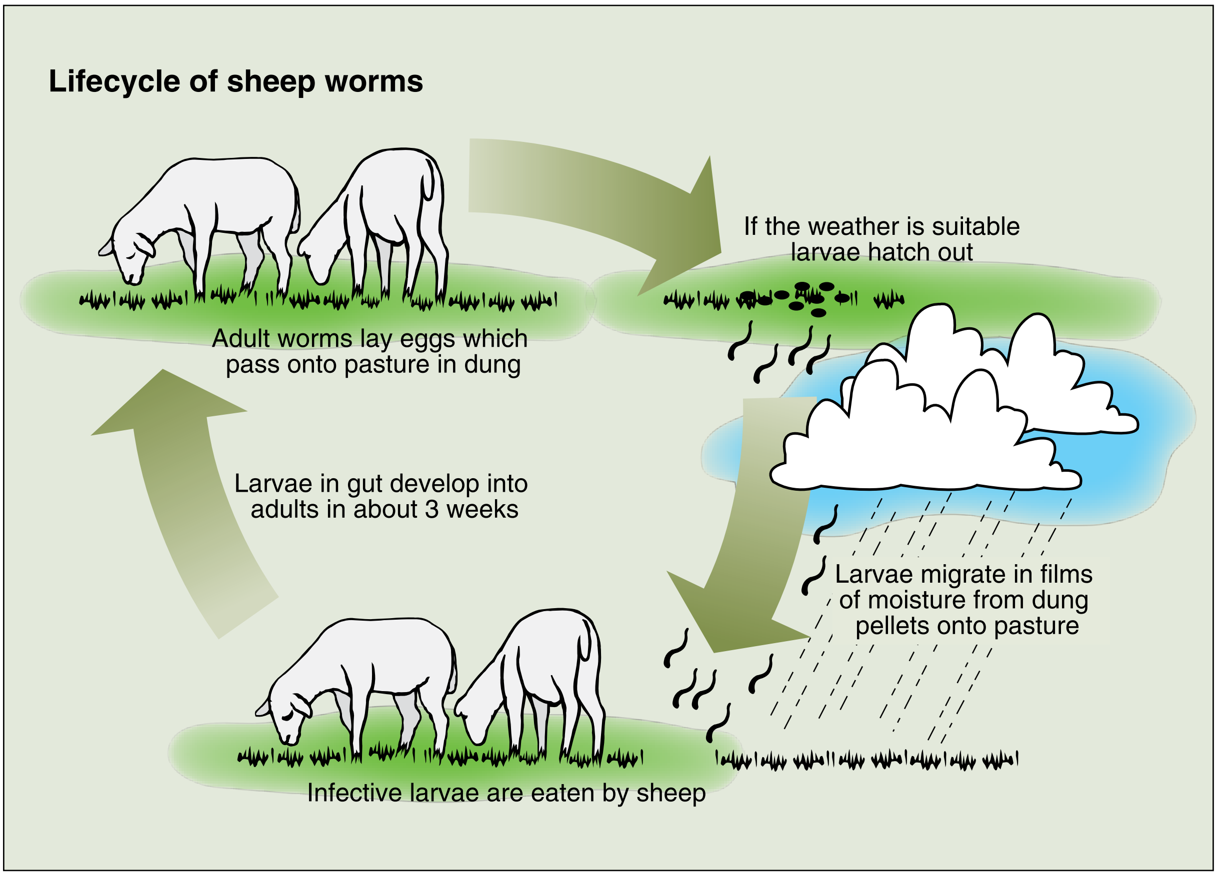

Figure 2.6 Lifecycle of sheep worms

2.5 Perennial pastures, plant diseases and the 'green bridge'

Roger Jones and Dominie Wright

The benefits provided from sowing perennial pastures need to be balanced against problems that may arise from their widespread use. One potential problem is the development of a continuous herbaceous 'green bridge' for legume and cereal pests and pathogens that would otherwise be unable to persist over summer. Such a 'green bridge' is absent with annual pastures, which senesce in late spring and only regenerate following the autumn rains. Also, pathogens and pests which are able to survive over summer without a 'green bridge', e.g. inside dormant seed, in trash or those in diapause, could continue to build-up in perennial pastures. With annual pastures, epidemics of such pathogens and outbreaks of such pests cease at the end of the growing season and then start again from a low base when the pasture regenerates in autumn.

In WA, the seasonally dry conditions, which can extend from late spring through to late autumn, ensure a substantial, continuous bridge of green foliage is rarely present away from isolated 'wet' spots. Even in years with good out-of-season rainfall the perennial pastures dry off and/or drop leaves in response to moisture stress. The summer dry period extends for four to seven months in any year. While this reduces leaf diseases, which only survive on green foliage (e.g. rust), it has less impact on viruses, which can persist in the root system of plants.

Another issue is that many perennial legume pastures are being sown with untested seed from regions where a number of seed-borne diseases of legumes occur. The widespread sowing of untested seed risks the potential large-scale introduction of seed-borne diseases. A survey of commercial lucerne seed entering WA from the eastern States showed 80% of the samples were infected with AMV (levels of 0.1-4%) and 11% were infected with CMV (0.1-0.3%), although no CMV was detected in survey samples taken at random in the field.[177]

Diseases reduce herbage production and seed yields of legume and grass pastures, reducing their persistence and favouring the build-up of weeds. In addition, diseases spread from legume pastures to nearby grain legume crops and annual legume pastures, or from perennial grass pastures to cereals.

If straightforward control measures are implemented, the disease risks from growing perennial pastures can be reduced.

Virus diseases

In WA, detailed surveys of virus occurrence have been undertaken in perennial pastures of lucerne,[177] irrigated white clover, perennial ryegrass and kikuyu,[72, 252, 253] with less detailed studies on irrigated perennial grass pastures containing couch grass.[145, 183, 251] These surveys revealed widespread infection with AMV in lucerne and white clover, WCMV in white clover, RyMV

Alfalfa mosaic virus (AMV) on lucerne. It is readily seed-borne and commercial stocks can be infected, so ensure disease-free seed is always sown

Alfalfa mosaic virus (AMV) on white clover

Table 2.3 Virus diseases of perennial pastures and susceptible annual crops and pastures

Virus (acronym)	Mode of transmission	Susceptible perennial pasture plants	Susceptible annual crops and pasture plants
SEED-BORNE VIRUSES THAT INFECT LEGUMES			
Alfalfa mosaic virus (AMV)	Seed-borne and non-persistently aphid-borne	Lucerne (readily seed-borne and many commercial seed stocks infected); white clover (susceptible but not seed-borne). Reaches very high incidences in lucerne and white clover pastures[72, 177, 252, 263] Sulla – highly resistant[197]	Annual medics (readily seed-borne), annual clovers (often seed-borne) French serradella, chickpea, lentil, faba bean, field pea, lupin
Bean yellow mosaic virus (BYMV)	Seed-borne and non-persistently aphid-borne	Lucerne – commercial seed not found infected,[177] white clover not a host Sulla – highly resistant[254]	All annual clovers, annual medics and other annual pasture legumes (often seed-borne at low levels). Biserrula very sensitive Lupin, field pea, faba bean, lentil
Cucumber mosaic virus (CMV)	Seed-borne and non-persistently aphid-borne	Commercial lucerne seed sometimes infected at low levels[177] Sulla – moderately resistant[198]	Annual medics and sub. clover (seed-borne), chickpea, lentil, balansa clover, crimson clover, other clovers
Subterranean clover mottle virus (SCMoV)	Seed-borne and contact transmitted	Lucerne – low level[111]	Subclover, arrowleaf clover (seed-borne at low levels) Annual medics and many other annual clovers are hosts
NON-SEED-BORNE VIRUSES OF LEGUMES			
White clover mosaic virus (WCMV)	Contact-transmitted	White clover – survey showed 52% of irrigated white clover infected with levels up to 83%[253] (lucerne – low level)	
Clover yellow vein virus (CYVV)	Non-persistently aphid-borne	White clover – survey showed 84% of irrigated white clover infected with levels up to 23%[253]	
Bean leaf roll virus (BLRV)	Persistently aphid-borne	Lucerne – low level[177]	Faba bean, field pea, lentil, chickpea
Beet western yellows virus (BWYV)	Persistently aphid-borne	Lucerne – low level[177]	Canola, chickpea, field pea, faba bean, lentil, all pasture legumes
Subterranean clover red leaf virus (SCRLV)	Persistently aphid-borne	White clover – survey showed 33% of irrigated white clover pastures infected with levels <12%[252] Lucerne also infected at low level[177]	Subclover, other annual clovers, chickpea, field pea, faba bean, lentil
Barley yellow dwarf virus (BYDV)	Persistently aphid-borne	Perennial ryegrass – survey showed 77% of irrigated perennial ryegrass infected with levels up to 5%[253] (kikuyu – low level)[72] Also cocksfoot, tall fescue, couch grass, lovegrass, Rhodes grass	Wheat, barley, oats, many annual grasses
Cereal yellow dwarf virus (CYDV)	Persistently aphid-borne	Cocksfoot, perennial ryegrass, tall fescue, couch grass, lovegrass, kikuyu, Rhodes grass	Wheat, barley, oats, many annual grasses
MITE TRANSMITTED VIRUS OF PERENNIAL GRASSES			
Ryegrass mosaic virus (RyMV)	Mite–transmitted	Perennial ryegrass – survey showed 60% of irrigated perennial ryegrass infected with levels up to 34%[253] Kikuyu grass also occasionally infected[72]	

in perennial ryegrass and BYDV and CYDV in various perennial grasses. Seed-borne infection with AMV was common in commercial lucerne seed stocks (Table 2.3).

Symptoms caused by viruses in pasture species vary in intensity and type depending on the combination of virus and plant species infected. Mottle, pallor, vein clearing, reduced size and deformation are common leaf symptoms, while dwarfing is a common whole plant symptom.

Factors that favour virus build-up and the risk of epidemics and increased production losses include long-term perennial pastures, the removal of non-host pasture species, e.g. grasses from legume pastures and legumes from grass pastures and a range of other factors that depend on the mode of transmission of the virus (Table 2.4).

Control measures for viruses

The aim with control measures is to minimise the build-up of virus infection and consequent losses to reduce the potential for the perennial pasture to be a source of infection to adjacent annual crop and pasture paddocks. The potential damage from infecting crops is sometimes greater than the direct damage to the pasture. The incidence of virus infection increases with the age of a stand. Economic loss is likely when incidences are high.

With viruses that are not seed-borne, rotation with a crop after about three years will reduce disease build-up, but this is only possible with phase farming. Other control measures vary with the mode of transmission of the virus (Table 2.4).

Fungal diseases

The principal fungal diseases of pastures can be divided into leaf diseases and root diseases.[446]

The major leaf diseases cause leaf spotting, which reduces the area for photosynthesis. These diseases are caused by a number of pathogens including common species such as *Phoma*, *Leptosphaerulina*, *Puccinia* and *Bipolaris* spp. These fungal pathogens are important because they also infect cereal and legume crops and annual pasture species. Perennial pastures act as a source for these fungal pathogens to survive over summer (‘green bridge’). The risk may be reduced during summer when there is minimal green leaf material present on herbaceous perennial pasture plants.

The biggest problem is when *Leptosphaerulina* and *Phoma* spp. are allowed to persist. These pathogens are widespread in WA and can cause major crop losses through defoliation.

Table 2.4 Factors that favour virus build-up and control measures in relation to the mode of transmission

Mode of transmission (viruses)	Pasture management and conditions which favour virus build-up	Control measures
Contact-transmitted (WCMV, SCMoV)	Frequent mowing, heavy grazing and trampling, rotational grazing, frequent driving of vehicles and machinery over pastures, lush soft growth.	Reduce mechanical damage by lowering grazing pressure and closing up for hay production, stop driving over paddock, increase the proportion of non-host grass species in a legume pasture.
Seed-borne (AMV, BYMV, CMV, SCMoV)	Sowing untested seed stocks that introduce new sources of seed-borne virus.	Sow new pastures with seed stocks that have been tested and found to be healthy in a 1000 seed test. For perennial legumes like lucerne select aphid resistant varieties.
Aphid- and mite-borne (AMV, BYMV, CMV, CYVV, BLRV, BWYV, SCRLV, BYDV, CYDV, RyMV)	Heavy grazing which prevents the infected (source) plants from being shaded over, which results in increased exposure of infected plants to aphids and eriophyid mites. Warm conditions that allow a rapid increase in aphid numbers.	Smother source plants by reducing the grazing pressure and closing up for hay production. Infected plants will be smaller and less vigorous and will be shaded by healthy plants in spring, which will restrict access by aphids and eriophyid mites. Kill vectors by applying a pesticide. Increase the proportion of non-host species in the pasture.

The major fungal root diseases found on perennial pasture plants: *Rhizoctonia solani*, *Fusarium* spp., *Gaeumannomyces graminis* var. *tritici* (take-all) and *Sclerotinia sclerotiorum,* are common to many crops in WA, although some are host-specific. These pathogens cause root diseases in most of the perennial pasture species as well as providing a source for diseases to spread to cereal and grain legume crops. The pathogens can survive in soil and crop debris for many years. The risk is reduced because most perennial pastures, with the exception of lucerne are managed as permanent pastures and are not grown in rotation with annual crops.

Control measures for fungal diseases

There are four approaches to disease control in annual pastures that are also useful for controlling diseases in perennial pastures:

(a) Cultural control

Grazing management, rotations, cultivation and sowing healthy seed stocks provide potential control of some leaf disease pathogens. A limitation is that most cultural practices are often determined by production imperatives, rather than disease management.

This is the main method used to control leaf and root diseases in pastures. Grazing management offers the best control options for most fungal leaf diseases while rotation is important for fungal root diseases. Unfortunately, heavy grazing can exacerbate root diseases, as the damage caused by grazing and trampling allows fungal pathogens to enter the crown and cause a rot that leads to plant death.

(b) Chemical control

Provides good short-term control of some leaf diseases, but provides poor long-term control for herbage diseases. The limitations include pollution, toxic effects on grazing animals, pathogen resistance and the cost.

(c) Host resistance

The benefit gained from durable, effective, multiple resistance is that there is little further cost once such varieties are established. The limitations from this approach are the lack of availability of such resistance and the time and cost of developing resistant varieties, which could soon become outmoded.

(d) Integrated control

The benefit from this approach is the complementary effect of methods operating in different ways. Examples include: partial resistance + grazing, or partial resistance + fungicides.

Nematode diseases

A number of nematodes are pathogenic to perennial pasture plants (Table 2.5). Most have a wide host range and their population density can increase, especially under perennial grasses. These nematodes can adversely affect cereal yields, e.g. cereal cyst nematode causes heavy losses in cereal crops and is hosted by many grasses. However, it is easily controlled by crop rotation that ensures the paddock is free of cereals and other grasses. Triticale is an alternative option, as it is resistant to both root lesion nematode and cereal cyst nematode. The perennial grasses are rarely grown in rotation with crops. Lucerne is often grown in a phase rotation with crops, and nematodes are not a common pathogen of lucerne in WA.

Among the greatest risks is the introduction of the stem nematode (*Ditylenchus dipsaci*) through pasture seed. Currently, there are no records of stem nematodes having been detected in crops in WA. This nematode would have a devastating impact on crops and could also affect the export of seed as it is seed-borne. Oats and canola are highly susceptible and introduction of this nematode would adversely affect the export hay industry as well as the canola industry.

Table 2.5 Nematode species that are pathogenic to perennial pastures

Nematode (Latin name)	Presence in WA	Perennial pasture host	Crop host
Root lesion nematode (*Pratylenchus* spp.)	Common pathogen, depends on nematode spp.	Range of sub-tropical and temperate grasses, lucerne	Wheat, barley, oats, chickpeas, faba beans (MR*), lentils (MR), field peas, canola
Cereal cyst nematode (*Heterodera* spp.)	Endemic	Perennial ryegrass	Wheat, barley, oats
Burrowing nematode (*Radopholus* spp.)	Endemic	Buffel grass, kikuyu, kangaroo grass	Wheat, barley, oats
Stem nematode (*Ditylenchus* spp.)	Seed-borne nematode not present in WA, (quarantine pathogen)	Buffel grass, couch grass, lucerne	Oats, chickpeas, faba beans, lentils, field peas, canola
Dagger nematode (*Xiphinema* spp.)	Endemic	Buffel grass, Rhodes grass, couch grass, kikuyu, perennial ryegrass, kangaroo grass	Lucerne
Root-knot nematode (*Meloidogyne* spp.)	Endemic, but prefers warmer climates where soil moisture is non-limiting	Rhodes grass, kikuyu, *Panicum* spp.	Lucerne (wheat, barley, chickpeas, faba beans) – depends upon nematode spp.

*MR – Moderately resistant

Chapter 3

Herbaceous perennial legumes

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Species descriptions – What the terms mean

A brief description of the terms used in the species descriptions in Chapters 3 to 9.

Soil–climate adaptation

Rainfall: Minimum annual rainfall (mm)

Season length: Minimum length of the growing season – Figure 1.3

Soil pH_{Ca}: Minimum (or range) soil pH as measured in 1:5 soil:0.01 M $CaCl_2$

Nutritive value

DMD: Dry matter digestibility (%) usually measured *in vitro*

ME: Metabolisable energy (Megajoule – MJ)

Crude protein: % crude protein usually derived from *in vitro* nitrogen

Drought tolerance:

Low drought tolerance	typically requires a growing season length >8 months to persist
Moderate drought tolerance	typically requires a growing season length >6.5 months to persist
High drought tolerance	typically requires annual rainfall >450 mm and/or growing season length >5.5 months to persist
Very high drought tolerance	can persist where annual rainfall >325 mm
Extremely drought tolerant	can persist when annual rainfall >250 mm

Frost tolerance:

Sensitive to frosts	extensively damaged by light frosts, with some plant deaths
Low frost tolerance	typically green-leaf is killed by mild frosts with occasional plant deaths
Moderate frost tolerance	withstands mild frosts, leaf damage when frosts less than –3°C
High frost tolerance	usually minimal damage to foliage from frosts

Waterlogging tolerance:

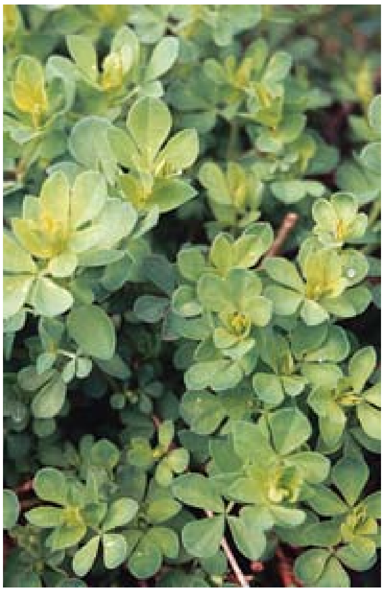
Nil waterlogging tolerance	only persists on well drained sites
Low waterlogging tolerance	persists on moderately well drained sites (perched watertable within 30 cm for 1-3 weeks depending on the season)
Moderate waterlogging tolerance	persists on imperfectly drained sites (perched watertable within 30 cm of the surface for 3-6 weeks in an average season, longer in a wet season)
High waterlogging tolerance	persists on poorly drained sites (perched watertable within 30 cm of the surface for more than 10 weeks in an average season)
Very high waterlogging tolerance	persists on very poorly drained sites, where the soil is inundated or the profile is saturated for more than 3 months in most years

Salt tolerance:

Nil salt tolerance	only grows on non-saline soils (EC_e <2 dS/m)
Slight salt tolerance	can grow on soils with an EC_e 2-4 dS/m
Moderately low salt tolerance	can grow on soils with an EC_e 4-8 dS/m
Moderate salt tolerance	can grow on soils with an EC_e 8-16 dS/m
Highly salt tolerant	halophytes which can grows on soils with an EC_e >16 dS/m

3.1 Birdsfoot trefoil *(Lotus corniculatus)*

Graeme Sandral, Daniel Real and Jonathan Warden



Features

- acid-tolerant, perennial legume
- suited to moderately winter-waterlogged soils
- moderate drought tolerance (>600 mm annual rainfall)
- palatable and high feed quality
- contains condensed tannins that prevent bloat and can improve animal production
- current varieties not well suited to conditions in WA.

Birdsfoot trefoil is a herbaceous, perennial legume native to the Mediterranean basin, Europe and parts of Eurasia and Africa. It is now cultivated in many of these areas and in parts of the United States, South America, Australia and New Zealand.

Birdsfoot trefoil is often compared to lucerne as both are tetraploid, out-crossing, long-day plants. However, birdsfoot trefoil is more tolerant of acid soils and waterlogging but less drought-tolerant than lucerne.[21, 301] This is probably because birdsfoot trefoil partitions 65-75% less carbohydrate into its root system than lucerne, and therefore relies more on remaining leaf area than root reserves for regrowth.[277] This means the rate of regrowth of birdsfoot trefoil is considerably slower than lucerne. Birdsfoot trefoil therefore requires a longer rest period between grazing or cutting for hay than lucerne.

Birdsfoot trefoil is grown in high rainfall, long season areas where lucerne production is difficult due to acid soil (pH_{Ca} <4.8), poor drainage or low fertility. In these conditions, with appropriate management, birdsfoot trefoil will be more persistent and productive than lucerne. It is not yet grown on a commercial scale in WA.

Description

- tap-rooted perennial legume, erect or slightly weeping 0.3-0.6 m high with many slender stems
- trifoliate leaves (appear to be pentifoliate) – with three leaflets at the tip of the leaf stalk plus two stipules at the base of the leaf stalk, which also resemble leaves. Leaflet length is usually 1-2 times leaflet width
- initial stem development is from the crown with regrowth often from nodes
- inflorescence can have from 1-10 (usually 4-6) yellow florets
- pods are cylindrical with 15-20 seeds/pod, which are prone to shattering
- deep tap-root with lateral branching.

A birdsfoot trefoil dominant pasture on the Swan Coastal Plain

Soil–climate adaptation

Rainfall: >600 mm (south coast >500 mm)

Season length: >7.5 months

Drought tolerance: Moderate

Frost tolerance: High

Soil type: Prefers medium-textured (e.g. loams and clay loams) but also sandy duplex soils

Soil fertility requirements: Low to medium, responsive to fertiliser but can grow well on low P[44]

Soil pH_{Ca}: >4.5

Aluminium tolerance: Moderate[350]

Waterlogging tolerance: Moderate

Salt tolerance: Nil

Nutritive value

DMD: 60-68%

Crude protein: 19-22%[3]

Seasonal growth pattern

Birdsfoot trefoil makes moderate growth in autumn and winter, but has good spring production. Summer growth depends on available soil moisture. The optimum temperature for growth is ~24°C.[112] It is a long day plant and requires day lengths of more than 16 hours to flower profusely.[112]

Individual birdsfoot trefoil plants are often short-lived (2-3 years) especially in stands affected by crown and root-rot, therefore stand longevity relies on seedling recruitment to maintain a good density.[44]

Establishment

Birdsfoot trefoil requires careful management for successful establishment because of its small seed size (0.8×10^6 seeds/kg) and low seedling vigour. It should be inoculated with the specific rhizobium (SU 343), lime pelleted and then sown at a shallow depth (5-15 mm) into a firm, level, seedbed free of weeds. Suggested seeding rates are 4-8 kg/ha when sown alone. Banding fertiliser 5-10 cm beneath the seed will improve seedling growth and establishment.

Birdsfoot trefoil is best sown in early autumn with pre- and post-emergent herbicides to control weed competition. It is not recommended that companion species be sown with birdsfoot trefoil in the establishment year, as it is a poor competitor and sensitive to shading during establishment.

Livestock disorders

Liveweight gains for animals grazing birdsfoot trefoil are higher than those for white clover at equivalent intake, which is largely attributed to the presence of condensed tannins that protect protein from degradation in the rumen and enable direct uptake of protein in the small intestine.[32] Condensed tannins also provide protection against bloat.

Birdsfoot trefoil can contain low levels of cyanogenic glucosides, but reports of cyanide poisoning are very rare. As with some other legumes, birdsfoot trefoil can be associated with cases of photosensitisation, however these reports are also rare.

Management

Once established, birdsfoot trefoil requires rotational grazing, as continuous grazing will reduce root carbohydrate reserves resulting in stand decline. To ensure root carbohydrate reserves are not depleted to critical levels, grazing or cutting should not be below 8-10 cm. Birdsfoot trefoil is not suitable for heavy grazing as it regrows from buds on the lower stems as well as from the crown. For this regrowth the plants depend largely on photosynthesis from the remaining leaves, in contrast to lucerne, which relies predominantly on carbohydrate reserves in the roots.

Recently grazed birdsfoot trefoil–tall fescue pasture. Birdsfoot trefoil is not suitable for heavy grazing as it regrows from buds on the lower stems as well as the crown

Stand decline can be overcome by allowing seed-set or sod-seeding. Subsequent autumn rains will allow new seedlings to establish, some of which will survive to become adult plants. To assist seedling survival the stand should be grazed to reduce shading. It is recommended that this practice be undertaken every few years.

Birdsfoot trefoil is susceptible to crown rots and root rots, which are caused by a complex of *Fusarium* spp., *Rhizoctonia solani* and *Sclerotinia* spp. especially under warm, humid conditions. The stems and foliage can also be affected by a number of fungi including *Rhizoctonia* and *Sclerotinia* spp. Insect pests usually have minimal impact on established plants, but can adversely affect seed crops.

Birdsfoot trefoil is suitable for hay or silage production. Stands should be cut for hay when 10% of the plants are flowering.

Companion species

To balance year-round feed supply established stands of birdsfoot trefoil can be over-sown with temperate perennial grasses and annual legumes and/or grasses tolerant of acid and waterlogged conditions.

Cultivars

No varieties have been released in Australia, but a number have been released overseas, including ‘Grasslands Goldie’ (New Zealand), ‘Draco’ and ‘San Gabriel’ (Uruguay) and ‘Empire’ and ‘Dawn’ from the US.

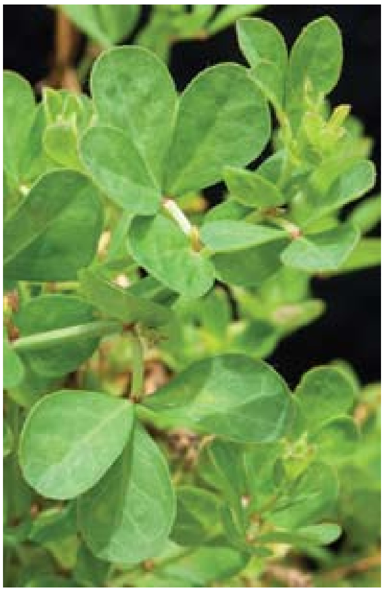
‘Grasslands Goldie’ (public variety) is grown in eastern Australia, but is not well suited to conditions in WA.

Cultivars are being developed specifically for southern Australian conditions. The aim is to develop new cultivars more suitable for seed production and/or more drought-tolerant than overseas cultivars (contact authors for more information).

Birdsfoot trefoil dominant pasture

3.2 Greater lotus *(Lotus uliginosus)*

Graeme Sandral, Daniel Real and Jonathan Warden



Features

- spreading perennial legume with extensive rhizome system (underground stems)
- very tolerant of acid soils
- highly tolerant of waterlogging and flooding, but not of saline soils
- non-bloating, with high feed quality comparable to clover and lucerne
- low drought tolerance.

Greater lotus or big trefoil (syn. *Lotus pedunculatus*) is native to Europe, eastern Russia and northern Africa. It is used as a pasture species in New Zealand, the United States and Uruguay. In addition, about 100,000 ha are sown in coastal New South Wales and Queensland.

Greater lotus is typically grown on acid soils that are waterlogged for extended periods. The relative waterlogging tolerance of the perennial lotus species is greater lotus > narrow-leaf trefoil > birdsfoot trefoil > lucerne.

The acid soil tolerance, based on native and naturalised distribution, is greater lotus > birdsfoot trefoil > narrow-leaf trefoil = lucerne.

Greater lotus plants produce a tap-root and spread by rhizomes. The stems are hollow, which assists oxygen transfer under waterlogged conditions. The feed quality of greater lotus is similar to lucerne, however it contains condensed tannins that provide protection against bloat.

The area of adaptation of greater lotus is similar to that of white clover, but greater lotus has a higher tolerance of waterlogging and high temperatures.[44] The potential for greater lotus in WA is still being determined, but it is likely to be suited to waterlogged soils in coastal districts (>600 mm). It is not yet grown on a commercial scale in WA.

Description

- prostrate to semi-erect perennial legume with extensive rhizomes (underground stems)
- tap-rooted with extensive lateral root branching
- many slender stems, which are often hollow
- trifoliate leaves (but appear to be pentifoliate) with three leaflets at the tip of the leaf stalk plus two stipules at the base of the leaf stalk that also resemble leaves. Leaflets are larger than both birdsfoot trefoil and narrow-leaf trefoil
- each inflorescence has 3-15 florets (usually 6-8), which are yellow with reddish veins. The florets are pea-shaped in compact groups or umbels. The flower head stalks arise in the fork of the upper leaves
- flower heads develop into clusters of slender cylindrical pods (20-40 seeds/pod), resembling an inverted birdsfoot. Pods are prone to shattering.

Soil–climate adaptation

Rainfall: >600 mm (>500 mm south coast)

Season length: >7.5 months

Drought tolerance: Low

Frost tolerance: High

Soil type: Range including sandy duplex, medium- and fine-textured soils

Soil fertility requirements: Low to medium, efficient at extracting P due to extensive lateral root system

Soil pH_{Ca}: >4.0

Aluminium tolerance: Moderate to high[350]

Waterlogging tolerance: Very high

Salt tolerance: Nil[350]

Nutritive value

DMD: 75% (young growth) to 65% or less in old growth

Crude protein: 20%

Seasonal growth pattern

Greater lotus prefers mild to warm conditions (optimum temperature for growth 24°C), so it makes moderate growth in autumn and winter, but has good spring production. Summer growth depends on available soil moisture. It flowers in late spring to early summer, but being a long day plant, requires a day length of more than 16 hours to flower profusely.[112] Greater lotus can be self-compatible; although it requires pollinators to produce seed. Stand persistence relies to a large extent on regrowth from the rhizomes.

Establishment

Greater lotus does not compete well with weeds due to its small seed size (1.2-2 x 10^6 seeds/kg) and low seedling vigour. Accurate seed placement and excellent weed control are therefore essential. Seed should be sown into a level, firm and weed-free seedbed at a depth of 5-10 mm. The suggested sowing rate is 1.5-3 kg/ha and seed should be inoculated with the specific *Rhizobium* (Group D) and lime pelleted (especially in acid soils).

The best sowing time is during the favourable temperatures of early autumn, as germination is suppressed when soil temperatures are less than 15°C.[44] Pre- and post-emergent herbicide applications are necessary to control weed competition.

Livestock disorders

Condensed tannins (CT) range from 2-8% of dry matter in greater lotus.[30] At low levels, tannins prevent bloat in ruminants while also protecting plant proteins from being degraded to ammonium in the rumen — enabling more protein to be absorbed in the small intestine.[409] However, voluntary intake and rumen digestion are adversely affected if CTs are more than 7%.[31]

In greater lotus high levels of CT are caused by significant plant stress, including low soil fertility. The impact of tannins on livestock is reduced in a mixed sward that contains species with low CT.

Management

Crown development in greater lotus swards is low and individual plants rely on an extensive rhizome system for survival, spread and carbohydrate reserves. The rhizome system is also a major site of shoot regrowth. Any grazing strategy that favours the growth and expansion of the rhizomes is therefore desirable.[144, 356] Rhizome development, shoot initiation and long-term stand persistence are favoured by a lax form of rotational grazing, particularly during peak rhizome expansion in summer to early autumn.[144, 424]

Greater lotus appears to be affected by crown and rootrots in a similar way to birdsfoot trefoil, but information on diseases of greater lotus is limited.

Companion species

Greater lotus is compatible with non-aggressive grasses and has been grown with white clover in warm, temperate areas in eastern Australia.[112] Established stands can be over-sown with early-maturing annual legumes that are tolerant of acid, waterlogged conditions.

Cultivars

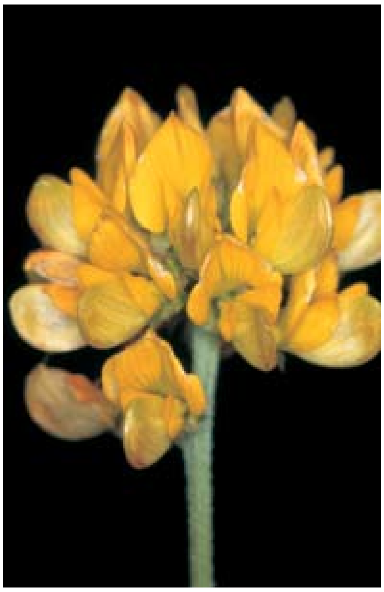
There are two greater lotus cultivars available in Australia, 'Grasslands Maku' and 'Sharnae'.

'Grasslands Maku' (public variety) is a tetraploid variety developed in New Zealand and has been extensively planted on poorly-drained acid soils in high rainfall coastal districts of eastern Australia.

'Sharnae' (public variety) was selected in NSW from material collected in the Algarve in southern Portugal. Sharnae is a diploid variety that commences flowering in mid-September in northern NSW while Maku starts flowering in mid-December. Sharnae has better spring and early summer production than Maku, but contains higher concentrations of condensed tannins.[442]

3.3 Lotononis *(Lotononis bainesii)*

Daniel Real and Ron Yates



Features

- creeping, sub-tropical forage legume with high feed quality
- persistent and drought-tolerant
- tolerant of soil acidity
- suited to a range of soil types especially sandy soils
- produces very small seeds and can be difficult to establish.

Lotononis is a perennial legume native to southern Africa – South Africa (Transvaal), Namibia, Botswana and Mozambique.[403] It is a highly palatable pasture with similar feed quality to lucerne and is grown in sub-tropical environments including coastal Queensland and Uruguay.[52, 308] The sown area in the eastern States has declined markedly in the last 30 years and it is now a minor species. Lotononis is starting to be evaluated in WA and appears to have potential on sandy soils in coastal districts (south coast, west coast).

Seasonal growth pattern

Lotononis requires warm to high temperatures for good growth with no growth when the average minimum temperature falls below 9°C.[53] As a result, it grows slowly or is dormant in winter and then starts actively growing during the warmer temperatures of spring (similar to the sub-tropical grasses) and continues growing into early summer until soil moisture is depleted. Summer growth depends on available soil moisture. It grows after the rains from autumn until early winter and flowers from August to April.

Individual plants are sometimes short-lived, but under favourable conditions a large seed bank can build up in the soil and seedling recruitment can aid persistence.[180]

Description

- creeping forage legume, which can form a dense stand less than 30 cm high, with individual plants up to 1 m in diameter
- long slender stems with smooth, trifoliate leaves
- tap-rooted as well as many roots developed from the nodes of the stolons
- inflorescence is a raceme with 8-23 yellow flowers (8-12 mm long) on erect peduncles (15-25 cm)
- pods are many-seeded (15-20 seeds/pod), tardily dehiscent
- tetraploid (2n=4x=32), cross-pollinated species.[309]

Soil–climate adaptation

Rainfall: >550 mm (south coast >475 mm)

Drought tolerance: Moderate to high[59]

Frost tolerance: Low to moderate[52]

Soil type: Adapted to a range especially coarse-textured

Soil fertility requirements: Efficient in the use of phosphorus and potassium, but responds well to fertiliser

Soil pH$_{Ca}$: >4.0[360]

Aluminium tolerance: Moderate

Waterlogging tolerance: Moderate to high

Salt tolerance: Unknown

Nutritive value

DMD: 65-70%

Crude protein: 15-20%

Establishment

Lotononis can be sown from late winter to early spring providing there is excellent weed control. It has small seeds (3 x 10^6 seeds/kg) and needs to be sown at a very shallow depth (less than 10 mm) or broadcast on the surface and rolled. The suggested seeding rate for pure stands is 1-2 kg/ha. Seedling growth is initially slow, but once plants are established the stoloniferous growth habit can compensate for poor seedling density.

Lotononis must be inoculated with specific Rhizobium (CB 376) and lime coated.[360] The associated root-nodule bacteria have been identified as *Methylobacterium* and are unique in having pink pigmentation. Physiological characterisations of these strains indicate they are tolerant of low and high pH and have the ability to grow at 40°C, so are well suited to the harsh conditions in WA.[449]

In field trials in WA lotononis has proven difficult to establish. The poor establishment is probably caused by a combination of sowing too deep and the rapid drying of coarse-textured surface soils in mid-spring. Improved establishment methods are currently being developed.

Livestock disorders

Lotononis is non-toxic, non-bloating (low condensed tannins) and no animal disorders have been reported.

Lotononis showing stoloniferous growth habit

Management

Lotononis is a stoloniferous plant, however the stolons will only root effectively if they are in contact with moist soil. Therefore grazing pressure that keeps the stand 5-10 cm high (either continuous or rotational grazing) will favour root development from the stolons. This management is essential for keeping the plants vigorous and healthy and improving persistence. Lotononis can recruit new seedlings and if the stand declines, it is best to let the pasture set seed and then manage it during autumn so competition is minimised and the seedlings can establish.

In Queensland, lush stands of lotononis can collapse from disease. Lotononis is susceptible to a range of diseases including: rhizoctonia (*Rhizoctonia solani*), legume little leaf and bean-yellow mosaic virus, *Cercospora* leaf-spot, *Botrytis* flower blight, *Sclerotium rolfsii* and Fusarium and Pythium root rots.[293, 393] Stand collapse has yet not been reported in WA perhaps because of the less humid conditions.

Lotononis needs pollinators to produce seed and seed crops should be supplied with honey bees to achieve good production. Commercial seed yields vary from 20-100 kg/ha per harvest.[153]

Companion species

Lotononis is sensitive to shading so companion annual or perennial species need to be selected and managed with this in mind.

In Queensland, lotononis combines well with low growing perennial grasses, but if grown with tall bunch grasses heavy grazing is required to keep the stand short.[59]

Cultivars

There are two cultivars of lotononis, 'Miles' (public variety)[293] and 'INIA Glencoe'[Φ].[308]

Miles was released in Queensland in 1966 after extensive agronomic evaluation in Australia.[293] It was collected by J.F. Miles in South Africa in 1952. Lotononis is now a minor species in Queensland due to disease problems and highly variable productivity between years. As a result, seed of Miles can be difficult to obtain.

A second cultivar INIA Glencoe was released in Uruguay in 2003. It has improved resistance to rootrot disease and improved forage and seed production.[308]

Lotononis has prolific seed production

3.4 Lucerne *(Medicago sativa)*

Christopher Loo, Perry Dolling and Soheila Mokhtari

Features

- drought tolerant, herbaceous perennial legume
- high palatability and feed quality
- very responsive to out-of-season rainfall
- suited to a wide range of soils with pH_{Ca} >4.8
- not suited to waterlogged or saline soils
- susceptible to a range of pests and diseases
- requires rotational grazing for long-term persistence.

Lucerne is a deep-rooted perennial originating from Asia Minor, Transcaucasia, Iran and the highlands of Turkmenistan.[46, 440] Lucerne's ability to grow in a wide range of climates makes it a valuable forage plant that is now cultivated throughout the world.

Since its introduction into Australia in the early 1800s, lucerne has demonstrated it is well adapted to both the southern and northern agricultural environments. While aphids devastated lucerne pastures in Australia in the late 1970s, the release of resistant varieties has seen it experience a renaissance in recent times.[163, 296] In Western Australia, the area sown to lucerne increased from 5,000 ha in 1995 to over 170,000 ha in 2001. This is largely because of the growing recognition of lucerne's ability to reduce recharge and produce out-of-season green feed, and the introduction of more acid-tolerant rhizobia.[206]

Lucerne is best suited to areas where the average annual rainfall is more than 325 mm. It has moderate to high frost tolerance and can survive prolonged droughts.[39, 166] Lucerne can be established in areas receiving less than 325 mm but it will only persist at low plant densities.

Description

- growth habit varies with winter-activity. The less winter-active types have a lower set crown and a more prostrate growth habit, while highly and very highly winter-active types have an erect growth habit (50-70 cm high)
- plants are hairless with many stems originating from the crown
- leaves are trifoliate, with leaflet length significantly greater than width
- new stems emerge from the crown following grazing. These stems may branch from the lower axillary buds as they develop
- flowers are compact racemes with purple florets
- pods are coiled spirally with 2-5 kidney-shaped, yellow or brown seeds
- seed count is 400,000/kg.

There are many advantages to integrating lucerne into mixed farming systems in south-western Australia including:

- provision of high quality out-of-season green feed at the start and the end of the normal winter-spring growing season and following summer and autumn rainfall[202]
- increased water use and pasture biomass than an annual pasture-crop rotation[201, 389]
- increased animal production in terms of liveweight and wool quality[34]
- a deep root system (2-3 m) that makes established plants highly drought-tolerant and enables recycling of nutrients leached below the root zone of annual crops
- creation of 'biopores' that can improve the structure of the subsoil[205, 370]
- provision of a disease break compared with continuous cropping[246]
- the ability to control weeds using non-selective chemicals, thereby providing another option to prevent or control herbicide resistant weeds.[204, 205] Good weed management will, in turn, increase the legume component and nitrogen accumulation for subsequent rotations.[202]

Lucerne provides high quality out-of-season feed

Characteristics of lucerne

Winter-activity

Lucerne varieties have been developed for a wide range of environments ranging from temperate regions with cold winters and mild summers to winter rainfall areas with hot, dry summers. Part of lucerne's adaptation to different climates is its variable growth rate during winter, which varies from dormant to actively growing.

Winter-activity rating (WAR) refers to a plant's ability to grow in low temperatures and less sunlight, with varieties graded from 1 (highly winter-dormant) to 10 (very highly winter-active). In summer, all varieties are productive when water is available from irrigation or summer rainfall. In general, the less winter-active lucerne types have crowns set lower in the soil, which makes them more resistant to grazing and trampling than the winter-active types with small, erect crowns.

Highly winter-active and very highly winter-active varieties (WAR 8-10) are suited to regions with a Mediterranean climate. They have good seedling vigour, established plants recover quickly following grazing and they compete with winter weeds and produce more biomass during winter than varieties with a lower WAR. These varieties are recommended for short-term lucerne pasture phases of two to four years in rotation with crops, but they do not persist under set-stocking.

Winter-active varieties (WAR 6-7) have slow growth during winter, but are not dormant. They are more persistent than the highly and very highly winter-active varieties under grazing and are best suited to short-term lucerne phases of three to six years in a crop rotation.

Less winter-active, or semi-dormant varieties (WAR 4-5) can be used for long phases, permanent pasture or for hay production under

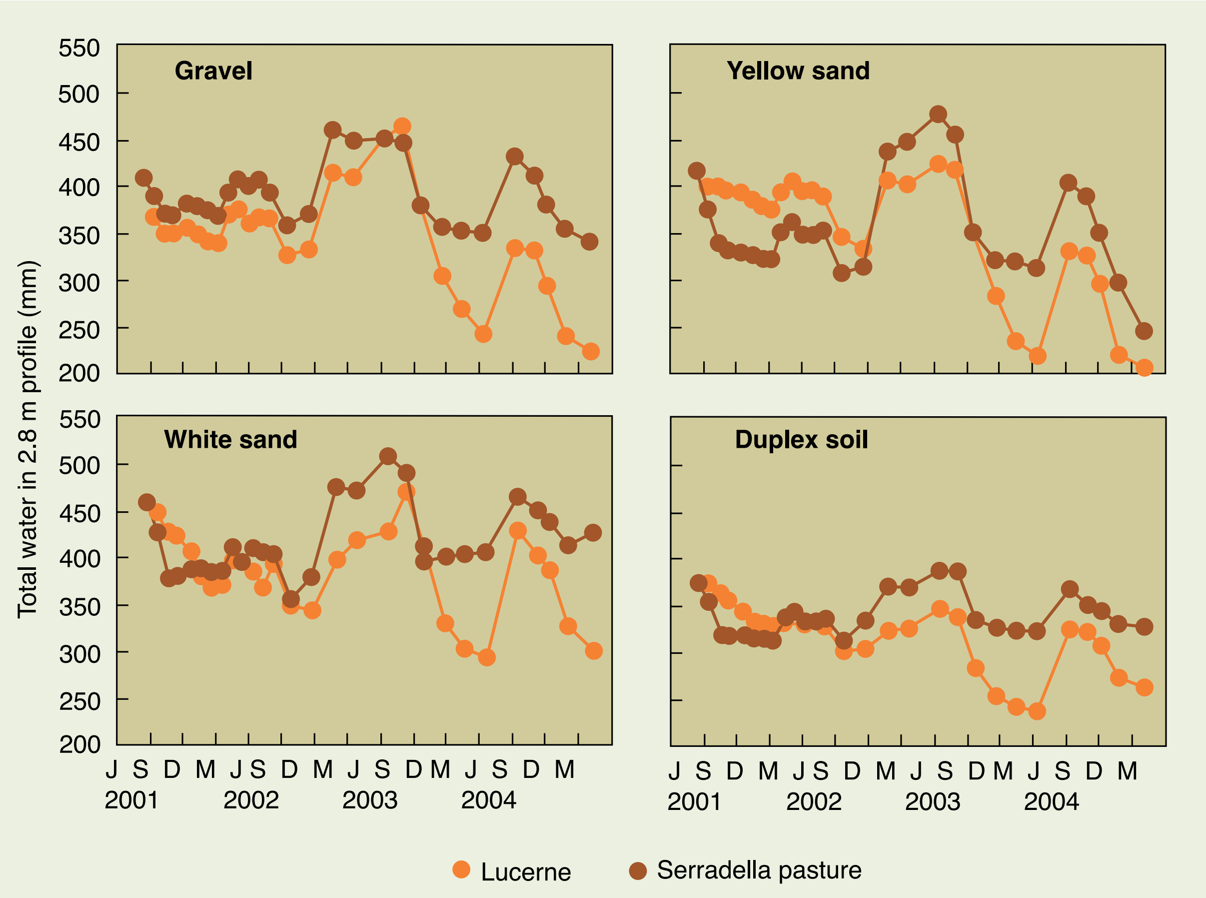


Figure 3.1 Soil water profiles under a lucerne-based farming system and an annual pasture based system with serradella on four soil types in Meckering, WA[104]

irrigation. They produce less annual biomass than winter-active varieties in a Mediterranean climate, but have better grazing tolerance and can persist for 5-10 years under rotational grazing. Semi-dormant varieties have lower crowns making them more resistant to grazing and trampling. They should be sown in August-September due to their low seedling vigour in winter.

The growth habit of semi-dormant types enables them to persist longer than highly winter-active types in extensive sheep or cattle pastures where paddocks are large and grazing management is usually not well controlled. In addition, their high leaf to stem ratio makes them ideal for hay production, particularly under irrigation. In a dryland system, winter-active varieties produce more annual biomass, but lose quality quickly due to their high proportion of stem and leaf drop when over-mature. This reduces their flexibility for cutting and baling.

Winter-dormant varieties (WAR 1-3) virtually stop growing for a period – usually when day length starts to shorten.[370] They were developed for regions with cold winters and are not normally grown in WA, however they may have a role in permanent mixed pastures and for over-cropping.

Lucerne water use

Lucerne is a high water use plant because it is perennial and grows actively outside the May-October growing season. On the other hand, annual plants only use water during their growth cycle from late autumn to spring (Figure 3.1). Lucerne develops a deep root system and as a result can greatly reduce 'deep drainage' below the root zone into the groundwater (also called leakage or recharge). Management of deep drainage is more effective in drier environments, but can still be important in medium and high rainfall environments.[104, 414]

Lucerne dries the soil profile to depth creating a 'buffer' (or 'drainage buffer') of dry soil which needs to be filled to capacity before drainage can occur. In the subsequent cropping phase this drainage buffer can store excess water from the cropping phase and prevent or reduce recharge to the groundwater. The size of this buffer depends on the depth to which lucerne can dry the soil and the water-holding capacity of the soil. In turn

Soil–climate adaptation

Rainfall: >325 mm

Drought tolerance: Very high

Frost tolerance: Moderate to high

Soil type: Grows well on a wide range of well drained soils including deep loams, deep yellow and brown sands, loamy sands over clay or gravel, deep sandy duplex soils and uniform clays, but is not suited to deep pale sands and shallow soils

Soil fertility requirements: Moderate to high

Soil pH$_{Ca}$: >4.8-8.0 in the top 30 cm (optimum growth pH$_{Ca}$ >5.5)

Aluminium tolerance: Low

Waterlogging tolerance: Low

Salt tolerance: Moderately low (if not waterlogged) with production reduced by 25% at 5.4 dS/m

Nutritive value

DMD: Whole plant 65-75%, with leaves 75-80% and stems 45-70%[58, 202]

ME: 8-11 MJ/kg DM[202]

Crude protein: 15-25%[202]

these factors are determined by the above-ground lucerne biomass (transpiration) and the rate of root growth through the subsoil.[84]

Lucerne roots have been measured to a depth of more than 8 m in deep, well-drained soils but in WA the maximum rooting depth measured is 4 m. Usually the roots only grow to 2.5-3 m, while on soils with unfavourable physical and chemical conditions in the subsoil this can be restricted to 1.5-2 m.[388] The rate of root elongation in sandy soils is typically 10-25 mm/day while in sodic clay subsoils root growth is restricted to only 2-3 mm/day (Figure 3.2).[84]

Seasonal growth pattern

When soil moisture permits, lucerne can grow actively from spring through to autumn. Winter growth varies from dormant to very highly winter-active (refer to *Winter-activity rating*).

However even the very highly winter-active lucerne has lower growth rates than temperate perennial grasses like phalaris and winter-active tall fescue in winter.

During summer, lucerne growth is dependent on water availability. Plants survive prolonged drought by limiting growth, dropping leaves, accessing stored soil water and using energy reserves in the crown and tap-root.[201] However, following summer rainfall, lucerne can respond with rapid growth. In general, plants require at least 20-25 mm rainfall to produce substantial growth. A dryland lucerne pasture typically produces between 4-8 t DM/ha/year (15-20 t/ha under irrigation), which is similar to an annual pasture, but production is more evenly spread over the year (Figure 3.3). In years with above-average summer rainfall, lucerne production can exceed annual pasture production.

A healthy lucerne stand can also add between 10 and 20 kg N/t of lucerne above-ground dry matter (~50-90 kg N/ha/yr) to the soil each year. In years with high summer rainfall, lucerne stands may fix more N than annual legumes.

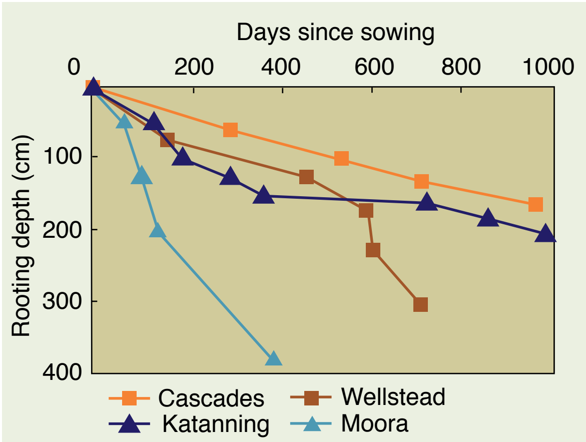


Figure 3.2 The rate of root growth on four contrasting soils in WA[84]

Moora	*deep yellow sand, moderately acidic on the surface.*
Katanning	*deep yellow sandy duplex soil with acidic subsoil.*
Wellstead	*deep grey sandy duplex soil with a neutral, non-sodic and permeable subsoil.*
Cascades	*shallow duplex soil with alkaline, sodic clay subsoil.*

Establishment

A reliable establishment package for lucerne has been developed and widely used by the WA Lucerne Growers. It includes: (a) appropriate site selection; (b) good weed control; (c) control of insect pests and disease; (d) shallow seeding depth and adequate sowing rate; (e) suitable sowing time; (f) inoculation with Group AL Rhizobia; (g) adequate fertiliser; and (h) attention to management.[20]

The key reasons for establishment failure are poor site selection (e.g. waterlogged or saline sites, low pH), poor control of seeding depth, weed competition and insect pests.

a) Site selection

Good site selection and preparation before sowing are crucial to successfully establishing a high density lucerne stand.

Lucerne will grow well on a wide range of well drained soils providing the soil pH_{Ca} is 4.8-8.0 in the top 30 cm, the soil is non-saline to mildly saline (if not waterlogged) and there is a deep soil profile (>1.5-2 m) with no limiting chemical or physical conditions in the subsoil such as poor structure. In practice, subsoil conditions often determine the ability of lucerne to create a large 'drainage buffer'. Lucerne is less suited to deep pale sands. If the pH_{Ca} <5.0 liming the topsoil one to two years before sowing the lucerne is recommended.

Lucerne is sensitive to Group B sulphonylurea herbicides, e.g. Glean®, Ally®, Logran® and to Lontrel®, a Group I herbicide. The site should not have been sprayed with Group B herbicides for at least one year prior to sowing.

b) Weed control

Lucerne seedlings have comparatively slow growth and are poor competitors, so good weed control is essential. If necessary, use a double knockdown (glyphosate, Spray.Seed®) and delay seeding to ensure good weed control. Trifluralin can be used as a pre-emergent for the control of annual ryegrass, wild oats and wireweed.

Good weed control in the year before lucerne establishment is recommended.[205, 246] Grazing, winter cleaning and spray topping are good pasture weed control strategies.[79, 202]

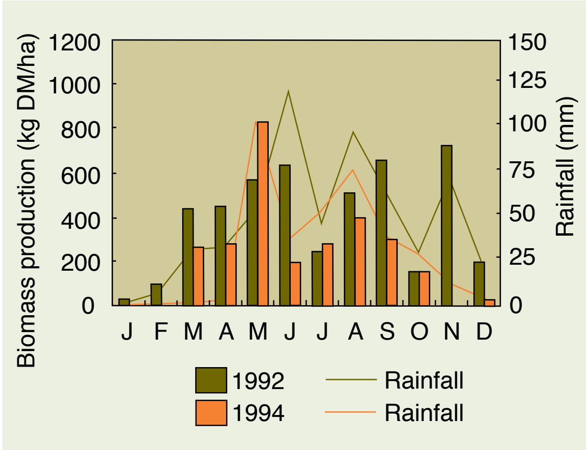


Figure 3.3 The seasonal production of winter-active lucerne at Katanning (479 mm average annual rainfall) in a wet year (1992 – 576 mm) and in a dry year (1994 – 351 mm) with the estimated annual lucerne biomass being 4.6 and 2.7 t DM/ha respectively

Particular attention should be paid to controlling spring and summer weeds such as melons, wireweed, mintweed, dock and sorrel as they are hard to control during establishment and can compete for water during the first summer.[80, 202]

c) Insect pests and diseases

Lucerne plants are very susceptible to insect and disease damage during the establishment year. There are three recommended steps to minimise damage:

(i) Use certified aphid and disease-resistant varieties free of seed-borne diseases.

(ii) Apply a pre-emergent insecticide immediately after sowing to protect emerging lucerne seedlings from redlegged earth mites (RLEM) and lucerne flea.

(iii) Monitor regularly during the establishment year. In the first month after sowing monitor every three to four days. All insect pest outbreaks should be controlled.

In WA, RLEM hatch in late autumn and August with damage appearing as silvery white blotches on the leaves.[342] Lucerne flea is most active in spring and can damage seedlings if left uncontrolled.[218] Winged aphids can arrive from other pastures and reproduce rapidly during cool to mild conditions in autumn and spring. Aphid damage appears as leaf curling and stunted plants. Check for aphid damage in the first spring and spray as necessary. In a mature lucerne stand, insect damage can usually be limited by grazing management.[205]

Poor lucerne density where the paddock is waterlogged in winter

d) Seeding depth and rate

Lucerne seed should be sown into moist soil at 5-10 mm. Press wheels or a rubber tyred roller improve seed-soil contact and increase germination. Deeper sowing results in reduced seedling emergence and patchy establishment.[80, 202]

The suggested seeding rate is 2-3 kg/ha in medium and low rainfall areas (<450 mm) and 3-4 kg/ha in areas receiving 450-600 mm. Areas receiving >600 mm can support higher plant densities, so seeding rates of 4-5 kg/ha can be used. Higher seeding rates are unnecessary as stands will thin out from competition after several years. Lucerne sown for irrigated hay requires seeding rates of 8-15 kg/ha to optimise production.

Good seedling densities of 20-40 plants/m^2 can be achieved at a seeding rate of 2-3 kg/ha. In lower rainfall zones a lower density may be acceptable, especially if pasture bulk during the growing season is increased with annual pastures.[202]

e) Sowing time

The optimum sowing time is a balance between the lucerne variety (winter-activity), weed control and the time taken for seedlings to establish before summer. In regions where there is a good chance of spring rainfall, delayed seeding in late winter-early spring will aid weed control and ensure reduced waterlogging and redlegged earth mite populations. The advantages and disadvantages of early, mid- and late sowing times are summarised in Table 3.1.

An indicative guide to the effect of sowing time and method on the likelihood of successful lucerne establishment for short or long phase rotation (winter-activity rating) in different rainfall zones is summarised in Table 3.2.

f) Inoculation

Lucerne requires inoculation with Group AL inoculum to nodulate and fix nitrogen. Paddocks with a history of lucerne cultivation can contain surviving soil rhizobia but inoculation is still advised.[202] To increase rhizobia survival, inoculated seed should be coated or pelleted with a protective layer of fine lime particularly when sowing into acid soils or if the seed is in direct contact with fertilisers (i.e. 3 kg of fine lime/25 kg of lucerne seed).[133, 202] The lime coating also protects seeds if they are being mixed with fertiliser when sowing, but using excessive lime can interfere with seed flow through seeding machinery.[80] Pelleted seed should be sown as soon as possible into moist, pre-prepared soil. Only sow into dry topsoil if rain is forecast within 48 hours.

Pre-inoculated lucerne seed is prepared using special coating processes, which may extend rhizobia survival and enable more flexibility with the sowing time. Granulated inoculant may be an alternative.

g) Fertiliser

The amount of fertiliser applied at seeding will depend on the soil type and soil test results. Concentrations of phosphorus (P) of 20-40 mg/kg and potassium (K) 100-200 mg/kg are important to maximise production, especially on sandy soils. As a general rule apply at least 10 kg P/ha. Sulphur can also be important.

Lucerne has a high demand for K, which should be applied when soil tests show a low level (about 80 ppm). Topdress 15-20 kg/ha of potash before seeding new lucerne (i.e. 30-40 kg/ha muriate of potash). Do not apply potash fertiliser down the tube with the seed because it is toxic to the germinating seed.

Table 3.1 Advantages and disadvantages of early, mid- and late sowing of lucerne[202]

Sowing time	Advantages	Disadvantages
Early sowing (early May to June)	Potentially better establishment due to longer growing season Forage production by summer Option to sow with a cover-crop	Competes with cropping program Paddock is 'locked-up' for whole season Weed and insect competition Frost damage
Mid-sowing (mid-July to August)	Increased moisture availability and longer growing season than with spring sowing	Low temperatures result in slow establishment Seedlings prone to weed competition and pest damage No option to sow with a cover-crop
Late sowing (late August-September)	Paddock can be used for grazing over winter Areas prone to mild waterlogging can dry out Allows time for excellent weed control	Risk of early summer drought, poorly developed seedlings and low persistence over summer Minimal summer grazing unless good late spring and summer rainfall Competition from summer weeds

Establishing new lucerne is also an opportunity to apply the minor trace elements like copper, zinc and molybdenum, if tissue tests identify a deficiency.[80] Nodulation and N-fixation are very dependent on molybdenum.

h) Management during the establishment year

Control grass and broad-leaf weeds during establishment using registered herbicides. The earliest that most broad-leaf herbicides can be applied is when lucerne is at the third trifoliate leaf stage.

During the establishment year lucerne should not be grazed until flowering starts or when the plants begin to drop their leaves and grow new buds from the crown.[82] A high stocking rate for a short period (five to seven days) is recommended to 'mow' the lucerne and encourage crown development without leaving stems totally stripped of leaves.[202] In favourable seasons, stands sown in late autumn-early winter can be grazed in October and again in November-December. Stands should then be left ungrazed until significant growth is made following rain in summer or autumn. After the rain, delay grazing for two to three weeks to allow the plants to replenish their carbohydrate reserves.

If lucerne has been undersown with a cover-crop (see below), it can be beneficial to graze for a short time after harvest. This will help to disperse the stubble and promote crown development through the initiation of new stems. Alternatively, wait until 10% flowering or wilting/leaf drop.[202, 246]

Cover-cropping

Cover-cropping (or companion cropping) refers to sowing lucerne with an annual crop such as wheat, barley, canola or oats.[201] This can reduce lucerne establishment costs by providing an economic return from a crop in the first year and also reduces sand blasting of seedlings on loose, sandy soils. However, these benefits may be offset by the increased competition for light, moisture and nutrients resulting in both lower crop yields and poor lucerne establishment, especially in dry seasons.

Cover-cropping can be improved by:

- using a short season crop variety to reduce competition in mid- to late spring when moisture becomes limiting
- alternate row sowing: sow lucerne and the cover crop in alternate rows to minimise inter-species competition. In WA, growers have successfully established lucerne under cover-crops using a range of modified row configurations (e.g. 3 lucerne:2 barley, or 1:1)
- using a wider row spacing which increases light in the crop canopy
- reducing the seeding rate of the crop in proportion to the row configuration (e.g. halve the seeding rate with alternate row sowing).

Table 3.2 An indicative guide to the effect of sowing time and method on the likelihood of successful lucerne establishment in different rainfall zones

Average annual rainfall (mm)	Suggested seeding rate (kg/ha)	Short or long phase rotation (Winter-activity rating* of lucerne)	Target plant density (plants/m²) (autumn after establishment)	Seeding time: Early (or autumn) sowing (early May to June)		Mid- (or winter) sowing (mid-July to early August)	Late (or spring) sowing (mid-August to September)
				Lucerne alone	Lucerne with cover-crop (in alternate rows)	Lucerne alone	Lucerne alone
<325	2		10–15	♣	NR	♣	NR
325–450	2–3	Long phase rotation (WAR 4–5)	15–25	♣♣	NR	♣	♣
		Short-term rotation (WAR 6–10)	15–25	♣♣–♣♣♣	♣–♣♣	♣♣	♣
450–600	2–3	Long phase rotation (WAR 4–5)	20–30	♣♣	♣	♣♣	♣♣
		Short-term rotation (WAR 6–10)	20–30	♣♣♣	♣♣	♣♣♣	♣♣
>600	4–5	Long phase rotation (WAR 4–5)	30–40	♣♣	♣♣	♣♣♣	♣♣♣
		Short-term rotation (WAR 6–10)	30–40	♣♣♣	♣♣	♣♣♣	♣♣♣
Summer irrigation	8–15	Long phase rotation (WAR 4–5)	60–100	–	–	♣♣♣	♣♣♣

KEY:
♣♣♣ Very good probability of successful establishment (i.e. achieving target plant densities).
♣♣ Good probability of successful establishment.
♣ Fair probability of successful establishment.
NR Not recommended.

* Semi-dormant types have a rating of 4–5, the winter-active types 6–7, and the highly and very highly winter-active types 8–10.


Lucerne cover-cropping with barley, with close (left) and wide row spacings (right)

Mature stand management

Nutrition

Lucerne nutrition can be monitored by visual observation, soil testing (especially for P and K) and plant tissue analysis. A mature lucerne stand will benefit from annual applications of **phosphorus** (9-12 units) and possibly **potassium** (15-20 units) particularly on sandy and acidic soils.[80, 205]

Phosphorus deficiency symptoms are difficult to detect visually but include stunted top growth with small, dark-green leaves that may develop a blue or purple tinge. Lucerne has a high requirement for potassium. Potash deficient plants are often seen in the establishment year and appear pale green to yellow or with white spots around the leaf margins and readily wilt during moisture stress.[132, 246]

Calcium in the soil regulates pH and is required for the structural integrity of plant cells. The $CaCO_3$ in lime applications will benefit lucerne as well as increasing the soil pH, while superphosphate also supplies calcium.

Lucerne has a high demand for sulphur (S) because of the nitrogen fixation process, therefore S deficient plants have a similar appearance to N deficient plants (i.e. stunted growth with pale green or yellowish leaves). Regular superphosphate applications usually supply sufficient S and P in correct ratios to sustain vigorous growth if used at recommended rates. Sulphur can also be applied as gypsum, S-fortified superphosphate and as elemental S as found in many compound fertilisers.[246]

Trace elements are required on most coarse-textured soils in WA and should be applied if tissue tests show a deficiency. However, if a lucerne stand appears healthy, then trace elements are likely to be adequate.[204]

Pest and disease control

A healthy and well managed lucerne stand is usually free of diseases but when infected, diseases can attack the foliage, crown or roots. To minimise pest and disease build-up, phases of lucerne should be followed by at least one year of crop and appropriate disease and pest resistant varieties should always be used.[204]

Lucerne is susceptible to a wide range of pests and diseases but many will only cause short-term damage with the stand subsequently recovering fully. However, legume pests and diseases can also spread to nearby crops of edible pulses and lupins and to annual pastures (Section 2.5).[176]

Lucerne paddock in the central wheatbelt

The most common pests of established lucerne in WA are aphids (spotted alfalfa, blue-green and pea), weevils, lucerne leaf rollers, lucerne fleas, redlegged earth mites, cutworms, native budworms and grasshoppers.[202] These common pests can usually be managed easily with a short grazing period in a mature lucerne stand or by using registered pesticides. Insect pests such as aphids can be managed effectively by sowing resistant varieties (Table 3.3) and encouraging natural predators such as ladybirds, parasitic wasps and predatory mites.[37]

Stem nematode, root-knot nematode and lesion nematodes can damage lucerne and infect a subsequent crop.[354] In particular, root-knot nematode is widespread throughout WA on a range of plant species and affects root development and function. Nematodes can be controlled by using certified seed, resistant varieties and rotation with non-host plants such as cereals.[354]

Phytophthora root rot is one of the most damaging diseases of lucerne and is favoured by damp conditions. Anthracnose, fusarium crown rot and common crown rot are also caused by continually damp conditions with high humidity such as after summer rainfall or in irrigated paddocks. These diseases can be avoided by growing lucerne on well drained soils, sowing resistant varieties and avoiding mechanical damage to crowns in the case of crown rot.[246]

Leaf infecting fungal pathogens such as rust, downy mildew, phoma black stem, pepper pot burn and Stemphylium leaf spot can be easily controlled by grazing or cutting infected material.[246] Cut material should be removed from the infected paddock to prevent re-infection. Downy mildew and phoma black stem fungus will usually clear up with warm dry weather.

In WA, alfalfa mosaic and white clover mosaic viruses are known to infect lucerne, but a number of other viruses including bean yellow mosaic, beet western yellows, cucumber mosaic and subterranean clover red leaf viruses (found on annual pasture legumes) can also infect plants.[22] Alfalfa mosaic virus is introduced on infected seed and spread by aphids, including blue-green and spotted alfalfa aphids. Control measures include sowing aphid resistant varieties, using disease-free seed and reducing aphid populations by heavy grazing and/or insecticide application.[202]

Managing weeds

To control annual grass and broad-leaf weeds, an established lucerne stand (more than 12 months old) can tolerate a range of broad spectrum chemicals such as paraquat, diquat, simazine and diuron.[151, 205] These chemicals are often applied after grazing during winter to control annual weeds without causing permanent damage to the lucerne (winter cleaning). Annual weeds should be removed as they can reduce lucerne biomass or carryover diseases into the cropping phase.

Annual pasture species such as subterranean clover and grasses can be tolerated and even welcomed to 'fill-in the gaps' to prevent wind erosion and increase the amount and diversity of the available forage.

Animal production and livestock disorders

Lucerne pastures can increase sheep liveweight and wool quality.[34, 57] Lucerne feed quality remains relatively constant throughout the year, is highly digestible (65-75%) with good levels of metabolisable energy (8-11 MJ/kg DM). It is also a reliable source of crude protein (15-25%), meeting the requirements for optimal growth of young animals (12-14% CP).[202]

Sheep grazing lucerne have achieved growth rates of between 1.0 and 1.75 kg/head/week or 146–250 g/head/day with the expected growth rate for cattle being about 0.7 kg/day.[82]

Bloat is the main health issue for cattle grazed on lucerne, but is less of a problem for sheep.[82] Adequate quantities of roughage (hay) should be made available to stock on lucerne. Alternatively, once lucerne is established, other species (grasses) may be allowed to invade without winter-cleaning to provide a wider diet and reduce the risk of bloat. Bloat can reduce weight gains significantly and in extreme cases cause death. Ensure that cattle are well fed before entering lucerne paddocks and if they show symptoms of bloat, remove them from the pasture.[202]

Other possible disorders include reproductive problems due to high levels of plant oestrogens, which are possible when lucerne produces coumestran in the leaves in response to disease or insect attack. Red gut is associated with lush, growing lucerne and symptoms are similar to those of pulpy kidney. Sheep in good condition are often affected. Adding roughage to the diet may reduce the incidence.

Grazing management

Grazing management affects the persistence of a lucerne stand, with excessive grazing damaging or killing lucerne crowns. For best results and to ensure good persistence, lucerne requires rotational grazing.

For sheep, the ideal rotation can vary from a three-paddock system with two to three weeks grazing followed by four to six weeks rest, to a six-paddock system with one week grazing followed by five weeks rest.[82] Stocking rates should be adjusted so that dry matter is reduced to similar levels after each grazing period (i.e. plants 1-2 cm high and DM <300-400 kg/ha). For sheep, ensure that lucerne stands receive adequate recovery time as animals tend to graze plants selectively due to their high digestibility and palatability.[82]

Rotational grazing is not as important for cattle as it is for sheep. Cattle can be left on lucerne for longer periods and stocking rates should be about one seventh of that for sheep.[82]

The optimum time to graze or cut lucerne is when about 10% of the plants are flowering. This early flowering period is a trade-off between herbage production and quality and coincides with the build-up of maximum levels of root reserves. As the plants continue to mature the feed quality declines as the stems become woody.

The following principles will ensure the long-term productivity of established stands:

- Graze at a high stocking rate for a short period of time. The grazing period should be as short as possible so that any regrowth is not prematurely grazed. This can be one to three weeks and depends on growing conditions and stocking rate. High grazing pressure also forces animals to be less selective, removing stems as well as leaves and ensuring the regrowth is better quality.[202]
- During the growing season the optimal recovery time for lucerne after grazing varies from four to eight weeks depending on growth rate. Stocking rates should be adjusted so that dry matter is reduced to similar levels after each grazing.[202, 246]
- During drought, lucerne should not be grazed and stock should be removed to prevent damage to the crowns.
- When lucerne flowers and is grazed, the new shoots generated from the crown should not be grazed repeatedly. Overgrazing of these new shoots will exhaust the plant's carbohydrate (starch) reserves.[202]

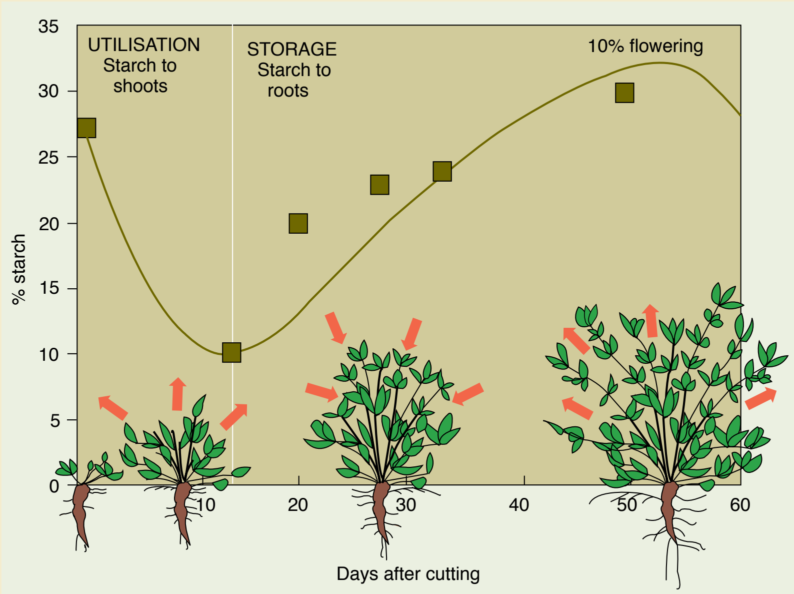


Figure 3.4 Starch levels in lucerne after cutting or grazing (adapted from Boschma and Williams, unpublished)

Starch reserves and grazing

After grazing or cutting there is minimal surface area for photosynthesis and to produce energy for plant regrowth. Lucerne grows new shoots and leaves during this period by using the starch stored in the crown and tap-root. As leaf area increases, photosynthesis produces enough starch to satisfy the plant's immediate needs, with excess carbohydrate being stored in the crown and tap-root. These stored reserves provide energy for regrowth after subsequent grazing or cutting. It takes about a month of active growth for the reserves to return to their original levels. Starch levels reach their maximum by the start of flowering before declining again as the plant invests energy in reproduction (Figure 3.4).[202]

Companion species

Lucerne is often grown as a monoculture but annual legumes (such as subterranean clover or medic) can be grown to maximise pasture biomass throughout the year. In long pasture phases where the lucerne density tends to decline, the annual legume density can increase to maintain the legume component and lift winter productivity.[202] Lucerne can also be grown with temperate perennial grasses like tall fescue and cocksfoot.[112]

Hay and silage production

In WA, using lucerne for hay production will normally only be viable with good spring-summer rain or irrigation. Semi-winter-dormant varieties are best suited for irrigation, due to their higher leaf: stem ratio. Most irrigated lucerne hay is produced on the Swan Coastal Plain and is sold mainly on the domestic market for the horse industry.[413]

For maximum yield and quality, lucerne should be cut for hay when 10% of plants are flowering. Leaf loss and feed value decline with later flowering. Quality hay depends on the growth stage at cutting, ratio of leaf to stem, the proportion of weeds, extent of weather damage and the presence of mould. Well-made hay can contain 18-21% protein but poorly-made, weedy hay could contain only 8% protein.

High-quality lucerne silage contains more protein and has higher digestibility than lucerne hay. However, due to its low sugar content, lucerne must be mixed with pasture grasses to improve the silage fermentation process.[202]

Companion cropping

Companion cropping (also known as over-cropping and inter-cropping) is the sowing of an annual crop into an established lucerne stand.

Companion cropping takes advantage of the different seasonal growth patterns of lucerne and annual crops. Lucerne is comparatively slow growing during winter when the crop is actively growing, but more active in spring and early summer when the crop begins to senesce.

Companion cropping is best suited to medium to high rainfall areas. Trials have demonstrated crop yield reductions of 3 to 50% depending on seasonal conditions, soil characteristics, effectiveness of lucerne suppression and the type of crop. Farmers in WA have used wheat, barley, oats, canola, lupin and peas as companion crops, with cereals being the most common.

Benefits of companion cropping:

- avoids difficult and costly lucerne removal before cropping
- lucerne can be retained, while still allowing grain production
- allows a higher proportion of the farm to be under lucerne than with a pasture phase. This reduces recharge across the farm as lucerne under crop or in a pasture phase can achieve similar levels of deep drainage control
- after harvest, the combination of stubble, lucerne and left-over grain provides a well balanced animal forage
- crops such as oats can provide extra early to mid-winter grazing from an established lucerne stand or add bulk to lucerne for spring hay production
- established lucerne stands tend to naturally decline in density over time, so companion cropping can form a transition between the end of a lucerne phase and the start of a cropping phase. A companion crop in this situation can also offer additional groundcover to prevent erosion.

Risks of companion cropping:

- failure to achieve an economic grain yield. The risk is higher in low rainfall environments (<350 mm) or dry years due to greater competition for moisture between the crop and lucerne
- chemicals used to suppress lucerne growth can kill lucerne plants
- presence of lucerne in the crop limits chemical options for broad-leaf weed control
- potential contamination of harvested grain with lucerne seed pods (may downgrade contaminated grain to feed quality)
- more dependence on N fertiliser particularly in high rainfall areas. The continued growth of lucerne means there is no seasonal flush of soil N released for the companion crop to use.

Managing competition

The key with companion cropping is to manage competition. Competition for moisture is higher in low rainfall years/locations, while in high rainfall years/locations competition for N is the main constraint.

To reduce initial competition, lucerne is grazed in summer and suppressed with chemicals prior to sowing the crop. The crop is then sown into lucerne at a normal seeding rate and row spacing

Companion cropping – barley sown in one year old lucerne

followed by a second chemical suppression of lucerne after eight weeks. Seeding can be undertaken either parallel with or perpendicular to the lucerne rows. Some growers use *knife points* to minimise damage to lucerne as well as breaking up the soil between the plants.

Competition can be reduced using several strategies:

- suppressing established lucerne with herbicides prior to sowing crops and during companion cropping will benefit crop production

WARNING: The effectiveness of chemical suppression of lucerne is dependent on the chemical used in relation to effects on lucerne and crop, timing of application and the rate used. Even if used correctly, chemical suppression will still result in the death of some plants. Advice from chemical specialists should be sought when planning lucerne suppression strategies. Always read chemical labels before product use.

- lucerne stands tend to self-thin over time so potential competition decreases as the stand density declines
- topdressing a companion crop can increase crop yields by 35-40%
- an early maturing crop (or variety) will reduce competition for moisture at the end of the season
- crops should be sown immediately after the break of season especially in low rainfall environments.

The tactical use of companion cropping can offer some benefits for a lucerne phase rotation. It can be used to *'phase in'* lucerne into a pasture phase, allowing more time for the lucerne to establish before grazing, or to *'phase out'* lucerne when the stand density has declined and competition for water is likely to be less. During *phasing out*, the dry soil profile created by the lucerne can affect crop yields. To reduce the risk of crop failure, an option is to use dual-purpose crops which can provide a grain yield if the season is favourable, or improve hay or forage yields if seasonal conditions are less favourable.

Lucerne seed production

Most recently released lucerne varieties are protected by Plant Breeders Rights (PBR) while most older varieties are public varieties. The seed of public varieties can be traded freely, however PBR variety seed cannot be traded without the owner's consent.

Commercial seed production is a specialised operation requiring close attention to the control of insect pests, weeds, pollination and irrigation scheduling. However when seasonal conditions permit, dryland stands can be used to produce seed for personal on-farm use.[202] Seed can be direct-headed using a conventional harvester. For maximum seed set bee hives should be used to increase pollination.

Lucerne removal

A lucerne stand might decline in productivity over time but this depends on the variety. Winter-active varieties tend to be shorter lived (three to five years) than semi-winter-dormant varieties, which can be productive for up to 10 years. If a lucerne phase is followed by a cropping cycle, the lucerne must be removed before the crop cycle to reduce competition for nutrients and water. Removing the lucerne will release nitrogen into the soil as the plants decay.

The best time to remove lucerne is during the spring or autumn when lucerne is actively growing. Removing lucerne in spring allows time for the roots to break down and nitrogen to be released and in low rainfall environments for rainfall to replenish the soil profile.[80, 202] In low rainfall environments crop yields can be lower following lucerne than annual pasture. This has been attributed to less stored water in the soil profile following lucerne.

Good establishment of lucerne on a sandy soil

Grazing before chemical desiccation will greatly assist removal. The herbicides 2,4-D amine and 2,4-D ester are being tested for their ability to kill lucerne. However they are not registered for this use and there is a minimum plant back time for a range of crops (always check the product label before using any agricultural chemical). The best time to kill lucerne is when it is actively growing, 8-10 cm in height, two to three weeks after a rainfall event, and when the net flow of carbohydrates is from the tops to the crown and root system (Figure 3.4). In some cases surviving lucerne plants can be suppressed in the cropping phase using in-crop herbicides such as Glean®, Ally®, MCPA or dicamba.[202]

Cultivars

Lucerne varieties vary in winter-activity (WAR) and pest and disease resistance. When selecting varieties, consider requirements for stand longevity, pest and disease resistance, establishment costs and timing.

Persistence and grazing tolerance

The life of a lucerne stand is determined by the interaction of pests, weeds, diseases, environmental factors and management. Under normal management there is negligible seedling recruitment and the stand density generally declines with age. The rate of stand decline tends to vary with the WAR as described above, however good management of pests, diseases and appropriate grazing will ensure a longer stand life. No variety can persist for long periods under continuous grazing but with rotational grazing, in the absence of pests and diseases, the stand life of all varieties is enhanced. Drought can reduce plant density but there are no demonstrated variety differences in drought tolerance.

Insect and disease resistance

Lucerne varieties are rated susceptible to highly resistant for a range of pests and diseases (Table 3.3). It is important to note that as lucerne is a highly out-crossing species, (i.e. no individuals are identical), resistance ratings are the average response of the population. For example, with a variety rated as highly resistant, more than 50% of the plants are resistant, with the remainder displaying varying degrees of damage. Therefore, it is important to use control measures (grazing, pesticides) to reduce yield losses even when growing the resistant varieties.

It is also important to use varieties with broad insect and disease resistance as many insect pests and diseases of lucerne are present in WA and have the potential to build up to problem levels. There are no varieties with resistance to redlegged earth mite, lucerne flea, native budworm, wingless grasshoppers, brown pasture loopers or cutworm.

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Table 3.3 Winter-activity rating of lucerne varieties and resistance to aphids, leaf and stem diseases and nematodes. A survey of seed companies in October 2005 show that 'shaded' varieties are commercially available in WA.

Variety	WAR	Aphids			Leaf and stem diseases								Nematodes	
		SAA	BGA	PA	PRR	CCR	FW	STAG	PHO	STEM	LEPT	BW	SN	RKN
SARDI 10[Φ]	10	HR	HR		R	R							R	
Rippa	10	HR	R	R	MR	S						LR	MR	
CUF101	9	R	R	R	MR	S						S	S	
Salado[Φ]	9	R	HR	R	LR	LR	HR						MR	HR
Cropper Nine	9	R	HR		HR	MR							MR	
Cropper 9.5	9	HR	HR	HR	HR	MR	HR						HR	
WL 925HQ	9	HR	HR	HR	HR	MR	HR						HR	
Sequel	9	R	LR		MR	R							S	
Sequel HR[Φ]	9	R	R		R	HR							R	
Siriver	9	HR	MR	R	S	S						S	S	
SuperSiriver[Φ]	9	R	HR		R	MR								
L90[Φ]	9	HR	HR	HR	HR	HR	R			MR	MR	LR	MR	HR
WL 612	9	HR	HR	HR	HR		HR			MR			HR	
Multileaf Generation	9	HR	HR		HR	HR							MR	HR
Sceptre[Φ]	8	HR	HR	HR	R	R	HR	R	MR	MR	MR	MR	R	R
Aquarius[Φ]	8	R	HR	R	HR	LR		MR		MR	MR	MR	R	R
Eureka[Φ]	8	R	HR	R	R	R		R	MR	MR	MR		R	R
L69[Φ]	8	HR	HR	HR	R	HR	HR					LR	LR	HR
WL 525HQ[Φ]	8	HR	HR	HR	HR	MR	HR			R	R	R	MR	
Hallmark[Φ]	8	HR	R		R	R							R	
Multi Foli-8	8	HR	HR	HR	HR	MR	HR					MR	R	
Quadrella[Φ]	7	MR	R	LR	MR	R				HR	MR	S	LR	
Q75[Φ]	7	HR	R	HR	HR	HR	HR					MR	R	R
Trifecta	7	R	HR		MR	R				LR	LR	R	LR	
SARDI 7[Φ]	7	HR	HR		HR	HR								
UQL-1[Φ]	7	HR	HR		HR	HR								
Flairdale[Φ]	7	MR	HR		R	LR		R	R				R	
Genesis[Φ]	7	MR	R	MR	R	R						S	MR	R
Hunterfield	7	HR	LR	MR	S	S	S					S	S	
SuperAurora[Φ]	7	HR	HR		HR	S								
Aurora	6	HR	HR	MR	R	MR	LR			LR	LR	LR	R	

Table 3.3 (continued)

Variety	WAR	Aphids			Leaf and stem diseases								Nematodes	
		SAA	BGA	PA	PRR	CCR	FW	STAG	PHO	STEM	LEPT	BW	SN	RKN
Stamina GT6	6	HR	R	HR	R	HR							HR	
WL 414Φ	6	HR	HR	HR	HR	MR	HR					R	R	
L55Φ	5	HR	R	R	HR	HR	HR			R	R	R	MR	MR
L56Φ	5	HR	HR	HR	HR	HR	HR					HR	HR	HR
KaitunaΦ	5	R	HR	HR	MR	R						R	HR	
SARDI 5	5	HR	HR	HR	HR	HR								
VenusΦ	5	HR	R		MR	LR								
Hunter River	5	S	S	S	S	S	S			LR	LR	S	S	
WL 342HQ-MF	4	R	R	R	HR	HR	HR					HR	R	
54Q53Φ	4	R	MR	MR	HR	HR	R					HR	HR	HR
PrimeΦ	3	R	MR	R	R	R	R	R	MR	MR	MR	R	R	

WAR – Winter-activity rating where 10 is very high to 1 is low (winter-dormant).

SAA – Spotted alfalfa aphid, BGA – Blue-green aphid, PA – Pea aphid, PRR – Phytophthora root rot, CCR – Colletotrichum crown rot (Anthracnose), FW – Fusarium wilt, STAG – Stagnospora crown rot (Common crown rot), PHO – Phoma, STEM – Stemphylium leaf spot, LEPT – Leptosphaerulina leaf disease, BW – Bacterial wilt, SN – Stem nematode, RKN – Root-knot nematode.

HR – Highly resistant, R – resistant, MR – moderately resistant, LR – low resistance, S – susceptible
(These ratings are based on the number of seedlings that survive pests and diseases in glasshouse tests. The reaction of established plants may differ (e.g. to BGA). A variety rated as resistant to a pest may still require control measures to avoid yield loss. Note that high resistance does not mean the variety is immune to the pest or disease, as a proportion of the plants may still be susceptible.)

3.5 Narrow-leaf trefoil *(Lotus glaber)*

Graeme Sandral, Daniel Real and Jonathan Warden

Features

- herbaceous perennial legume
- suited to waterlogged, medium- to fine-textured soils
- similar pH tolerance to lucerne but often grown on alkaline soils
- more tolerant of waterlogging and salt than birdsfoot trefoil
- good feed quality
- not available (cultivars currently being developed).

Narrow-leaf trefoil or narrow-leaf lotus (syn. *Lotus tenuis*) is an out-crossing perennial legume native to most of Europe including parts of the Mediterranean basin. It has become widely naturalised on the waterlogged, alkaline clay soils in the 'pampas' of Argentina.[44]

Narrow-leaf trefoil is typically grown on medium- to fine-textured soils that are winter waterlogged and which also could be mildly saline. The management of narrow-leaf trefoil is similar to that for birdsfoot trefoil, with the main difference being adaptation to soil conditions (pH, waterlogging, salinity).

There are currently no commercial varieties of narrow-leaf trefoil available, however there is a plant improvement program to develop new varieties suited to southern Australia. Narrow-leaf trefoil is a diploid which is self-incompatible and requires pollinators to produce seed.

Seasonal growth pattern

Narrow-leaf trefoil grows most during spring and summer with moderate growth in autumn and winter. Summer growth depends on available soil moisture. Narrow-leaf trefoil flowers in late spring. Like the other Lotus species individual plants can be short-lived (two to three years), so stand persistence relies on seedling recruitment.

Description

- prostrate perennial legume with many slender stems
- tap-rooted with extensive lateral root development in surface soil (adventitious roots)
- trifoliate leaves (appear to be pentifoliate) – with three leaflets at the tip of the leaf stalk plus two stipules at the base of the leaf stalk, which also resemble leaves
- leaflets are more than twice as long as they are wide (this is a distinguishing feature compared with other *Lotus* spp.)
- inflorescence can have 1-7 (usually 2-4) lemon–yellow florets
- slender, cylindrical pods 15-20 mm (15 seeds/pod), prone to shattering.

Soil–climate adaptation

Rainfall: >600 mm (>500 mm south coast)

Season length: >7 months

Drought tolerance: Low to moderate

Frost tolerance: High

Soil type: Medium- and fine-textured

Soil fertility requirements: Low to medium

Soil pH$_{Ca}$: >5.0

Aluminium tolerance: Medium to high[350]

Waterlogging tolerance: Moderate to high

Salt tolerance: Moderately low

Nutritive value

DMD: 60-68%

Crude protein: 19-22%

Establishment

Like other perennial lotus species, narrow-leaf trefoil does not compete well with weeds, due mostly to its small seed size (0.9-1.0 x 10^6 seeds/kg) and poor seedling vigour.[405] Good control of seeding depth and excellent weed control are therefore essential for successful establishment.

The best sowing time is in early autumn with pre- and post-emergent herbicide applications necessary to control weed competition. Seed should be inoculated with the specific rhizobium (SU 343) and lime pelleted. The suggested sowing rate is 4-6 kg/ha. Sowing should occur into a level, firm and weed-free seedbed at a depth of 5-15 mm.

Livestock disorders

Narrow-leaf trefoil contains nil to low concentrations of condensed tannins. Bloat has not been reported.[125]

Management

A lax form of rotational grazing will stimulate tiller formation and provide growing points for rapid regrowth. To this extent, grazing management is similar to that for birdsfoot trefoil.

Cultivars

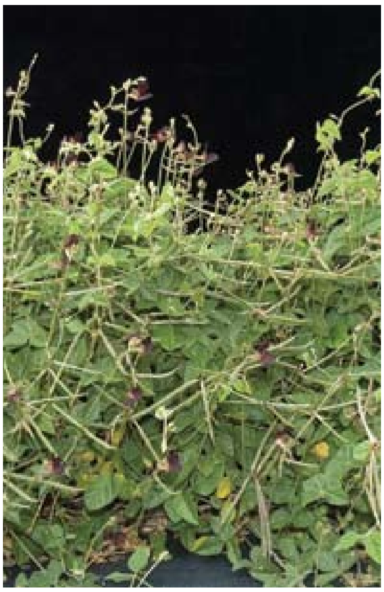
Fewer cultivars of narrow-leaf trefoil have been developed than for either birdsfoot trefoil or greater lotus, with none released in Australasia.

Cultivars are being developed specifically for Australian conditions (contact authors for more information). The aim is to improve drought-tolerance and increase seed production compared with overseas cultivars.

Narrow-leaf trefoil flowers and seed pods

3.6 Siratro, atro *(Macroptilium atropurpureum)*

Daniel Real and Geoff Moore



Features

- tropical, herbaceous, twining legume
- palatable, persistent and drought-tolerant
- adapted to a range of soil types
- easy to establish
- moderate salt tolerance but low waterlogging tolerance
- persists better with moderate to light grazing.

Siratro or atro is one of the major tropical forage legumes in sub-tropical and tropical environments. It is native to central and tropical South America and is best suited to areas with summer rainfall and a low frost incidence. Flowering and seed-set occur mainly in autumn in response to short day lengths.

The first release of this species (cv. *Siratro*) in Queensland in 1960 marked the start of a boom in pasture plantings and it has subsequently been widely sown in Mexico, Brazil and other areas.[101, 355] The potential of this species in WA is largely unknown but it is likely to be limited by its low frost tolerance.

Seasonal growth pattern

Mostly spring, summer and autumn production. Summer growth depends on available soil moisture. The optimum temperature for growth is 26.5-30°C. Growth is greatly reduced below 21°C/16°C (day/night temperature) and ceases at 14°C.[360, 383] It is dormant in winter and slow to start growing again in spring.

Establishment

Siratro has a relatively big seed (80,000/kg) with 40-70% of hard seed. The suggested seeding rate is 1-4 kg/ha in pure stands. It is preferably drilled into a well-prepared seedbed, with a maximum sowing depth of 25 mm. In Queensland, it is also over-sown into existing pastures. It has very good seedling vigour and a rapidly elongating tap-root, which gives it some tolerance of moisture stress during establishment.[71]

Seeds must be inoculated with *Bradyrhizobium* (Group M – CB756) and lime coated. It is considered a promiscuous host that can also nodulate with the background bacteria.[449]

Siratro has similar soil temperature requirements for germination as the sub-tropical grasses.

Description

- perennial legume with twining habit and long trailing stems
- leaves are dark green on the upper surface, and silvery and very hairy on the lower surface
- inflorescence is a raceme with 6-12 deep purple flowers
- pods are straight, about 75 mm long and many-seeded
- seeds are light brown to black, with a flattened ovoid shape.

Soil–climate adaptation

Rainfall: >600 mm (south coast >500 mm)

Season length: >6 months

Drought tolerance: Moderate to high

Frost tolerance: Highly sensitive, heavy frosts kill the plant back to the crown[175, 355]

Soil type: Adapted to most types, except poorly drained soils

Soil fertility requirements: High phosphorus and potassium are beneficial

Soil pH$_{Ca}$: >4.5-8.0

Waterlogging tolerance: Low

Salt tolerance: Moderately low[337]

Nutritive value

DMD: 60% (seasonal range 55-64%)[444]

Crude protein: 15%

Good establishment of siratro in the northern agricultural region

Livestock disorders

Non-toxic, non-bloating and no disorders reported.

Management

Siratro should be lightly grazed at all times leaving at least 15 cm of stubble with green leaves after grazing. In thinning stands, it should be allowed to set seed to improve the recruitment of new plants. Individual plants are not long-lived and die out after three to four years and need to be replaced by natural seedling regeneration.

It has the potential for high seed yields but because there are several flower flushes and the pods readily shatter, seed yields are seldom more than 200 kg/ha.

It is compatible with Rhodes grass, green panic and setaria.[360]

Siratro dominant pasture

Cultivars

The first cultivar released in the world was 'Siratro' (public variety), which was bred by E.M. Hutton (Queensland) from two ecotypes from Mexico.[293]

'Aztec atro'[⊕] was released in 1994 to introduce resistance to the leaf rust (*Uromyces appendiculatus*). It was bred from Siratro, so has very similar morphology and agronomic properties.[101]

3.7 Strawberry clover *(Trifolium fragiferum)*

Kathi McDonald (nee Davies)

Features

- prostrate, stoloniferous perennial legume with pink flowers
- very good spring and autumn growth
- high feed quality
- tolerant of waterlogging, inundation and mildly saline soils
- suited to winter waterlogged and summer moist areas.

Strawberry clover is a perennial legume native to the eastern Mediterranean, central Europe and southern Asia Minor. It is widely naturalised and is now found throughout the temperate climates of the world.

It is a palatable, semi-prostrate, stoloniferous (surface runners) legume. It is moderately deep-rooted and can survive prolonged flooding, as well as being one of the more tolerant legumes of mildly saline conditions.[295, 326]

In WA, strawberry clover has been grown in the high rainfall pastures of the south-west, in the West Midlands and on summer moist sites and mildly salt-affected land in the high rainfall wheatbelt. It is best suited to areas with more than 600 mm annual rainfall, or niche areas in the agricultural region that are subject to winter waterlogging and are moist in summer.

Seasonal growth pattern

Strawberry clover grows actively in autumn and from early- to mid-spring through to early summer. Summer growth depends on moisture availability. Cool season growth is generally slow, except in areas with mild winters. It generally flowers from mid-spring to early summer and in early autumn.

Under hot, dry conditions the plants die back to the stolons over summer. They can regenerate from seed if killed by drought or poor management.

Description

- prostrate creeping legume with stolons which root from the nodes
- leaflets are narrow and elliptical in shape with conspicuous leaf veins that are clearly arched and branched, and meet the edge of the leaf at right angles
- leaflets generally have no markings but the margins may be toothed
- compact, globular flower heads occur on erect stalks and consist of many small, pinkish flowers
- mature flower heads resemble a strawberry
- seeds are yellow to brown, with 650-800,000/kg.

Establishment


Strawberry clover showing stoloniferous growth habit

Strawberry clover has low seedling vigour, so can be difficult to establish. It should be sown at 0.5-1 kg/ha in a mixture, or 1-2 kg/ha when sown alone (2-4 kg/ha irrigated). It can be sown in either autumn or spring, although autumn sowing is generally recommended so the plants can develop a strong, deep root system before summer. For areas that are waterlogged or subject to inundation over winter, then late winter or early spring sowing is recommended. Under controlled conditions 'Palestine' had good germination at day/night temperatures of 15/10°C or above with slow germination at 12/6°C.[154]

Strawberry clover has a small seed and requires shallow sowing (<10 mm). Seed should be inoculated with Group B inoculum and lime pelleted. Sowing seed with 100-200 kg/ha of superphosphate is recommended.

Seedlings are extremely susceptible to redlegged earth mite, so a residual insecticide at seeding is essential. The seedlings are slow to establish and may seem inconspicuous in the first summer, but will thicken over time.

Livestock disorders

Strawberry clover contains oestrogens and has been reported to occasionally cause infertility problems in sheep.[380]

Clover dominance in pastures may predispose cattle to bloat and increase the incidence of urinary calculi (clover stones) in sheep. These problems can be managed by maintaining a significant grass component in the pasture.

Soil–climate adaptation

Rainfall: >600 mm (>500 mm south coast) or access to soil moisture in summer

Season length: >6.5 months

Drought tolerance: Low to moderate

Frost tolerance: High

Soil type: Sandy duplexes and medium-to fine-textured soils, particularly those subject to periodic waterlogging

Soil fertility requirements: Responsive to P (S, K, Mo)

Soil pH$_{Ca}$: >4.8-8.5 (optimum 5.5-8.0)

Aluminium tolerance: Moderate (?)[112]

Waterlogging tolerance: High to very high. Tolerates prolonged inundation (and flooding) for up to one to two months due to a tropic response which elevates stolon tips above the surface of the water[394]

Salt tolerance: Slight to moderately low[326]

Nutritive value

DMD: 72-78%[148]

Crude protein: 18-24%[148]

Environmental benefits

Soil erosion control: Thick swards provide year-round groundcover

Management

Strawberry clover is grazing-tolerant once the plants have developed strong runners and the sward is well established. It is suited to either rotational grazing or set-stocking. Grazing pressure should maintain a short sward (<5-10 cm) to reduce shading by grasses, so that the strawberry clover persists. Allowing the plants to set seed in the first and possibly second seasons will ensure a good seed bank to thicken the stand in subsequent years.[380]

Topdress with 50-100 kg/ha/annum of superphosphate and muriate of potash. Trace elements should be also applied if the pasture shows deficiency symptoms.

Susceptible to sclerotinia and crown root rot.[394] Susceptible to redlegged earth mite and root-knot nematodes (*Meloidogyne* spp.).[112]

Companion species

Strawberry clover can be sown with many grasses and legumes (perennial or annual). In waterlogged, mildly saline conditions it can be included in a pasture mix with tall wheat grass, puccinellia and balansa clover.

For non-saline, waterlogged conditions, kikuyu, perennial ryegrass, tall fescue and paspalum are suitable, depending on the soil type and moisture availability.

When sowing annual and perennial species in a mix, it is recommended that they be established separately to prevent the annual pasture species out-competing the perennials during the establishment phase (e.g. establish the perennial species in year 1, followed by the annual pasture species in year 2).

Cultivars

‘Palestine’ (public variety) is the most widely sown in Australia. It originates from an ecotype near the Dead Sea in Israel and was introduced in 1929. It is a vigorous, large leaf variety with good production in spring and summer and fair winter growth.

‘Prinsep Park’ (public variety) is a natural selection from Palestine from the Bunbury area and has similar yield and persistence to Palestine. Seed may no longer be available.

‘O’Connors’ (public variety) was selected in South Australia. It is similar to Palestine, but the stems are finer, leaves and seeds are smaller and the plants are generally more prostrate and cover the ground faster. It has good summer growth and withstands heavy grazing or cutting, but has poor winter and early spring growth. It is commonly used in lawns.

‘Grasslands onward’Φ – is a small-medium leaf variety which was bred in New Zealand from local ecotypes, germplasm from overseas and the cultivars Palestine and O’Connors.

‘Grasslands upward’ (public variety) was bred in New Zealand. It is a large-leaf type with an upright growth habit and has better winter production than Palestine.

3.8 Sulla *(Hedysarum coronarium)*

Kevin Foster

Features

- erect, biennial legume with showy crimson flowers
- excellent autumn-winter production in second year
- palatable and high feed quality
- requires fertile, well drained soils
- contains condensed tannins that prevent bloat and can enhance animal performance
- current varieties more suited to fodder crop production than grazing.

Sulla (also called French honeysuckle, sweet vetch and Italian or Spanish sainfoin) is a biennial or short-lived perennial herbaceous legume from the western Mediterranean, where it is generally found on medium- to fine-textured calcareous soils. It is a crop of agricultural importance in north Africa (Algeria, Morocco and Tunisia) and is widely sown in southern Sicily mainly for hay and silage production. It has also been used for erosion control and roadside beautification in New Zealand. The flowers are attractive to bees and it is a major source of nectar in southern and central Italy.

Sulla produces high-quality forage that is well received by livestock. Biomass production can be outstanding with 12-18 t DM/ha measured from a cutting trial in New Zealand.[339] However for optimal production, sulla appears to have specific requirements in terms of soil texture, site drainage, soil fertility, temperature and pH. If these requirements are met, then sulla is a highly productive option. When grown under other conditions (e.g. coarse-textured soils, low fertility) its productivity and persistence are low and generally inferior to lucerne.

Description

- mostly upright, 30-150 cm high with thick, succulent stems that become slightly woody after flowering
- leaves consist of 7-15 pairs of oval leaflets (pinnate) with a single terminal leaflet
- flowering from early to mid-spring, flower heads are racemes of 10-35 florets, usually bright crimson
- out-crossing species that is predominantly pollinated by honey bees[448]
- brown segmented pods (2-8 segments/pod) with a rough, thorny surface – pods are non-shattering, but will split into segments (hulled seeds)
- deep, branching tap-root (up to 2 m), with many secondary roots.

Soil–climate adaptation

Rainfall: >450 mm (south coast >400 mm)

Drought tolerance: High

Frost tolerance: Moderate to high

Soil type: Well drained, fertile, medium-to fine-textured. Generally does not grow well on coarse-textured soils with inconsistent nodulation reported[110]

Soil fertility requirements: Moderate to high

Soil pH$_{Ca}$: >5.0-5.5
Prefers neutral to alkaline, especially highly calcareous soils, however will tolerate slightly acid soils providing the fertility is good[109, 379]

Aluminium tolerance: Unknown

Waterlogging tolerance: Low to moderate

Salt tolerance: Nil

Ability to spread naturally: Moderate from seed (variable)

Nutritive value

DMD: 60-70%[109]

ME: Approximately 12 MJ[109]

Crude protein: 18-21%[109]

The potential role and adaptive range in WA are still being determined. Sulla has been grown successfully in low to high rainfall areas on medium- to fine-textured soils. However, it has performed poorly in dry seasons, when sown under cool conditions or on coarse-textured soils. Its role on low rainfall, alkaline soils may be limited by inconsistent results, with poor establishment and persistence in dry seasons.

Seasonal growth pattern

Sulla grows rapidly after rain in autumn to early winter, with comparatively slow growth from late June to August unless conditions are mild. It then grows actively in spring. In WA it is essentially summer-dormant, induced by high temperatures and increased day length. However, sulla can respond to summer rainfall on the south coast with the milder summer temperatures.

Sulla normally dies back to the crown after seed-set in late spring or early summer and then re-shoots from the crown following the first rains in autumn. It is noted for its vigorous autumn-winter production in the second year. The stand density generally declines sharply in the third year.

Establishment

Seed can be sown as hulled (in segments) or de-hulled (removed from pod) seed. However, hulled seed can germinate unevenly and if broadcast, would need to be followed by harrowing and rolling. Seeding rates vary from

Sulla has potential on the alkaline soils in the Great Southern (left), but is limited by variable establishment and poor growth in dry seasons (right)

5-10 kg/ha for de-hulled seed, to 15-30 kg/ha for hulled seed.[108]

Inoculation of the seed or pod with the specific rhizobia strain (*Rhizobium sullae* CC1335 – to be replaced by WSM1592 in 2007) and lime pelleting is essential. Seed should be sown into a firm, weed-free seedbed at a depth of 10-20 mm.

Healthy sulla plants showing excellent autumn-winter growth in the second year growing alongside lucerne which is affected by lucerne flea (photo 1 September at Manjimup)

Sowing sulla during early to mid-autumn will enable it to compete strongly with annual weeds during establishment. Sulla has good seedling vigour when there are warm to mild conditions during establishment. However, when sown in early winter or under cool conditions, seedling growth is slow and annual weeds, like capeweed, can dominate the sward. After germinating, sulla remains at the rosette stage (100-150 mm) for several weeks, so is susceptible to competition from broad-leaf weeds. A pre-emergent herbicide like trifluralin can be used to control weed competition during establishment.[112]

Livestock disorders

No livestock disorders reported.

Sulla contains condensed tannins (CT) in the foliage, flowers and stems. CT concentration is typically about 8% of the DM, but can be 3-12%.[410] CTs in sulla have been attributed to higher growth rates in lambs relative to those grazing lucerne and can reduce methane emission (forage methane inhibitors) and increase milk yield and milk protein in cows.[282, 445]

Management

Sulla responds well to potash and superphosphate, while liming may be required on marginally acid soils. Grazing during the establishment year will vary depending on seasonal conditions, but well established plants in the rosette stage can be lightly grazed.[112]

Established stands require rotational grazing. Current varieties do not tolerate heavy grazing or set-stocking as the relatively high soft crowns and succulent stems are easily damaged.[191] Research in Italy suggests that reducing seed-set in the first year may reduce plant death during summer and increase stand persistence.[381]

Sulla is not seriously affected by pests and diseases but under wet conditions it can be susceptible to root rot and is occasionally affected by powdery mildew and Rhizoctonia. Sulla has good tolerance to aphids,[274] redlegged earth mite[280] and lucerne flea.

Herbicide options for broad-leaf weed control are currently being investigated.

With its high dry matter yields and ease for cutting, sulla is suitable as green forage crop or for hay or silage. It should be cut before flowering as the stems can become woody after flowering. Sulla has advantages over lucerne for hay production as it has better retention of dry leaf on the stems and for silage as it has a higher soluble carbohydrate content (18-25% of DM). The condensed tannins (moderate levels) also slow down protein degradation during the ensiling of sulla, which improves its nutritional value.

Most plants die after two years and the stand would require re-sowing unless there is good seedling recruitment which tends to be variable.[74]

Sulla in flower

Seed production

Sulla starts flowering in early to mid-spring and peaks in late spring to early summer. Flowering to seed maturity takes about eight weeks. Seed pods are divided into two to eight elliptical segments. The pods separate on maturity or during harvesting into segments (hulled seed) each containing a single, creamy-white to dark-brown seed. Optimal seed yields are obtained when about 50-60% of the seed pods are brown and the remainder are purplish-red or changing to brown (pods are non-shattering). The crop should be swathed and left in windrows for three to five days before harvesting or alternatively a desiccant can be applied. In drier areas, direct heading of the crop would be possible without desiccation or swathing.

In NZ, seed yields range from 200 kg/ha in the first year to more than 500 kg/ha in subsequent years and occasionally exceed 1000 kg/ha.[85] The proportion of hard seed at harvest is usually high (70-80%), particularly if there is dry hot weather during seed-ripening.[113] Removing the seed from the surrounding hull requires specialised machinery (e.g. similar to yellow serradella) and this process also tends to provide some scarification of the hard seed.

Cultivars

Five cultivars have been developed in Australasia: two from New Zealand and recently three varieties have been released in Australia, two by SARDI (South Australia) and one in WA.

The New Zealand cultivars are 'Grasslands Aokau' (public variety) and 'Necton' (public variety), however there is currently no certified seed of either being produced.[1]

'Grasslands Aokau' is a semi-erect variety which has been tested in field trials in WA, but has lower production, later maturity and is less persistent than accessions tested from north Africa.[340]

'Necton' is a semi-erect to erect variety selected on the basis of the number of flowering stems, earlier flowering (15 days earlier than Aokau in NZ) and vegetative yield. It has not been evaluated in WA.

The Department of Agriculture and Food with CLIMA, released 'Flamenco'⁽ᵈ⁾ an erect variety, in 2006. It is early flowering, with high seed production and was bred from germplasm collected in Tunisia.

Two cultivars were released by SARDI in 2005:

- 'Moonbi'⁽ᵈ⁾ is a semi-erect type suited to grazing. It is earlier flowering than Grasslands Aokau and sets more seed in areas with shorter growing seasons and in more marginal environments.
- 'Wilpena'⁽ᵈ⁾ is a mid-flowering erect type which has a similar flowering time to Grasslands Aokau. It is more suited to fodder/hay production, but as it develops a strong crown it may be useful for grazing.

Future developments

Post-harvest seed de-hulling contributes to the relatively high seed cost. Current technology can also damage seed during hull removal. A fully soft-seeded cultivar, which would not require de-hulling is currently under development. This would also allow for the opportunistic harvesting of seed on-farm which could be resown in the pod (as with Cadiz French serradella).

3.9 White clover *(Trifolium repens)*

Kathi McDonald (nee Davies)

Features

- stoloniferous perennial legume with white flowers
- palatable and very high feed quality
- suited to a wide range of soils
- low drought tolerance
- limited to irrigated and high rainfall pastures in WA.

White clover is a herbaceous perennial legume that reproduces from seed as well as vegetatively from stolons. It is most likely native to Mediterranean Europe and has been used as a pasture legume in both Europe and the British Isles for centuries.[295] It is widely sown throughout the world and has become naturalised in temperate and sub-tropical climates in all States of Australia where the rainfall exceeds 600 mm. An estimated six million hectares of pastures contain white clover in Australia, predominantly in the eastern States.

The potential role and adaptive range in WA is limited to high rainfall and irrigated dairy pastures in the south-west. It has been estimated that only 1% of the agricultural area is climatically suited to white clover.[152]

White clover has been grown successfully in irrigated dairy pastures and on the sandy soils of the south-west coastal plain. However, it has low drought and heat tolerance and a tendency to disappear from pastures when not managed correctly. In marginal environments, white clover behaves as an annual, regenerating each autumn from seed.

Seasonal growth pattern

The growth cycle of white clover comprises a flush of primary growth in spring with plants flowering in early to mid-spring and setting seed by early December. There is regrowth and intermittent

Description

- prostrate legume with runners (stolons) radiating from the crown and rooting at the nodes
- stems and trifoliate leaves are hairless
- leaflets are oval or heart-shaped and may or may not have light crescent markings on the upper surface depending on the variety
- flower head is round and prominent. It contains 30-40 white or pink flowers which mature to small oblong pods enclosing 3-4 yellow, tan or brown, egg or heart-shaped seeds
- seed count is 1.4-1.6 million/kg.
- maximum rooting depth is ~1.2 m, although it is usually <1.0 m, with most of the roots in the top 30 cm.

Soil–climate adaptation

Rainfall: >700 mm or irrigation

Minimum growing season: >8 months

Drought tolerance: Low

Frost tolerance: High

Soil type: All except deep sands

Soil fertility requirements: Good supply of P and K

Soil pH_{Ca}: >4.5-7.5 (optimum >5.5)

Aluminium tolerance: Moderate

Waterlogging tolerance: Moderate

Salt tolerance: Nil to slight (50% production at 2.7-3 dS/m)[329]

Nutritive value

DMD: 64-82%[17]

Crude protein: 12-27%[17]

flowering over summer when the conditions are mild and moist. Growth is depressed at high temperatures (>35°C), due to moisture stress, which is induced by the excessive transpiration demand and the inability of the soil to supply adequate water even under irrigation.

In autumn there is a second smaller flush of vegetative growth. There is relative dormancy in winter especially where cold conditions prevail. White clover is winter hardy and frost tolerant but has poor growth when the soil temperature is <5°C.[112] It prefers mild temperatures with maximum growth at 20-25°C.[112] In high rainfall coastal areas or under irrigation white clover can grow throughout the year.

The white clover seedling develops an extensively branched tap-root system, but this primary root system is typically shed during or before the second summer after planting. New plants with a mixture of (semi-) tap-roots and adventitious roots develop from the nodes on the stolons.[112] This is the mechanism by which white clover persists as a perennial. However, because the secondary root system is shallow, from year 3 the white clover stand is vulnerable to moisture stress.

Under hot, dry conditions the plants die back to the stolons, but with prolonged summer drought the stolons die. Persistence of the stand then relies on regeneration from seed reserves in the soil the following autumn.

Establishment

White clover is normally sown at rates of 1-4 kg/ha as part of a mixture or 4-5 kg/ha when sown alone. It can be established in autumn with temperate perennial grasses or in spring with warm season grasses like paspalum or kikuyu. Seed should be inoculated with Group B *Rhizobium* and lime pelleted and then sown into a firm, level, weed-free seedbed no deeper than 10 mm. White clover seedlings are susceptible to redlegged earth mite and cutworm caterpillars, so a residual insecticide should be applied at seeding.

White clover-kikuyu pasture on the Swan Coastal Plain

White clover sward

Livestock disorders

Bloat can be a problem in clover dominant pastures, especially in early spring before flowering. White clover contains cyanogenic glycosides, which can potentially cause cyanide (prussic acid) poisoning.[19] All varieties have low concentrations of oestrogen.[92]

Management

White clover withstands close grazing and is valuable for all classes of livestock. White clover-based pastures should be kept short (8-15 cm) to minimise shading. They respond well to regular topdressing with superphosphate.

Old pastures in which the white clover has become sparse can be 'pasture fallowed' (companion grasses allowed to become rank) over summer to stimulate stolon extension and improve spread, or alternatively they can be re-seeded in autumn at 1-2 kg/ha with an application of superphosphate.

White clover is susceptible to blue-green aphids. To minimise damage the pasture should be grazed hard as the aphid numbers build up. White clover is susceptible to two main viruses, rugose leaf curl virus and white clover mosaic virus.

Companion species

In suitable areas, white clover can be sown in mixtures with perennial ryegrass, cocksfoot, phalaris or tall fescue, or with warm season grasses such as kikuyu, Rhodes grass and paspalum.

Cultivars

There are many cultivars categorised in terms of leaf size and stolon density (Table 3.4). The small-leaf types are better suited to close grazing by sheep, while the large-leaf types are more suitable for cattle.

Table 3.4 Summary of white clover varieties (adapted from[293, 447] and PBR database)

Variety	Leaf size	Stolon density	Notes
Aran (public variety)	Large	Low	Winter-active, late flowering, suited to irrigated dairy pastures
Grasslands Kopu (public variety)	Large	Low	Suited to irrigated dairy pastures
Haifa (public variety)	Large	Low	Broad adaptation and winter-activity
Ladino (public variety)	Large	Low	Widely used in the US. It has good early growth, but is a short-lived forage type which requires irrigation to persist over summer
Super Haifa[Φ]	Large	Low	Selection from Haifa
Super Ladino[Φ]	Large	Low	Selection from Ladino
Waverley[Φ]	Large	Low	Winter-active, with good spring, early summer production
Will Ladino (public variety)	Large	Low	Erect variety with good spring, summer production
Grasslands Challenge[Φ]	Medium-large	Medium	Good autumn, winter production suitable for rotational grazing with cattle
Grasslands Nusiral[Φ]	Medium-large	High	Alternative to Haifa with good cool season growth
Tribute[Φ]	Medium-large	Medium	Good autumn, winter growth
Grasslands Sustain[Φ]	Medium-large	High	Good autumn, winter, spring production suitable for rotational grazing
Grasslands Bounty[Φ]	Medium	Medium	Good autumn production
Grasslands Huia (public variety)	Medium	Medium	Developed in NZ from local ecotypes, and is adapted to moist, temperate climates. Low winter-activity. It was the most widely sown variety worldwide, now superseded
Mink[Φ]	Medium	Medium	Selection from long-term pastures previously sown to Irrigation
Super Huia[Φ]	Medium	Medium	Selection from Huia
Tribute[Φ]	Medium	Medium	Good autumn, winter growth and foliar disease resistance
Grasslands Demand[Φ]	Medium-small	Medium	High persistence and suited to set-stocking with sheep. Good spring, summer production
Grasslands Prestige[Φ]	Medium-small	Medium	Good winter, spring, summer production with good pest and disease resistance
Grasslands Tahora[Φ]	Small	Medium	Dense prostrate growth habit suitable for close grazing by sheep. Low winter-activity
Prop (public variety)	Small	Medium	Very early flowering, behaves as an annual pasture under dry conditions

3.10 Future perennial legumes

Geoff Moore

The following perennial legumes are considered to have potential for southern Australia.[77] There are no commercial varieties presently available for these species but they may become available over the next few years through the CRC for Plant-based Management of Dryland Salinity and other plant improvement programs or from imported seed.

Flowers and green pods on hairy canary clover

Hairy canary clover

(Dorycnium hirsutum):
A drought-tolerant, perennial legume native to the Mediterranean basin where it grows on well-drained, medium-textured soils. It has a shrub-like growth habit to 0.3-0.7 m and up to 1.2 m across.

Hairy canary clover is almost dormant in winter but grows actively from early spring through to early summer, with summer production dependent on seasonal conditions. It will start growing again after the rains in autumn through to early winter.

Good weed control during establishment is critical, as seedling growth is slow even when sown in late winter or early spring with increasing temperatures.

Established plants have good drought tolerance and survived an eight month drought at Narrogin in 1999/00.[266] Hairy canary clover has slightly woody stems but is well eaten by sheep, especially when the available feed is of average quality (dry annual pasture). Sheep will graze the plants down to a height of 10-20 cm.

Hairy canary clover – a temperate perennial legume under development in Tasmania may have a role in the wheatbelt on medium-textured soils

Hairy canary clover has fair to moderate feed quality (DMD 49-73%, CP 5-13%).[73, 390] It contains moderate to high levels of condensed tannins, which could reduce animal intake and consequently animal production if it was the only feed source. It is generally resistant to attack by most insect pests.

Lespedeza, a warm season perennial legume

A plant improvement program in Tasmania expects to release a cultivar within the next few years.

In WA, hairy canary clover could be an option on well drained, sandy duplex and medium-textured soils in areas with an average annual rainfall of 400-650 mm.[340]

Lespedeza *(Lespedeza cuneata):*
Lespedeza or sericea is a warm-season, perennial legume native to eastern Asia. It has an erect (0.6-1.0 m) growth habit and is generally herbaceous, although the old stems are slightly woody. It has many leafy branches, with the trifoliate leaves arranged alternately along the stem. Flowers are pink (or purple) and arranged singly in the axils of the upper leaves.

Lespedeza is drought-tolerant and has good tolerance of acid soils (pH_{Ca} >4.2 est.), high aluminium and grows well on infertile soils (low P and K). It has moderate waterlogging tolerance but low salt tolerance. Lespedeza is highly productive and generally has better forage quality than the warm season grasses.

Heavy frosts will kill the top growth but not the plant. Lespedeza is winter-dormant and regrows in spring from crown buds at the base of the old stems. Once they start actively growing in spring, plants should not be grazed (or cut) to ground level as subsequent regrowth will occur from axillary buds on the stems not from the crown.[92] Lespedeza has a similar growth pattern to the warm season grasses and similar temperature requirements for germination.

When and if available in WA, lespedeza would be sown as soil temperatures increase in late winter and early spring as with the sub-tropical grasses (Chapter 5). 'Au Lotan' had good germination at 20/15°C (day/night temperature), slow germination at 15/10°C with no germination below this temperature under controlled conditions.[154] Lespedeza seedlings had slow

Sainfoin, a temperate perennial legume which may have potential as a non-bloating alternative to lucerne, especially on alkaline soils

growth at 20/15°C and moderate growth at 24/20°C.[154] Seed is inoculated with specific Rhizobia strain Group M (CB 756).

Lespedeza has been widely grown in the south-eastern United States. The 'common' type has naturalised over large areas and is a declared weed in some areas of Kansas. This type has low forage quality, due to its high concentrations of condensed tannins. However, varieties with lower condensed tannin and fibre concentrations have been developed (e.g. 'Au Lotan'). In general, lespedeza does not persist well under heavy grazing. To maintain the stand density a minimum stubble height of 10 cm needs to remain after grazing. A grazing-tolerant variety ('Au Grazer') has recently been released in the US which can persist under close or frequent grazing.

The potential role for lespedeza in WA is still to be determined. Seed is currently not available.

Sainfoin leaf

Sainfoin *(Onobrychis viciifolia):* An erect, herbaceous perennial legume from Europe and the Mediterranean basin where it predominantly grows on neutral and calcareous soils. It has been cultivated in temperate Europe for several hundred years.

Sainfoin has a growth habit similar to lucerne. It has many erect, hollow stems (0.4-1.0 m) with each leaf comprising many small leaflets borne in pairs on the petiole with a terminal leaflet. It has distinctive pink flowers in a long raceme on erect stems.[294] The hairy pods contain a single, kidney-shaped seed.

Sainfoin has a deep tap-root with many lateral roots. Persistence of the stand is affected by carbohydrate reserves in the roots, which usually decline over winter and spring and then build up again by the end of autumn.[113]

Sainfoin has moderate to high feed quality and a high protein content and is non-bloating, due to the presence of condensed tannins. It has good drought tolerance and is frost and cold tolerant.[92] It has large seeds (70,000/kg) and on suitable soils has good seedling vigour.

Sainfoin has not been widely evaluated in WA but could have potential on well drained, neutral to alkaline, medium- to fine-textured soils in areas with an average annual rainfall 350-500 mm (more than five months growing season), especially as part of a pasture mixture. Sainfoin does not tolerate acid, waterlogged or saline soils and is likely to have poor establishment and production on sandy soils. It is suited for hay or silage production or can be rotationally grazed on a long rotation (suggested six-week grazing cycle).[293] The suggested seeding rate is 3-5 kg/ha. Seed is inoculated with specific rhizobia strain 1099.

A cultivar 'Othello' (public variety) was released in South Australia in 1980 as a non-bloating, alternative to lucerne with resistance to a wide range of insect pests (spotted alfalfa aphid, blue-green aphid, redlegged earth mite, lucerne flea, sitona weevil and native bud worm).[293] Seed is currently not available, but SARDI is working on this species.

Chapter 4
Temperate perennial grasses

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Mike Gout (Wrightsons Seeds): page 104; **Peter Maloney (DAFWA Image Resource Centre):** pages 106, 107, 109 (plant), 113 (seed heads), 115, 119, 120; **Geoff Moore (DAFWA):** pages 96, 99, 108, 110, 111, 113 (plant), 114, 116, 117, 121, 122; **Paul Sanford (DAFWA):** page 109 (seed head, leaf blade).

Temperate perennial grasses

Paul Sanford

- high winter and spring growth rates
- summer-active temperate grasses can provide out-of-season green feed
- high nutritive value with correct management
- mostly suited to permanent pasture in the medium to high rainfall zones
- best grown on relatively fertile soils that have moisture at depth in summer
- most species require rotational grazing to persist
- need to be established like a crop with no weed competition
- best sown in autumn
- research has demonstrated that tall fescue (temperate) and phalaris can increase livestock production in summer and winter respectively
- companion legumes are essential for a productive pasture.

Pastures in southern Australia are based largely on introduced annual and perennial temperate species, including sown, productive species and volunteer species that are typically less productive or less nutritious, e.g. silver grass (*Vulpia* spp.). The sown species include several valuable temperate perennial grasses (also called 'cool season' or 'C3' grasses) that are widely grown in NSW, Victoria and Tasmania and to a limited extent in south-western Australia. The main species – cocksfoot (*Dactylis glomerata*), perennial ryegrass (*Lolium perenne*), phalaris (*Phalaris aquatica*) and tall fescue (*Festuca arundinacea*) were introduced during the nineteenth century. Veldt grass (*Ehrharta calycina)* was introduced much later from South Africa and is grown only in WA and South Australia.

The limited success of the European temperate grasses in south-west WA is generally attributed to unsuitable soils, dry summers and incorrect grazing management.[267] Historical research undertaken by the Department of Agriculture and CSIRO suggested that perennial ryegrass, cocksfoot, phalaris and tall fescue had potential in WA.[13] However, they concluded that the climatic conditions suitable for growing these species occur only within 30 to 70 km of the west and south coasts from Perth to Albany and the near-coast land between Cape Riche and Esperance. A more recent modelling study suggested that perennial ryegrass is unsuited to south-western Australia based on its climatic adaptation.[152] This finding is partly supported by the poor persistence of perennial ryegrass in a number of field trials, albeit mostly under set-stocking.[129, 267, 328] South-western Australia is marginal for perennial ryegrass, but it can be grown successfully in high rainfall districts if the more drought-tolerant varieties are sown on suitable soils and then managed appropriately.

Comparisons of livestock performance on temperate grasses in the high rainfall areas showed that summer-active tall fescue resulted in the greatest improvement in out-of-season performance due to the availability of green feed

Annual legumes are an essential component of a productive perennial pasture – temperate perennial grasses with subterranean clover

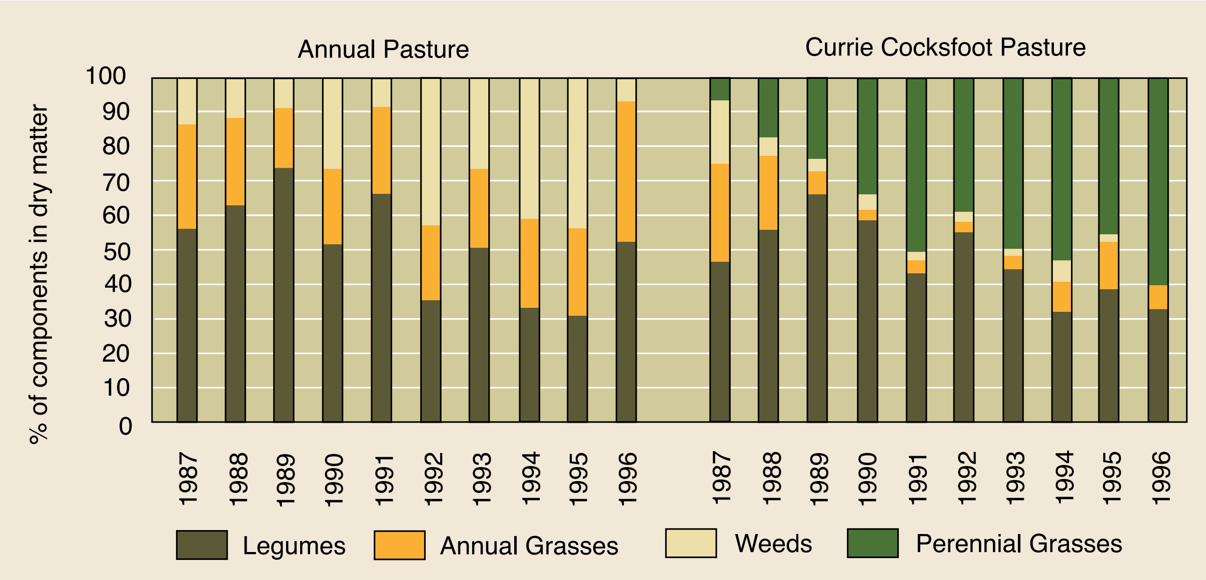


Figure 4.1 Botanical composition in spring of an annual and perennial pasture (cocksfoot) over 10 years at Mt Barker[129]

in summer in comparison to phalaris, perennial ryegrass, cocksfoot and annual pasture.[129] In most years of the study, phalaris, perennial ryegrass and cocksfoot were dormant in summer and therefore livestock only had access to dry residues.

In addition to increasing livestock production, it is important that perennial pastures help prevent land degradation, especially dryland salinity and soil erosion. To reduce the spread of salinity, perennial pastures need to use more water than the annual pastures. High water-use perennial pastures are characterised by deep root systems and green leaf in summer.[431] Most of the common temperate grasses have relatively shallow root systems, particularly perennial ryegrass and cocksfoot and possess little or no green leaf in summer as they are typically summer-dormant (e.g. phalaris, perennial ryegrass, cocksfoot, winter-active tall fescue).

Studies in WA have demonstrated that phalaris can use more water than annual pastures particularly in the medium rainfall zone.[83, 351] However, in eastern Australia water-use by phalaris in high rainfall environments (>600 mm) was similar to annual pastures.[60, 320]

Two species that could use substantially more water than annual pastures are tall fescue (temperate, summer-active types) and veldt grass as both can grow actively in summer. Preliminary data on rooting depth of tall fescue suggest it is a high water-use species.[338]

Why grow temperate perennial grasses?

Grasses are productive under grazing because the growing tip is located at the base of the plant and therefore remains protected during grazing. Grasses are suitable companion plants to legumes and consistently increase the yield of legume-dominant pastures through their use of previously fixed legume nitrogen. Their presence also provides livestock with a more varied diet. Research suggests that a mixed sward may provide animals with a more balanced diet, increase intake, reduce stress and increase feed-use efficiency.[304]

Temperate grasses are particularly suited to permanent pasture and when well managed maintain a more desirable pasture balance compared to annual swards (Figure 4.1). The varying botanical composition of annual pastures is associated with the pattern of the opening rains and/or amount of seed set the previous spring. Perennial grasses depend little on seed set and germination and are therefore more stable across years. In addition, perennial grasses displace broad-leaf weeds resulting in a pasture with a low weed burden (Figure 4.1).

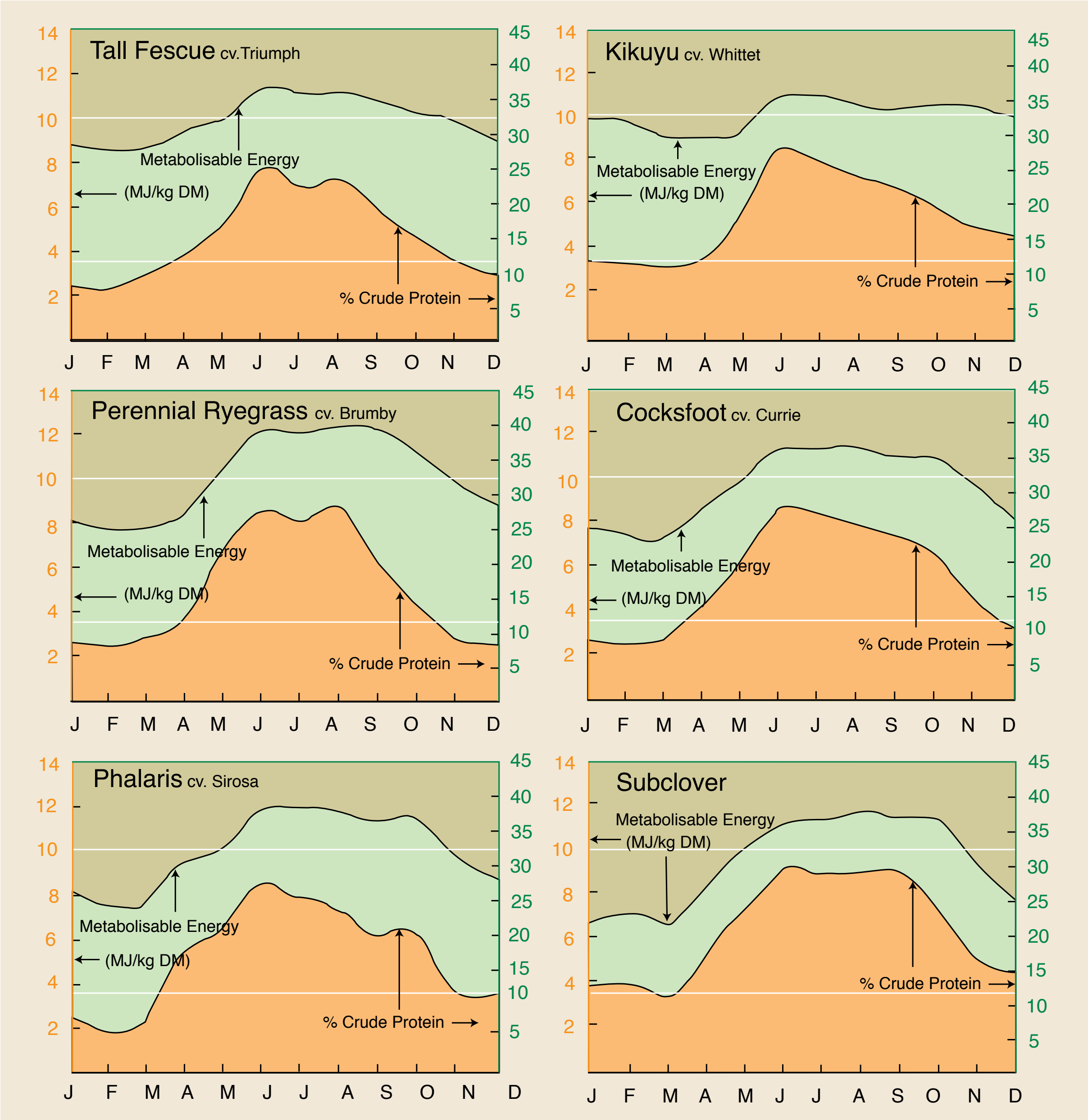


Figure 4.2 Annual profiles of metabolisable energy and % crude protein for grazed tall fescue, perennial ryegrass, cocksfoot, phalaris and subterranean clover in south-western Australia[129]

Temperate and sub-tropical grasses

There is a role for both temperate and sub-tropical grasses. The advantages of temperate grasses over sub-tropical grasses include:

- As a group they have higher nutritive value (Figure 4.2). Temperate grasses generally have a higher dry matter digestibility, due primarily to a lower lignin content.
- Superior winter-activity. The optimum temperature for growth of temperate grasses is about 20°C, while for sub-tropical grasses it is much higher (25-35°C). Consequently, temperate grasses grow actively in winter when sub-tropical grasses are dormant or at best growing slowly.
- Good persistence over winter. There is a 'cold zone' where the persistence of most sub-tropical grasses is adversely affected by the combination of cold, wet soils and frosts (Figure 5.1). Recent trials have demonstrated that the temperate perennial grasses are persistent and highly productive in this area.[2] As a result there is a large potential for temperate perennial grasses to be grown widely in the medium to high rainfall (>550 mm) areas of this 'cold zone', which is largely used for growing pastures with only a small proportion under crop.

Temperate perennial grasses with yellow serradella

Summer-active temperate grasses increase the period of green feed allowing producers to reduce supplementary feed and/or increase the stocking rate. However, in hot moisture-limiting conditions many sub-tropical grasses show less signs of wilting than the temperate grasses. They are more water efficient under hot, dry conditions as they use the 'C4 photosynthetic pathway' (Chapter 5). As a consequence, the dry matter production of sub-tropical grasses declines less than temperate grasses when subject to high temperatures and moisture stress.

Under ideal conditions in summer with prolonged wet soils, sub-tropical grasses can be substantially more productive than temperate grasses, however in south-west WA these conditions are not common.

Where would you grow temperate perennial grasses?

Temperate grasses are best suited to permanent pasture in the medium to high rainfall zone or in paddocks that are uneconomic to crop in mixed farming areas. However, recent research from NSW has demonstrated that perennial grasses, including temperate species, can be incorporated successfully into phased rotations with wheat without affecting grain yield.[78] In the absence of a legume for crop rotations perennial grasses may be an option, albeit one that may reduce grain protein.[78]

The length of the growing season (Figure 1.3) is a reliable guide as to where temperate perennial grasses can be grown successfully. For the main species (except for veldt grass) the minimum growing season required is 6-6.5 months for winter-active types and 6.5-7 months for summer-active types.

In general, the temperate grasses are best grown on relatively fertile soils that have plant available soil moisture at depth outside the growing season. Exceptions are cocksfoot and veldt grass, which can be successfully grown on infertile soils. There are temperate grass options for both acid soils and waterlogged soils.

Temperate perennial grasses can be established successfully in the higher rainfall areas of the central and northern agricultural regions. However, their persistence is adversely affected by the high summer temperatures and the short growing season (<5.5 months) in these regions. In marginal environments there is typically a strong 'edge effect' in field trials, with plants on the outside of plots growing well due to access to more soil water. Therefore, in marginal environments use a wide row spacing (~50 cm) to increase the soil volume available to the plants.

Out-of-season production of temperate grasses is improved substantially with summer rainfall and mild summer temperatures, e.g. the south coast. In environments with a short growing season and little or no summer rainfall, temperate grass growth is restricted largely to the annual growing season. As a result, the seasonal feed supply is similar to that of annual pastures, but with higher production in autumn and early to mid-winter (i.e. for winter-active cultivars).

Refer to the individual species descriptions for their specific requirements.

Establishment

The first objective when planting perennial grasses is to achieve an adequate seedling density at emergence. The second is to ensure the survival of these seedlings through the first summer. With the exception of cocksfoot and veldt grass there is little evidence of seed recruitment by temperate grasses after the initial establishment, so the highest perennial plant density will be that following germination. Second year management should focus on the development of a strong crown and root structure. In general, plant density will decline over time, but this can be offset by larger plants with more growing points or tillers.

Site preparation

The philosophy should be to treat the pasture the same as a crop. This means controlling annual weeds, meeting nutrient requirements and possibly controlling drainage. Perennial grass seedlings are poor competitors and can be swamped by annual weeds, particularly annual grasses, as there are very limited post-emergence herbicide options. Annual grass control (e.g. annual ryegrass, barley grass) needs to start in the previous spring. Use minimum tillage to reduce soil disturbance and exposure of buried, dormant seeds to germination. Control of other perennial broad-leaf weeds (e.g. dock) may need to commence two years before planting.

Sowing perennials into a previously cropped paddock is a useful way of reducing weed competition, but in practice areas suitable for annual crops are unlikely to be sown to perennial pastures. However, cropping the target area the year before sowing perennial grasses can reduce specific weeds. Cropping can also help clean up and level paddocks ready for future fodder conservation. In areas with fragile sandy soils, crop stubbles help reduce the risk of erosion at seeding. However, a drawback is the depletion of annual clover seed reserves.

Time of sowing

Given adequate weed control, temperate perennial grasses are best sown in autumn. This gives the plants a longer period to develop a strong root system before summer and gives them a better chance of surviving the first summer. Seeding should be two to three weeks after the break of season (longer in non-wetting sandy soils) as this allows for a good germination of annual weeds, which can then be removed with a non-selective herbicide before seeding. It is important not to compromise weed control at this stage.

Seeding objectives

Three requirements when sowing perennial grasses are:

- *Accurate delivery rate of seed*. If the seeding machine cannot handle the delivery of small quantities of small seeds, mix the seed with coarse sand or superphosphate at seeding. However, avoid storing it in this form.
- *Accurate seeding depth*. Accurate seed placement (up to 10 mm) is achieved best by using machines with independent floating tyne or disc assemblies, each unit being able to maintain a constant seeding depth. Using conventional machines with relatively rigid tyne assemblies on uneven or sandy soils can result in a variable seeding depth and patchy emergence.
- *Minimal soil disturbance*. Covering weed seeds will stimulate their germination while spring sowing on sandy soils will increase the risk of wind erosion. Minimal disturbance can be achieved using narrow pointed tynes, inverted T-tynes or triple disc assemblies, ideally followed by press wheels as rolling will enhance seed germination.

Sowing mixtures of perennial grasses

Sowing mixtures of temperate grasses can make better use of soil variation and achieves a more even feed supply. When sowing mixtures remember that seed numbers per kilogram are likely to be different and that species could have different competitive characteristics as seedlings. For example, sowing a mixture of 3 kg/ha each of cocksfoot and tall fescue delivers more than three times as many cocksfoot seeds as tall fescue seeds. In addition, tall fescue seedlings are weak competitors so the pasture is likely to become dominated by cocksfoot. To overcome these problems sow the different species in alternate rows or sow one species across the paddock and the other at a 90 degree angle. Alternatively, adjust the sowing rate based on the number of seeds per kilogram and percentage germination to give the desired proportion of each species.

Management after sowing

Insect control

Redlegged earth mites (RLEM) are normally associated with silvering of subterranean clover cotyledons and leaves, so damage to other sward components is often overlooked. When perennial grass seedlings make up most of the available green material they can easily be destroyed by RLEM. Carefully check emerging pastures regularly for the presence of insect pests (e.g. RLEM, webworm, cutworm and cockchafers) and control as necessary. Failure to apply sprays could result in poor or failed establishment.

Early grazing management

In the establishment year, careful grazing management is required. Pastures should not be grazed before they reach 1200 kg/ha of feed-on-offer (FOO) and ideally the pastures should enter summer with 2500-3000 kg/ha FOO. This allows the grasses to develop to a reasonable size and store reserves for the first summer.

Refer to individual species descriptions for specific establishment advice.

Grazing management

The key objectives of grazing management are to optimise pasture growth, maintain pasture composition in a desirable state, use pasture efficiently, meet livestock goals and prevent land degradation.

Pasture growth depends on water, nutrients, carbon dioxide and sunlight. Producers have some control over the amount of sunlight that is intercepted by pasture through the impact of grazing on leaf area. In general, the higher the leaf area the higher the potential growth (refer to kikuyu example Figure 2.1).

The grazing management of temperate grasses also needs to focus on persistence because the majority do not recruit new plants (cocksfoot is an exception). To persist, all species require rest from grazing because:

- continuous grazing under stressful conditions reduces the activity of root systems
- grazing causes a run-down of below-ground reserves

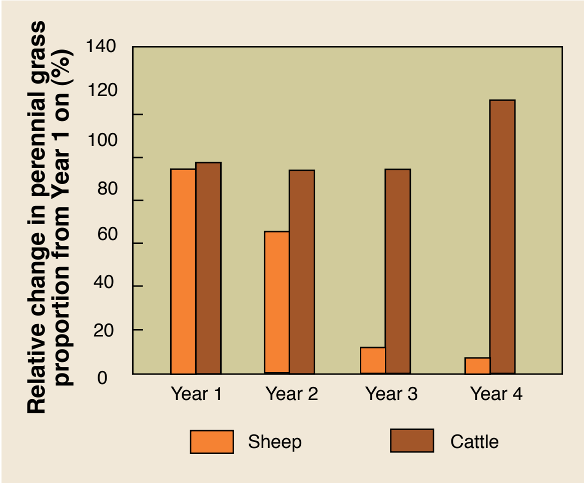


Figure 4.3 Persistence of temperate grasses under set-stocking by sheep and cattle over four years[129]

- continuous grazing damages either the base of tillers or dormant buds
- during the reproductive or regeneration phase grazing further depletes already low plant reserves and increases plant death.[187]

Rest is of particular importance in summer when growth has ceased and excess FOO has been removed via grazing. The type of livestock also influences persistence. All of the temperate grasses persist when continuously grazed by cattle at modest stocking rates, but decline under sheep (Figure 4.3).

The key to grazing management from the plant's perspective is to understand the biology of the particular species. For example, phalaris is particularly sensitive to repeated or continuous heavy grazing or cutting in spring.

For further discussion of grazing management refer to the individual species descriptions.

Livestock production

There have been few comparisons of livestock production on temperate perennial grasses in WA. In addition, some of the studies used set-stocking which could have adversely affected both the persistence and production of the perennial grasses.

The performance of sheep grazing subterranean clover-based pastures with and without temperate perennial grasses (phalaris, cocksfoot, perennial ryegrass and tall fescue) was compared at two sites in the 500–550 mm rainfall environment under set-stocking.[328] Including perennial grasses tended to reduce liveweight losses during autumn

Table 4.1 Average fleece weights (kg/head) for Merino wethers on temperate perennial grasses at Kojonup and Takalarup between 1968 and 1974 (set-stocked at 10 DSE/ha)[328]

Location	Year	Phalaris CPI 14697	Cocksfoot cv. Currie	Perennial ryegrass cv. Kangaroo Valley	Tall fescue cv. Melik	Annual pasture
Kojonup	1968–69	5.94a[1]	4.64b	4.19c		4.10c
	1969–70	4.94a	4.73a	4.29ab		3.85b
		Phalaris cv. Australian				
Takalarup	1972	4.51a	3.97bc	4.04bc	4.32ab	3.82c
	1973	5.38a	4.71b	4.94ab	5.28a	5.20ab
	1974	4.21ab	4.17b	4.29ab	4.47a	4.18b

[1] In any one year fleece weights not followed by a common letter differ significantly.

and early winter with the most consistent results being obtained on phalaris and tall fescue. Significant differences were also found in wool production (Table 4.1). Sheep grazing tall fescue and phalaris averaged fleece weights of 0.29-0.76 kg/head higher than sheep on annual pasture. The perennial ryegrass density declined rapidly under set-stocking with <1 plant/m^2 remaining at the end of the experiment.

The performance of steers on temperate perennial pastures was compared with an annual pasture control at two sites in a high rainfall environment (600-800 mm).[128] At Mt Barker Research Station perennial grasses reduced the need for hay supplements by 20 to 67% (Table 4.2). Across the four years of the study the average additional liveweight gain over the annual pasture control was 39, 46 and 97 kg/ha for cocksfoot, tall fescue and phalaris respectively (Table 4.2 for annual results). The pattern of steer growth varied between the different perennial species, with those grazing cocksfoot and tall fescue performing slightly better in late summer and autumn while those grazing phalaris grew faster in winter and spring. Steers on perennial ryegrass consistently lost more weight in autumn and were unable to make up the loss in the winter and spring.

At Pardelup Prison Farm, tall fescue (temperate) gave superior animal production to cocksfoot, phalaris and perennial ryegrass, particularly during the out-of-season feed gap.[128] Over the duration of the experiment the average additional liveweight gain compared with the annual pasture control was 9, 47 and 28 kg/ha for cocksfoot, tall fescue and phalaris respectively (Table 4.2). Similar to Mt Barker Research Station, steers grew well on phalaris during spring. Perennial ryegrass failed to perform better than the annual pasture and was replaced with kikuyu in late 1993. When feed ran out on the experimental plots in autumn steers were agisted elsewhere on the farm. Steers grazing the annual pasture were agisted for an average of 43 days, those on cocksfoot for 19 days and those on phalaris for 29 days, while no agistment was required for steers grazing tall fescue (Table 4.2).

There are no experimental comparisons between veldt grass and annual pasture, but anecdotal evidence suggests that a pasture comprising veldt grass with serradella can provide valuable summer feed and increase livestock production.

In summary, limited research in WA suggests that introducing phalaris and tall fescue into an annual pasture can increase livestock production, phalaris in winter/spring and tall fescue (temperate) in summer/autumn. Given the high value of pasture in summer and autumn, the temperate tall fescue is likely to be the more profitable option.

Persistence – summer-dormancy vs. summer-activity

To persist in the south-west agricultural zone of WA perennial pastures must be able to survive the hot, dry summer. One successful adaptation of temperate grasses that originate from the Mediterranean region is to remain dormant during summer. This is characterised by a reduction in green leaf via senescence to conserve moisture while retaining sufficient living tissue for

Table 4.2 Liveweight gains for steers on pastures at Mt Barker Research Station and Pardelup Prison Farm between 1993 and 1996 (stocked at 1.5 steers/ha)

Year	Location	Measurement (kg/ha/yr)	Annual pasture	Cocksfoot cv. Currie	Perennial ryegrass cv. Brumby	Tall fescue cv. Au Triumph	Phalaris cv. Sirosa
1993	**Mt Barker Research Station**	Liveweight gain	489 (100%)[1]	566 (116%)	436 (89%)	573 (117%)	587 (120%)
		Hay or grain fed	343	0	0	0	0
	Pardelup Prison Farm	Liveweight gain	409 (100%)	499 (122%)	400 (98%)	504 (123%)	492 (120%)
		Agistment period (days)	0	0	0	0	0
1994	**Mt Barker Research Station**	Liveweight gain	377 (100%)	419 (111%)	337 (89%)	426 (113%)	488 (129%)
		Hay or grain fed	0	0	0	0	0
	Pardelup Prison Farm	Liveweight gain	319 (100%)	285 (89%)	–[2]	322 (101%)	255 (80%)
		Agistment period (days)	84	20	–	0	20
1995	**Mt Barker Research Station**	Liveweight gain	377 (100%)	411 (109%)	318 (84%)	402 (107%)	486 (129%)
		Hay or grain fed	329	137	400	168	18
	Pardelup Prison Farm	Liveweight gain	336 (100%)	333 (99%)	–	346 (103%)	381 (113%)
		Agistment period (days)	46	36	–	0	39
1996	**Mt Barker Research Station**	Liveweight gain	317 (100%)	320 (101%)	211 (67%)	343 (108%)	387 (122%)
		Hay or grain fed	1195	249	859	299	597
	Pardelup Prison Farm	Liveweight gain	228 (100%)	208 (91%)	–	306 (134%)	277 (121%)
		Agistment period (days)	41	41	–	0	55

[1] Liveweight gain relative to annual pasture control.

[2] Due to loss of perennial ryegrass plants this pasture had reverted to an annual pasture by 1994.

Tall fescue with Max P showed superior persistence under stressful conditions (left), compared with endophyte-free tall fescue (right) in this NSW trial

regrowth in autumn. Winter-active phalaris uses this strategy and following flowering the leaves senesce and the plant dies back to the dormant vegetative buds, while the shallow roots die when the surface soil dries out, leaving a deep root system to maintain adequate moisture for the living tissue.[256] Following autumn rains the buds break dormancy and develop into new tillers.

Summer-dormant temperate grasses persist in WA with good management, however they rarely provide high value green feed in summer or reduce groundwater recharge to the same extent as summer-active temperate grasses. On the other hand, summer-activity can compromise persistence particularly in marginal rainfall environments. For example, summer-dormant tall fescue is more persistent than summer-active cultivars under grazing at Hamilton, Victoria.[315] One suggested approach is to grow summer-active and summer-dormant types together to provide a more even distribution of feed throughout the year while maintaining good persistence.[315]

When selecting a temperate grass consideration needs to be given to summer activity vs. summer dormancy, the time(s) in the year the pasture is required to provide feed and how long the pasture needs to persist. In medium rainfall environments (<6.5 month growing season) the moderately to highly summer-dormant types are often the only option with the exception of veldt grass. In high rainfall (>600 mm) areas along the south coast the summer-active types will often perform well.

Endophytes + temperate perennial grasses

Kevin Reed

This section discusses using grass endophyte technology to improve the performance of perennial grasses. Cultivars of perennial ryegrass and tall fescue which contain 'novel' or safe endophyte are now available. The use of safe endophyte can improve plant persistence under stressful conditions and provide some resistance to insect attack while presenting minimal risk to livestock.

Background

Old naturalised populations of perennial ryegrass in eastern Australia are infected with the endophyte, *Neotyphodium lolii,* a microscopic fungus living entirely between the plant cells. Toxic alkaloids produced by the fungus cause perennial ryegrass toxicosis, a disorder associated with heat stress and animal production losses and with which some livestock exhibit staggers and may die.[314] Livestock problems have led some farmers to use seed of endophyte-free grass. (Note: the cause and effect of 'ryegrass staggers' is distinctly different to 'annual ryegrass toxicity'.)

Table 4.3 Effect of endophyte on perennial ryegrass establishment[313]

Cultivar	Endophyte frequency (%)	Seedling density (plants/m²)*
Victorian	0	105d**
Victorian	80	136cd
Ellett	1	151bc
Ellett	68	228a

* 400 certified, pure live seeds were sown per square metre

** means with a common letter do not differ $P < 0.01$

Similarly, a different endophyte (*N. coenophialum*) associates with tall fescue and causes fescue toxicosis. However, unlike the situation with perennial ryegrass, old popular cultivars of tall fescue in Australia are free of endophyte.

Plant persistence and endophyte

The association between the grass and the endophyte is mutually beneficial. The association provides the fungus with food, a home and a means of reproduction. In return the fungus helps the grass host resist grazing herbivores, insect pests, nematodes and diseases. The fungus also helps the grass adapt to low nutrient and moisture limiting conditions.

Under stressful conditions, plants infected with endophyte show better persistence than endophyte-free plants. These differences are most evident when there the plants are subject to multiple stresses, e.g. the concurrence of pests and drought.

In Victoria, endophyte-free perennial ryegrass has shown poor establishment, less tillering and poor persistence in comparison with endophyte-infected perennial ryegrass (Table 4.3).[305, 313] The drought tolerance functions of tall fescue endophyte are presently being investigated in the USA.[235]

Alkaloids produced by endophytes

There are many substances produced in varying amounts by different endophytes. Four substances are of current interest:

- **Lolitrem B** is a cause of ‘ryegrass staggers’ and is found in perennial ryegrass.
- **Ergovaline** is one of the ergot alkaloids which cause fescue toxicosis (which includes heat stress, summer ill thrift, reproductive problems and fescue foot). It occurs in both wild endophyte-infected perennial ryegrass and tall fescue. It also protects the plant against attack by some insects including African black beetle.
- **Peramine** can occur in both endophyte-infected perennial ryegrass and, to a small extent, in tall fescue. It has no known deleterious effects on livestock and helps to protect the plant against some insect attack.
- **Lolines** are found in tall fescue and some *Lolium* species, but not commonly in perennial ryegrass. They are potent insecticides and deter some insects (including some virus-vectors/aphids) from feeding on plants.

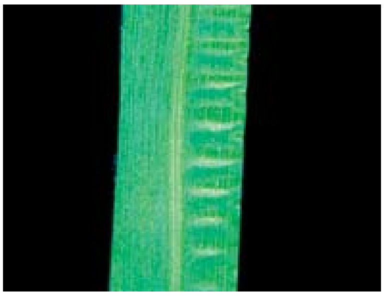
Novel or safe endophyte

Cultivars of perennial ryegrass or tall fescue infected with a select/beneficial endophyte sometimes referred to as a novel endophyte are now available. These are developed by removing the common (or wild, natural) endophyte and replacing it with a genetically distinct strain of the same fungal species. The selected strain is one that has been identified as producing little or no livestock toxin but carries the defence capability so valuable to the plant when it faces the threat of drought or pest attack.

Beneficial endophytes inoculated into some cultivars of perennial ryegrass sold in Australia are known as AR1, AR5 and NEA2, while AR37 is being tested.[302] It is estimated that about 10% of the perennial ryegrass seed sold in Australia in 2004 was endophyte-free, while a further 10% contained a beneficial endophyte.

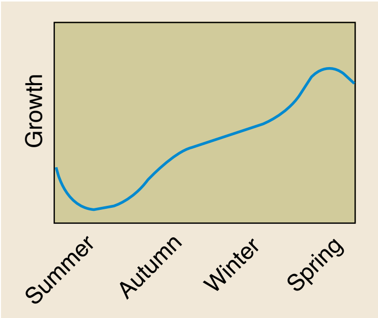
Tall fescue with Max P endophyte which produces peramine and lolines but no ergovaline is showing promise in areas of NSW prone to African black beetle attack.[429]

4.1 Cocksfoot *(Dactylis glomerata)*

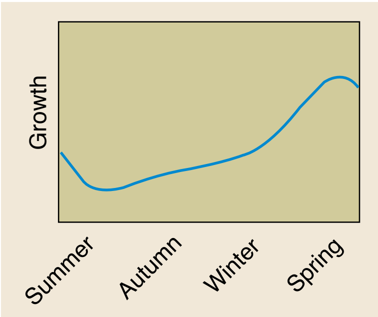


Ligule

Seasonal growth patterns



Mediterranean types



Intermediate types

Features

- persistent, acid-tolerant perennial tussock grass
- mostly summer-dormant with high drought tolerance
- contains no substances harmful to animals
- does not tolerate waterlogging
- requires rotational grazing, particularly with sheep.

Cocksfoot is a tussock grass native to Europe, northern Africa and temperate Asia. It has been introduced to other temperate parts of the world including North and South America, South Africa, New Zealand and Australia because of its value as a pasture plant.[194] Cocksfoot is valued throughout the world for its better persistence than perennial ryegrass on soils prone to drying out quickly and of moderate fertility.[227]

In Australia, the area planted to cocksfoot has expanded, particularly in the eastern States, from the poorer and drier parts of dairy farms in the high rainfall zone to the sandy or shallow soils in wool producing areas with moderate rainfall.[227]

Varieties of cocksfoot available in Australia can be classified into two main groups – 'Mediterranean types' with moderate to high summer dormancy and 'intermediate types' which are more summer-active.[93]

Establishment

Cocksfoot possesses a small, very light seed averaging about 1.3 million/kg. It needs to be sown close to the surface at a depth of 10 mm or less on most soils.[93] The suggested rate is 2-3 kg/ha when sown alone.[226] A rate of 2.5 kg/ha gives about 240 viable seeds/m^2.[129]

Cocksfoot is best sown in autumn.[129] Early growth is slow, although it is generally more vigorous than phalaris and tall fescue.

Livestock disorders

Cocksfoot does not contain any substances harmful to animals.[227]

Description

- tussock-forming perennial up to 1.5 m high with strongly flattened vegetative shoots
- greyish-green to green foliage, leaves are long (up to 80 cm) usually flat but may be folded lengthwise to give a shallow V-shaped cross-section
- white translucent ligules 2–10 mm long
- leaf sheaths very much flattened, hairless, prominent keel
- inflorescence is an erect one-sided panicle, 10–20 cm long, with the upper branches close together and the lower ones more widely spaced. The spikelets are in dense clusters at the end of the branches.

Soil–climate adaptation

Rainfall: >500 mm (south coast >425 mm)[129]

Season length: >6 months[129]

Drought tolerance: High[227]

Frost tolerance: Moderate

Soil type: Well-drained, sand or loam over clay or gravel[129, 227]

Soil fertility requirements: Moderate

Soil pH$_{Ca}$: >4.0[227]

Aluminium tolerance: Moderate[430]

Waterlogging tolerance: Low[227]

Salt tolerance: Nil[330]

Nutritive value

DMD: 53-79%[129]

ME: 7.3-11.3 MJ[129]

Crude protein: 8.5-27.8%[129]

Environmental benefits

Cocksfoot's groundwater recharge control is poor as it does not have a deep root system.[321] Most of the roots die back over summer and then regrow in autumn.

Management

When cocksfoot seedlings are sufficiently anchored in the ground (six to eight months after sowing) they can be lightly grazed to promote tillering and stimulate crown formation. Cattle are preferred for this task but if only sheep are available, graze for short durations to prevent defoliation of young plants. Rotationally graze to maintain a height of about 5-7 cm (about 1500-2000 kg DM/ha). If plants are stressed, then graze lightly or delay grazing until after flowering.[93]

Cocksfoot can persist well with proper management, particularly under cattle. Established swards are best managed with rotational grazing however they can tolerate set-stocking during winter and spring. The best grazing management is one that prevents over-grazing and minimises grass content in summer and autumn to maintain vigorous growth and a good legume density.[93] The pasture should be maintained at about 1000-2500 kg DM/ha, i.e. around 3-8 cm in height.

Cocksfoot stands can thin out quickly under sheep if not carefully managed, particularly during hot dry summers. However, if grazing is controlled cocksfoot can persist. Avoid heavy close grazing that damages the crown of the plant or lax grazing that produces tall, rank growth of low digestibility.[93]

Cocksfoot responds to increasing soil fertility. New sowings require fertiliser to promote early root development and enhance seedling vigour.[93] Mature stands should have major deficiencies corrected on the basis of soil tests. Cocksfoot, like all grasses, responds to nitrogen either via a companion legume or fertiliser application. It makes good quality hay or silage.

Companion species

Cocksfoot combines well with subterranean clover, lucerne and serradella.[245]

Cultivars

While most of the cocksfoot cultivars have been available for many years, recently the Department of Primary Industries in collaboration with the University of Tasmania released three new varieties.

The cultivars can be grouped according to their relative growth in winter and summer, which reflects their origins from the Mediterranean region (winter-active, summer-dormant) to temperate Europe (low winter growth, summer-active).

Mediterranean type, moderate to high summer dormancy

'Kasbah' (public variety) – has good growth from late autumn to mid-winter but growth in late winter and spring is poor. Kasbah flowers in early September, about one month earlier than Currie. This variety is highly summer-dormant and survives summer drought better than Currie. It is useful in dry locations for short-term rotations.

'Sendace'ᵠ – is a new variety developed in Tasmania from germplasm collected in Spain with good drought and cold tolerance. It has a prostrate to semi-erect growth habit with a high tiller density and moderate to high summer dormancy.

'Uplands'ᵠ – is a new variety developed in Tasmania from germplasm collected in Spain. It has a semi-erect to erect growth habit and moderate summer dormancy similar to Currie.

'Currie' (public variety) – derived from germplasm collected in Algeria. Persistent and productive and grows well from autumn through to spring. Summer growth depends on rainfall and temperature. Persists well on sandy soils.

'Porto' (public variety) – derived from germplasm collected in Portugal. Porto is more productive than Currie, particularly in autumn and winter but is less drought-tolerant. Matures about one week later than Currie. Good potential production in summer if moisture is available.

Intermediate type, summer-active

'Cambria' (public variety) – a new variety with year-round production.

'Grasslands Kara'ᵠ – was bred in New Zealand to replace Grasslands Apanui. Improved winter growth and disease resistance. Upright growth habit more suited to cattle than sheep. For persistence it should be rotationally grazed. Flowers about three weeks later than Porto. It is suited to dryland dairy production and high rainfall beef enterprises.

'Grasslands Tekapo' (public variety) – replacement for Grassland Wana was bred for improved nutritive value. It has moderate drought tolerance but in field evaluation in WA had lower persistence than Currie or Porto.

'Grasslands Vision'ᵠ – was selected by crossing Grasslands Kara with Grasslands Wana. The morphology is intermediate between the parents, although more like the erect Kara than the prostrate Wana. Grasslands Vision is intended for use on dairy farms and is slightly more persistent and productive than Kara.

'Megatas'ᵠ – a new summer-active variety developed in Tasmania.

Cocksfoot (foreground) has good persistence in dry summers providing it is not grazed heavily

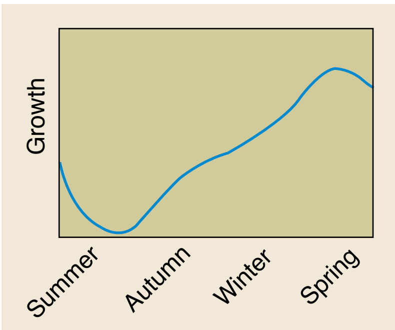
4.2 Perennial ryegrass *(Lolium perenne)*

Features

- highly nutritious and palatable perennial grass
- with good management can be very productive in suitable environments
- excellent seedling vigour
- high temperatures constrain summer growth
- low drought tolerance, so best suited to fertile soils (>600 mm)
- requires rotational grazing for persistence, high yields and to maintain nutritional quality.

Perennial ryegrass is one of the most valuable pasture grasses for temperate regions of the world. It is a native of Europe, temperate Asia and north Africa and was introduced into Australia in 1803.[194] Under favourable conditions perennial ryegrass can produce large amounts of high quality feed throughout the growing season. It grows predominantly from the autumn break until late spring, but can make useful growth in summer if it receives substantial amounts of out-of-season rainfall or irrigation.[194] Summer growth is restricted by high temperatures (>30°C), even if sufficient moisture is available. Perennial ryegrass has low drought tolerance and a relatively shallow root system.[48] As a result, its role in WA is limited to fertile soils in high rainfall areas and irrigated pastures.

Seasonal growth pattern



Description

- tussock-forming perennial up to 60 cm in height with a fibrous root system
- dark-green foliage, leaf blades are hairless, flat, upper surface evenly ribbed, lower surface smooth and shiny. Length to 30 cm, width to 7 mm. Young leaves normally folded in the bud, with a V-shaped cross-section
- ligule membranous, white, transparent, shorter than wide. Auricles small and narrow
- leaf sheath hairless with fine longitudinal ribs as in leaf blades, base of sheath may be reddish-purple
- inflorescence is an erect narrow spike up to 20 cm long to which the spikelets are attached alternately, on opposite sides of a wavy stalk.

Soil–climate adaptation

Rainfall (est.): >600 mm (south coast >500 mm)[129]

Season length: >8 months[129]

Drought tolerance: Low[48]

Frost tolerance: High[241]

Soil type: Well-drained medium- to fine-textured. Coarse-textured soils tend to dry out too much during summer[241]

Soil fertility requirements: High[241]

Soil pH$_{Ca}$: >4.0

Aluminium tolerance: Sensitive (but varies with cultivars)[430]

Waterlogging tolerance: Low to moderate[241]

Salt tolerance: Slight to moderate[330]

Nutritive value

DMD: 56-85%[129]

ME: 7.8-12.3 MJ[129]

Crude protein: 8.0-27.7%[129]

Environmental benefits

Groundwater recharge control: Low, as perennial ryegrass does not develop a deep root system.[41] The roots are short-lived, with most dying over summer and regrowing the following autumn.

Establishment

Perennial ryegrass is relatively easy to establish due to its excellent seedling vigour, however it is still necessary to minimise weed competition.[363] It should be sown into a prepared seedbed or direct drilled at 6 kg/ha which should give about 240 viable seeds/m^2 based on 530,000 seeds/kg and a minimum germination rate of 75%.[128] It is best not to sow other perennial grasses with perennial ryegrass due to its highly competitive nature. Perennial ryegrass is sown in autumn no deeper than 10 mm.

Livestock disorders

A disorder called 'ryegrass staggers' can occur in livestock grazing perennial ryegrass in late summer and early autumn. Stock often appear normal until moved, when they usually exhibit a high-stepping gait and may collapse in severe spasm. Young stock are generally more susceptible than older ones. Symptoms usually begin 7-14 days after the animals have been placed on toxic pasture.[194]

The condition is caused by the endophyte fungus (*Neotyphodium lolii*), which produces the toxic compound lolitrem B.[62] If ryegrass staggers occurs stock need to be moved quietly to a non-toxic area and/or given supplementary feed. The 'do-nothing' approach is also viable as most stock recover.[194] The endophyte causes a range of animal problems including reduced growth rates and milk production.[62] Endophytes can be eliminated by storing seed at 20-25°C for 18-24 months.[363]

Management

The first grazing of perennial ryegrass should be delayed until seedlings are firmly established and feed-on-offer has reached about 1800 kg DM/ha to avoid stock pulling plants out of the ground.[241]

Autumn growth of perennial ryegrass at Kojonup

Perennial ryegrass–subterranean clover pasture in winter

An alternative management approach is to allow plants to develop three leaves per tiller, graze intensively for a short period and then move stock on. Preventing the plant going beyond the three-leaf stage maximises pasture production and quality.[119]

N and P levels can influence perennial ryegrass productivity and persistence significantly.[241] Ideally N should be provided via a companion legume, however autumn and winter growth can be improved with fertiliser N in autumn (25 to 50 kg N/ha). Maintain soil phosphorus levels around a Cowell P of 30 ppm.

Use a heavy stocking rate for a short period to promote the development of new tillers and graze down to ~1200 kg DM/ha.[241]

Remove dry residues from established stands of perennial ryegrass during autumn to encourage new tillers. But do not graze too hard during this period – rotationally graze if possible to keep feed-on-offer (FOO) >1200 kg DM/ha. In winter, continue rotational grazing and maintain FOO between 1200 and 2000 kg DM/ha. Most tillering is initiated during autumn and winter and the yearly production is largely reliant on management during this period.[392]

In spring, maintain between 1600 and 3000 kg DM/ha while continuing to rotate stock. To increase plant density, reduce the stocking rate to enable a more plants to set seed.[188] Aim to have between 2000 and 3000 kg DM/ha at the end of spring to protect the soil surface and provide feed for stock during summer.

In summer do not graze hard or allow FOO to fall below 1500 kg DM/ha.[392] Do not set-stock perennial ryegrass stands affected by moisture or heat stress otherwise plant death will occur. Pastures should be rested in areas with mean summer temperatures >30°C.

In a pasture mix with clovers, perennial ryegrass makes good quality hay or silage. The best time to cut hay is in the early flowering stage, as after this the nutritive value quickly declines.

Companion species

It is compatible with most pasture legumes including subterranean clover, serradella, lucerne and perennial lotus.[188]

It is compatible with other temperate perennial grasses such as tall fescue, phalaris and cocksfoot, however the companion species need to be sown in separate rows or the more vigorous perennial ryegrass seedlings will dominate the sward.[188]

Cultivars

There are many cultivars of perennial ryegrass available in Australia. These can be grouped according to their maturity and number of chromosomes – very early maturing diploids, early maturing diploids, mid-late season diploids and late season tetraploids.[10] The mid- to late-season diploids and tetraploids are suited to regions such as south-west Victoria with fertile soils, high rainfall, long growing seasons and mild summers, so are less suited to WA.

Most (~70%) perennial ryegrass seed sold in Australia contains endophyte, but some varieties are now available with 'novel' endophyte or are free of endophyte. The 'wild' endophyte produces three main chemicals: peramine, lolitrem B (causes ryegrass staggers) and ergovaline (toxin that can reduce animal performance). The novel endophyte AR1, produces peramine to provide some insect resistance but produces no ergovaline or lolitrem B.

Cultivar	Description
Very early maturing diploids	
'Boomer'ᶲ	Kangaroo Valley type with good winter growth and drought tolerance. Suitable for sheep and cattle production.
'Fitzroy'ᶲ	Kangaroo Valley type selected for high winter production, reduced rust and improved persistence by Agriculture Victoria. Suitable for sheep and cattle pastures (including dairy), in marginal dryland areas.
'Kangaroo Valley' (public variety)	Old Australian ecotype. One of the earliest maturing perennial ryegrass cultivars with strong growth in autumn, winter and early spring. Contains both erect and prostrate types. Variable rust resistance. Suitable for sheep and cattle grazing. Persistent, but now replaced by newer varieties with Kangaroo Valley parentage such as Boomer and Fitzroy which are tolerant of drier conditions. Suited to areas with an annual rainfall >700 mm or where irrigation is available.
'Matilda' (public variety)	Kangaroo Valley type, very early maturing cultivar with good winter and spring growth. Rust resistant. Suitable for sheep and cattle pastures.
'Meridian'ᶲ	A cross combining the very early maturity and higher winter production of Kangaroo Valley with the performance of Yatsyn 1. Good persistence. Particularly suited to dairy systems with early calving and winter milking. Early seeding under harsh summer conditions ensures persistence.
'Meridian Plus AR1'ᶲ	As for Meridian, but with novel endophyte that retains insect resistance while reducing incidence of ryegrass staggers.
Early maturing diploids	
'Camel'ᶲ	Persistent, more drought-tolerant variety, with good autumn and winter production. Suited to lower rainfall areas than other perennial ryegrasses. Bred from material collected from central Victoria. Suitable for sheep and beef cattle production.
'Ceres Kingston'ᶲ	Bred for improved tolerance to acidic soils including soil aluminium. Tolerant to dry periods. Good autumn/winter growth. Mid-season maturity with average aftermath heading. Suitable for sheep and cattle grazing.
'Roper'ᶲ	Selected from later maturing Kangaroo Valley types. Good winter and spring growth. Summer-dormant and has good drought tolerance. Moderate rust resistance. Suitable for sheep and cattle pastures.
'Victorian' (public variety)	Old Australian cultivar widely used for many years but now being replaced by newer cultivars. Drought-tolerant, but susceptible to rust and yellow dwarf virus. Good growth in autumn and spring though less productive than most other cultivars. Possibly better adapted to hot dry summers and suitable for sheep grazing as well as cattle. An option for areas that are marginal for perennial ryegrass.
Mid- to late season diploids	
'Aries HD'ᶲ, 'Avalon'ᶲ, 'Banks' (public variety), 'Bronsyn'ᶲ, 'Bronsyn Plus AR1'ᶲ, 'Ceres Cannon'ᶲ, 'Dobson' (public variety), 'Ellet' (public variety), 'Embassy' (public variety), 'Grassland Supernui' (public variety), 'Grasslands Lincoln'ᶲ, 'Grasslands Nui' (public variety), 'Grasslands Samson'ᶲ, 'Jackaroo'ᶲ, 'Matrix*'ᶲ, 'Prolong'ᶲ, 'Tolosa' (public variety), 'Vedette' (public variety), 'Yatsyn 1' (public variety)	
Late season tetraploids	
'Nevis' (public variety), 'Quartet'ᶲ	

* 'Matrix' is a hybrid between perennial ryegrass and meadow fescue *(Festuca pratensis),* but is included as it has similar characteristics and management requirements to perennial ryegrass.

4.3 Perennial veldt grass *(Ehrharta calycina)*

Features

- productive, palatable tufted grass
- suited to infertile sandy soils including deep pale sands
- very high drought tolerance
- summer activity depends on seasonal conditions
- requires rotational grazing to persist
- widespread weed of roadsides, which can invade bushland.

Perennial veldt grass is native to South Africa where it thrives on sandy soils with an annual rainfall of 250-750 mm. It is thought to have been accidentally introduced to Australia via South African fodder purchased for the Perth Zoo. Perennial veldt grass then became naturalised on roadsides, vacant land and in parklands.[443] The only registered cultivar 'Mission' was selected from this naturalised population.[229] Today perennial veldt grass is an invasive weed of bushland and disturbed sites on sandy soils from Geraldton to Esperance. On farms it should not be sown near remnant bushland or nature reserves.

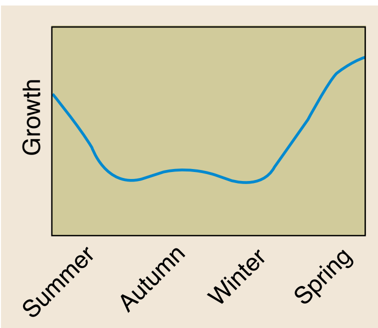
Perennial veldt grass is a hardy, productive and palatable grass especially suited to low fertility and sandy soils.[106] It is most productive in autumn and spring but will also grow actively in summer if it has access to moisture. Perennial veldt grass has also become valued for its ability to stabilise drifting soils in harsh environments.[106]

Establishment

Perennial veldt grass has a small seed (1,500,000/kg) and is sown in autumn at 2-3 kg/ha when planted alone. The recommended sowing depth is no more than 10 mm. Seedlings are slow to establish so it is important to ensure they are sown into a weed-free seedbed.[106]

On non-wetting sands, weed germination can be delayed because of the uneven wetting pattern. Ensure there is a full germination of the weeds before spraying and seeding. Furrow seeding can

Seasonal growth pattern



Description

- tufted slender perennial, 30–75 cm high
- foliage is dull or blue-green, leaves are tinged purple and red or purple colouration also occurs where the leaf meets the stem
- leaves are pale, straight and lax, 2-9 cm long, flat or inrolled in cross-section, with wavy margins
- ligule is membranous, short, ragged and frayed with short hairs. Auricle present with a few hairs
- leaf sheath is tight and hairless
- inflorescence is a narrow but loose panicle, 7-22 cm long, with fine wavy branches, spikelets are red to purple and when mature hang down towards one side.

Soil–climate adaptation

Rainfall (est.): >350 mm (south coast >300 mm)[332]

Season length: >4 months

Drought tolerance: Very high[332]

Frost tolerance: Moderate (becomes dormant after heavy frosts)[106]

Soil type: Deep sandy soils, including pale deep sands. Not usually suited to medium- to fine-textured soils, especially when surface is firm or hardsetting[106, 332]

Soil fertility requirements: Moderate, responsive to N

Soil pH_{Ca}: >4.0

Aluminium tolerance: Moderate[430]

Waterlogging tolerance: Low[159]

Salt tolerance: Unknown

Nutritive value

DMD: 50-72%

ME: 7.3-10.7 MJ

Crude protein: 9.0-30%

Environmental benefits

Weed control and ability to spread: Has a competitive advantage and grows well on loose, sandy soils with low fertility. On these soils veldt grass sets profuse amounts of seed and will readily move into disturbed areas or invade native bushland. On farms has a low risk of invading paddocks which are regularly grazed or set-stocked.

give a more even germination of the sown seed and also help to reduce weed competition in the seeding rows.[106]

Livestock disorders

None reported.

Management

New stands of perennial veldt grass should not be grazed in the first year until they have flowered and set seed. Perennial veldt grass persists poorly under continuous grazing as it is selectively grazed. Rotational grazing that includes a short period of heavy grazing and removal of stock once the plant height is 3-4 cm above the crown provides the best management. Aim to maintain a balance of legumes and grass in the pasture and prevent the perennial veldt grass from forming large dominant tussocks.[106]

Productive veldt grass requires a good supply of soil N ideally provided via a companion legume. To maintain legume density ensure an adequate supply of P, K and trace elements, particularly on deep sands.[106]

Companion species

On deep acid sands the best companion legume is serradella, however veldt grass can also be grown with subterranean clover on slightly acid soils. To stabilise sand dunes mix perennial veldt grass with a low rate of cereal rye to provide ground cover during the establishment phase.[106]

Cultivars

'Unarlee' (public variety) is the original naturalised form thought to have been accidentally introduced into Australia. This variety contains a wide range of types ranging from leafy plants to those with erect stems. It typically sheds its seed. Unarlee seed is not certified.

'Mission' (public variety) was bred at the University of California from material selected by R.C. Rossiter of CSIRO, Perth for its ability to retain seed. The seeds are bigger, heavier and darker brown than Unarlee.

Autumn growth of veldt grass

4.4 **Phalaris** *(Phalaris aquatica)*

Ligule

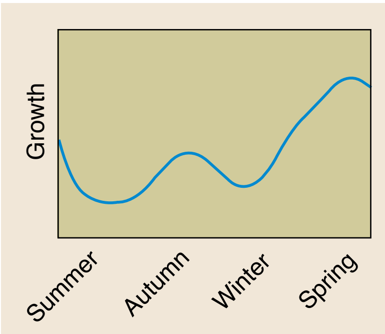
Features

- drought-tolerant, tufted temperate perennial grass
- excellent winter production
- mostly dormant in summer in WA
- toxicity problems are occasionally experienced
- requires rotational grazing for persistence and optimum production.

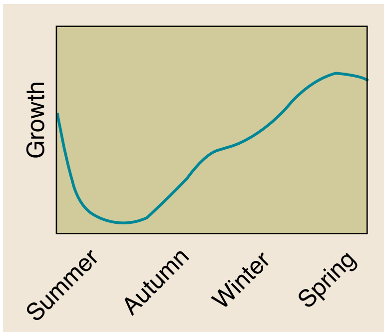
Phalaris is a winter-active perennial grass that has erect stems and short rhizomes. It is native to the Mediterranean region and was introduced into Australia in the late 1800s.[433] Phalaris has since become naturalised and is common along roadsides in high rainfall areas. It is widely grown in pastures in south-eastern Australia.

With correct management phalaris is a productive, palatable and persistent grass. Winter-active types provide good winter production but in most regions of WA are dormant in summer. Phalaris is one of the most drought-tolerant of the so-called 'big-4' temperate grasses that include cocksfoot, tall fescue and perennial ryegrass.[420] Phalaris is not seriously affected by any plant diseases other than the occasional ergot and stem rust.[420]

Seasonal growth pattern



Prostrate, semi-winter dormant, low summer dormancy types



Semi-erect, winter-active, medium to high summer dormancy types

Description

- tussock-forming grass up to 2 m high that spreads by short rhizomes and seed
- bluish-green foliage, leaves 15-40 cm, broad (4-15 mm), flat and hairless – young leaves are rolled in bud
- ligule 3-5 mm long and membranous, transparent to white and rounded at the tip
- leaf sheath bluish-green, hairless, round in cross-section – when cut through at the base a pink sap exudes that is useful for identifying seedlings
- inflorescence is a dense compact cylindrical panicle 50-150 mm long and 10-15 mm in diameter.

Soil–climate adaptation

Rainfall (est.): >500 mm (south coast >400 mm)[129]

Season length: >6 months[129]

Drought tolerance: High[194]

Frost tolerance: High[420]

Soil type: Deep medium- to fine-textured, will grow on coarse-textured if clay within 30 cm of surface[420]

Soil fertility requirements: High

Soil pH$_{Ca}$: >4.7[129]

Aluminium tolerance: Moderate[430]

Waterlogging tolerance: High[194]

Salt tolerance: Slight[326]

Nutritive value

DMD: 53-82%[129]

ME: 7.4-11.8 MJ[129]

Crude protein: 5.7-26.8%[129]

Environmental benefits

Phalaris has limited to modest groundwater recharge control in areas with <600 mm.[83]

Establishment

Phalaris is small-seeded (600,000/kg) and should be sown at a depth of 5-10 mm.[420] If sown alone the suggested sowing rate is 3-5 kg/ha, which gives 140-230 viable seeds/m^2.

Phalaris is sown in autumn and can be established using conventional methods or direct drilling. Direct drilling is the preferred method because there is less weed competition.[311] Germination and early seedling growth is very slow when average daily temperatures are less than 10°C. The optimum temperature for seedling growth is 15-20°C.[420]

Weed control is critical to successful establishment and many phalaris sowings fail because of annual grass competition.[420] To establish and maintain phalaris on acid soils, lime should be applied at 2.0-2.5 t/ha. Alternatively, a more acid-tolerant grass could be sown.[420]

Livestock disorders

Phalaris is a valuable pasture species but occasionally animals suffer toxicity problems. Phalaris contains several dimethylated tryptamine alkaloids and these alkaloids are thought to interfere with the heart, spinal cord and brain. The alkaloid content varies with the pasture's stage of growth. Young, vigorously growing phalaris is more likely to be toxic. Risk is also higher following a break in the weather. Animals are most at risk when moved onto fresh phalaris after grazing poor quality, low protein feed such

Good growth of phalaris in autumn

On suitable soils, phalaris is highly productive

as dry autumn residues. High soil nitrogen, low light intensities within the sward and high temperatures are likely to increase the incidence of toxicity. Sheep are more commonly affected by toxicity problems than cattle.[194]

Three types of phalaris poisoning have been identified:[194]

Sudden death: This is a cardiac disease and sheep can die within 2-24 hours of being put onto a phalaris pasture. Dead sheep have extended necks and rigid limbs, with some evidence of thrashing before death. Froth and blood stained discharges from the mouth and nose may be present. There is no treatment.

Acute nervous disorder: Signs only appear obvious if sheep are disturbed. Sheep appear nervous and walk aimlessly with a high stepping, stiff gait. In severe cases convulsions can occur.

Phalaris staggers: Characterised by nervous signs, which persist even when sheep are removed from toxic pastures. Staggers usually occur after long exposure to phalaris, particularly on soils deficient in cobalt. Affected sheep exhibit persistent nodding of the head and weakness in the front legs making them difficult to handle. Treating sheep with cobalt can prevent this form of poisoning but it will not cure affected sheep or prevent other forms.

Management

New phalaris stands sown in autumn can be crash grazed to a height of 10 cm in spring to control weeds and encourage tillering. Phalaris should then be allowed to set seed before further intense grazing or cutting.[392] In marginal environments defer grazing until the plants are well anchored and can resist being pulled out. The length of deferral can be up to 12 months.[392] A phalaris pasture may not reach its peak production for two to three years.[311]

It is recommended that phalaris be rotationally grazed in a four-paddock rotation as continuous grazing will reduce its persistence – particularly when grazed by sheep. In late summer and early autumn, before the break of season, graze to about 1000-1200 kg DM/ha to remove dry residues, as this will provide room for annual clovers to establish. To prevent the plant crowns from being exposed over the hotter months do not graze below 1000 kg DM/ha, then after the autumn break, defer grazing until the pasture reaches about 1500 kg DM/ha (about six weeks). Rotationally graze pastures with six weeks rest and two weeks grazing between 500 and 1500 kg DM/ha through autumn and winter. This strategy will increase the phalaris content but could also reduce the clover content. If the annual clover content declines then continuously graze to shift the balance back in favour of the legume.[392]

In spring, graze to keep phalaris under control (<3000 kg DM/ha, ~15 cm), but avoid repeated or continuous heavy grazing or cutting and prevent shading of flowering clovers.[392]

In marginal environments the phalaris should be allowed to flower in late spring, so that enough underground dormant buds can develop for the stand to re-establish in the following autumn.[293] These ‘buds’, which resemble small swellings at the base of the stems, are carbohydrate stores and help the plants to survive during the hot, dry conditions over summer.

A productive phalaris pasture has a high requirement for N, P, K and S. Phalaris is more responsive to increases in soil fertility than cocksfoot and tall fescue. Regularly topdress using a phosphate-based fertiliser on soils with a low to moderate phosphorus availability or use a sulphur-based fertiliser on soils highly deficient in phosphate and sulphur to maintain a vigorous legume component. Phalaris is also sensitive to sulphur deficiency. Phalaris has a high requirement for N and this can be supplied either by a companion legume or by applications of fertiliser.[420] Phalaris makes good quality hay or silage.

Companion species

Suitable companion legumes include subterranean clover, serradella, lucerne, strawberry clover and perennial lotus.[94] Phalaris can be grown with other temperate grasses such as tall fescue, cocksfoot and ryegrass,[94] however for successful establishment they need to be sown in separate rows. Subsequent grazing management needs to meet the requirements of all the species.

Cultivars

Prostrate, semi-winter dormant, low summer dormancy types

'Australian' (public variety) was the original phalaris ecotype in Australia and is the most grazing-tolerant cultivar due to its prostrate, spreading growth habit. It needs to be grazed heavily to maintain feed value. It can tolerate drought conditions in cool, high rainfall zones but is less persistent in drier marginal rainfall areas. It is resistant to insect attack. Limitations include poor seedling vigour, low winter production, high alkaloid content and poor seed retention (superseded by Australian II).

'Uneta' (public variety) was bred from Australian and is identical in agronomic performance but has superior seed retention (superseded by Australian II).

'Grasslands Maru' (public variety) has similar agronomic characteristics and performance to Australian but has better seedling vigour and lower alkaloid content.

'Australian II'⦶ was bred by CSIRO as a replacement for Australian, with equal or superior productivity, grazing tolerance and persistence, plus good seed retention.

'Seedmaster' (public variety) has identical appearance to Australian but with improved seed retention. However, compared to Australian, it is less vigorous and has inferior persistence (superseded).

Semi-erect to erect, winter-active, medium to high summer dormancy types

'Sirolan' (public variety) has an erect growth habit and does not spread laterally. It is a low alkaloid variety with high seedling vigour, high winter production and good survival through summer. Sirolan has a lower incidence of sudden death, although 'phalaris staggers' can still occur. It is the most persistent variety in marginal rainfall areas.

'Sirosa' (public variety) has a semi-erect growth habit and is similar to Sirolan but with better tolerance of acid soils, later flowering and higher alkaloid content. Sirosa is less drought-tolerant than Sirolan but superior to Australian (superseded by Holdfast).

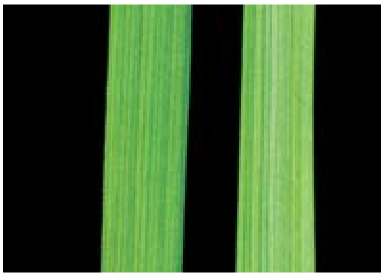
'Sirocco' (public variety) has an erect growth habit. High summer dormancy but can cause poisoning if it produces sufficient summer growth (superseded by Atlas PG).

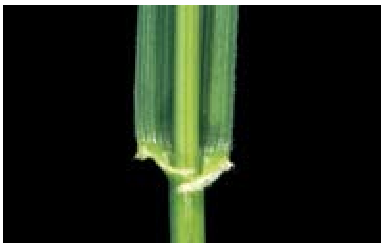
'Holdfast'⦶ is a semi-erect type with minimal lateral spread. Similar agronomic performance to Sirolan and Sirosa but with superior seed retention. Good seedling vigour and establishment and low in alkaloids. Persistent under harsh conditions and one of the most acid-tolerant varieties.

'Landmaster'⦶ is an erect type selected by CSIRO for its ability to grow on shallow, stony and moderately acid, infertile soils. Landmaster is the most tolerant cultivar of acid soils and intermediate in alkaloid content.

'Atlas PG'⦶ is an erect, winter-active cultivar with high summer dormancy bred by CSIRO to persist in areas that are usually marginal for phalaris. It has a low tolerance of acid soils. Atlas PG has good seedling vigour and winter production and is early flowering. It requires rotational grazing for good persistence and production.

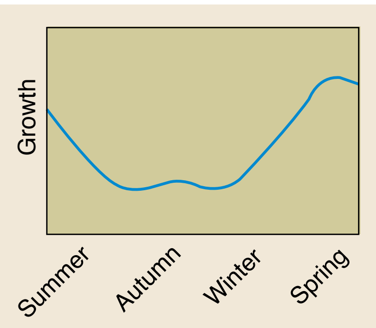
4.5 Tall fescue *(Festuca arundinacea)*



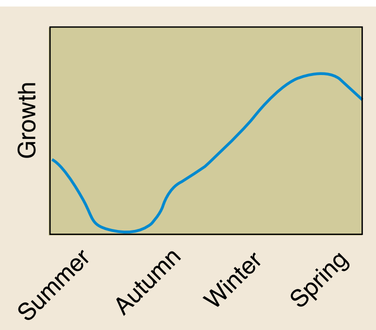


Ligule

Seasonal growth pattern



Temperate types



Mediterranean types

Features

- palatable tufted grass tolerant of waterlogging
- 'temperate' and 'Mediterranean' types have distinct seasonal growth patterns
- supplies nutritious feed in spring and early summer
- relatively drought and heat tolerant compared to perennial ryegrass
- low seedling vigour so competition from annual grasses will cause establishment failure
- requires rest from grazing particularly with sheep.

Tall fescue is a native of Europe, temperate Asia and north-west Africa and has been introduced into temperate North and South America, New Zealand, South Africa and southern Australia because of its value as a forage.[194]

Tall fescue is one of the best temperate perennial grasses for supplying nutritious feed in late spring and early summer.[312] Tall fescue is deep-rooted and relatively drought and heat tolerant compared to perennial ryegrass.[143, 312]

There are two types, each with distinct seasonal growth patterns. The spring/summer-active (temperate) types are from temperate Europe or America and the winter-active/summer-dormant types (Mediterranean) types are from the Mediterranean regions of southern Europe and north Africa.[143]

The temperate types grow vigorously in spring, summer and autumn following rain. They grow slowly in winter but do not get frosted off as easily as cocksfoot and phalaris.[143] In WA the temperate types are best suited to areas with at least seven months growing season.

The Mediterranean types are winter-active and summer-dormant and consequently have greater tolerance of summer drought.

Description

- perennial tussock-forming grass with erect stems typically 0.5-1.2 m in height
- dark-green foliage, leaves are large and flat 10-60 cm long and usually 3-10 mm wide, the upper surface is dull with prominent veins and the lower surface smooth and glossy (leaves are similar to annual ryegrass but not as shiny)
- ligule membranous and very short
- leaf sheaths hairless, rounded at back, may be smooth or rough, typically green but can be red to brownish-purple at base
- inflorescence is an open panicle 10-20 cm long, erect and nodding, green or purplish.

These varieties are very productive in autumn, winter and early spring with variable summer dormancy ranging from totally dormant to modest growth in response to summer rain.[143]

Soil–climate adaptation

Rainfall (est.): >500 mm (south coast >450 mm)[129]

Season length:
>6 months (Mediterranean types)
>7 months (temperate types)

Drought tolerance: Moderate to high[18]

Frost tolerance: High

Soil type: Wide range, best suited to medium- to fine-textured soils[97]

Soil fertility requirements: High

Soil pH_{Ca}: >4.3[129]

Aluminium tolerance: Moderately sensitive[430]

Waterlogging tolerance: High[327]

Salt tolerance: Slight to moderate[330]

Nutritive value

DMD: 60-80%[129]

ME: 8.5-11.5 MJ[129]

Crude protein: 7.5-25%[129]

Environmental benefits

Groundwater recharge control: Preliminary data suggest temperate types will provide some degree of groundwater recharge control, however Mediterranean types may not use much more water than a deep-rooted annual pasture.

Establishment

Tall fescue has a small seed (410,000/kg) and should be sown no deeper than 10 mm. The suggested sowing rate is 7-10 kg/ha when sown alone. A seeding rate of 7 kg/ha will result in about 200 viable seeds/m^2.

Tall fescue is usually sown in autumn. Low temperatures slow its germination and seedling growth more than other temperate species.[61] Seedlings have poor vigour and grow slowly in the first six months compared to perennial ryegrass and phalaris.[97] To obtain good establishment do not sow tall fescue with other grasses, as it is a weak competitor.

Livestock disorders

On rare occasions stock are subject to tall fescue toxicity and fescue foot. Symptoms include heat stress, severe lameness, reduced feed intake and poor weight gains. The condition is caused by the toxin ergovaline produced by an endophyte associated with the grass. The condition is rare because the current cultivars of tall fescue are either low in or free of endophyte.[143]

Management

New stands of tall fescue should not be grazed until the root system is well developed so the plants will not be pulled out of the ground. For autumn sowings this is typically in late winter to mid-spring. If weeds are a problem during establishment a registered herbicide or heavy grazing for a short period is recommended to reduce competition.[143]

Ideally tall fescue pastures should be kept in the 'active-growth' phase to maximise tillering, growth and quality, and to enable rapid recovery following grazing and encourage companion legumes. This will normally require some form of rotational grazing between feed-on-offer limits of 800-2500 kg DM/ha.[143]

An alternative method is to allow plants to develop three leaves per tiller then graze intensively and move stock on. Mature swards of tall fescue can tolerate continuous grazing under cattle particularly in winter and spring at low to moderate stocking rates.[129] For plant survival defer grazing in dry conditions, only grazing again when there is vigorous new growth.

Tall fescue responds well to applications of P, S and N. On soils with low levels of P and S, apply 20-30 kg P/ha and 20 kg S/ha annually for the first few years. Fertiliser rates can then be reduced to maintenance dressings. Tall fescue is generally grown with a companion legume, which if adequately fertilised will provide sufficient N.[143] Tall fescue makes good quality hay or silage.

Companion species

Suitable companion legumes include subterranean clover, serradella, lucerne, strawberry clover and perennial lotus depending on the rainfall and site drainage.[143] Lucerne and winter-active tall fescue should have complementary growth patterns.

Cultivars

Temperate (summer-active) types

'Au Triumph' (public variety) – bred in the United States for winter growth. It has good establishment, flowers early and produces large amounts of dry matter. It is endophyte-free and has been widely used in Australia since 1987.

'Demeter' (public variety) – a hardy cultivar with good production levels but low palatability and seedling vigour.

'Dovey' (public variety) – selected in south-eastern France and capable of year-round growth. Has rapid emergence and good seedling vigour. It has moderate palatability and digestibility and similar rust resistance to Au Triumph.

'Quantum' (public variety) – selected from Au Triumph for improved rust tolerance and softer leaves. Also available as 'Quantum Max P', which contains safe endophyte.

'Grasslands Advance'$^{\Phi}$ – bred by New Zealand AgResearch. Compared with Grasslands Roa, Advance has better seedling vigour and dry matter production and retains its feed quality. It is free of endophyte.

Mediterranean type (winter-active, varying degrees of summer dormancy)

'Melik' (public variety) – selected by CSIRO in WA with most of the field evaluation undertaken at Kojonup. It is highly summer-dormant. (Seed is no longer available.)

'Flecha'$^{\Phi}$ – bred in Argentina. Quite palatable with fine leaves and a semi-erect growth habit. Has rapid growth following autumn break with good winter and spring growth. Highly summer-dormant. Good persistence under sheep grazing. Rust tolerant. Also available as 'Flecha Max P'$^{\Phi}$ which contains safe endophyte.

Tall fescue has considerable potential for areas where the growing season is more than 6.5 months

The relative growth in winter of a temperate, summer-active tall fescue variety (left) and a winter-active variety (right)

'Fraydo'ᵠ – selected by Agriculture Victoria from Melik. Has an erect habit, medium leaf width and is early maturing. Highly summer-dormant.

'Prosper'ᵠ – has fine leaves and semi-erect growth habit which is intermediate between Fraydo and Flecha. Can be used on irrigated pastures.

'Resolute'ᵠ – selected from Melik. Highly summer-dormant. Also available as 'Resolute Max P'ᵠ which contains safe endophyte.

A winter-active tall fescue showing excellent autumn growth

A wide row spacing should be used in marginal environments, as demonstrated by the strong edge effect in this plot

Chapter 5
Sub-tropical grasses

Photographic credits:
Phil Barrett-Lennard (Evergreen Farming): page 135; **Peter Maloney (DAFWA Image Resource Centre):** pages 138, 140 (seed heads), 142 (seed head), 144, 148 (seed heads, plant), 150 (seed head, stolons), 153 (seed heads, stem), 156, 158, 160, 161, 164 (seed head); **Geoff Moore (DAFWA):** pages 124, 126, 132, 133, 136, 137, 139, 140 (plant), 142 (plant), 143, 145, 146, 147, 148 (seedling), 149, 150 (plant), 151, 153 (seedling), 154, 155, 157, 162, 163, 164 (plant), 165; **David Stanton (DAFWA):** page 166.

Sub-tropical grasses

Geoff Moore

- spectacular production on summer-moist areas
- highly responsive to summer-autumn rainfall
- tolerant of high temperatures
- adapted to sandy soils that are marginal for cropping
- feed quality depends on grazing management and nitrogen nutrition
- most species require rotational grazing to persist
- establishment can be difficult
- susceptible to frost damage
- can persist under stressful conditions (drought, cold, low fertility) but productivity is likely to be low.

There is increasing interest in sub-tropical grasses to:

- increase production from land with a low productivity
- reduce supplementary feeding in autumn and to allow grazing on annual pastures to be deferred after the break of season until they are well established (e.g. feed-on-offer is 500-800 kg of DM/ha)
- integrate with other annual and perennial pasture types to achieve year-round green feed. Sub-tropical grasses with a high plant density can be expected to produce in the order of 20-30 kg DM/ha/mm of rainfall over the summer-early autumn period (assuming rainfall events >20 mm over seven days)
- increase water use to reduce the spread of salinity
- reduce the risk of wind erosion, especially on the south coast
- enable stock to be turned off all-year-round to meet market requirements.

Sub-tropical grasses (also called summer-active, warm season or C4 grasses) are not new to Western Australia. Kikuyu and paspalum have been grown in high rainfall districts, on the Swan Coastal Plain and on the south coast for many years. Buffel grass was observed growing on the north-west coast of WA in the late 19th century and was subsequently widely sown by pastoralists. However there has been a marked increase in the use of sub-tropical grasses in the last 5-10 years.

In 1990 two series of trials commenced to test alternative perennial pastures in the West Midlands, where farmers were struggling to adapt wheatbelt farming systems to the highly leached sands. Jesse Skoss, a private agronomist, tested several sub-tropical grasses and legumes on behalf of local farmers. At the same time, the Department of Agriculture evaluated a range of annual and perennial pasture options for sandy soils. The temperate perennial grasses (phalaris, tall fescue, cocksfoot) failed to persist over summer, but the sub-tropical grasses persisted and showed promise. These trials were not continued but a group of innovative farmers and Tim Wiley, a district adviser (DAWA), continued with on-farm testing and tackled establishment and management on a commercial scale.

French serradella with Rhodes grass pasture

C4 photosynthetic pathway

The sub-tropical grasses use the C4 photosynthetic pathway whereas most plants assimilate carbon dioxide (CO_2) via the C3 photosynthetic pathway. The names are simply derived from the number of carbon atoms in the first product of photosynthesis (C4 = 4 carbon compound, C3 = 3 carbon compound). Photosynthesis is the process by which plants take in CO_2 from the atmosphere through open pores (stomata) in the leaves (and stems) which is then combined with water (H_2O) to produce sugar and oxygen (O_2) using the sun's energy.

The C4 plants have some important advantages over C3 plants in hot, dry conditions. They are more water and nitrogen efficient, but require more energy (light) as there is an additional step in the photosynthetic pathway. The C4 plants only need to keep their stomata open for short periods, so they lose much less water (transpiration) for the same amount of CO_2 fixed by photosynthesis. This is a significant advantage under hot, high light intensity, moisture-limiting conditions, which aptly describe the conditions in WA in summer and early autumn.

The C3 plants have their stomata open for longer periods, so transpire more water. When it is hot and dry, the stomata close to conserve water but this slows photosynthesis (growth). Also, at high temperatures (>30°C) C3 plants can photo-respire whereby respiration occurs instead of photosynthesis and previously fixed CO_2 is released instead of O_2. Consequently, under hot, moisture-limiting conditions the C3 plants revert to other drought survival mechanisms like leaf senescence and dormancy well before the C4 grasses use these adaptations.

On the other hand, C3 plants are more efficient than C4 plants under cool, moist conditions and at lower light intensities. The temperate pasture species are all C3 plants and they grow actively in winter when the C4 plants are dormant or only able to grow slowly.

Their interest and enthusiasm evolved into the Evergreen Farming Group, which has been instrumental in promoting the widespread on-farm testing and use of sub-tropical grasses.

The widespread distribution of wild African lovegrass (*Eragrostis curvula*) along roadsides in south-western Australia from Kalbarri to Esperance provides some indication that most of the agricultural area is suitable for growing sub-tropical perennial grasses. But whether they can be reliably established and provide an economic return in drier regions has yet to be demonstrated.

In general, the sub-tropical grasses are better suited to the conditions in southern Australia than many of the tropical legumes, which come from true tropical regions and have higher temperature requirements for growth. The legumes are C3 plants and as a result do not have the same water use efficiency advantages. Lotononis and to a lesser extent siratro are exceptions to this rule (Chapter 3 Herbaceous perennial legumes).

Soil–climate requirements

Sub-tropical grasses are generally grown as permanent pastures on land that is non-arable or where the return from annual crops is marginal or unprofitable. They are occasionally used in rotation with crops, but perennial or annual legumes are generally preferred because of their nitrogen benefits to the following crop. The climatic factors affecting their growth and persistence are different to many of the temperate species as they predominantly grow outside the May-October growing season for annual crops and pastures. The key climatic features affecting the sub-tropical grasses are summarised in Table 5.1.

Sub-tropical grasses are similar to other crops and pastures in that the highest production under ideal conditions will generally be from soils with good physical and chemical properties, such as fertile, deep loamy soils. These soils are also the most productive cropping soils and as a result are usually used in an intensive crop rotation.

Table 5.1 The key climatic factors affecting the growth and persistence of sub-tropical grasses

Frequency and amount of summer and early autumn rainfall
The sub-tropical grasses mainly grow outside the normal May to October growing season of annual crops and pastures. The grasses can grow slowly in early winter (June) in coastal districts and slowly right through winter in the northern agricultural region, however in most areas they are dormant over winter. They start growing in spring as the temperature increases. They respond rapidly to rain when the temperatures are warm to hot. As a result, sub-tropical grasses largely rely on moisture outside the normal growing season. In regions with low rainfall outside the growing season, production will be low in many years. The exception is sites with extended subsoil moisture into late spring, or a fresh watertable within the root zone.
Frequency and severity of frosts
There is variation in frost tolerance between species. Sensitive plants can be killed. With other species, heavy frosts can kill the above-ground parts of the plant, but the plant will regrow when the temperature increases. Some species will tolerate mild frosts and retain green leaf. The sub-tropical season grasses are grown successfully in central Queensland and northern New South Wales, areas that experience a higher frequency and severity of frosts than WA. Areas subject to frosts will not preclude growing sub-tropical grasses, but they will influence the selection of species and there may be minimal growth from the start to the end of the frost period.
'Cold zone'
There is growing evidence that persistence of sub-tropical grasses over winter is adversely affected in a 'cold zone' which extends from approximately Northam in the north to Manjimup in the south and to the eastern boundary of the agricultural area. This 'cold zone' has been spatially defined from maps of July-August mean minimum temperature and frost frequency (Figure 5.1). The poor persistence seems to be due to combination of cold, wet soils and frosts. Typically there is a high mortality of bunch grasses with 70-100% of the plants dying over winter. The grasses are burnt off by the first frosts in winter, but instead of regrowing in spring they have died over winter. Species affected include setaria, panic, bambatsi panic, signal grass and digit grass. On the other hand, grasses with rhizomes, kikuyu, paspalum, couch grass plus African lovegrass, all show good winter survival. The persistence of Rhodes grass varied from fair to poor, with diploid varieties showing better persistence than Callide (tetraploid).
Temperatures in late winter and early spring
The sub-tropical grasses start growing actively between late winter and mid-spring depending upon the temperature. Mild to warm conditions in early to mid-spring enable the sub-tropical grasses to grow actively in the growing season and this lessens their reliance on rainfall outside the May-October growing season. This is the case in the northern agricultural region, where the sub-tropical grasses grow slowly over winter and actively in spring. With most species there is a marked decrease in growth below 20°C with minimal growth below 15°C. Species with better growth at 15-18°C include setaria, Rhodes grass and kikuyu. Low temperatures at night can have a marked effect on growth even when the day temperatures are mild to warm. For instance, with day temperatures of 20°C, the growth of Rhodes grass was reduced by 60% when night temperatures were reduced from 8 to 4°C.[165]

The relative cold tolerance of (a) signal grass, (b) panic grass, and (c) Rhodes grass

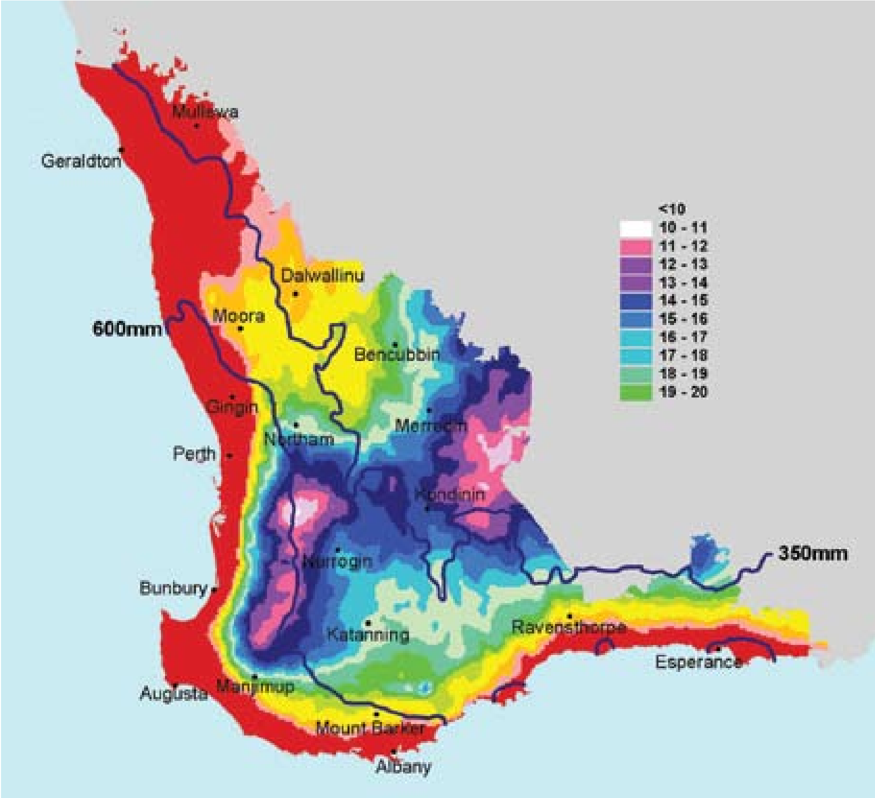


Figure 5.1 The mean minimum temperature for August showing the 'cold zone' where there is poor persistence of most sub-tropical grasses (D. van Gool, DAFWA using BoM Base Climate data)

Which species to grow?

Most of the sub-tropical grasses are native to summer rainfall regions in southern and central Africa or South America. The commercial varieties currently available were developed for sub-tropical and tropical environments in eastern Australia, which have a summer dominant rainfall pattern. These grasses can be grown successfully in a winter-dominant rainfall environment like WA due to their ability to persist though dry periods and because of their cold and frost tolerance. In Africa many summer rainfall regions have either extended dry periods or the summer rainfall is highly variable, so the grasses from these regions have some drought tolerance.

Like most plants, sub-tropical grasses prefer certain soils and have varying tolerances of waterlogging, inundation, soil acidity, soil salinity and low fertility.

The soil type recommendations developed for the eastern States of Australia are not directly transferable to WA. Some species have been grown successfully in WA on soils that would be considered marginal or unsuitable in Queensland, however other species have specific soil requirements (e.g. bambatsi panic).

In WA we are still determining where many of the sub-tropical grasses are well adapted, as many have only been grown in a limited number of field trials and/or farmer paddocks. Table 5.2 attempts to summarise the soil adaptation for the main species currently grown commercially or with potential for WA. It has been compiled from preliminary trial results and observations in WA and will continue to be a work in progress.

However, there are a number of land management units (soil types) with the potential for increased production from sub-tropical grasses including:

- summer-moist sites – with a shallow non-saline watertable
- winter waterlogged sites that are too wet for cropping – with a perched watertable for extended periods from winter through to mid-spring
- deep leached sands and gravelly sands that are marginal for cropping
- moderately deep sandy duplex soils
- marginally saline land with a watertable at 1.5-2.5 m, where sub-tropical grasses could be sown between rows of saltbush. The saltbush acts as a water pump to keep the watertable at depth so that salt does not accumulate on the surface through capillary rise
- highly acidic sandy soils.

Shallow soils have a low potential for perennial pastures due to their restricted soil depth.

Table 5.2 Potential for sub-tropical grasses on the main land management units in WA (see key below)

Land management unit	Bambatsi panic	Digit grass	Kikuyu	Lovegrass (Consol)	Panic grasses	Paspalum	Rhodes grass	Setaria	Signal grass
Minimum rainfall* (mm)	>375	>450	>500	>375	>475	>550	>425	>550	>500
Minimum rainfall* (mm) (south coast)	>325	>400	>400	>350	>400	>475	>400	>475	>450
Summer moist soils (non-saline)	✔✔	✔	✔✔✔	✔✔	✔	✔✔✔	✔✔	✔✔✔	✔
Winter waterlogged sandy soils	✔	✔	✔✔✔	✔✔	✔–✔✔	✔✔	✔✔	✔✔	✔
Mildly saline soils	✔	✘	✔	✔	✘	✘	✔	✘	✘
Saline soils	✘	✘	✘	✘	✘	✘	✘	✘	✘
Loamy soils (mod. well to well drained)	✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔	✔✔✔	✔
Clay soils (imperfectly to well drained)	✔✔✔	✔	✔	✔	✔✔	✔	✔	✔✔	✘
Shallow sand (<0.3 m) over gravel or clay	✔	✔	✔–✔✔	✔–✔✔	✔–✔✔	✔	✔–✔✔	✔–✔✔	✘
Moderately deep sand over clay or gravel	✔	✔✔	✔✔	✔✔	✔✔	✔	✔✔	✔✔	✔✔
Deep coloured sands	✔	✔✔	✔✔	✔✔	✔✔✔	✔	✔✔✔	✔	✔✔
Deep leached sands	✘	✔	✔–✔✔	✔✔	✔✔	✘	✔✔	✘	✔
Deep acid sand (pH_{Ca} 4.0-4.3)	✘	?	✔	✔–✔✔	✔	✘	✔	✘	✔–✔✔

* Except for moisture gaining sites

Key: ✔✔✔ = well adapted, ✔✔ = adapted, ✔ = will grow, but may have poor persistence or productivity, ✘ = not suited.

Confidence level for Western Australian conditions

- Low – limited testing or grower experience
- Moderate – some testing or grower experience
- High – extensively grown or tested

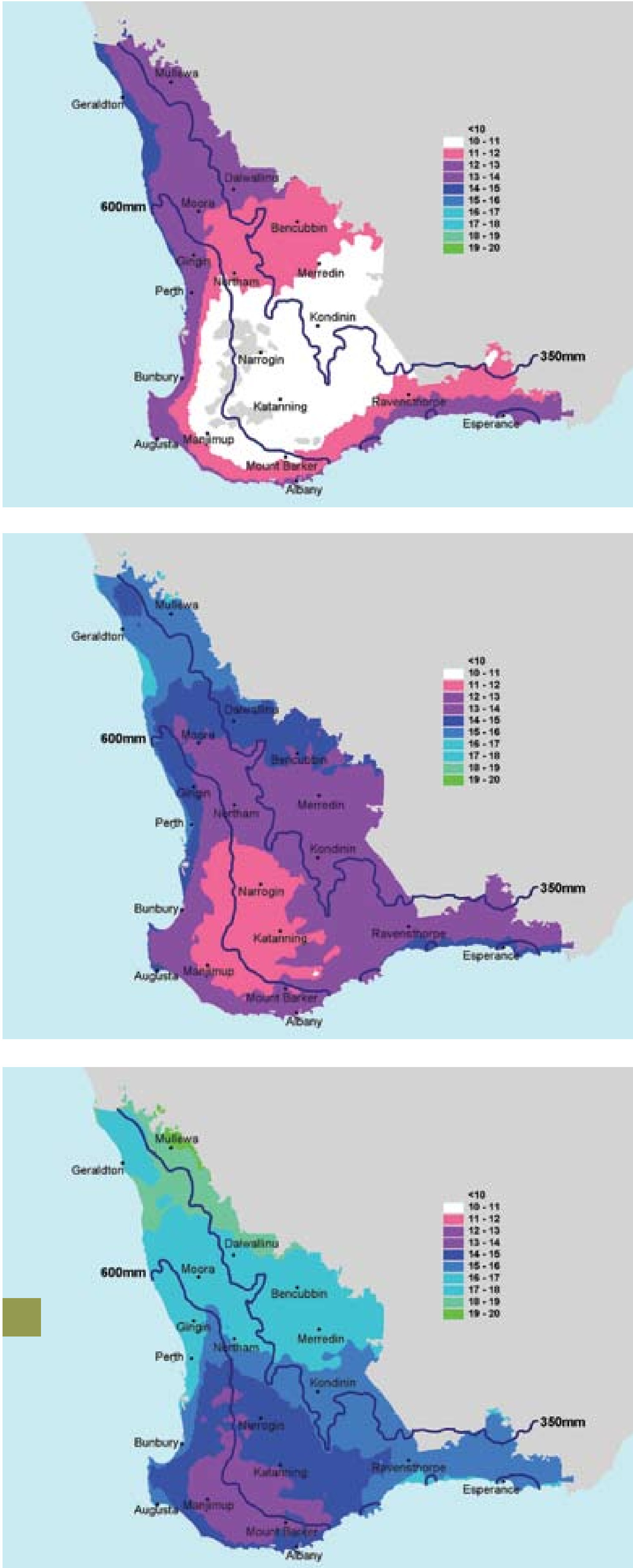


Figure 5.2 The mean monthly temperature for (a) August, (b) September and (c) October (D. van Gool, DAFWA using BoM Base Climate data)

Establishment

With Phil Barrett-Lennard

Sub-tropical grasses require soil temperatures greater than 15-18°C to germinate, so the options are to sow in either autumn or spring.

Autumn sowing is risky as annual volunteer weeds will germinate over an extended period and compete strongly with the perennial grasses, which then have to persist through winter as small plants. However, there are examples where spring-sown grasses that have failed to germinate due to the dry seasonal conditions have subsequently germinated following rain in March-April and established well.

The preferred time to sow sub-tropical grasses is in late winter to early to mid-spring when the soil temperature is favourable.
The sowing window for sub-tropical grasses depends on the region. Figures 5.2a-c show the mean monthly temperatures for August, September and October, which is a surrogate for soil temperature.
The soil temperature is also affected by the colour of the surface soil, with dark soils absorbing more heat. In addition, wet soils take much longer to warm up (i.e. up to six weeks longer to reach the critical temperature for sowing), because of water evaporating from the surface.

In general, seeding should be as early as possible in each region to maximise the likelihood of good follow-up rain. The approximate 'sowing window' for each region is summarised in Figure 5.3.

All areas have adequate soil temperatures sometime between late August and early October for the germination of sub-tropical grasses. However, in low rainfall districts the likelihood of adequate rain after seeding decreases, so there is a higher risk of poor or failed establishment.

Many commercial sowings of sub-tropical grasses result in about 1 plant/m^2 per kilogram of seed per hectare. This is an unsatisfactory result as it correlates to a strike rate of only 1-2%, assuming seed viability of 50%. Failure to achieve complete weed control, poor control of seeding depth and not over-coming non-wetting sands seem to be the primary reasons for poor or failed establishment.

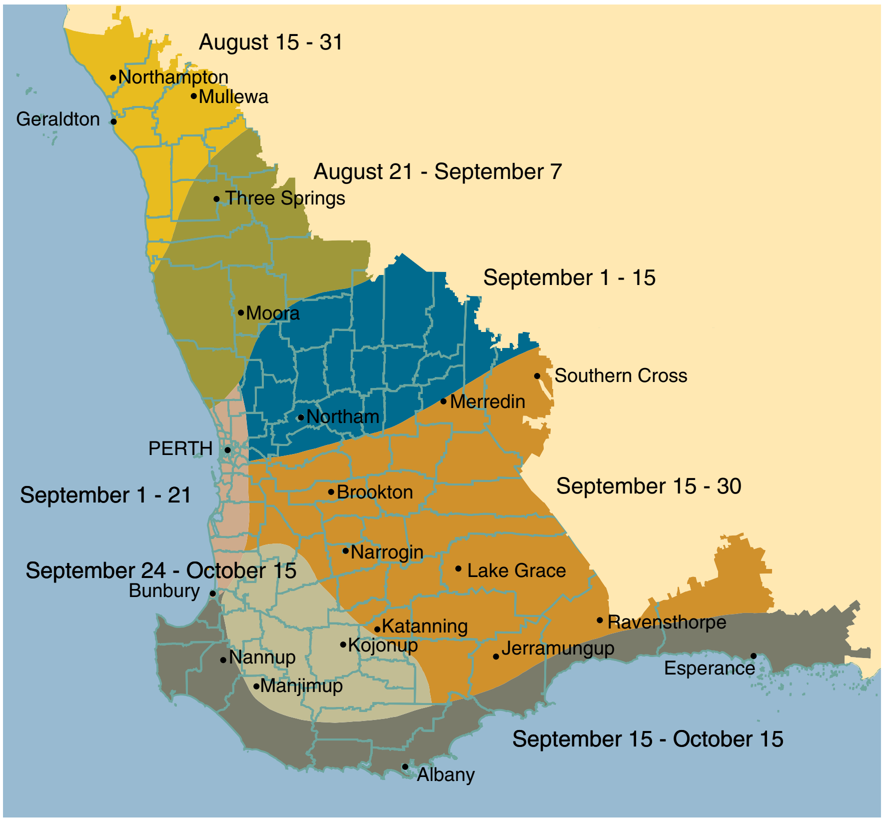


Figure 5.3 The approximate 'sowing window' for sub-tropical grasses

Seven key factors for successful establishment are listed below. If these are followed, then a greatly improved strike rate should be achieved and the potential production from the perennial pasture will not be compromised.

Key factors for successful establishment

a) Total weed control during the establishment phase

Total weed control is essential as the sub-tropical grasses have low seedling vigour and compete poorly with weeds. For example, typically there is very poor or failed establishment in areas that are missed by the boomspray.

Weed control at sites with potential problem weeds should commence in the year before seeding. Some of the problem weeds that adversely affect the establishment of sub-tropical grasses are listed in Table 5.3.

At most sites a double knockdown is required to give complete weed control, although under certain conditions a single knockdown with glyphosate will give good results.

Table 5.3 Problem weeds that adversely affect the establishment of sub-tropical grasses

Weeds germinating in spring	Cool season weeds
Afghan melon *(Citrullus lanatus)*	Annual ryegrass *(Lolium rigidum)*
Fleabane *(Conzya* spp.)	Capeweed *(Arctotheca calendula)*
Ice plant *(Mesembryanthemum crystallinum)*	Silver grass *(Vulpia* spp.)
Mint weed *(Salvia reflexa)*	Subterranean clover *(Trifolium subterraneum)*
Prickly paddy melon *(Cucumis myriocarpus)*	Wild radish *(Raphanus raphanistrum)*
Roly-poly *(Salsola kali)*	
Wireweed *(Polygonum arenastrum)*	

Double knockdown strategy:

- Graze the paddock heavily in early winter and then spell it for one to two weeks before the first knockdown to allow new leaf growth for chemical uptake.
- Apply glyphosate (usually 1.5-2 L/ha) as the first knockdown about six weeks before seeding to allow time for any biomass to break down. Consider adding a spike if large broadleaved weeds are present. Avoid using herbicides with a soil residual effect like Atrazine as these will affect some sub-tropical grasses.
- A second knockdown is usually required a few days before seeding. This will kill any newly germinated seedlings plus weeds that are difficult to control such as silver grass and large broad-leaf weeds that have recovered from the first spray. Plants that are stressed when the first knockdown is applied are also likely to recover. The second knockdown should also be glyphosate. Spray.Seed® is not recommended when the second knockdown is more than 10 days after the first. A broad spectrum systemic insecticide can be applied at seeding for short-term insurance.

b) Selecting appropriate species for the environment (soils, climate)

To select the most appropriate species or mix of species for a site, use the summary in Table 5.2 plus the descriptions of individual species together with results from local trials and on-farm test strips. When using a 'pasture mix' ensure that all of the species in the mix are adapted to the soil and climatic conditions to avoid wasting seed.

When sowing mixtures, pasture composition appears to be affected by the sowing depth and the soil moisture conditions during establishment. If the seed is sown on the surface and rolled (shallow sowing <5 mm) or the soil moisture after seeding is marginal, then these conditions appear to favour Rhodes grass, while a slightly deeper seeding depth (5-10 mm) tends to favour the bunch grasses. A number of sub-tropical grasses display a secondary dormancy (hydropedesis) if they begin to germinate and the soil temperature and moisture conditions are unfavourable. However, this is not the case with Rhodes grass, so under marginal conditions it will be the first species to germinate.

It is preferable to sow a seed mix that contains both bunch grasses and stoloniferous (spreading) grasses in alternate rows, although this is not always practical.

In some instances there may not be any sub-tropical grasses well adapted to the soils and climate at a site. Investigate the use of alternative perennial pasture types to meet the identified need (e.g. reduce supplementary feeding in autumn) rather than use poorly adapted sub-tropical grasses.

c) Good quality seed

Sub-tropical grass seed can vary widely in quality (germination rate, purity, weed seeds). Freshly harvested seed of some species has a low germination due to post-harvest seed dormancy, so do not sow freshly harvested seed of these species. Use good quality seed with a known germination, which is free of weed seeds.

The germination of sub-tropical grasses can vary from as low as 10% to more than 70% – 40% germination is considered quite acceptable, while 70% is excellent. When purchasing seed compare the price per kilogram of viable seed. The seeding rate should be adjusted if the germination is less than 50% (i.e. if 25% germination then double the seeding rate).

Most commercial sub-tropical grass seed is currently produced in eastern Australia and imported into WA. By law all seed entering the State is required to pass through WAQIS before it is released. This ensures that (i) the species is permitted in WA and (ii) it does not contain any prohibited weed seeds. There are some serious weeds in eastern Australia that are not present in WA, so ensure these protocols are always followed.

d) Soil temperature and moisture

A combination of soil temperature (>15-18°C) and follow-up rain is required for sub-tropical grass seed to germinate. As a guide the grasses will germinate when the soil temperature at 9:00 am is more than 15-18°C for several consecutive days. The soil temperature can be measured or estimated from the air temperature.

Deep furrow sowing is a must on non-wetting sands. The furrow acts to harvest water and channel it below the seed (left), which improves the reliability of establishment (right)

{Soil temp. at 9.00 am ≈ [daily minimum temp. (°C) + daily maximum temp. (°C)]/2}.

Sub-tropical grasses have been established successfully with only 25 mm of rain after seeding in spring, provided there is stored moisture in the soil profile and excellent weed control. However, for the seedlings to access the subsoil moisture there needs to be a continuous band of moisture from the topsoil down to the subsoil. Provided the plants are well established by the start of summer, there is usually a good survival rate even through a dry summer.

With poor or failed establishment there is often poor seedling emergence in spring or the grasses are still small at the start of summer making them very susceptible to drought stress. If there are dry conditions in early to mid-summer many of these plants will not survive.

e) Seeding method

Sub-tropical grasses have small seeds (400,000 to 4 million/kg), so shallow sowing at 5-10 mm with good seed-soil contact is essential. The seeding requirements seem straightforward, but many commercial sowings achieve only poor to fair establishment. A wide range of seeding equipment can be used, but it should be set-up carefully to achieve accurate seed placement and good seed-soil contact (apply heavy press wheel pressure). Alternatively, on sandy soils seed can be dropped onto the soil surface and rolled in.

On non-wetting, sandy soils placing the seed in a deep furrow (8-10 cm) while maintaining good seed to soil contact can improve establishment. The benefits include: (i) the seedbed wets up evenly as most of the non-wetting soil is removed; (ii) the deep furrow channels light rain to the seedling; (iii) most of the weed seeds are removed from the seeding row; and (iv) the deep furrow maintains some shape well into autumn.

Some species have light, fluffy seeds (e.g. Rhodes grass) and a carrier (sand, fertiliser) can be used to improve flow through the seeder (mixing 1 kg of seed with 25 kg of carrier will improve the flow through the seeder). Alternatively use coated seed and adjust the seeding rate accordingly.

With air seeders, the air velocity required to move the fertiliser-seed mix can cause seed bounce, so it may be necessary to fit a 'diffuser' just above the seeding boots to allow the seed to drop into the furrow (or onto the soil surface) under gravity.

A wider row spacing (40-60 cm) may be beneficial especially in low to medium rainfall areas or in poorer soil types, as it allows the plants to explore a greater soil volume. Reduce the seeding rate in proportion to the row spacing, e.g. halve the seeding rate with a 50-55 cm row spacing. With wide row spacing the inter-row annual pasture takes on even more importance to maintain good production from the paddock.

f) Insect, pest and weed control after sowing
Post-sowing weed and insect control can be critical, especially along the south coast. Consider adding a 'coal-mine canary' such as lucerne, chicory or serradella to the seed mix that can act as an early warning indicator for insect damage. As these plants are unaffected by soil temperature they will germinate quickly and attract any insects that are present. Sow very low rates (50-100 g/ha) so they are not competitive and monitor regularly for damage. If they do not appear or quickly disappear there is a problem which needs to be addressed.

Monitor the paddock regularly, every 10-14 days after seeding to check for pests, weeds and the emergence of the grass seedlings.

Use a selective herbicide if broad-leaf weeds are an issue. There is currently limited information available on the use of pre-emergent herbicides and also on selective herbicides for post-emergent weed control, however mixtures of Dicamba and 2,4-D amine have been used successfully in the past.

When there is good spring and summer rain, grazing can be used strategically to control weeds, provided the grasses are well established and strongly anchored. However, in dry seasons grazing will need to be deferred and even low numbers of weeds will compete strongly for the limited soil moisture.

Uncontrolled grazing by kangaroos and rabbits during the first summer will adversely affect plant persistence, especially in dry seasons.

g) Grazing during the first summer
Seasonal conditions will determine when sub-tropical grasses can be grazed in the first year. Under favourable conditions it might be possible to graze 8-10 weeks after seeding, but when the seasonal conditions are very dry no grazing will be possible until late autumn or early winter. Grazing should always be short and intense to ensure that new regrowth is not grazed. A light grazing will encourage tillering.

Excellent establishment of sub-tropical grasses by Grant Bain from Walkaway, south-east of Geraldton

Sub-tropical grass seedlings have a very weak primary root system, so are very susceptible to grazing damage over the first summer. Plants with reasonable top-growth can still have a weak root system. It is important not to graze the grasses during the first summer until they have developed a strong root system. Grazing too early will result in stock up-rooting and killing many plants. Check whether plants are firmly anchored by testing how easily they can be pulled out by hand. Rhodes grass has long runners (stolons) that do not root down in dry soils and is therefore particularly susceptible to grazing damage in the first summer (test by pulling on the stolons).

What is successful establishment?

Successful establishment refers not only to a good seedling density in spring, but most importantly to persistence of the sown grasses through the first summer to give a good plant density in autumn.

With bunch grasses a plant density in the first autumn (e.g. mid-April) of 20-30/m^2 or more is excellent, 10-20/m^2 is very good, 6-10/m^2 is good while 1-5/m^2 is only fair and may not be adequate for good production. A stand with less than 1 plant/m^2 is a poor result and potential production will be severely constrained due to the low plant density. Under normal management there is negligible recruitment of bunch grasses and as with many perennial pastures there tends to be a slow decline in plant numbers over time. In the long-term, a pasture with 3-10 large bunch grasses/m^2 (depending on rainfall and the size of the crowns) will give good production.

Figure 5.4 shows the establishment and then the decline in plant numbers over a dry summer at three sites. At Mingenew and Badgingarra the grasses were well established before summer and there was still a good to very good plant density in autumn (except for setaria at Mingenew) despite the very dry summer conditions with little rain from early December until the end of March. However at the drier site at Buntine the grasses were small at the start of summer and most of the setaria and green panic plants died over summer. There was a second germination in autumn but survival of these plants over winter was problematic.

Grasses like Rhodes grass and kikuyu have the ability to spread and form new plants through their stolons and/or rhizomes. As a result, initially fairly poor stands with 1-5 plants/m^2 can be thickened by allowing the runners to root down and form new plants before they are grazed.

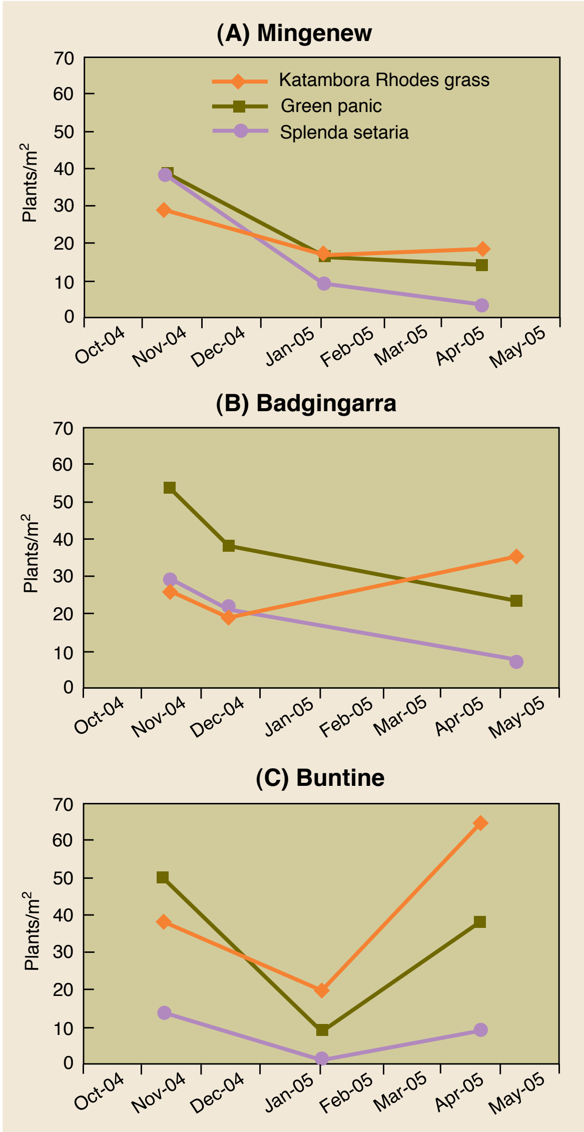


Figure 5.4 The initial establishment and persistence over the first summer of Katambora Rhodes grass, green panic and 'Splenda'⁽ᵇ⁾ setaria at (a) Mingenew, (b) Badgingarra and (c) Buntine (G. Moore, J. Titterington, G. Woolston and B. Peake unpublished results)

Animal production

Animal production from sub-tropical grasses is linked to the amount and quality of the pasture produced. The energy and protein requirements of the animal need to be met (Section 2.2).

The main advantage of summer-active perennials is that they produce out-of-season green feed, which is of comparatively good quality compared to the dry annual pasture residues at the same time of the year. They also provide a source of vitamin E.

In general, the feed quality of temperate perennial grasses is higher than sub-tropical perennial grasses when measured at an equivalent growth stage. But both species have a lower feed quality than annual legumes in spring. Table 5.4 summarises the dry matter digestibility and crude protein for a range of sub-tropical grasses from a trial at Wellstead.

Table 5.4 Dry matter digestibility (DMD) % and crude protein (CP) % in summer and autumn 2002/03[343]

Common name	Cultivar	12 February 2002		18 May 2002		14 January 2003		8 May 2003	
		DMD (%)	CP (%)	DMD (%)	CP (%)	DMD (%)	CP (%)	DMD (%)	CP (%)
Setaria	Solander	79	13	72	12	70	11	62	8
Rhodes grass	Katambora	69	10	65	11	58	8	58	9
Finger grass	Strickland	78	11	72	11	62	7	66	10
Rhodes grass	Pioneer	68	10	63	10	57	8	63	10
Signal grass	Basilisk	71	15	62	12	63	10	64	13
Guinea grass	Gatton	75	15	64	11	–	–	–	–
Setaria	Splenda	75	14	70	13	70	12	67	9
Digit grass	Premier	71	13	65	12	67	11	66	11
Makarikari grass	Bambatsi	72	13	62	14	64	12	64	14
Digit grass	Jarra	–	–	73	11	–	–	–	–

The feed quality of sub-tropical grasses varies widely with management to a much greater extent than annual pastures or perennial legumes. Some factors that affect the amount, quality and feed intake of the sub-tropical grasses are summarised in Table 5.5. With most sub-tropical grass species there is a marked response in both pasture production and animal production to fertiliser nitrogen (N), providing soil moisture is available and temperatures are non-limiting.

Balanced pasture

To maintain the productivity and quality of sub-tropical grasses a good supply of nitrogen is essential. The cheapest form of nitrogen is from an annual legume-based pasture. The ideal sub-tropical grass pasture should be indistinguishable from an annual legume dominant pasture in winter and early spring. If well managed, then similar production can be achieved over winter and early spring to an annual pasture.

Good growth of panic grass on a deep sand near Moora in autumn following a dry summer

In general, the annual legumes that have the most potential as companion species are those that are best suited to the particular soil and climate. However, it may be preferable to use an early flowering variety to reduce competition with the sub-tropical grasses in mid- to late spring.

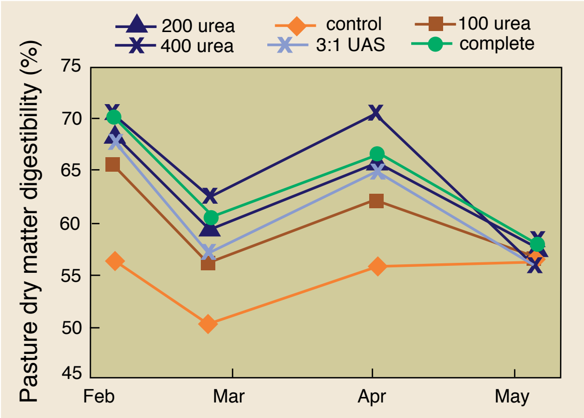


Figure 5.5 Dry matter digestibility of kikuyu in response to application of fertiliser nitrogen (urea, urea + sulphate of ammonia, complete fertiliser) on 20 January 2000 at Esperance[247]

Suggested annual legumes for some of the key land management units include:

- deep sands – blue lupins, hard-seeded French serradella, yellow serradella
- winter-waterlogged sites – subterranean clover, balansa clover, burr medic, Persian clover
- summer-moist sites will support perennial legumes including strawberry clover as well as balansa, Persian and arrowleaf clovers.

The role of lotononis as a companion perennial legume is still to be investigated. Lucerne can be grown with sub-tropical grasses but they will be competing for soil moisture from mid-spring to late autumn and will grow more slowly in winter and early spring than annual legumes.

Establishing annual legumes

The ideal situation is to establish the annual legume in year one and manage the pasture to produce a large seed-bank. In year two, the annual pasture can be grazed hard and then sprayed out in early August with the sub-tropical grasses sown in early spring. The annual legumes will then regenerate from the seed-bank in year three.

However, in practice sub-tropical grasses are often sown into paddocks with a low annual legume content. With this scenario there are two options to increase the annual legume content.

(a) *Over-sow annual legumes*. This is necessary when the seed bank of annual legumes is very low.

In year 3 or subsequent years (only in year 2 if there are favourable growing conditions over the first summer-autumn) graze the paddock hard three to four weeks after the break and then apply Spray.Seed® (1.5 L/ha). This will kill the volunteer annual pasture and burn-off the perennial grasses which will regrow in spring. Annual legumes can then be over-sown using a disc seeder or broadcast and trampled in by stock. Manage the pasture in spring to maximise seed-set of the annual legume.

(b) *Manipulate the pasture to encourage the existing annual legumes*. This option may be suitable when there is an existing seed-bank of hard-seeded annual legumes, but it is insufficient to give an annual legume dominant pasture.

Lotononis with Rhodes grass. The potential for growing perennial legumes with sub-tropical grasses is still being evaluated

Table 5.5 Some key factors affecting the amount, quality and feed intake of sub-tropical grasses

Growth stage of plant
There is a strong effect of stage of growth (maturity) on feed quality. The best quality feed is new regrowth and quality declines rapidly from the commencement of flowering as there is an increase in the proportion of structural carbohydrates and lignin, which reduce digestibility. Typically across a range of species, the dry matter digestibility of regrowth declines by 0.1-0.4% per day.[261] Rank growth has low palatability, poor feed quality and will be avoided by stock. Providing a protein lick can increase the intake of rank (mature) grasses.
Fertiliser nitrogen – Effect on dry matter production
Many trials in the eastern States and overseas have shown large increases in dry matter production with nitrogen (N) fertiliser. Typically for a range of species, there is a linear response in herbage production to fertiliser N up to high annual application rates of 300-600 kg N/ha, depending on rainfall. The herbage response is often in the range 10-20 kg DM for each kg N/ha, but it can be highly variable.[157] For example, in Queensland a range of sub-tropical grasses produced 3-11 kg DM for each kg N/ha during a period of low productivity and 17-48 kg DM for each kg N/ha during a period of high productivity (high temperatures, good rainfall).[70A] There have been limited studies in WA, but kikuyu growing on a deep sand near Esperance gave a response of ~11.5 kg DM for each kg N/ha up to 184 kg N/ha under favourable seasonal conditions (50 mm rain immediately after fertiliser application in January).[247]
Fertiliser nitrogen – Effect on protein and digestibility
There is usually a positive response of protein content to fertiliser nitrogen, but as sub-tropical grasses are very efficient at utilising N, the main response is increased herbage production.[263] Nitrogen fertiliser often has a small positive (although sometimes negligible) effect on dry matter digestibility depending on soil fertility and the time of the year.[263] However, in the N fertiliser trial on kikuyu at Esperance (see above) there was a marked increase in the dry matter digestibility from 50-55% with no fertiliser to 60-70% with fertiliser N which would be sufficient for growing animals (Figure 5.5).[247]
High temperatures
With most sub-tropical grasses the optimum temperature for growth given non-limiting nutrients and soil water is high, often 25-35°C. Kikuyu and setaria have lower optimum temperatures for growth because they come from high altitude environments. On the other hand, high temperatures result in rapid growth, which may hasten maturity and result in a decrease in feed quality. Conversely, with mild temperatures the growth rate is lower, but the feed quality may be higher.

Rhodes grass–subterranean clover pasture in late winter

In year 3 (or later) graze the paddock hard three to four weeks after the break and then apply Spray.Seed® (~1.5 L/ha). This will kill the volunteer annual pasture, burn-off the perennial grasses and allow the annual legumes to become more dominant. The timing of the pasture manipulation will depend on seasonal conditions. Subsequently manage the pasture in spring to maximise seed-set of the annual legume.

On-going management

Reduce competition at the break of the season by grazing the perennial grass hard in late autumn and early winter. In spring the annual legume needs to be allowed to set-seed. The specific management will depend on the grazing pressure and whether the annual legume is an aerial seeder.

5.1 Bambatsi panic *(Panicum coloratum)*

Features

- palatable, drought-tolerant tufted grass
- good tolerance of flooding
- adapted to fertile, clay soils
- will persist on sandy soils, but with low productivity
- slow to establish
- poor cool season growth.

Bambatsi panic (also makarikari grass) is an out-crossing species that is identified readily by its greyish-blue leaves with a distinctive white mid-rib. It is native to summer rainfall areas of southern and eastern Africa where it occurs on fine-textured soils, clay loams to cracking clays.[216] This strong soil preference is borne out in Queensland and northern NSW where bambatsi panic is grown almost exclusively on self-mulching and cracking clay soils.[216] The requirement is related to soil texture and not simply high soil fertility.[216] It is cultivated in the United States where it is known as 'klein grass'.

The potential of this species in WA is still being investigated. It will persist on coarse-textured soils, but productivity is usually very low. It may have a role on medium- to fine-textured soils in the eastern and north-eastern wheatbelt.

Seasonal growth pattern

Bambatsi panic has poor cool season growth, but in Queensland retains green leaf longer than most other sub-tropical grasses.[179] In WA it appears to have slow autumn growth and is dormant in winter. It grows actively from mid-spring through to early December depending on moisture availability and then opportunistically over summer.

In summer rainfall environments, peak growth is in January to February and summer growth is much higher than either spring or autumn growth. Bambatsi panic has an indeterminate flowering pattern and can flower throughout summer.

Establishment

Bambatsi has small (960,000/kg), free flowing seed that can be sown with conventional seeding equipment. The suggested rate is 2-4 kg/ha when sown alone or 1-2 kg/ha in mixtures. Bambatsi seed is usually of good quality, with >50% germination. It should be sown no more than 10 mm deep and requires soil temperatures of about 17°C to germinate.

Description

- tufted perennial grass (1.5-1.8 m high) with very short rhizomes
- greyish-blue leaves with a distinctive white mid-rib
- inflorescence is an open panicle.

Soil–climate adaptation

Rainfall: >375 mm (>325 mm south coast)

Drought tolerance: High to very high

Frost tolerance: Low

Soil type: Strong preference for fertile clays. Will persist on a range, but production is usually very low on coarse-textured soils

Soil fertility requirements: High

Soil pH_{Ca}: >5.0 (est.)

Aluminium tolerance: Unknown

Waterlogging tolerance: Moderate (also tolerant of inundation)[4]

Salt tolerance: Moderately low (if not waterlogged)[337]

Ability to spread naturally: Low

Nutritive value

DMD: 57-64% (monthly cuts); 43-51% (when cut after 91-98 days);[161] 62-72%[343]

Crude protein: 12-14%[343]

Good establishment of bambatsi panic

Germinating seed will enter a period of dormancy ('hydropedesis') if moisture is limiting, enabling the seed to germinate later under more favourable conditions.[422] Seedlings have slow growth and compete poorly with weeds. In a comparison of seedling vigour, bambatsi seedlings were less than 20% of the weight of Rhodes grass seedlings nine weeks after sowing in the field.[215] Under favourable conditions bambatsi will continue to produce new tillers into late summer, but in WA it is usually restricted by moisture availability.

Livestock disorders

Secondary photosensitisation of young sheep and goats grazing wilted bambatsi panic during dry periods or from grazing fresh regrowth has been reported. Young cattle and horses can also be affected, but rarely mature animals (Section 2.3).[317]

Management

With its slow establishment, grazing in the first year should be delayed until the plants have set seed. Check the plants are well anchored before grazing.

When established, bambatsi panic has good grazing tolerance and in Queensland there have been no problems with persistence under set-stocking.[216] It is a palatable species, which is preferentially grazed by stock – particularly the young regrowth. It maintains good feed quality provided it is grazed to prevent it becoming tall and rank.

Companion species

The poor cool season growth should assist with the establishment of annual legumes in autumn. Bambatsi has been successfully grown with barrel medic in Queensland.[217]

In WA, bambatsi is often sown as part of a mixture with other bunch grasses and Rhodes grass. Sowing it in a mixture is likely to favour the species with greater seedling vigour like Rhodes grass and green panic.

Cultivars

Three cultivars of makarikari grass have been released in Australia: 'Pollock' (a slightly stoloniferous type with short rhizomes), 'Bambatsi' (an erect bunch grass) and 'Burnett' (intermediate between other types). In the field there were no agronomic or production advantages of one cultivar compared with another, except Bambatsi had better seed production.[216]

All commercial seed in Australia is now Bambatsi (public variety) due to its superior seed production. Cross-pollination between varieties has resulted in commercial bambatsi panic now having some traits from the other cultivars.[216]

5.2 Consol lovegrass *(Eragrostis curvula* type *conferta)*

Features

- persistent, drought-tolerant, tufted perennial
- suited to well drained, sandy and loamy soils
- highly tolerant of soil acidity
- low feed quality and weed reputation result in low adoption.

African lovegrass or weeping lovegrass is a highly variable species native to southern Africa. It is now widely sown for rangeland regeneration and soil conservation in southern parts of the United States, South Africa and Argentina.

This is a controversial species as it includes both the pasture cultivar 'consol' and strains with low palatability that are serious weeds in many parts of Australia. Consol can be readily distinguished from the naturalised lovegrass in WA, as they belong to different 'types' within the *E. curvula* complex. The 'wild' type has prominent ridges on the leaf sheaths and long, thin, in-rolled leaves with greyish-green foliage.

Wild African lovegrass (*E. curvula* type *robusta blue*) is naturalised on roadsides throughout south-western Australia, but has low palatability and is an aggressive coloniser of disturbed areas.[162]

Consol lovegrass (*E. curvula* type *conferta*) was selected by the NSW Soil Conservation Service for superior palatability, is less competitive than the naturalised type and is well grazed by sheep.[168, 169, 324] Consol is recommended for controlling spiny burr grass in central NSW, where it is grown with serradella on acid, sandy soils.[115, 170]

Consol lovegrass has not been widely tested in WA. The widespread distribution of the naturalised type indicates that it could be grown over much of south-western Australia.

Seasonal growth pattern

Consol lovegrass starts actively growing from early spring, while summer growth depends on moisture availability. It then grows actively from the first rains in autumn to early winter. It continues to grow slowly in winter, unlike many sub-tropical grasses which are

Description

- densely tufted perennial, with erect or weeping stems, 0.5-1.2 m high
- light blue-green to grey-green foliage
- leaves are flat, 15-25 cm long and up to 7 mm wide
- ligule is about 1 mm long with fringe of hairs and long lateral hairs
- leaf sheaths are purple at base, ridged with more hairs on the lower surface
- inflorescence is an open, olive green panicle up to 15 cm long which droops as it matures
- the plant develops into a solid tussock and as it ages the inner stems die, leaving an unproductive centre of the plant.

Soil–climate adaptation

Rainfall (est.): >375 mm (>350 mm south coast)

Drought tolerance: High to very high

Frost tolerance: Moderate

Soil type: Suited to a range, including coarse-textured soils and deep sands

Soil fertility requirements: Will grow on infertile soils, but requires fertiliser for high production

Soil pH_{Ca}: >4.0 (est.)

Aluminium tolerance: High

Waterlogging tolerance: Low to moderate

Salt tolerance: Slight

Ability to spread naturally: Low, much less competitive than naturalised type

Nutritive value

DMD: 55-60%[170]

ME: 7.7-8.4 MJ

Crude protein: 10-12.5%

Environmental benefits

Groundwater recharge control: Good[174]

Soil erosion control: Very good[172, 195]

Ability to reduce rate of soil acidification: Good[171]

dormant. However, at a range of sandy sites in the central wheatbelt less than 12.5% of the total annual biomass was produced between April and August.[103]

Establishment

Consol lovegrass has very small seeds (5 million/kg) and needs to be sown at a very shallow depth (1-5 mm). A carrier (e.g. fine sawdust, fertiliser) may assist with uniform seed distribution. Rates of 1 kg/ha will give seedling densities of 100 plants/m^2 under favourable conditions, which subsequently decline to a stable sward with about 20 plants/m^2 in a medium rainfall environment.[173]

Consol lovegrass can be sown earlier in spring than other sub-tropical grasses or even dry sown, as it induces seed dormancy until the conditions (soil moisture, temperature) are favourable for germination.[173, 115] It has the ability to germinate at slightly lower soil temperatures than most sub-tropical grasses, with some germination at 10°C, increasing at 15°C with highest germination at 20°C.

If initial establishment is poor, the plant density can be increased by periodically allowing the stand to set seed.

Livestock disorders

None reported.

Management

New stands should not be grazed until the plants are well anchored. Good grazing management is essential, as coarse rank growth loses quality and is unattractive to livestock.

Consol lovegrasss can tolerate short periods of set-stocking, but rotational grazing is preferable. It should be grazed regularly so that stock are always grazing young to medium regrowth. The grazing intensity should be sufficient to graze the area in less than three weeks, after which the paddock should be spelled for two to six weeks depending on rainfall. In Queensland, lovegrass rotationally grazed every eight weeks resulted in much higher dry matter production compared with a four-week grazing cycle.[375]

Application of nitrogen to consol lovegrass stands will increase production and forage quality substantially. If P and K are applied to meet the needs of a companion legume, the requirements of the consol lovegrass will also be met.

Consol lovegrass tolerates fire which can be used strategically to rejuvenate old stands. Rank pastures that have been under-grazed can be burnt in early spring to promote a new flush of growth.

Pests and diseases are usually not a major problem.

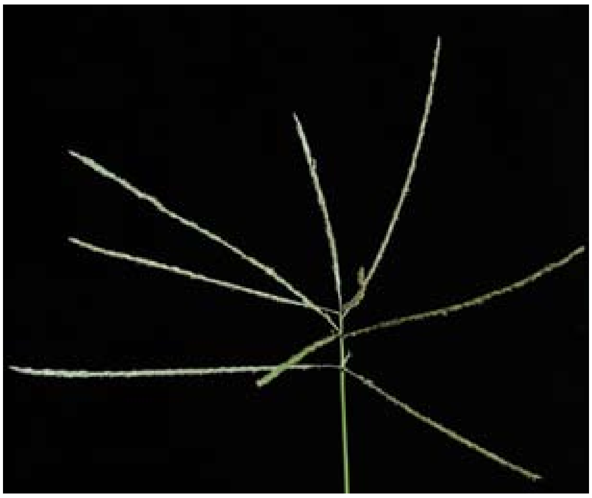
Companion species

Serradella and subterranean clover are suitable annual legumes depending on the soil type. In NSW, consol lovegrass has been grown with lucerne on mildly acid soils and also with Rhodes grass and ‘premier’ digit grass.

Cultivars

‘Consol’ (public variety) is the only cultivar available in Australia. Seed may be difficult to obtain.

5.3 Digit grass *(Digitaria eriantha)*



Features

- persistent, drought-tolerant, tufted grass
- adapted to a wide range of soils
- good drought and cold tolerance
- tolerates heavy grazing once established
- low tolerance of waterlogging.

Digit grass (formerly *Digitaria smutzii*) is an out-crossing species native to South Africa (Transvaal, Orange Free State, northern Cape) where it occurs in a range of habitats in summer rainfall areas (400-1000 mm). It is cultivated in South Africa, Argentina and Australia. This species also includes 'Pangola grass' (*Digitaria eriantha* ssp. *pentzii*, formerly *D. decumbens*) which must be vegetatively planted and is widely grown in tropical regions (not discussed here).

Digit grass has not been widely sown in WA, so its potential is largely unknown. However, in NSW digit grass has persisted and performed well on a wide range of soils and environments. It has survived severe droughts and persisted in the long-term under commercial grazing.[65]

Seasonal growth pattern

Digit grass grows actively from early spring and after the first rains until late autumn. It will grow opportunistically over summer if moisture is available. In WA, digit grass has negligible growth in winter, but in Queensland it is reported to produce new leaf growth in winter. Cool season growth (April to September) of Premier digit grass was similar to kikuyu in south-east Queensland.[377]

Description

- medium to tall (60-130 cm), tufted grass
- lowest leaf sheaths are densely hairy, but the leaves have few or no hairs
- stems are usually unbranched and up to 130 cm high
- finger-like seed head with one to three whorls arranged on a central axis.

Soil–climate adaptation

Rainfall (est.): >450 mm
(south coast >400 mm)

Drought tolerance: Moderate to high

Frost tolerance: Low to moderate[293]
Used in South Africa as 'foggage'
(i.e. standing frosted hay)[310]

Soil type: Grows on a range from acid sands to clay soils[376, 378]

Soil fertility requirements: Responsive to nitrogen. Persists on infertile soils, but production will be low

Soil pH_{Ca}: >4.2 (est.)

Aluminium tolerance: Moderate to high[65]

Waterlogging tolerance: Low

Salt tolerance: Nil

Ability to spread naturally: Low

Nutritive value

DMD: 64% (regular cutting), 51% (feed deferred to winter)[123]

Crude protein: 12.1% (regular cutting), 5.0% (feed deferred to winter)[123]

Establishment

Digit grass has a small, slightly hairy seed (3.3 million/kg), which may require a carrier to improve flow and ensure even distribution when sowing. Suggested sowing rate is 1-2 kg/ha of good quality seed when sown alone. Check the seed purity as many lines are contaminated with up to 30% Rhodes grass. Digit grass should be sown at 5-10 mm with good seed to soil contact. Seedlings can be slow to establish and are sensitive to moisture stress over the first summer.

Livestock disorders

No livestock disorders reported. It has a low soluble oxalate content.[178]

Management

Digit grass can withstand heavy grazing for short periods (7-40 days), which should be followed by a rest period to allow the root reserves to be replenished and the opportunity to occasionally re-seed.[65] Standing feed is still palatable after frosting and green shoots may be found near the ground.

Digit grass tolerates fire, has good insect resistance and is generally disease-free, but the seed heads can be infected by a false smut (*Ephelis* sp.) under humid conditions.[293]

Companion species

Digit grass is suitable for growing with a range of annual legumes. In NSW it is grown with Rhodes grass, Consol lovegrass and lucerne on coarse-textured, acid soils.[65]

Cultivars

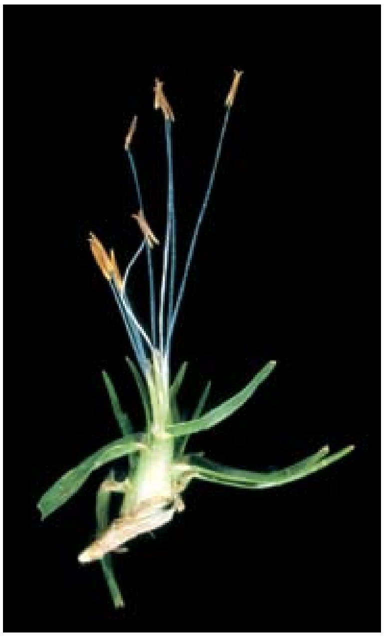
Two varieties, 'Premier' and 'Apollo', have been released in Australia.

'Premier' (public variety) was the first cultivar released in Australia. It has shown good persistence and production on a range of soils in Queensland.[376]

'Apollo' (public variety) was selected for superior spring growth, but had inferior seed production to 'Premier' and has not persisted in commerce.

Good establishment of digit grass in a trial

5.4 Kikuyu *(Pennisetum clandestinum)*



Features

- creeping grass which forms a dense turf
- highly productive pasture, especially when grown with annual legumes
- tolerant of heavy grazing
- needs to be well managed to maintain feed quality
- excellent for stabilising soil and erosion control.

Kikuyu is a creeping sub-tropical grass that forms a dense turf and is tolerant of heavy grazing. It is widely used as a highly productive pasture for dairying and as a turf or lawn grass.

Kikuyu is native to the highlands of east and central Africa (i.e. Kenya, Ethiopia) where it grows on deep, red loams of volcanic origin.[257] This region has high rainfall (1,000-1,600 mm), mild temperatures and occasional frosts.[257, 359] The common name ‘kikuyu’ comes from the tribe in Kenya where it was first collected.

Kikuyu was introduced into WA in the early 1920s.[368] Compared with many other sub-tropical grasses the area suitable for growing kikuyu is well defined. It is largely confined to the high rainfall south-west, west coast and the south coast, although it may have a role in the West Midlands. There are currently about 60,000-90,000 ha of kikuyu based pastures in WA, mainly on the south coast. Kikuyu is competitive and has naturalised in moist disturbed areas from Dandaragan to Albany and along roadsides in high rainfall districts.[162] Can be invasive in riparian zones so avoid planting near these areas.

A kikuyu-subterranean clover pasture enabled stocking rates to be increased by 65-95% and wool production by 70-103% compared with a subterranean clover pasture on the south coast of WA.[345] It is suitable for fine wool production.

Description

- prostrate, creeping grass that spreads via rhizomes (underground stems) and stolons (runners) that readily root from the nodes
- left ungrazed it forms a loose, rank sward, but under grazing forms a dense turf
- leaf sheaths overlap and the leaf blades (5-20 cm) have a prominent mid-rib
- flowering is inconspicuous. The seed heads are mainly concealed within the leaf sheath and only white filaments are exposed for short periods.

Kikuyu showing stoloniferous growth habit

Seasonal growth pattern

The optimum temperature for growth is lower than for most sub-tropical grasses due to its origin (i.e. high altitude near the equator), where the mean maximum and minimum temperatures range from 16-22°C and 2-8°C respectively.[257]

In areas with a low incidence of frost, kikuyu starts growing rapidly in early spring and it can respond rapidly to summer or autumn rains. Very low growth rates are measured in winter. In more frost-prone areas it grows actively after the last frost in spring and in autumn until the first frost in late autumn or early winter.[148, 368]

Establishment

Kikuyu is normally sown alone and the suggested seeding rate is 1-2 kg/ha, resulting in 30-40 plants/m^2.[307] It is often sown at 1 kg/ha or less because of the high seed cost. Seed should be sown at a depth of 10-20 mm. Seedlings are slow to establish and susceptible to moisture stress and waterlogging. Under controlled conditions, the optimum temperature for germination was 19-29°C, but at 14°C about 50% of the seed still germinated.[42]

Kikuyu will readily spread through animal dung. As a result, animals can be used to spread seed to new paddocks as a low cost method of establishment. Conversely animal movement from kikuyu paddocks into paddocks that are regularly cropped should be controlled.

Livestock disorders

A number of livestock disorders associated with kikuyu are reported in the literature, however they are not common.

Soil–climate adaptation

Rainfall (est.): >500 mm (south coast >400 mm)

Drought tolerance: Moderate to high

Frost tolerance: Moderate. The first frost in autumn results in leaves turning yellow and the plant becomes dormant. Stolons/rhizomes are unaffected and will regrow when temperatures exceed minimum for growth

Soil type: A wide range, including deep sands. It will grow on fine-textured soils, but spreads more rapidly on coarse-textured soils.[368] Not suited to shallow soils and waterlogged-saline soils

Soil fertility requirements: High, very responsive to N fertiliser (Figure 5.5)[236]

Soil pH$_{Ca}$: >4.0

Aluminium tolerance: Good

Waterlogging tolerance: Moderate[236]

Salt tolerance: Slight to moderately low (if not waterlogged)[337]

Ability to spread naturally: Very good from stolons, rhizomes and seed spread in animal dung

Nutritive value

DMD: 59-63% (monthly cuts)[263]

Crude protein: 10.4-14.3% (low to high fertiliser N with monthly cuts)[263]

Environmental benefits

Groundwater recharge control: Good, roots were measured to 3 m on a sand over laterite soil[345]

Soil erosion control: Very good

Weed control: Competitive and suppresses summer weeds

Kikuyu showing frost damage

Kikuyu contains low to moderate levels of oxalic acid (0.039-2.4%), but no problems have been reported.[236]

Occasional deaths due to kikuyu poisoning have been reported with cattle, sheep, goats and horses from New Zealand, South Africa and Australia. The cause of death is unknown, but it may be associated with the army worm caterpillar.[236] The incidence in WA is low, but deaths have been recorded, so it is useful to outline the symptoms.[299, 368]

Poisoning is normally associated with hungry stock grazing lush, rapidly growing kikuyu following rain (or nitrogen fertilisation). Typically, stock show symptoms one to two days after consuming toxic pasture. These symptoms include depression, inappetence, sham drinking, rumen distension, dehydration, staggering and collapse. If symptoms occur, remove stock immediately and either feed hay or move to a paddock with no kikuyu grass. Unfortunately, poisoned stock are likely to die.

Kikuyu can accumulate nitrogen compounds in excess of animal requirements when heavily fertilised with N, and this can reduce animal performance.[236] The solution is to avoid large single applications of N (>50 kg/ha/month). Apply as split applications to avoid excessive nitrogen levels in the pasture.

Management

New stands should not be grazed until the runners are >20 cm and the plants are strongly anchored. When grazing, monitor the paddock regularly to ensure stock are not pulling out runners.[344]

Managing for quality is the key to success with a kikuyu pasture. Kikuyu produces stem material throughout the year, so feed quality is strongly influenced by the stage of regrowth (i.e. the proportion of leaf to stem).[316] Kikuyu pastures are most productive when kept short, 2-5 cm (depending on density), which corresponds to about 1400 kg green DM/ha. This promotes new leaf growth, which is more nutritious than older growth.

A high stocking rate is required after the break in autumn to maintain kikuyu at 1400 kg DM/ha. This stocking rate enables the annual clovers and grasses to germinate. Kikuyu provides a good refuge for redlegged earth mite, which can drastically reduce the number of clover seedlings. Control RLEM with strategic sprays in spring (e.g. Timerite®).

In winter the pasture should contain about 30-40% kikuyu with the rest being annual grasses and legumes, which will increase the winter production. In spring, when the kikuyu starts growing actively, graze the pasture to 1400 kg DM/ha and do not let the kikuyu exceed 3,000 kg DM/ha (this amount resembles a well-mown lawn with one to two weeks regrowth). Graze hard in late spring to avoid rank growth.[344]

Over summer use a high stocking rate to graze the pasture to ~800 kg DM/ha (about 1 cm or less) to maintain the pasture quality. If there is prolonged drought, defer summer grazing particularly if stock are pulling up kikuyu runners.[344]

Kikuyu is very tolerant of heavy grazing and can tolerate set-stocking. However, in some cases, set-stocking has reduced the carrying capacity compared with rotational grazing. If growth is rank, then slashing old growth to 5 cm will promote new leaf growth and will also promote the growth of annual legumes and grasses.

In a kikuyu dominant pasture, energy may be limiting resulting in a protein to energy imbalance, due to the low content of readily digestible (i.e. non-structural) carbohydrates.[236] Also, kikuyu is low in sodium, which could be a problem in kikuyu-dominant pastures.[146]

'Kikuyu yellows' is a fungal disease where affected yellow patches spread out leaving bare areas which are invaded by weeds. It occurs mainly in the sub-tropics and is unlikely in south-western WA.

Companion species

Kikuyu combines well with subterranean clover, although in years with a dry autumn the annual legume can struggle to establish.[248] On deep duplex soils and deep sands kikuyu combines well with yellow serradella.

On summer moist sites it combines well with perennial legumes like strawberry clover or possibly greater lotus. It is not normally sown with other perennial grasses, although can be sown with Rhodes grass.

There is some evidence that decaying stolons release compounds that can be allelopathic, i.e. reduce germination of other species.[236]

Cultivars

'Common' kikuyu is a non-seeding type that is propagated by runners. It is narrow-leafed and forms a dense sward.

'Whittet' (public variety) is the main variety sown in WA. Compared with the 'common' type, it is a comparatively taller variety characterised by broad leaves, thicker stems and longer internodes on the stolons. It persists well under lower fertility conditions and is free-seeding, but is susceptible to 'kikuyu yellows'.

Three other varieties have been released, but seed may be difficult to obtain.

'Breakwell' (public variety) is similar to the common type, but is a seeding type as 80% of the plants are bisexual. It is more densely tillered than Whittet and spreads more quickly, but is less productive. Recommended for soil conservation and turf, but not pastures.

'Noonan' (public variety) was developed from Whittet and Breakwell for tolerance to the disease kikuyu yellows. Will set seed without the regular cutting that is required to stimulate seed production in other cultivars.

'Crofts' (public variety) is a taller variety with more upright, narrower leaves and has better cold tolerance than Whittet, but is susceptible to kikuyu yellows.

These kikuyu plants are the result of seed spread in dung

5.5 Panic grasses *(Megathyrsus maximus)*

Features

- tufted, highly palatable, leafy grass
- moderate drought tolerance
- good spring growth
- requires fertile conditions for good performance
- does not tolerate waterlogging or flooding.

The panic grasses (formerly *Panicum maximum*) are one of the major sown sub-tropical grasses and are widely used in South America, Japan, and India as well as eastern Australia. They are shade tolerant and are often found around tree lines in their native environment (tropical and sub-tropical Africa) taking advantage of the improved nutrition from the leaf litter.

M. maximus is a diverse species as it includes both the tall (up to 4 m), tropical Guinea grasses and the shorter sub-tropical panic grasses (formerly called *P. maximum* var. *trichoglume*) which are the type of interest for WA. The latter are better known by the variety names: 'Gatton' panic and 'Petrie' (or green) panic.

Panic grasses appear to have good potential in WA, both along the south coast and in the northern agricultural region.

Seasonal growth pattern

The panic grasses have a similar growth pattern to the other warm season grasses. If the prevailing weather conditions are mild there can be moderate growth in early winter, otherwise they are dormant in winter. The panics are one of the first sub-tropical grasses to start growing in spring when the temperatures increase. They will continue growing until soil moisture is depleted, then opportunistically over summer and after the rains in autumn. They respond rapidly to light showers of rain and also after the rains in autumn when the temperatures are mild to warm.

Like most sub-tropical grasses, panic grasses prefer high temperatures with maximum growth at 30-36°C/25-31°C (day/night temperature) under controlled conditions. The growth rate falls sharply when the temperature is below 18°C/13°C, with negligible growth below 15°C/10°C.[383]

Establishment

The panics have very small seeds (1.2 million/kg) that must be sown into a fine seedbed with shallow sowing (<10 mm) and good seed-soil contact. Sow 2-4 kg/ha of good quality seed when sown alone or 1-2 kg/ha when sown in a mixture. The seed requires contact with moist soil for three days to germinate. Seedlings have good vigour.[215]

Description

- moderately tall, leafy, tufted grass (0.8-1.8 m)
- leaf sheath is often hairy
- flower heads are an open, branched panicle.

Good autumn growth of Petrie (or green) panic

Soil–climate adaptation

Rainfall (est.): >500 mm, (>425 mm south coast)

Drought tolerance: Moderate to high

Frost tolerance: Sensitive to low (depends on variety)

Soil type: Prefers well drained, fertile loams but performs well on coarse-textured soils, including deep white sands in WA

Soil fertility requirements: Moderate to high

Soil pH_{Ca}: >4.3 (est.)

Aluminium tolerance: Good[367]

Waterlogging tolerance: Low

Salt tolerance: Nil[337]

Ability to spread naturally: Low

Nutritive value

DMD: 60-64% (monthly cuts), 48-51% (when cut after 91-98 days)[261]

Crude protein: Av. 11.4% (range 6.3-15.6%)[262]

Livestock disorders

Panic grasses contain low to moderate levels of oxalate (0.52% summer, 0.80% autumn) which can result in big head in horses and occasionally nephrosis or hypocalcaemia in ruminants (Section 2.3).[178]

Pastures dominated by panics can cause secondary photosensitisation in stock. Reports from Queensland suggest it is more likely to occur when the grass is young or growing rapidly after a dry spell, with young stock (especially sheep) and when the stock are in a stressed condition (Section 2.3).[244]

Management

In the first year, the pasture should not be grazed until the plants have developed crowns, have set some seed and/or are well anchored.

The panics are very palatable and often preferentially grazed in mixed swards. However, they are not tolerant of heavy grazing and require rotational grazing. Allow the plants to set seed every two years.[359]

Companion species

Should be compatible with a range of annual legumes. Panic grasses are sometimes sown in a mix with Rhodes grass and digit grass in eastern Australia.

Cultivars

There are two commercial varieties in Australia:

'Petrie' or green panic (public variety) is an erect, tall (seed heads up to 1.8 m), tufted grass which is distinguished from Gatton panic by its light green foliage, the lower surface of its leaves and its leaf sheaths have sparse, long hairs (compared with short down-like hairs) and the leaf mid-rib is less pronounced.[293] Has low frost tolerance.

'Gatton' panic (public variety) originates from Zimbabwe and is a robust, tufted grass that is agronomically similar to green panic, slightly less drought-tolerant and more sensitive to frosts, but superior on low fertility soils. Gatton panic has longer and broader leaves than green panic, with a more prominent mid-rib, finely pubescent leaf sheaths, greener foliage and often contains anthocyanins (purple pigmentation) near the base of the stems.

5.6 Rhodes grass *(Chloris gayana)*

Features

- creeping perennial which spreads through stolons (runners)
- adapted to a range of soil and climatic conditions
- easy to establish with good seedling vigour
- moderate to high drought tolerance
- moderate feed quality
- may not persist under stressful conditions.

Rhodes grass is one of the main sub-tropical grasses used in agriculture and is widely grown in Africa, Australia, Japan, South America and under irrigation in the Middle East for both forage and soil conservation purposes. Rhodes grass is a morphologically variable out-crossing species, which is native to east, central and southern Africa where it occurs in open grasslands.[45] It was introduced into Australia by soldiers returning from the Boer war, who brought with them the common variety (cv 'Pioneer').[221]

In WA, Rhodes grass has been one of the most widely sown sub-tropical grasses in the last 10 years. It often dominates when sown in a mixture due to its good seedling vigour and ability to spread through runners. There is a query as to the longevity of stands under stressful conditions, as some Rhodes grass pastures only persist for one to three years, due to a combination of stresses including: low fertility, cold-wet soils, frost, over-grazing and competition from annual pastures.

Description

- stoloniferous and tufted, leafy perennial grass
- erect or ascending stems 0.5-2 m tall
- leaves are hairless and 15-50 cm long
- leaves on the stolons are shorter with 2-4 leaves per node
- brown, digitate seed head in the shape of an open hand.

Soil–climate adaptation

Rainfall (est.): >425 mm (>400 mm south coast)

Drought tolerance: Moderate to high (depends on variety)

Frost tolerance: Low

Soil type: Range of medium- and coarse-textured soils[45]

Soil fertility requirements: Favours more fertile soils in its natural habitat and is considered a 'high fertility' species. Very responsive to N fertiliser[221]

Soil pH_{Ca}: >4.3

Aluminium tolerance: Moderate[221]

Waterlogging tolerance: Moderate

Salt tolerance: Slight (tetraploids) to moderately low (diploids). Has a number of mechanisms to deal with salinity including the ability to excrete sodium from salt glands on the leaves, accumulate salt in plant tissues and actively exclude salt from the roots[75, 230, 384]

Ability to spread naturally: Very good from stolons

Nutritive value

DMD: 61-65% (monthly cuts) 49-56% (when cut after 105-140 days)[258]

Crude protein: 6.3% (unfertilised),[359] 10.4-13.8% (low to high fertiliser N with monthly cuts)[263]

Environmental benefits

Soil erosion control: Creeping habit provides good soil stabilisation

Weed control: Competes well with summer weeds

Seasonal growth pattern

Rhodes grass grows actively following the opening rains in autumn until early June. It is generally dormant in winter, although it will continue to grow slowly in the northern agricultural region when winter temperatures are mild. It resumes active growth in early spring and grows opportunistically throughout summer depending on moisture availability.

Rhodes grass seedling

Like most sub-tropical grasses, Rhodes grass prefers high temperatures with maximum growth at 30°C/25°C (day/night temperature) under controlled conditions. Growth is reduced greatly below 18°C/13°C and there is negligible growth when the average daily temperature is below 8°C.[383]

Establishment

Rhodes grass is readily established from seed. The seed germinates quickly (1-7 days) depending on temperature.[393] Rhodes grass displays good seedling vigour and often achieves full groundcover within three months of sowing. Rhodes grass has a high shoot/root ratio and a weak primary root system, so plants rely on developing a strong secondary root system and are easily pulled out by stock during the establishment period.

The suggested seeding rate is 2-3 kg/ha of good quality seed when sown alone, or 1-2 kg/ha when sown as a mixture.[272] The seed can be drilled at 5-10 mm followed by press wheels, or alternatively broadcast onto a firm, fine seedbed and then rolled to give good seed-soil contact. Rhodes grass seed is light and fluffy and as a result is difficult to handle. Use coated seed, or with uncoated seed use a carrier to improve the flow through the seeder.

The optimum temperature for germination is 15-40°C, but a small proportion of seeds will germinate at lower temperatures. Unlike some sub-tropical grasses, Rhodes grass seeds germinate at low soil water contents and once germination has started it is irreversible.[422, 423] Under conditions of marginal soil moisture Rhodes grass may be the first species to germinate.

Rhodes grass can compensate for poor seedling establishment by rapid stoloniferous growth to form a dense stand if it is carefully managed in the first two years.

Livestock disorders

None have been reported.[359] Contains low levels of oxalate, so is not hazardous for horses.[221]

Management

Premature grazing can severely damage a new Rhodes grass pasture as stock can up-root plants. Rhodes grass should not be grazed in the first year until the plants and runners are well anchored which may not occur until the autumn rains, as the stolons will only root into moist soils. Test the plants to see how well they are anchored before grazing.

Established stands can withstand periods of set-stocking, but heavy grazing can damage the stand. In more intensive systems, rotational grazing should result in higher production and better persistence.[221]

In general, palatability is good but declines rapidly with maturity, so Rhodes grass should be grazed to prevent flowering. The digestibility of Rhodes grass varies widely, but is generally similar to other sub-tropical grasses at an equivalent growth stage.

Rhodes grass can survive fire, although hot fires can kill the small plants growing on stolon nodes.[6, 221]

Companion species

Can be grown with annual legumes like subterranean clover, burr medic and serradella on sandy, well-drained soils, or subterranean clover, balansa clover and slender serradella on winter-waterlogged soils. Graze the sward hard in late autumn to give the annual legumes an opportunity to establish.

Can be sown as a monoculture, but is often sown in a mix with bunch grasses or occasionally with kikuyu.

Cultivars

There are two main groups of Rhodes grass cultivars – diploid and tetraploid types – the latter having double the number of chromosomes.

Diploid types: These come from sub-tropical regions, are more robust and flower over a wide period as the flowering response is insensitive to day length. In general, they have superior frost tolerance, salt tolerance and drought tolerance than the tetraploid types.

‘Pioneer’ or common (public variety) is quite variable but is characterised as an early flowering, erect plant with moderate leafiness. It is widely naturalised in sub-tropical eastern Australia, but has been superseded by newer varieties.[221]

‘Topcut’⦶ is a selection from Pioneer developed primarily for hay production, which is reported to be leafier, finer-stemmed and produce more dry matter.[185]

‘Katambora’ (public variety) is mid-flowering and is characterised by strong stolon development, heavy seeding and drought tolerance. In Queensland, it is more persistent on low fertility soils than other cultivars.[221]

‘Finecut’⦶ is a selection from Katambora developed primarily for hay production and is reported to be leafier, finer-stemmed and to produce more dry matter in Queensland.[185]

‘Nemkat’⦶ is a selection from Katambora that has resistance to all the known root-knot nematodes in the north-Queensland tobacco growing areas. Untested in WA.

Tetraploid (giant) types: Late flowering types from tropical regions that are tall (>1.8 m) and have coarse leaves, stems and stolons. They are strongly stoloniferous, leafy, late flowering, drought-tolerant and have high dry matter production.[221] Their main advantage is that they only flower late in the season (as they flower in response to short-day lengths), so feed quality is maintained for longer. However, when grown under optimal conditions and grazed regularly there is little if any difference in the animal intake or the digestibility of different types of Rhodes grass.[258]

‘Callide’ (public variety) an introduction from Tanzania is widely grown in Australia and is the only tetraploid variety on the market.

Future developments: Salt-tolerant varieties are being developed in eastern Australia, but these are principally being selected for use with brackish irrigation water rather than salt-affected land.

5.7 **Setaria** *(Setaria sphacelata* complex)

Features

- moderate to tall, bunch grass
- comparatively good cool season growth
- some varieties have good frost tolerance
- contains moderate to high levels of oxalate.

The genus *Setaria* includes a number of species that are used in agriculture. *Setaria sphacelata* var. *sericea* (setaria) is an out-crossing species that is widespread in its native Africa, but is mainly from regions where the rainfall is more than 750 mm and without a pronounced dry period.[136] In Queensland and northern NSW setaria is mainly grown in coastal districts.[64]

Setaria splendida is suited to humid lowland tropics, but has to be planted vegetatively as the seed is sterile. However, the variety 'Splenda'⊕ is a seeding hybrid, which has shown some promise in limited testing in WA.

Purple pigeon grass (*Setaria incrassata*) is a bunch grass native to Zimbabwe where it grows on black cracking clays.[293] In northern NSW and Queensland it is grown on fine-textured soils with bambatsi panic and Rhodes grass. On these soils it is easy to establish and shows excellent seedling vigour. To date attempts to grow this species in south-western Australia have been unsuccessful. It appears to require high soil temperatures (~25°C) to germinate, which would preclude its use in WA.

The following refers to *Setaria sphacelata* var. *sericea* and the seeding hybrid Splenda⊕.

Seasonal growth pattern

In WA, setaria grows actively in autumn after the rains. In areas with mild temperatures, winter growth is better than the other sub-tropical grasses, but in cold areas the plants are dormant over winter. Setaria resumes active growth in early spring and will grow opportunistically in summer depending on soil moisture. In northern NSW, setaria has a similar growth pattern to kikuyu.[64]

Description

- robust, erect, densely tufted grass (0.9-1.8 m)
- base of vegetative tillers is flattened (fan-shaped)
- leaves are generally broad and mostly hairless
- 'cigar'-shaped seed head.

Soil–climate adaptation

Rainfall (est.): >550 mm (>475 mm south coast)

Drought tolerance: Moderate

Frost tolerance: Sensitive to moderate. Nandi and Kazungula are frost sensitive,[134] while Narok and Solander will survive frosts of -2.0 to -3.3°C, but heavier frosts kill the leaves[432]

Soil type: Adapted to a range, especially those with a good water-holding capacity

Soil fertility requirements: Medium to high for good production. Highly responsive to N fertiliser and has a high P and K requirement.[64] It will persist on low fertility soils

Soil pH_{Ca}: >5 (est.)

Aluminium tolerance: Unknown

Waterlogging tolerance: Good

Salt tolerance: Nil[337]

Ability to spread naturally: Low

Nutritive value

DMD: 57-65% (monthly cuts) 47-53% (when cut after 72 days)[137]

Crude protein: Av 9.8% (range 5.5-13.2%)[262]

Setaria showing frost damage

Establishment

The suggested seeding rate is 1.5-2.5 kg/ha of good quality seed when sown alone. Sow less than 15 mm deep into a firm seedbed. Seedling growth is slow in the first year, but once established the plants grow vigorously.[136] Plants are sensitive to moisture stress over the first summer and dry conditions can result in a high mortality.

Livestock disorders

Setaria contains moderate to high levels of oxalate, so is unsuitable for horses and can occasionally cause nephrosis or hypocalcaemia in ruminants.[184] Pastures containing a high content of setaria (>95%) have resulted in cattle poisoning in Queensland.[352]

The oxalate content depends on the variety, the growing conditions, stage of growth and increases with fertiliser nitrogen and potassium.[181] The oxalate tends to be higher in the leaf blades than the stems while there is no oxalate present in the seed heads (Section 2.3).[181]

Good autumn growth of setaria

Management

In the first year defer grazing until the plants are well anchored. Test the plants to ensure they are strongly anchored before grazing.

When established, heavy grazing is required to maintain vegetative growth and palatability. Young leafy regrowth has good digestibility, but this decreases rapidly as the plant matures, so regular rotational grazing is required.

Setaria is often used for hay and silage in South Africa.[136, 404]

Companion species

Can be grown with other bunch grasses and Rhodes grass, but under good growing conditions is reported to suppress the growth of companion grasses.[136] Should be compatible with a range of annual legumes.

Cultivars

There are four cultivars of *S. sphacelata* var. *sericea* and one seeding hybrid. The early cultivars grown in Australia, Nandi and Kazungula, were direct introductions from Kenya and Zambia respectively.

'Nandi' (public variety) is from a highland region of Kenya and was selected for leafiness and vigour. It has less drought tolerance than Kazungula and is susceptible to frost damage.[293] Nandi contains the lowest levels of oxalate (3.0-3.7%) among the commercial varieties.[184]

'Kazungula' (public variety) is an ecotype from Zimbabwe that has good flood and drought tolerance and has slightly better frost tolerance than Nandi. It is a more robust and coarser grass than Nandi and flowers about one month later in spring.[293] Kazungula contains high levels of oxalate (3.3-7.0%).[178, 184]

'Narok' (public variety) was bred for improved frost tolerance and will withstand frosts of -3°C with negligible leaf damage, although heavier frosts will kill the leaves.[293] It has better cool season growth than Nandi and Kazungula and is also more leafy and palatable.[293] It contains moderate levels of oxalate. Seed production is poor, as it has a low number of flowering tillers.

'Solander' (public variety) is similar to Narok in both appearance and agronomy, but has superior seed production. It was developed because of problems with low seed production in Narok.[8, 293]

Cultivar 'Splenda'[⊕] is a seeding hybrid from a cross of *S. sphacelata* var. *sericea* and *S. sphacelata* var. *splendida*. It is a tall (>2 m at flowering), robust, leafy grass which is later flowering than Nandi and Narok and has some frost tolerance. It has a high content of oxalate with the concentration in young leaf (4.7%) comparable to Kazungula.[135] Splenda[⊕] was developed for the humid tropics of north Queensland, but has shown some promise in preliminary testing in coastal districts of WA.

5.8 Signal grass *(Urochloa decumbens)*

Features

- slowly creeping grass which can form a dense sward
- grazing-tolerant once established
- tolerant of acid soils and high soil aluminium
- poor cool season growth and sensitive to frosts
- can cause secondary photosensitisation in stock.

Signal grass (formerly *Brachiaria decumbens*) originates from open grasslands on the Great Lakes plateau in Uganda and the surrounding countries.[359] It is now widely sown in central Brazil where 40 million hectares of the savannas have been sown to *Urochloa-Brachiaria* species.[76] Signal grass prefers the wet tropics, but has reasonable drought tolerance as it is adapted to areas with a dry season up to 4-5.5 months.[219]

Signal grass has not been tested widely in WA. Limited observations and testing suggest it has some potential on moderately well to well-drained sandy soils in coastal districts and in the northern agricultural region in areas with mild winters and a low incidence of frosts. However, even in these environments there are questions about its long-term persistence.

Seasonal growth pattern

Signal grass is one of the first warm season grasses to stop growing as the temperature cools down in late autumn and has negligible growth over winter even in areas with mild temperatures. It is often one of the last sub-tropical grasses to start growing actively in spring and then grows opportunistically in summer if moisture is available.

Establishment

Signal grass has a comparatively large seed (220,000/kg), so it usually establishes readily. The suggested sowing rate is 2-4 kg/ha when sown alone, at a depth of 5-10 mm. Under good conditions it will establish quickly and achieve full groundcover within three months.[359]

Signal grass seedlings are tolerant of pre-emergent application of atrazine.[359]

Description

- low to medium height (30-45 cm), slowly creeping grass (stoloniferous) that can form a dense sward under ideal growing conditions
- weakly stoloniferous with trailing stems that can root at the nodes
- stems are hairy with leaves 8-10 mm wide and often of light-green colour
- seed head is arranged like a railway signal with 2-5 racemes (2-5 cm long)
- flowers in response to short day lengths.

Signal grass sward

Soil–climate adaptation

Rainfall (est): >500 mm (>450 mm south coast)

Drought tolerance: Moderate

Frost tolerance: Sensitive

Soil type: Adapted to coarse-textured including acid soils

Soil fertility requirements: Will persist on low fertile soils, but requires fertile conditions (high P and N) for good production

Soil pH_{Ca}: >4.0 (est.)

Aluminium tolerance: Good[367]

Waterlogging tolerance: Low to moderate[219]

Salt tolerance: Nil

Ability to spread naturally: Spreads very slowly under WA conditions

Nutritive value

DMD: 60-70% (immature forage), 50-60% (mature forage)[196]

Crude protein: 7.5-13.2% (when N fertiliser increased from 0 to 150 kg/ha)[306]

Livestock disorders

There are reports from Queensland that sheep grazing pastures dominated by signal grass have been affected by secondary photosensitisation.[219] Contains low (1.0-1.1%) concentrations of oxalate (Section 2.3).[359]

Management

The feed quality of signal grass is similar to other warm season grasses, but it requires heavy grazing to maintain quality when actively growing, as feed quality declines rapidly with maturity.[196] The palatability is good except when the flowering stems are mature.

High animal production (liveweight gains of 225-950 kg/ha) has been reported from various grazing studies with cattle in Queensland and South America.[196]

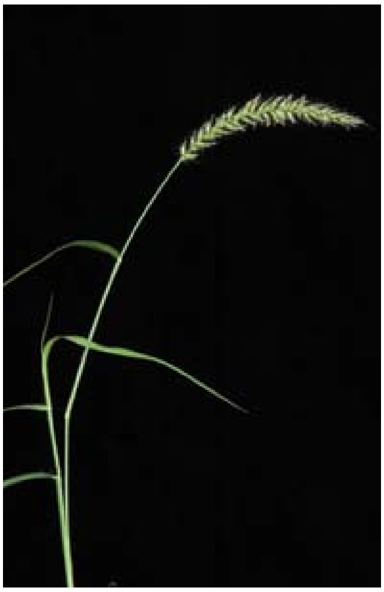
Companion species

Where it is well suited, signal grass is aggressive and out-competes other species to form a pure sward. In north Queensland signal grass is used strategically to reduce pressure on mixed (grass-legume) pastures during the cool season as it can tolerate heavy grazing.[219] In WA the conditions are less favourable for signal grass and a companion annual legume can be grown.

Cultivars

'Basilisk' (public variety) often simply called 'signal grass' is the only cultivar available in Australia.

5.9 Other warm season grasses



Buffel grass *(Cenchrus ciliarus)*

Features

- hardy, drought-tolerant bunch grass
- suited to warm to hot environments
- widely sown and naturalised in northern Australia
- not recommended due to weedy history
- moderate feed quality
- contains moderate to high concentrations of oxalate.

Buffel grass is a bunch grass native to the hotter and drier areas of India, the Mediterranean basin and tropical and southern Africa.[359] It has been widely sown in similar dry, warm to hot environments, including northern Australia, Queensland and western NSW.

Buffel grass is widely naturalised in arid environments, including central Australia and the pastoral regions of WA. It is a widespread weed from Shark Bay to the Pilbara and adjacent desert. Buffel grass is invasive and displaces native species and can be difficult to remove where it is well suited.

With this history as a problem weed, buffel grass is not recommended for south-western Australia.

From limited evaluation in south-western Australia, it appears that buffel grass will only persist in the north-eastern wheatbelt. In other districts it is unlikely to persist because of its limited cold tolerance.[139] Buffel grass prefers high temperatures with maximum growth at 30°C/25°C (day/night temperature) under controlled conditions. The growth rate falls sharply when the temperature is below 18°C/13°C, with slow growth below 15°C/10°C.[383]

Buffel grass has a light and fluffy seed, which makes it difficult to sow with conventional machinery. A carrier such as fertiliser or cracked grain will improve distribution through an airseeder or combine.[126] The suggested sowing rates vary from 2-3.0 kg/ha, but 1.0 kg/ha of good quality seed can be sufficient to establish a pasture. Under suitable conditions buffel grass establishes readily. In the first year, buffel grass should not be grazed before seed-set. Stands can be thickened by allowing seed-set and then resting the paddock after summer rain.

Description

- moderate to tall bunch grass (0.4-1.5 m)
- stems have a number of branches
- foxtail shaped seed head with many bristles
- individual spikelets fall when ripe.

Soil–climate adaptation

Rainfall (est.): >300 mm (in areas with mild to warm winters)

Drought tolerance: Extreme

Frost tolerance: Low

Soil type: Adapted to a range of well drained soils, except deep sands

Soil fertility requirements: Good fertility with a high P content

Soil pH_{Ca}: >5.5 (est.)

Aluminium tolerance: Very sensitive[359]

Waterlogging tolerance: Low

Salt tolerance: Slight

Ability to spread naturally: High by seed, where well adapted

Nutritive value

DMD: 67% (leaf), 53% (stem)[385]

Crude protein: 6.2-11.0%[359]

When it is actively growing buffel grass can be set-stocked or rotationally grazed. The young regrowth is very palatable for stock and even at maturity the palatability is fair.[359] Buffel grass contains moderate to high levels of oxalate (3.5-4.3%), so can cause big head in horses and occasionally hypocalcaemia or nephrosis in ruminants (Section 2.3).[357]

Cultivars

There have been 11 buffel grass cultivars released in Australia, but many are no longer commercial. They can be grouped according to height into tall, medium and short types:

Tall buffel grasses (1.3-1.5 m at maturity)

'Biloela' (public variety) is now the main tall variety. It is late maturing and is suited to fine-textured soils.

Medium height buffel grasses (1.1 m at maturity)

'Bella'ᶲ was selected for improved spring growth, is late maturing and suitable for medium- to fine-textured soils.[138, 139]

'Viva'ᶲ was selected for improved spring growth, is late maturing and suitable for medium-textured soils.[138, 139]

Short buffel grasses (0.4-0.9 m at maturity)

'Gayndah' (public variety) has mid-season maturity and is suitable for coarse- to medium-textured soils.

'American' (public variety) is a early maturing variety (USA buffel is similar) and is suitable for coarse- to medium-textured soils.

'West Australian' (public variety) is a short (0.4-0.7 m), early flowering variety which was first observed growing on the north-west coast of WA in the late 19th century and was probably introduced by camel traders. It was subsequently widely sown in the pastoral districts of northern Australia, but has been superseded by more productive varieties.[293]

Couch grass *(Cynodon dactylon)*

Features

- creeping, sward-forming grass
- spreads by both stolons and rhizomes
- tolerates heavy grazing
- widely naturalised on sandy soils in the agricultural region
- low productivity unless good fertility
- difficult to remove once established.

Couch (or Bermuda grass) is native to southern Africa and south-east Asia. It has been widely used in tropical and warm temperate regions as a pasture grass and is one of the major turf grasses in the world. Couch grass is widely sown in the south-eastern United States, where they have developed hybrids with improved productivity and forage quality.

Pastures in south-eastern US consisting of Bermuda grass and Italian ryegrass have produced animal liveweight gains of 1132 kg/ha from 204 grazing days.[333] With adequate N fertiliser, improved forms can produce twice the biomass of naturalised types.[374]

In WA, couch grass has been sown widely as a lawn and occasionally in paddocks, but it has now naturalised on sandy soils (rainfall >350 mm) in the agricultural region.[162] The deep rhizomes result in couch grass being difficult to remove with cultivation once it is established and it can cause problems with cropping. The naturalised couch grass will compete with sown warm season grasses during the establishment phase.

Couch grass is dormant in winter and grows actively from mid-spring to summer and then in autumn until the first frosts. For good growth it requires warm temperatures with daily mean of about 24°C.[393]

Couch grass can be sown from seed or vegetatively propagated from runners. The suggested sowing rate is 2-5 kg/ha and the seed should be broadcast on the surface and rolled, or drilled no more than 5 mm deep. Couch grass is tolerant of grazing and must be grazed heavily as the feed quality and palatability decline with maturity.

Description

- low, creeping grass (<30 cm) that spreads by both rhizomes and stolons
- roots and tillers form at the nodes on the stolons
- forms a 'dense sward' under high fertility conditions
- fine leaves, 2-5 cm long, 2-4 mm wide
- seed heads are digitate (finger-like) with 2-7 spikes on erect stems which turn purple or reddish-brown after flowering.

Soil–climate adaptation

Rainfall (est.): >450 mm

Drought tolerance: Moderate to high

Frost tolerance: Moderate, leaf growth killed by –2°C, but grows back from rhizomes in spring

Soil type: Adapted to well drained soils, particularly coarse-textured including deep sands

Soil fertility requirements: Moderate to high for good production, will persist under low fertility, very responsive to N fertiliser

Soil pH$_{Ca}$: >4.0 (est.)

Aluminium tolerance: Good

Waterlogging tolerance: Moderate

Salt tolerance: Moderate (if not waterlogged)

Ability to spread naturally: Spreads by stolons, rhizomes and seed

Nutritive value

DMD: 64% (leaf), 59% (stem)[385]

Crude protein: 8.3-14.0%[359]

Environmental benefits

Soil erosion control: Useful pioneer plant

Weed control: Moderate ability to out-compete weeds under fertile conditions

Stock deaths grazing young plants have been recorded due to hydrocyanide, but they are very rare.[393] Toxicity seems to be confined to the coarser leaf, loosely branched forms rather than the fine-leaf types.[380]

The prostrate, creeping growth habit results in couch grass being a useful plant for soil conservation and as a pioneer species on denuded areas. The improved types of couch grass may have a role as a permanent pasture on sandy soils, particularly on soils where subsoil moisture is available over summer.

Cultivars

Numerous cultivars of couch grass have been developed, especially as turf grasses. Couch is rarely sown as a pasture grass, but seed is available. The main varieties are:

Giant NK37 (public variety) is a giant Bermuda grass developed in the US as a pasture grass. It requires some subsoil moisture over summer to be productive.

Bermuda grass (or common) is a smaller form which is used as a lawn grass.

Couch grass stolon

Young elephant grass plant

Elephant grass *(Pennisetum purpureum)*

Features

- very tall, robust grass
- vegetatively propagated
- rapid growth under moist, warm conditions
- useful windbreak species.

Elephant grass is a very tall grass that is native to Zimbabwe, but has now been introduced into most sub-tropical and tropical countries. High animal production has been recorded from elephant grass pastures in tropical environments, e.g. beef cattle on mature elephant grass had liveweight gains of 549 kg/ha.[359] In Queensland, elephant grass is a highly productive pasture in the humid tropics (850-2,500 mm).

Elephant grass is planted vegetatively as cuttings, because the seed quality is poor. Cuttings are taken from the hard sections of the stem, and each cutting requires at least three nodes, with two nodes buried in the soil.[393] The cuttings are sown in spring, usually in rows (alleys) with a within row spacing of about 1 m.[5]

Elephant grass needs to be managed to keep it at a height of 1 m or less, as young shoots are soft, succulent and palatable, while the tall growth is coarse and has a low palatability. Feed quality depends on the ratio of leaf to stem and declines with age.[393]

In WA elephant grass is used as a windbreak for market gardens on the Swan coastal plain, with very limited plantings as forage on farms. The potential of elephant grass as a forage (non-irrigated) in WA is unknown, but it will be limited by the requirement for vegetative propagation. It has naturalised along creeklines in the Darling Scarp near Perth and should not be sown near waterways.[162]

Cultivars

The common form is a robust, coarse plant which can grow very tall (up to 4 m).

The only variety in Australia, 'Capricorn' (public variety) was selected as a late flowering, 'grazing type' with medium height (1.8-2.4 m) and thick succulent stems, strong crowns and vigorous stooling.[293]

A dwarf type ('Mott') has been developed in the US.

Description

- tall, erect grass with cane-like stems (1.8-3.5 m)
- produces broad leaves, up to 80 cm long
- spreads by short rhizomes (underground stems) spread to form a clump about 1 m across
- extensive, deep root system.

Soil–climate adaptation

Rainfall (est.): >650 mm (particularly summer moist soils)

Drought tolerance: Moderate

Frost tolerance: Sensitive

Soil type: Adapted to moist, fertile soils

Soil fertility requirements: High, very responsive to N fertiliser

Soil pH_{Ca}: >4.3 (est.)

Aluminium tolerance: Unknown

Waterlogging tolerance: Low to moderate

Salt tolerance: Unknown

Ability to spread naturally: Low (but forms large clumps)

Nutritive value

DMD: 70% (young leaves) declines rapidly with age to <55%[393]

Crude protein: 5.9-15.1%[359]

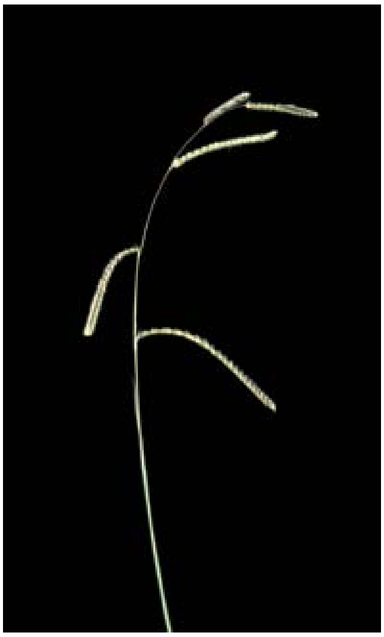
Environmental benefits

Soil erosion control: Used as a windbreak

Elephant grass

Humidicola *(Urochloa humidicola)*

Humidicola is a low growing, stoloniferous grass which forms a tight sward. It is tolerant of waterlogging and very acid soils (pH_{Ca} >4.0), but has low drought and frost tolerance. It has moderate feed quality (DMD: 68 (54-75)%[196] and crude protein: 6.9-11.7% when N fertiliser increased from 0 to 150 kg/ha).[306] It is slow to establish under WA conditions. From very limited testing in WA, humidicola may be an alternative to kikuyu on acid soils in coastal districts (rainfall >600 mm) but otherwise appears to have few advantages over kikuyu.



Paspalum *(Paspalum dilatatum)*

Features

- slowly creeping, sward-forming grass
- highly tolerant of grazing
- very good late spring-early summer growth
- moderate drought tolerance
- seed heads susceptible to ergot infection.

Paspalum (or Dallis grass) is a summer-active perennial grass native to the humid sub-tropics of southern Brazil, Argentina and Uruguay. It is now widespread in many areas of the world and under suitable conditions is capable of very high production.[359]

Paspalum was introduced into Australia in the late 19th century and was one of the first warm season grasses to be widely cultivated. In WA it was first sown in the irrigation areas and has now naturalised in disturbed moist areas, along irrigation channels and in lawns from Kalbarri to Albany.[162] It can be an invasive weed of claypans.

Paspalum has relatively small seeds (570-700,000/kg) and should be sown no more than 10 mm deep. The suggested sowing rate is 2-5 kg/ha when sown alone.

In WA, paspalum is dormant in winter and grows actively from October to May, providing soil moisture is non-limiting. It grows rapidly in late spring and early summer and then opportunistically over summer if moisture is available. It will run to seed rapidly in summer and needs to be heavily grazed to prevent seeding. Palatability drops markedly in rank or old growth.

Paspalum can withstand heavy grazing due to its rhizomatous growth habit, but for high production it should not be grazed below 5-7 cm.[38] Paspalum pastures can become sod-bound, so periodic renovation to maintain productivity and retain the annual clover content is recommended. The pasture can be cultivated in autumn and then if required, re-sown with temperate species to provide the cool season growth.[122]

Description

- tufted perennial grass with short rhizomes
- leaves are 7-40 cm long, flat and hairless with a distinct mid-rib and often wrinkled along the leaf margins
- seed heads have 4-6 lateral spikes on stems 0.6-1.5 m tall
- spikes are usually 4-10 cm long with a double row of spikelets along one side.

Soil–climate adaptation

Rainfall (est.): >600 mm plus summer moist sites

Drought tolerance: Moderate

Frost tolerance: Moderate, underground root-stocks allow it to recover from frosts[359]

Soil type: Grows on sands to clays, but prefers fertile soils

Soil fertility requirements: Moderate

Soil pH$_{Ca}$: >4.3 (est.)

Aluminium tolerance: Unknown

Waterlogging tolerance: Moderate to high

Salt tolerance: Nil

Ability to spread naturally: Slowly by rhizomes and seed

Nutritive value

DMD: 56.7-58.4% (monthly cuts)[137], 68.1% (leaf), 59.8% (stem)[385]

Crude protein: Av. 10.1% (range 5.7-12.9%)[137]

Seed heads can be infected with ergot (*Claviceps paspali*) a dark-coloured, sticky fungus that can poison stock. Animals grazing affected pastures can develop 'paspalum staggers'. Poisoned animals that are removed from the infected pasture at an early stage can recover within a few days. To control the disease, graze hard in summer to prevent seeding, or mow to remove the seed heads.

Paspalum has moderate drought tolerance, so is not confined to irrigated pastures. The role for paspalum in WA is mainly for soils that remain moist in summer and in southern coastal districts, either as part of a pasture mix or sown alone.

Cultivars

'Common' paspalum is the only type available.

Cows grazing a paspalum-dominant pasture on the Swan Coastal Plain

Vetiver grass *(Vetiveria zizanioides)*

With David Stanton

Vetiver grass is mainly used as a living contour for soil conservation

Features

- tall, hardy, bunch grass
- mainly used as a 'living contour' for soil conservation
- planted vegetatively as splits
- strong, very deep root system
- tolerant of extreme soil and climatic conditions, especially soil acidity.

Vetiver grass is widely distributed through Africa, India, Myanmar, Sri Lanka and south-east Asia.[359] It is mainly used as a 'living contour', being planted on the contour to trap soil while allowing water to flow through. The coarse roots contain an aromatic essential oil (vetiver oil) which is used as a perfume. In India the roots are woven into coarse mats and hung up to scent the room.[359]

A key feature of vetiver grass is the thick, strong root system which can potentially grow to a depth of 5 m, is able to penetrate compacted soil layers and has minimal lateral growth.[396] The depth of root growth gives vetiver grass considerable drought tolerance. Vetiver is a tall, bunch grass which can reach a height of 2 m at maturity.

The minimum rainfall is >400 mm (est.) and it will grow on a range of soils from sandy duplex soils to clays. Vetiver grass tolerates extremes of pH (3-10), high aluminium, sodicity and moderate salinity.[396] Vetiver grass tolerates high concentrations of metals like cadmium, lead, mercury and arsenic, so has been used in minesite rehabilitation.[396] It is also tolerant of flooding and waterlogging. The nutritive value is adequate if new regrowth is grazed, but mature growth is coarse and has a low palatability.

The role for vetiver grass in WA is mainly limited to soil conservation and possibly to revegetate moderately affected saltland or acid sulphate soils. There have been limited small plantings to date in south-western WA.

Vetiver grass is planted vegetatively as 'splits', at about 1 m spacing in rows, often on the contour. It spreads slowly by short rhizomes to form a large clump. The only available type of vetiver grass is a non-seeding type, called 'Monto' (public variety).[396]

Chapter 6
Herbs

Photographic credits:
Carol Harris (NSW Ag.): page 170; **Peter Maloney (DAFWA Image Resource Centre):** pages 168 (sheep's burnett), 169, 172; **Geoff Moore (DAFWA):** pages 168 (evening primrose), 171, 173.

Herbs

Geoff Moore

Evening primrose flower

Evening primrose with serradella, a pasture option for deep sands

Herbs are broad-leaf perennial plants which are non-leguminous (i.e. do not fix nitrogen from the atmosphere). Forage herbs have not been widely grown in WA, so there is limited information on their performance under local conditions.

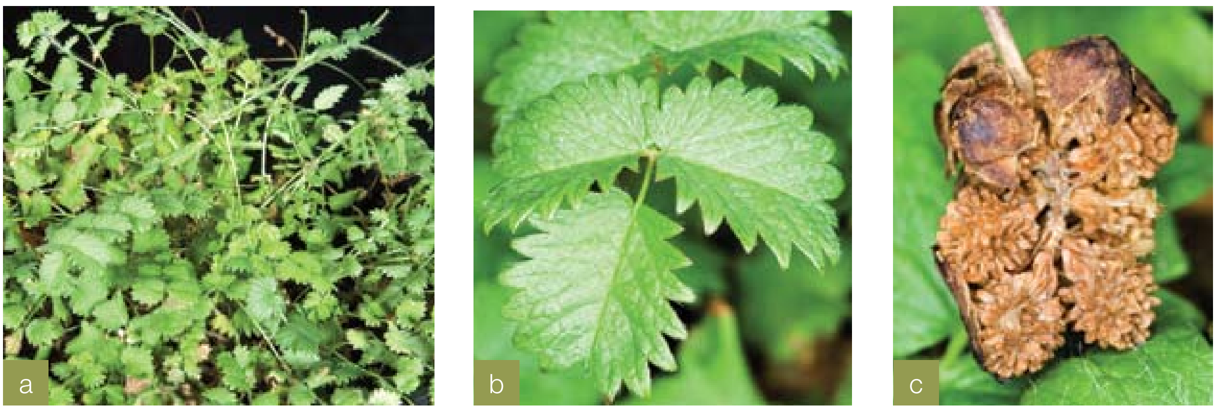
The main herbs are chicory and plantain (see below). Other herbs include evening primrose and sheep's burnett.

Evening primrose (*Oenothera stricta*) also called sweet-scented or common evening primrose is a biannual herb with a strong, fleshy tap-root which comes from South America. Evening primrose and related species have naturalised in WA and occur on roadsides and paddock margins from Gingin to Esperance.[162] Evening primrose is readily eaten by sheep and can be grazed to the crown without damaging the plant, however it will not persist under set-stocking and requires some form of rotational grazing.[380] Evening primrose has been successfully grown on deep sands on the south coast along with perennial veldt grass and serradella. It has mainly been grown to help stabilise sandy soils subject to wind erosion.[380]

Sheep's burnett (*Sanguisorba minor*) is a long-lived, deep-rooted perennial herb, which is native to parts of Europe and western Asia. It has been grown in New Zealand, mainly for revegetation and as a forage in harsh environments.

It has numerous fine stems and dark green dissected leaves which form a dense clump, 20-40 cm in height. It has pinky-red flowers on short stems, while the seeds form within hard, brown, oval seed pods with a roughened surface. Each pod contains a single yellowish-brown oval seed.[380]

Sheep's burnet is palatable, can contain high levels of protein and is a good source of vitamin A. It mainly grows in autumn, winter and early spring.[380] Its role in WA is unknown. Seed is currently not available.



Sheep's burnett is a perennial herb – (a) plant, (b) leaflets, and (c) seed

6.1 **Chicory** *(Cichorium intybus)*

Features

- warm season growing herb
- excellent feed quality, suitable for finishing stock
- good acid soil tolerance
- requires deep, fertile soils
- moderate drought tolerance.

Chicory is a short-term (two to five years) perennial herb native to Europe, temperate and tropical Asia and North Africa. It has been cultivated as both a summer forage and as a 'coffee substitute' for centuries and was introduced into Australia in the 19th century.

High animal growth rates, e.g. 290 g/day (lambs) and 900 g/day (calves) have been measured on chicory.[114, 142] Chicory provides a good balance between crude protein, energy and minerals and combined with rapid passage through the animal results in high feed intake and liveweight gain.[9]

The potential of chicory in WA is still being investigated. It has been evaluated in field trials by the CRC Salinity and grown by a small number of farmers. Chicory is also gaining popularity as a cover crop in vineyards. On the Esperance sandplain the dry matter (DM) production from chicory was superior to lucerne, while at Katanning it was persistent but DM production was lower than lucerne.[340]

In high rainfall districts chicory could be a perennial option on cropping soils that are too acidic to grow lucerne, as a specialist pasture for finishing stock, or as a high quality component of a mixed perennial pasture.

Seasonal growth pattern

In temperate environments where there is adequate summer rainfall, chicory grows actively from early spring to late autumn. In winter, growth is checked by frosts but it will continue to grow slowly providing the soil temperature is more than 9°C.

In WA chicory grows from early spring to late spring/early summer, opportunistically over summer depending on soil moisture and after the autumn rains until the first frosts in winter. Chicory requires vernalisation over winter for its reproduction with plants flowering in

Description

- forms a rosette of broad, prostrate leaves in winter
- with warm temperatures, many leaves are produced from the crown (20-30 cm)
- in late spring, a few, thick, hollow leafy stems emerge bearing the inflorescence
- flowers over several weeks with single blue flowers on the long flowering stems (up to 1.5 m if ungrazed)
- deep tap-root with the top section resembling a turnip.

Chicory paddock on the south coast

late spring to early summer in response to increasing day length. In a given season not all the plants will be reproductive and those that are vegetative in one year are more likely to be reproductive in the following year.[63]

Establishment

The time of sowing is flexible as chicory can be sown in autumn or late winter to early spring – similar to lucerne. The keys to successful establishment are: (i) good weed control (there are few post-emergent broad-leaf herbicide options); (ii) avoid frosting the young seedlings; and (iii) sufficient soil moisture for the plants to be well established before summer.

Seed should be sown at a depth of 10 mm,[341] with a seeding rate of 4-5 kg/ha when sown alone or 0.5-1 kg/ha when sown in a mixture (seed size 830,000/kg). A residual insecticide is essential as chicory is susceptible to redlegged earth mites. Chicory has good seedling vigour when sown under favourable conditions. A good stand will have 45-60 plants/m^2 at the start of the first summer.

Livestock disorders

Chicory does not cause bloat in cattle as it contains condensed tannins (0.04%).[390] It has been reported to taint milk when it comprises more than 50% of the diet of dairy cows.

Meat flavours/odours for sheep on chicory are similar to those for sheep fed grass and are less intense than the meat from sheep fed legumes.[335]

Management

Chicory requires rotational grazing to persist and can die out within 12 months if set-stocked. To maintain production and quality the key is to maximise leaf growth (highly palatable) and minimise stem growth (reduced palatability). A ratio of 70% leaf to 30% stem is considered optimal in terms of production and feed quality.[66]

Soil–climate adaptation

Rainfall: >500 mm (>400 mm south coast)

Season length: >6.5 months

Drought tolerance: Moderate

Frost tolerance: Moderate to high[361]

Soil type: Prefers deep, well-drained fertile

Soil fertility requirements: High for good production, responsive to N[70]

Soil pH$_{Ca}$: >4.3

Aluminium tolerance: Good

Waterlogging tolerance: Low

Salt tolerance: Slight[51]

Nutritive value

DMD: 66-80%[51, 70], 79% (leaf), 45% (stem)[66]

ME: 9-11 MJ[402]

Crude protein: 14-24% (depending on N nutrition)[402]

Environmental implications

Weed control and ability to spread: Chicory can compete with weeds in spring but in winter it is almost dormant. It can recruit new seedlings but is unlikely to become a problem weed.

Under favourable conditions chicory has good recruitment

A three to four week rotation is often suggested.[213] Chicory can tolerate hard grazing to ground level providing it is then rested. As the stem content increases with longer periods between grazing, chicory is not a suitable species for accumulating biomass to overcome feed shortages.

Hard grazing in late autumn can reduce the persistence of the stand over winter, as insufficient leaf growth remains to replenish the root carbohydrate reserves.[213] Grazing of the annual component of the pasture over winter should be controlled so that stock do not chew the crowns of the chicory, as this can increase the potential for crown infection from fungal diseases.

The plant density of a chicory sward will decline over time even when it is rotationally grazed and supplied with adequate N.[156] Under favourable growing conditions in New Zealand, plant density declined from 66 plants/m^2 in the first year, to 49 and 24 plants/m^2 in years three and four respectively.[212] The remaining plants grew larger and had more stems to compensate for the reduced density up to year three, but from year four onwards chicory production declined.[212] Seedling regeneration in established stands can occur under favourable conditions and management.

Established stands are susceptible to redlegged earth mite damage. The main diseases of chicory are sclerotinia (*Sclerotinia sclerotiorum*) and charcoal rot caused by *Fusarium* spp. where the lower stem and tap-root darken in colour until they appear black. Avoid sowing chicory following crops susceptible to sclerotinia, like the pulse crops and canola.

Chicory is not suitable for making hay, as the leaves turn black and dusty on drying but it does make good quality silage.

Companion species

Chicory needs to be grown with annual legumes or supplied with sufficient N to maintain quality and production. It can be combined with a winter-active perennial grass like phalaris, which has a complementary growth pattern. If lucerne and chicory are grown in a mixture they are likely to be competing for the limited soil moisture in late-spring and summer.

Cultivars

The currently available varieties of chicory have been selected for New Zealand conditions. Drought-tolerant varieties for southern Australia will be released through the CRC Salinity.

'Grasslands Puna' (public variety) was the first forage cultivar of chicory. It was selected for its densely leaved habit and vigour from the north island of New Zealand from an unselected commercial line.[334] It appears to be the hardiest of the current varieties and has the best persistence and the lowest rainfall requirement.

'Puna II'[Φ] is a selection from Puna for more upright growth habit, greater winter-activity and improved uniformity. However it requires a longer growing season to persist.

'Choice'[Φ] is also a selection from Puna and is similar to Puna II, but was specifically selected for dairy pastures as it has a low content of lactucin, which can taint milk.

'Grouse' (public variety) and 'Forager' (public variety) are both erect short-term varieties (one to two years) developed as summer cropping options.

'INIA Le Lacerta'[Φ] is a variety selected in Uruguay for its tall, erect growth habit, leaf type, lateness in stem elongation and uniformity. It is more winter-active and earlier flowering than Puna and contains low levels of lactucin.

6.2 Plantain *(Plantago lanceolata)*

Plantain

Features

- winter-active, perennial herb
- stands can regenerate from seed
- adapted to a wider range of soils than chicory
- moderate drought tolerance
- moderate feed quality with a high mineral content.

Plantain (narrow-leaved plantain) is a deep-rooted, short-lived perennial herb from Europe, temperate Asia and north Africa. It has been used for various medicinal purposes for centuries and only more recently as a forage plant. It is widely naturalised in temperate regions and is a weed of lawns and disturbed areas in southern Australia and North America.

Plantain can be highly productive,[193] is more drought-tolerant than chicory and can regenerate from seed to maintain the sward. Sheep on plantain gained 183 g/day liveweight, compared with 232 g/day on chicory and an average of 110 g/day on grasses.[335] In a grazing trial in NZ, palatability was similar to white clover.[335]

The potential role for plantain in WA is still to be identified, but it may have a role as a component of a mixed perennial pasture. It may have a similar climate adaptation to some of the temperate perennial grasses.

Seasonal growth pattern

Plantain grows moderately in winter with its main growth periods being in spring and autumn with opportunistic summer growth.

Meat flavours/odours for sheep on plantain are similar to those for sheep fed grass and are less intense than for sheep fed legumes.[335]

Establishment

Plantain is usually sown in autumn. Seed should be sown at a depth of 10 mm[341] and the suggested seeding rate is 8-10 kg/ha when sown alone, or 1-3 kg/ha when sown in a mixture (seed size 500,000/kg). Plantain is fairly slow to establish, so does not compete well with species with a high seedling vigour. It does not tolerate phenoxy-based herbicides (e.g. 2,4-D, MCPA).[401]

Description

- basal rosette of leaves which are lance-shaped
- dense upright foliage (leaves ~25 cm) with flowering stems (60-90 cm)
- inflorescence is a brown cylinder (3-6 cm) with a mass of creamy-white stamens
- deep tap-root which provides some drought tolerance.

Soil–climate adaptation

Rainfall: >500 mm (>450 mm south coast)

Season length: >6 months

Drought tolerance: Moderate

Frost tolerance: Moderate[361]

Soil type: Range, but not deep sands or waterlogged soils

Soil fertility requirements: Low, but can be highly responsive to N when actively growing, but best grown with a companion annual legume

Soil pH_{Ca}: >4.2-7.8 (est.)[401]

Aluminium tolerance: Unknown

Waterlogging tolerance: Low to moderate

Salt tolerance: Nil

Nutritive value

DMD: 72% (leaf), 59% (stems)[401]

Crude protein: 23.5% (leaf), 13.8% (stems)[401]

Plantain-dominant pasture

Livestock disorders

None have been reported. Plantain contains desirable levels of condensed tannins and is non-bloating.

Plantain is reputed to have some medicinal properties and evidence was obtained in a NZ study which identified anti-microbial, diuretic and some anthelmintic properties (the latter were identified in the laboratory but were not evident in grazing trials).[335]

Management

Plantain requires regular rotational grazing to persist and maintain feed quality, although the variety Grasslands Lancelot is reputed to tolerate some set-stocking.[401] Feed quality declines with flowering as the proportion of stalk increases and overly mature feed has a low palatability.

Field observations show established plantain is highly susceptible to redlegged earth mite. Snails and slugs are also potential pests at all stages of growth.[401] Ascochyta leaf spot and *Rhizoctonia* spp. root rot have been observed in old stands.[401]

Companion species

Plantain is mainly sown as a component of a mixed perennial pasture to add diversity to the diet. It can also be grown with a range of annual legumes depending on the soil type.

Cultivars

'Grasslands Lancelot'⊕ was selected from local ecotypes in the North Island of NZ for its erect, bushy growth habit and ability to tiller strongly under close grazing. It was the first pasture cultivar of plantain.[335]

'Ceres Tonic'⊕ was selected in New Zealand from germplasm from northern Portugal for its erect growth habit and large leaves. When compared with Grasslands Lancelot it has larger leaves, flowers six days earlier (under NZ conditions) and has better autumn-winter production.[335] It requires rotational grazing.[401]

Chapter 7
Native perennial pastures

Photographic credits:
Roy Butler (DAFWA): page 177; **Peter Maloney (DAFWA Image Resource Centre):** page 182; **Geoff Moore (DAFWA):** page 183; **John Schneider (DPI Victoria):** All photos in sections 7.1, 7.2, 7.4, 7.5, 7.6 and 7.7.

Native perennial pastures

Richard Bennett and Meredith Mitchell

The use of native perennial plants in pastures is gaining popularity in the eastern States of Australia. Their use in WA has so far been limited, however they could offer similar advantages to WA farmers as to their eastern States counterparts.

In this section we describe some native perennial species that are persistent, productive, drought-tolerant and can be sown or encouraged in low input pastures to improve productivity if managed appropriately.

The major advantage of native plants is their adaptation to local environmental conditions such as low rainfall, infertile soils and acid soils. Native-based pastures are generally considered to be less productive than introduced pastures but their adaptation can enable them to be more productive and persistent than introduced species in marginal areas or in difficult situations. Even in areas where introduced pastures are productive, native pastures can offer the advantages of lower input (fertiliser) requirements and more sustainable, resilient pastures.

In addition to their hardiness, native grasses can offer an alternative source of income from the collection and sale of seed, which can be relatively expensive.[67, 68, 220] Licences to collect and sell seed from native plants on private property can be obtained from the Department of Environment and Conservation (www.naturebase.net/plants_animals/watscu_licensing.html) and seed can be sold to commercial suppliers or local parties. No licence is required to collect seed of non-registered cultivars on private property for non-commercial uses, provided the permission of the landholder is obtained.

An impediment to the productive use of native pastures is a lack of knowledge about their characteristics, establishment, management and harvesting. Farmers considering investment in native pastures need to be innovative, prepared to take some risks and observant.

There are many perennial species native to Australia that can be used as fodder plants. Some of these species are naturally abundant in protected areas of the WA wheatbelt and require simple changes to pasture management to become established and persist. Cultivars of some native grasses have been developed for specific traits and purposes, however seed can be expensive for broadacre use.

Species from the wheatbelt of WA that show some promise in pastures are: wallaby grasses (*Austrodanthonia* spp.); windmill grass (*Chloris truncata*); common wheat grass (*Elymus scaber*); curly windmill grass (*Enteropogon ramosus*); weeping grass (*Microlaena stipoides*); mulla mulla (*Ptilotus polystachyus*); and kangaroo grass (*Themeda triandra*). Suitable species that are available as cultivars are common wheat grass, wallaby grasses, kangaroo grass and weeping grass.

Establishment

Difficulties in establishing native pastures mean that it is most profitable when they are used in permanent pastures or long pasture rotations. There are two approaches to establishing native pastures. Where available, seed can be used to sow a pasture. Good weed control before sowing is essential since most native plants have limited or nil herbicide tolerance. Notable exceptions are windmill grass and weeping grass, which have moderate herbicide tolerance.[67, 358, 372] Specialised machinery is usually required for sowing native grasses since the seeds can possess hairs, bristles or awns that cause seeds to clump and prevents accurate metering.[68] Broadcasting by hand can be effective for establishing small areas.

Where native pasture species occur in the immediate area, the best form of establishment is natural regeneration. This process, although slower than sowing seed, is a low cost way of developing native pastures and can lead to a more resilient pasture in the long-term. Look out for the occurrence of useful native species in undisturbed or neglected corners of paddocks or in protected remnants such as tree lines or rock outcrops. It is likely that native grasses are already common on many farms and simple management changes can enable them to spread into new areas of the farm. Developing pastures should be allowed to set seed and grazing should be relatively light for the first few years. Windmill grass, curly windmill grass and wallaby grass are the most widely and commonly distributed in the WA wheatbelt.

Native grass-based pasture in the eastern wheatbelt

At an average stocking rate of 3.8 DSE/ha, over 100 kg liveweight was turned off per hectare. No fertiliser was applied and supplementary feeding was 300 small hay bales and an average of 70 g/h/day lupin seconds. The overall return was $40/ha.

Roy has observed that windmill grass responds rapidly to summer or autumn rainfall and that curly windmill grass is very tolerant of drought and grazing.

Native pastures are best suited as a component of a pasture mix, rather than as a monoculture. Consider a system where annual legumes are grazed hard in early spring, enabling native C4 grasses to grow over spring and summer. Mixtures of C3 and C4 native grasses can also be effective.

Grazing management

Grazing management differs between native species. Some species respond well to grazing, increasing in density while other species can be grazed out in poorly managed pastures. As with most perennial grasses, older foliage may have a low palatability to stock and slashing or burning may be required to generate desirable new growth. For this reason, heavy stocking for short durations is recommended for most species (see species descriptions). Grazing may need to be more frequent at certain times of the year and should be avoided when the pasture is seeding heavily.

Case studies

Roy Butler, the Merredin District Veterinary Officer (DAFWA), has allowed a stand of native grasses on his farm near Merredin to regenerate naturally. The pasture consists mainly of windmill grass and curly windmill grass along with introduced annual grasses, weeds and legumes. Roy made some measurements of animal production from a flock of crossbred Dorpers from April 2000 to March 2001 during which the rainfall was 324 mm.

Mike and Jeanette Buegge noticed considerable windmill grass growing in a 40 ha paddock that had been continuously cropped for three years. When they realised that pure seed could be worth harvesting and selling, they developed a system to generate three sources of income.

First, Mike finds the windmill grass reasonably easy to harvest with a conventional header. Harvest from about 20 ha in February 2000 produced about 1 tonne of reasonably pure seed. Mike estimated that about 25% of the seed is recovered using the conventional header.

Second, they are able to over-sow crops in the windmill grass paddock using no till points and a conventional herbicide regime. There has been no indication of crop yield penalties compared with the rest of the farm. This is attributed to the winter dormancy of windmill grass. In addition, the early growth of the windmill grass before the crop is harvested suppresses the growth of summer weeds like caltrop and paddy melons.

A third source of income is generated from the use of the paddock as a summer pasture to fatten wether lambs. Usually the paddock is stocked at 7.5 lambs/ha straight after harvest. During 2000 the sheep gained 2-3 kg/week over the three months they were grazing the windmill grass paddock. Before the windmill grass pasture, the area would have been grazed for only one month.

7.1 Common wheat grass *(Elymus scaber)*

Features

- tussocky perennial
- good palatability and feed quality
- suited to a wide range of soil types and acidity conditions
- frequent recruitment.

Common wheat grass is a tussocky cool-season perennial found in all Australian States, but is more common in districts with cool winters. Within WA, it is sparsely distributed throughout the wheatbelt, from as far north as Geraldton and east to Kalgoorlie. Common wheat grass is found on various soil types from sands to clay-loams. It will tolerate mildly acidic to alkaline soils. It is one of the first native grasses to start growing in spring, providing early green feed. There is considerable variation within this species. Common wheat grass is usually a minor component of native regenerated pastures and therefore only makes a small contribution to total pasture production.

Seasonal growth pattern

Temperate (C3) perennial grass – winter productivity depends on temperature. It flowers from late winter into summer.

Establishment

Wheat grass is easier to establish than most other native grass species. The seed heads should be clipped into individual florets, each containing one seed. Preferred depth for sowing is around 10 mm in autumn to early winter. With moist conditions, the seed takes 7-10 days to germinate. The seedlings are hairy and bluish in colour. They progress rapidly through to the 5-7 leaf stage. Seed should be sown at a rate of between 8-10 kg/ha.

Livestock disorders

None reported.

Description

- tufted perennial, 30-60 cm high
- green flowers, bronze when mature
- leaf blades are narrow with rough edges
- seed heads are 15-25 cm long, narrow and rough to touch.

Soil–climate adaptation

Rainfall: >350 mm

Drought tolerance: Moderate

Frost tolerance: High

Soil type: Wide range

Soil fertility requirements: Medium

Soil pH$_{Ca}$: >4

Aluminium tolerance: Sensitive

Waterlogging tolerance: Unknown

Salt tolerance: Nil

Nutritive value

DMD: 53-90% [214, 419]

Crude protein: 10-36% [214, 224]

Management

Dry matter yields of 3-7 t/ha have been recorded.[214] Common wheat grass is a palatable species and can be grazed preferentially and lost from a pasture. Rotational grazing is the best method to maintain this grass in pastures.

Companion species

Unknown.

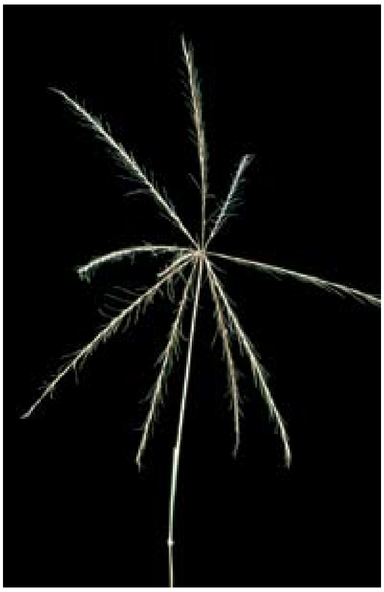
Cultivars

Currently there are two cultivars of common wheat grass commercially available, both developed from the LIGULE program.[214]

'LIG 363' (public variety) was selected from wheat grasses found on the higher tablelands of NSW. It is adapted to cooler conditions with slightly higher rainfall.

'LIG 473' (public variety) was selected from wheat grasses occurring in the wheat-sheep zone and is better adapted to warmer and drier conditions.

7.2 Curly windmill grass *(Enteropogon ramosus)*



Characteristic old curly leaves

Features

- densely tufted perennial
- moderate palatability and feed quality
- old leaves are curly
- seed head with radiating spikes in several planes.

Curly windmill grass or spider grass (formerly *E. acicularis*) was once the dominant species of the drier parts of many types of grassland but is now confined to protected remnant areas.[349] Within WA, curly windmill grass is distributed widely from north to south and into the interior. It is generally found in undisturbed, protected areas such as tree lines or roadsides in the wheatbelt. Characteristic features are the seed head with spikes radiating from the top of the stem in several planes and the tightly curled old leaves. Although slower to respond to summer rainfall events than windmill grass, curly windmill grass is much more persistent, deep-rooted and drought-tolerant. This species is generally considered to have low to moderate forage quality.

Seasonal growth pattern

A warm season (C4) grass that grows actively during spring and summer when moisture is available. It flowers from summer through to autumn and is a valuable fodder in early summer.

Establishment

Curly windmill grass seed should be sown on or just below the surface, no deeper than 5 mm. It is best to sow in late winter to early spring, when soil moisture is available. Good weed control or heavy grazing is recommended prior to sowing.

Livestock disorders

None reported.

Description

- tussocky, perennial grass with a sprawling habit, 25-60 cm tall
- leaf blades folded in the bud
- leaves flat, old leaves curled or spiralled
- purple inflorescence of 2-14 spikes stiffly radiating from central stem in several planes
- leaves are often bluish-green in colour.

Soil–climate adaptation

Rainfall: >300 mm (will persist in lower rainfall areas)

Drought tolerance: Very high

Frost tolerance: Moderate

Soil type: Sandy loams to fine-textured soils

Soil fertility requirements: Low

Soil pH_{Ca}: >4.5

Aluminium tolerance: Unknown

Waterlogging tolerance: Moderate to high

Salt tolerance: Nil

Nutritive value

DMD: 46-66%[56, 214, 419]

ME: 8.4-9.6 MJ[56]

Crude protein: 5-13%[214, 322]

Management

Annual dry matter production ranges from 0.7-1.5 t/ha.[214] Curly windmill grass is of most value over the summer months, particularly before the seed heads form. Young plants are moderately palatable, but plants that have been left ungrazed can become harsh and may be ignored. Heavy stocking rates may eliminate this grass from a pasture but light stocking will stimulate growth and dispersal. It responds well to increased soil fertility.

Companion species

Windmill grass is a good companion for curly windmill grass, as windmill grass responds much more rapidly to rainfall, but it is less persistent. Curly windmill grass would also complement annual legume-based pastures.

Cultivars

Currently there are no cultivars of curly windmill grass commercially available.

7.3 Green mulla mulla *(Ptilotus polystachyus)*

Features

- deep-rooted ephemeral or short-lived perennial
- tolerant of low nutrition and acid soils
- productive, with prolific seed production
- can contain moderate to high nitrates.

Green mulla mulla is a short-lived or opportunistic perennial herb. Its natural distribution extends over the majority of Australia except for northern Queensland and the high rainfall zones of New South Wales, southern Western Australia and Victoria. Green mulla mulla is very palatable to cattle and sheep, particularly when green. It is very productive, seeds freely and is naturally abundant in wheatbelt areas with low rainfall and deep, nutrient-poor acid sands. Its upright flowering stems may make harvesting with a conventional header possible. Research on the agronomic traits of green mulla mulla and its potential for wide scale use in southern Australian agriculture is underway.

Seasonal growth pattern

Green mulla mulla grows mainly during spring and summer and is dormant in winter. Flowers are produced year-round but are prolific in mid-summer.

Establishment

Seed can be threshed to remove woolly flower parts and improve germination. Naked seed should be sown no deeper than 10 mm and un-threshed seed can be sown on the surface. Sowing rates have not been determined, but about 3 kg/ha of naked seed should be sufficient. The best time to sow is in late autumn with stock excluded until the plants are well anchored.

Livestock disorders

Green mulla mulla accumulates large amounts of nitrates and can pose a danger to livestock at times of year when nitrate accumulation is at a peak.[297] Key factors increasing the chance of excessive nitrate accumulation are weather conditions that limit plant growth (drought or cool, cloudy weather) and high levels of available nitrogen in the soil.[102] Nitrate concentrations are usually higher in the lower third of the plant stems. Management practices that reduce the risk of nitrate poisoning of livestock include: allowing

Description

- upright, spreading herb to 140 cm
- many green to brown flowers in terminal spikes to 20 cm long
- variable species with regard to growth form, leafiness and seeding characteristics.

Soil–climate adaptation

Rainfall: May act as an ephemeral/annual in areas <300 mm

Drought tolerance: Very high

Frost tolerance: Unknown

Soil type: Prefers sandy or gravelly soils, but will grow in fine-textured soils

Soil fertility requirements: Low

Soil pH_{Ca}: >4.5

Aluminium tolerance: Unknown

Waterlogging tolerance: Low

Salt tolerance: Low

Nutritive value

DMD: 59.8%[56]

ME: 8.5-9.6 MJ[56]

Crude protein: 14-22%[56, 264]

at least 14 days after drought breaking rains before grazing; avoiding heavy applications of fertiliser before grazing and lighter stocking rates or shorter grazing periods of green mulla mulla pastures to allow animals to select plant matter lower in nitrate content.[189] Recent tests on field harvested material have shown levels of nitrate of 600-4,800 mg/kg. High values were found in large plants at advanced seeding stage. At the highest reported level, green mulla mulla intake should be limited to less than one fifth of overall dry matter intake.

Management

Young plants are very palatable and will be killed by over-grazing. Older plants seem to be more resistant but can still be killed. Heavy grazing for short periods is expected to produce the best results. Grazing should be monitored carefully and old plants grazed before new recruits germinate in autumn or slashed to promote fresh, palatable growth.

Companion species

Green mulla mulla should be suited to a companion pasture of annual legumes or perennial grasses with similar management requirements like kangaroo grass, although this has not been tested.

Cultivars

Currently there are no cultivars available.

7.4 Kangaroo grass *(Themeda triandra)*

Features

- tall, tufted perennial
- moderate palatability and feed quality
- tolerant to soil acidity.

Kangaroo grass is one of Australia's most widespread species, extending from the arid interior to alpine regions. Although once common throughout Australia, its persistence has been heavily affected by grazing animals, indicating a lack of tolerance to heavy grazing. It is a drought-resistant, deep-rooted, warm-season perennial grass with a tussocky habit. The leaves are long and thin and turn from green to red/brown/purple as they mature. Kangaroo grass flowers throughout summer and has attractive rusty-red seed heads on 30–50 cm long inflorescences with dark nodes. The seed heads have a distinctive shape. Kangaroo grass becomes dormant during winter. The grass is more common in areas that are not heavily grazed, like roadsides.

Seasonal growth pattern

Warm season (C4) grass growing actively from mid-spring. Summer-autumn growing, with winter dormancy. It flowers from summer to autumn.

Establishment

Kangaroo grass seed requires shallow sowing, 5-10 mm deep. The seed needs to stay moist for about a week for it to germinate. No fertiliser is needed at sowing, but the seedbed should be free of weeds and not too finely tilled. Seed germinates readily in spring and summer when the air temperature is >25°C and soil temperature is >20°C. A sowing rate of 5 kg/ha for pasture is recommended.

When collected or harvested on-farm, seed stored for 12 months will have higher germination than fresh seed.

Livestock disorders

None reported.

Description

- densely tufted, tussocky habit to 120 cm
- long (to 50 cm) inflorescence with distinctive seed heads
- seeds large (to 10 mm) and shiny black
- older leaves have red/brown tinge.

Soil–climate adaptation

Rainfall: >350 mm

Drought tolerance: Very high

Frost tolerance: Low to moderate

Soil type: Sandy loams to fine-textured soils

Soil fertility requirements: Low

Soil pH_{Ca}: >4.5

Aluminium tolerance: Very highly tolerant

Waterlogging tolerance: Nil

Salt tolerance: Nil

Nutritive value

DMD: 55-75%[12, 214]

Crude protein: 5% (winter) to 17% (summer)[214]

Management

The annual dry matter production for kangaroo grass can range from 1.6 to 8.3 t/ha depending on the climate and age of the plants.[214, 323]
The plant density increases under regular burning (autumn) and light stocking.[225, 276] Kangaroo grass requires rotational grazing and does not persist under set-stocking. Kangaroo grass is best grazed over summer when the grass is actively growing. It responds well to being rested over winter.

Companion species

Unknown.

Cultivars

Currently there is only one cultivar of kangaroo grass that has been selected for pastoral use.

'LIG 520 Kangaroo grass' (public variety) was selected by LIGULE for long-term persistence and high productivity.[214] It is suited to grazing by sheep and cattle.

7.5 Wallaby grass *(Austrodanthonia spp.)*

Seed head (A. richardsonii)

Features

- tufted perennial
- good palatability and feed quality
- tolerant to soil acidity
- attractive, white fluffy seed heads.

Wallaby grasses are among the most valuable native grasses in pastoral areas of Australia, due to their persistence and productivity. They are tufted perennial grasses with fine leaves that remain green all year. There are five wallaby grasses that are native to Western Australia – *Austrodanthonia acerosa*, *A. caespitosa*, *A. occidentalis*, *A. pilosa* and *A. setacea*. Of these, *A. acerosa*, *A. caespitosa* and *A. setacea* are the most common in the WA wheatbelt.

Seasonal growth pattern

Temperate (C3) grass with typical winter growth, which flowers in spring and sometimes in autumn, depending on the seasonal conditions.

Establishment

Wallaby grasses prefer well drained soils. It is essential to have a weed-free seed bed before sowing. Sowing in autumn allows for the best establishment, however seed can be sown at all times of the year as long as soil moisture is available. Germination can be expected within 14-21 days in autumn and spring, but it may take up to 60 days in winter. The cleaned seeds are very small and need to be sown just below the surface (5-8 mm). If sowing in a dryland situation, use fluffy (uncleaned) seed. The seeds of wallaby grass are fairly small with 1-1.5 million per kilogram. A sowing rate of 1–2 kg/ha for cleaned seed and 5–10 kg/ha for fluffy seed is recommended.

Livestock disorders

None reported.

Description

- white fluffy seed heads 30-100 cm high when mature
- ligule has long hairs at base of leaf blade
- leaf blade folded in the bud with parallel lines of thickening
- individual species are identified primarily by hair arrangement, shape and length on back of the lemma and by shape and size of palea.

Soil–climate adaptation

Rainfall: >300 mm,
most productive >400 mm

Drought tolerance: Very high

Frost tolerance: High

Soil type: Light sandy loam to medium clays

Soil fertility requirements: Low

Soil pH$_{Ca}$: >4 (depends on species)

Aluminium tolerance: Tolerant (but dependent on species)

Waterlogging tolerance: Low

Salt tolerance: Nil

Nutritive value

DMD: 45-82%[12, 214]

Crude protein: 10-25%[214, 224, 276]

Management

Annual dry matter production can be 1.8-7.8 t/ha depending on the species and the location.[12, 214] A pasture that contains both wallaby grass and clover needs to be managed to ensure that the clover does not dominate. This is best achieved with a short period of heavy grazing in the spring. Wallaby grass is very sensitive to glyphosate, so spray topping cannot be used to remove annual grasses from native grass pastures dominated by wallaby grass.[358] Wallaby grasses respond well to fertiliser and grazing, increasing growth even at fairly high stocking rates.

Companion species

Annual legumes and other warm season (C4) grasses.

Cultivars

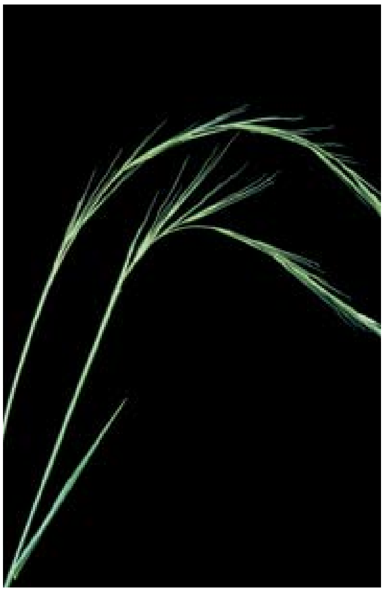
There are currently three pasture cultivars of wallaby grass commercially available. They were all selected in eastern Australia.

'Bunderra'⁽ᵇ⁾ (*A. bipartita*) was selected by the NSW Department of Agriculture as a forage grass for low fertility, fine-textured soils. It produces significant amounts of foliage and has been shown in grazing trials in eastern Australia to be palatable and of high feed value.

'Taranna'⁽ᵇ⁾ (*A. richardsonii*) was selected by the NSW Department of Agriculture as a forage grass for low fertility, medium- to fine-textured soils. It produces significant amounts of foliage and has been shown in grazing trials in eastern Australia to be palatable and of high feed value. Taranna can establish on sandy soils but may perform poorly.

'LIG 179' (*A. fulva*) (public variety) was selected by LIGULE for revegetation and pasture uses on shallow and infertile soils.[214]

7.6 Weeping grass *(Microlaena stipoides)*



Features

- rhizomatous perennial
- good palatability and feed quality
- tolerant to soil acidity
- tolerant to glyphosate herbicide.

Weeping grass is a tufted perennial grass with a short rhizome and remains green throughout the year in higher rainfall areas, producing high-quality feed. Weeping grass is a highly competitive species that responds well to increased fertility and moderate-to-heavy grazing while it is actively growing. Within WA, weeping grass rarely extends further east than a line between York and Albany. However, cultivars have been selected in the eastern States for persistence and drought tolerance and these may expand its adaptation.

Seasonal growth pattern

Temperate (C3) grass, but stays green all year in suitable environments. Flowers are produced from summer through to autumn.

Establishment

The seeds of weeping grass are fairly large and each dispersal unit weighs about 0.005 g. Autumn sowing is preferred. Begin with a weed-free seedbed. Sow seed 10-15 mm below the soil surface. Germination may take 10-14 days. Weeping grass should be sown at 5-10 kg/ha.

Livestock disorders

None reported.

Management

Annual dry matter production 1.7-7.4 t/ha, and to 25 t/ha under ideal conditions.[214, 323, 427] Weeping grass can withstand moderate-to-heavy grazing while actively growing.[225] This grass needs to be kept short, especially over summer, as rank growth becomes unpalatable to stock and should be grazed short to ensure that clover germination is not suppressed in the autumn.[358] Heavy grazing in the early spring may minimise seed contamination problems. Weeping grass is tolerant of glyphosate herbicides. Spray topping therefore can be used to control annual grasses in weeping grass pastures.[358]

Companion species

Annual pasture legumes.

Description

- erect to prostrate form to 50 cm high with short rhizomes
- leaves soft, slightly rough to touch, distinctive crimp at leaf tip
- slender seed bearing stems to 70 cm with the inflorescence portion weeping
- seeds quite large, up to 15 mm.

Soil–climate adaptation

Rainfall: >450 mm for WA native stands, (>400 mm for cultivars)

Drought tolerance: Moderate

Frost tolerance: Moderate

Soil type: Range of soils

Soil fertility requirements: Medium

Soil pH$_{Ca}$: >4.0

Aluminium tolerance: Very high

Waterlogging tolerance: Unknown

Salt tolerance: Nil

Nutritive value

DMD: 55-80%[214]

ME: 10-11 MJ[428]

Crude protein: 10-27%[214]

Cultivars

There are currently four pasture cultivars of weeping grass commercially available which were all selected in eastern Australia.

'Shannon'$^{\Phi}$ was selected by the University of New England for revegetation and pasture applications. It has performed well on very shallow soils under exposed conditions. It grows well in higher altitude environments, having performed well in the higher test sites in north-eastern Victoria, but also persists well at lower altitudes.

'Wakefield'$^{\Phi}$ was selected by the University of New England for pasture applications. It can persist in soils of low fertility but has the capacity to respond to increased nutrient levels. The annual dry matter production for a well established Wakefield weeping grass pasture can exceed that of introduced pasture grasses.

'LIG 183' (public variety) was selected by LIGULE program from a grass population that originated in the wheat-sheep zone near the NSW-Victorian border and has considerable heat and drought tolerance. It is a larger plant, which produces considerable dry matter of high grazing quality.

'LIG 704' (public variety) was developed in the LIGULE program from a grass population that originated in the medium rainfall zone where grazing is the principal activity. It is an upright plant with medium textured leaves and is highly tolerant of acid soil conditions.

7.7 Windmill grass *(Chloris truncata)*

Features

- tufted or prostrate, short-lived perennial
- moderate palatability and feed quality
- seed head with 5-13 spikes radiating like blades of a windmill from the stem.

Description

- tufted or prostrate, 10-50 cm high
- may be stoloniferous
- short, narrow, pale green leaves
- inflorescence with 5-13 spikes radiating from stem like the blades of a windmill
- seeds are black when mature, with a broad obtuse apex on the upper (infertile) lemma.

Windmill grass

Windmill grass is a short-lived (two to three years) perennial and makes rapid growth in early spring. In some drier situations it can act as an annual grass but its very rapid germination and growth after summer rainfall allow it to use excess water from out-of-season rainfall. It is distributed widely throughout Australia and is found in the WA wheatbelt on a range of soil types. It commonly occurs in disturbed areas such as firebreaks or paddocks under crop and this has led to it often being considered a weed, although growth over spring and after summer rain can provide valuable out-of-season forage. The plants are tufted or prostrate with small fibrous leaves that have moderate palatability.

Seasonal growth pattern

Warm season (C4) grass, which grows rapidly during spring and summer when moisture is available. It is dormant in winter and begins flowering four to six weeks after growth starts or germination. Flowers can appear from late winter through to autumn.

Establishment

Windmill grass seed should be sown on or just below the surface, no deeper than 3-5 mm. It is best to sow in the early spring, when soil moisture is available. Recommended sowing rate varies between 5-15 kg/ha. Windmill grass is moderately tolerant of most herbicides so weed control can be conducted on mature stands.[372]

Livestock disorders

Can cause hepatopathy and secondary photosensitisation in sheep and cattle.[3]

Soil–climate adaptation

Rainfall: >300 mm

Drought tolerance: Very high (can act as an annual in poor seasons)

Frost tolerance: Low to moderate

Soil type: Wide variety

Soil fertility requirements: Low to moderate

Soil pH$_{Ca}$: >4.5

Aluminium tolerance: Unknown

Waterlogging tolerance: Moderate

Salt tolerance: Nil

Nutritive value

DMD: 35-68%[214, 419]

Chapter 8
Fodder shrubs

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Fodder shrubs

Tim Wiley

Tagasaste and saltbush are the main fodder shrubs used in Western Australia:

- they increase total feed production and animal carrying capacity on difficult soils
- they supply green feed in autumn
- they enable deferred grazing of annual pastures after the break of season
- they use more water than annual pastures and therefore reduce recharge to the groundwater
- they help control wind erosion.

The two main types of fodder shrubs used in WA are tagasaste (*Chamaecytisus palmensis*), which is grown mostly on pale deep sands and saltbush (*Atriplex* spp.), which is grown mainly on salt-affected land (Saltland pastures – Chapter 9).

There are a number of other fodder shrubs. The native legume *Acacia saligna* has been tried as a fodder shrub, but poor palatability and a short lifespan have limited its use. Leucaena (*Leucaena leucocephala*) is a tropical legume grown under irrigation in the Kimberley region. The evaluation of other fodder shrubs such as perennial lupins, tree medic (*Medicago arborea*) and the native *Rhagodia* species has been very limited and they are not being used commercially in WA.

Well managed alleys of tagasaste

8.1 Tagasaste *(Chamaecytisus palmensis)*

Features

- drought-tolerant fodder shrub
- well suited to deep sandy soils
- can replace supplementary feeding in autumn, but animals will only maintain weight
- feed quality and animal growth rates in winter and spring are similar to annual pastures
- can be grazed continuously by cattle
- sheep should not graze tagasaste for more than six weeks at a time
- requires hard grazing or cutting in the first half of the year to prevent flowering.

Tagasaste or tree lucerne (formerly *C. proliferus*, *Cytisus proliferus*) is a woody perennial legume shrub that originates from La Palma in the Canary Islands off the north-west coast of Africa. Tagasaste was first introduced into Australia in 1879.[210] While several people originally championed the use of tagasaste, it was not until intensive research and development on the West Midlands sandplain in the 1980s that farmers planted tagasaste on a large scale.

Tagasaste was initially developed to supply feed to sheep during the autumn-early winter feed gap. In this situation, tagasaste was profitable as it replaced the need to supply stock with supplementary feed.[292] There are several sandplain farms in the West Midlands with extensive areas of pale deep sands where about 50% of the farm is planted to tagasaste.[443] On these farms tagasaste supplies the majority of the feed and is grazed year-round by cattle.

Tagasaste is a productive, drought-tolerant perennial pasture option in areas receiving >325 mm, especially on pale deep sands where the growth of annual crops and pastures is poor. There are currently about 100,000 ha of tagasaste in WA, mainly in the northern agricultural region. Tagasaste plantations have persisted and been productive under grazing for at least 20 years on deep sands in the West Midlands. Intensive grazing management that is designed to prevent flowering does not appear to weaken the plants or limit their life span.

Tagasaste has naturalised along roadsides and adjacent bushland in most areas where it has been planted from Badgingarra to Esperance. It is also a serious invader of disturbed bushland on lateritic soils in high rainfall areas.[162]

Tagasaste for autumn feed

A whole farm systems experiment carried out at ‘Dunmar’, Badgingarra by the Martindale Research Project found that planting 10% of the farm to tagasaste could replace the need to hand feed sheep in autumn.[292] The tagasaste was locked up for 11 months and then grazed by 100 sheep/ha for about four weeks, which was equivalent to an average stocking rate of 8 DSE/ha over the year compared with 1-2 DSE/ha on volunteer annual pastures.

The tagasaste had to be mechanically cut each year as the 11 months regrowth was beyond the reach of the sheep. This system was profitable, despite the cost of mechanical cutting as it replaced grain feeding.[438]

Year-round grazing

Some sandplain farms have large plantations of tagasaste.[211, 386, 443] In such cases the tagasaste forms the bulk of the feed supply and is grazed throughout the year.

Tagasaste varies seasonally in growth rate and feed quality (see below), but these fluctuations are much smaller than with annual pastures. Where fodder shrubs supply the bulk of the feed there is still a need to adjust the animal enterprise to match the seasonal pattern of feed supply and quality.

The combination of feed supply and quality means that 80% of the animal liveweight gain from a tagasaste plantation comes from just six months of the year. Farmers should maximise stock numbers/grazing pressure from just after the break of the season through to late spring. Stock numbers should then be reduced through summer by selling finished livestock and using other feeds such as crop stubbles.

Tagasaste flowers

Tagasaste pods

Seasonal growth pattern

Tagasaste grows rapidly after the break of the season in autumn, especially in April and May while the weather is still warm. Growth slows down during the low temperatures in June and July, but the plants do not become dormant (Figure 8.1).

The highest growth rates occur in spring when there is adequate soil moisture and warm weather. The growth rate slows down over summer as soil moisture becomes more limiting. Tagasaste

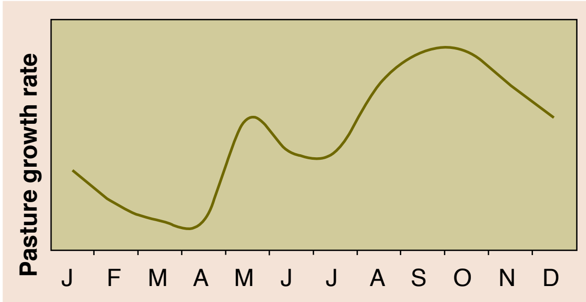


Figure 8.1 Typical seasonal variation in the growth rate of tagasaste

is also affected by high temperatures. When the temperature exceeds 35°C the leaves close up and show signs of wilting, however these symptoms disappear as the plants recover in the evening.

The feed quality is highest in winter and spring and then declines steadily over summer and autumn (Figure 8.2). By late autumn tagasaste on its own is only adequate for maintaining animals. During the growing season from May to October animal growth rates on tagasaste should be similar to those on green annual pasture, e.g. cattle growth rates of 1.0-1.8 kg/head/day. Leaves have a dry matter digestibility (DMD) of 70-82%, while fine stems have a DMD of 50-60% and large stems 40-50%.[47, 86]

Establishment

Tagasaste can be established either by direct seeding or by planting seedlings.[7, 438] Direct seeding is cheaper but requires more attention in terms of weed, insect and vermin control. Seedlings can be tougher once they are established, but are susceptible to planting shock

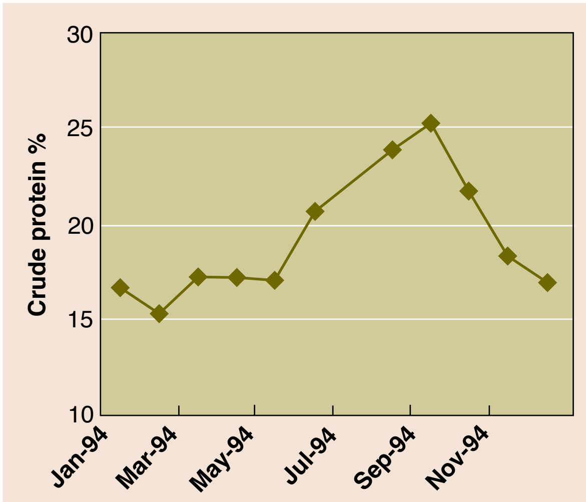


Figure 8.2 Seasonal variation in the crude protein percentage in the edible fraction of tagasaste, Badgingarra (T. Wiley unpublished data)

Description

- when properly managed tagasaste is a multi-stemmed spreading shrub
- when not managed tagasaste becomes a large shrub or small tree 5-8 m
- drooping branches with trifoliate leaves on short petioles
- inflorescence is white, and is predominantly cross-pollinated
- seed pods are black, flattened, 4-5 cm long and contain 8-12 seeds.

Tagasaste shoot growth on well managed plants

and are also more expensive. Potted seedlings cost 50 cents to $1 each with 1,000 to 1,500 plants required per hectare depending on the row spacing. Bare-rooted seedlings are cheaper than potted seedlings, but are still more expensive than direct seeding.

In WA, most stands are direct seeded in winter. In the mature stand there needs to be a plant every 2 m within a row to create a hedge row. With direct seeding, there should be about 10 plants/m of row 6-8 weeks after seeding. Seedling numbers decline over the first year with many stands ending up with about 1 plant/m of row. This density is adequate and productivity is not reduced until the density falls below one plant to every 2-3 m of row.

Site selection

Tagasaste is adapted to deep, well drained soils. It is particularly suited to the highly leached, pale deep sands where annual crop and pasture growth is poor. The deeper the sand the greater the soil volume for the tagasaste roots to explore and the better the plant growth. Tagasaste roots have been measured to a depth of 10 m on a pale deep sand at New Norcia. These sandy soils have a limited water and nutrient holding capacity but this is compensated for by the deep soil profile. A sand with a water-holding capacity of 40-50 mm/m of soil can store 400-500 mm within the root zone of tagasaste. Physical or chemical properties that limit the rooting depth of tagasaste will reduce production, persistence and water use.

Tagasaste does not tolerate waterlogging or salinity and requires at least 1 m of well drained soil to persist and be productive. When there is a fresh watertable below 1 m then tagasaste is capable of high growth rates and will transpire up to twice the average annual rainfall.[209]

Tagasaste will not tolerate extreme soil acidity and high aluminium as is common on the Wodjil sands in the eastern wheatbelt. The soil pH_{Ca} should be 4.0-7.5.

Tagasaste can be grown successfully on a wide range of soils including loamy and fine-textured soils, However, fine-textured soils can restrict root growth and are vulnerable to winter waterlogging.

Frost affects tagasaste by burning the tips of the most actively growing shoots. Established plants will not usually be killed by frosts, except where fresh regrowth is burnt off. Seedlings are sometimes vulnerable to frost damage.

Rhizobium and nitrogen fixation

Tagasaste is promiscuous, so does not have highly specific rhizobial requirements. It will form effective nodules with a wide range of Rhizobia, including the native or background strains that are present in the soil. Seed can be inoculated with a commercial strain of Rhizobium, i.e. 'Tagasaste special' CC1502, but it is not essential. Tagasaste can fix atmospheric nitrogen, however like all legumes it is cheaper for the plant to extract nitrogen from the soil when it is available. In an older stand much of the plant nitrogen can be recycled from the soil profile rather than being fixed by the rhizobia. In a young stand high rates of N fixation (83-390 kg N/ha) have been reported.[400]

Seeding method

Tagasaste is planted and seeded with specialist machines that scalp away the topsoil to form a furrow. The scalping helps to remove weeds from near the seedlings and also to collect water. Generally no further weed control is required, but the seedlings need to be monitored closely for insect damage. Deep ripping below the seed along with scalping help to ensure that tagasaste seedlings survive their first summer (Figure 8.3).

Fertiliser application in the first year

Applying fertiliser at seeding may have limited benefits on plant establishment, however fertiliser

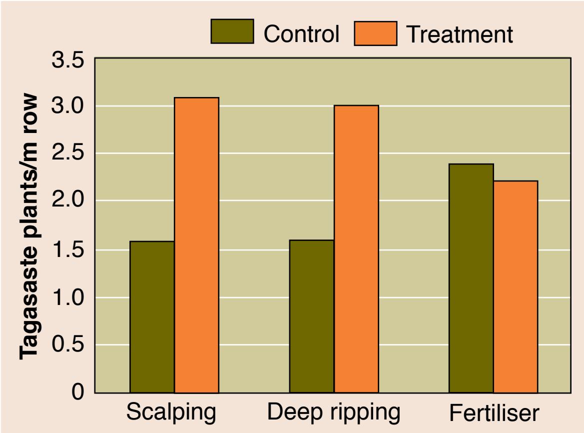


Figure 8.3 The effect of scalping, deep ripping and fertiliser application on the persistence of tagasaste when direct seeding. Plant counts were made in autumn of year 2[434]

applied in the first spring once the seedlings are established can be beneficial.[435] For small seedlings the fertiliser is only applied along the scalped furrow rather than being spread over the whole paddock. Superphosphate and potash fertiliser can improve seedling growth greatly but this may not necessarily result in more plants surviving summer (Figure 8.4).

Applying potash fertiliser can improve seedling growth, but high rates can kill seedlings. Muriate of potash should be applied at 25 kg/km of row (or 25 g/m of row) while rates above 50 kg/km of row can kill tagasaste seedlings.

Pest and insect control

Young tagasaste seedlings are susceptible to attack by insects, grazing animals or rabbits in their first year. Newly emerged seedlings are at risk from redlegged earthmite, lucerne flea and a range of caterpillars. Spraying the entire paddock at seeding with an insecticide is cheap insurance. Regular inspection of the paddock is also required as new pests can invade the paddock.

In coastal areas wingless grasshoppers hatch in spring. If the hatching sites are identified early then the grasshoppers can be controlled before they become mobile and spread over large areas. New tagasaste paddocks should be inspected regularly for grasshoppers from October until the end of December.

Rutherglen bugs are one of the most serious pests of tagasaste and other shrub/tree seedlings. The adult form of this insect is commonly seen during harvest and is referred to as 'radish flies'. These small grey insects are attracted to radish plants and fly off in large numbers when approached. However it is the juvenile form of the Rutherglen bug that kills seedlings. These are very small brown to black bugs that are difficult to see, as they tend to hide underneath leaves and only move when disturbed. The juveniles are sap-suckers and can kill seedlings quickly in warm conditions. Their numbers tend to peak during harvest when farmers are often too busy to inspect tagasaste carefully. Whole paddocks of tagasaste can be destroyed.

Grazing management during establishment

Grazing by livestock or rabbits needs to be controlled during the establishment year. Seedlings should be cut or lightly grazed when they are about 10-11 months old or 25 cm high to encourage the development of multi-stemmed shrubs tolerant to grazing.

Livestock disorders

The feed value of tagasaste is affected by the presence of phenolic compounds (tannin-like compounds), which are produced by tagasaste in response to stress. The phenolic content is lowest in winter and peaks in summer and autumn (Figure 8.5). Phenolics can interfere with the microflora in the rumen of sheep and cattle. High concentrations in summer and autumn reduce feed intake, so animal growth rates decline.

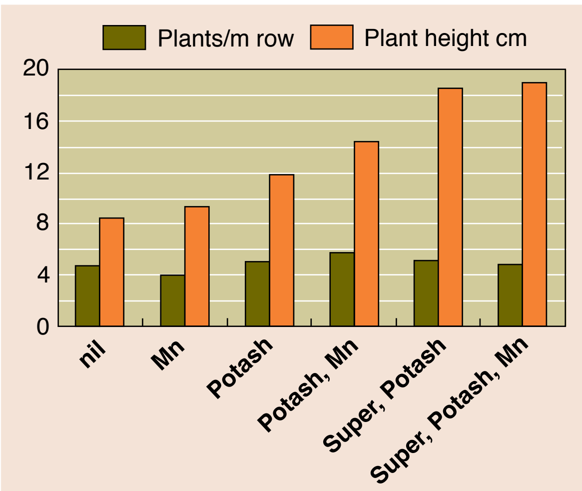


Figure 8.4 The effect of fertiliser on the growth and establishment of 5-month old tagasaste seedlings[435]

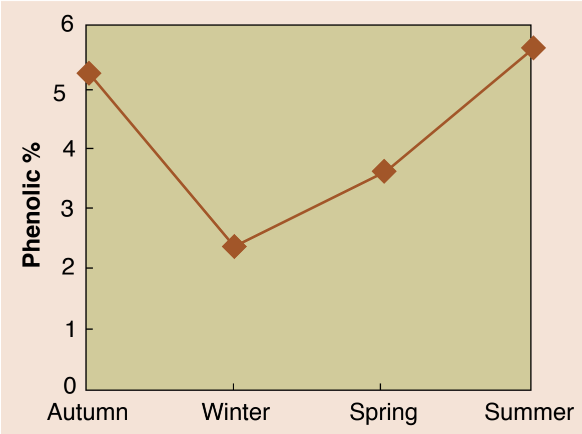


Figure 8.5 Seasonal variation in the concentration of phenolic compounds in the edible fraction of tagasaste (C. Oldham and T. Wiley unpublished data from Dunmar 1995)

Phenolic compounds interfere with the protein metabolism in the rumen and this can lead to animals becoming deficient in protein, even though the crude protein levels in the tagasaste never fall below 15% in autumn. Feeding a high protein supplement such as lupins to animals on tagasaste in autumn will over come this problem and stimulate the animal's appetite.[397]

In autumn, the mineral concentration in the leaves of tagasaste can be less than the minimum necessary for grazing animals. If growing animals in autumn, supply a well balanced salt-based mineral lick.

'Tagasaste staggers' can occur in cattle. The condition will only become apparent when the cattle are moved, with affected animals dropping behind the mob and staggering and collapsing if forced to keep moving. However, if left alone, the animals will recover. The cause of this condition is unknown and it can occur at any time of the year.

Cows grazing tagasaste during late pregnancy can occasionally give birth to calves affected by a unique form of leucoencephalomalacia. Most affected calves are born dead or die soon after birth. Affected calves born alive exhibit consistent, sudden and wild swinging and twirling of the tail, giving rise to the name 'dancer calves'. Other factors may be involved because the majority of cows grazed on tagasaste in late pregnancy give birth to normal cows. On two occasions mature cows grazing tagasaste have died with a severe disease affecting the liver and kidneys. No definite cause was ever established.

Mature stand management

Once established, tagasaste usually only requires fertilising, good grazing management and the occasional cutting for persistence and production. Mature shrubs are comparatively free of pests and diseases. They are the last plants to be attacked by grasshoppers or locusts and they readily recover even when all the foliage is eaten.

Fertiliser

Phosphorus fertiliser drives the feed and animal production from tagasaste plantations (Figure 8.6). Trials at the Dunmar Research Station found there was an additional kilogram of cattle liveweight produced for every kilogram of superphosphate applied.[100, 434, 439]

Established tagasaste (i.e. >three years old) does not respond to potash fertiliser even on highly leached sands. Tagasaste typically delivers low soil test results for potassium (K), because the shrub's extensive root system can recycle K from depth. Phosphorus and trace elements are far less mobile in the soil and are usually concentrated close to the soil surface.

Plant tissue testing is the only reliable method for testing the nutrient status of tagasaste. Samples collected in spring will show the shrub's phosphorus status and also whether any trace elements need to be applied.[436] Pluck about 10 shoots (10 cm long) from at least 20 plants for tissue testing. Fertilise in autumn to maintain >0.32 mg P/kg when tested in spring.

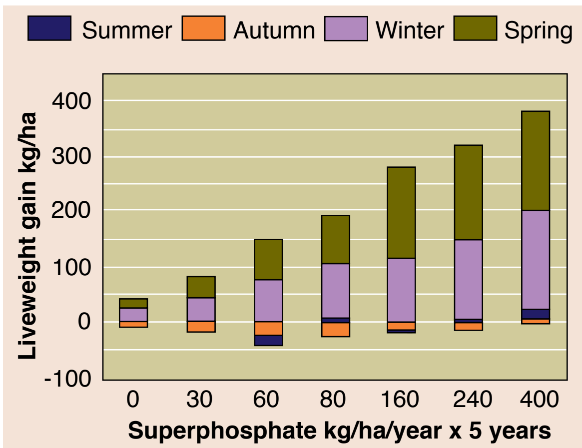


Figure 8.6 The effect of superphosphate on cattle production from a tagasaste plantation[100]

Cattle grazing tagasaste

Tagasaste growing on pale deep sands can be deficient in manganese (Mn). These are the same soils where Mn deficiency causes split-seed in white lupins. Manganese deficiency is permanently treated once 40 kg/ha of manganese sulphate has been applied. Symptoms of Mn deficiency are best seen in winter and spring when tagasaste is actively growing. Deficient plants are yellow, but characteristically this symptom is not uniform across all plants. A distinctive feature of Mn deficiency in tagasaste is that pale yellow plants will be growing next to dark green plants.

The requirement for copper and zinc has not been determined, but it is probably good practice to re-apply these trace elements every 5-10 years.

Grazing

Grazing management can affect the persistence and production of tagasaste and both over-grazing and under-grazing can be a problem.

Tagasaste can tolerate very hard grazing provided the plants are then allowed to recover.[439] With intense grazing sheep can remove every leaf from tagasaste plants. Six weeks after heavy grazing commences new buds start to form on the branches. If the sheep are left in for more than six weeks and allowed to remove the new buds then plants can die. Cattle can be set-stocked successfully on tagasaste as they are unable to graze as tightly as sheep and do not remove the new buds.

When cattle are set-stocked on tagasaste the plant develops a 'broccoli' form with a dense covering of short shoots and leaves. Trials comparing continuous grazing with cattle against a three-month rotation found there was no difference in either tagasaste growth or animal production.[255] On the other hand, production from a tagasaste stand was reduced when grazing only once a year compared with every four months.[434]

Under-grazing can also reduce the productivity and long-term survival of tagasaste, as grazing helps to prevent the plant from switching from the vegetative to the reproductive phase. Once tagasaste plants start their reproductive phase the growth rate slows and the plants become less palatable to stock. Plants that are allowed to flower in spring will drop their leaves and stop growing in the following summer. The leaves become less palatable while the bark seems to become more palatable. 'Bark stripping' normally only occurs on plants or limbs that have flowered. If tagasaste is hard grazed and/or cut in the first half of the year it will not flower that year.

The long-term effects of grazing on the persistence of tagasaste are not yet fully understood, but it appears that plants can be maintained permanently in the vegetative state without causing damage. More plants seem to die in plantations that regularly flower.

Aerial photo of tagasaste alley farming

Cutting tagasaste

Under-grazing results in large tagasaste shrubs that grow beyond the grazing height of stock. Sheep can graze to a height of 1.2-1.5 m but once the tagasaste gets beyond this height it will slowly turn into a 'tree' form with minimal grazing value. Cattle can graze to about 2 m but the tagasaste can still get out of control if not grazed regularly.

Tagasaste can be cut back using 0.9-1.5 m circular saw blades mounted on articulate arms. These machines are capable of cutting about 2 ha of tagasaste per hour. Cutting machines with smaller circular saw blades or reciprocating knives are slower and can only handle thin stems.

Tagasaste is usually cut with two passes to form a cone-shaped hedge. Cut tagasaste to a height of about 1 m for both sheep and cattle. Tagasaste can be cut at almost any time of the year, but it is best done when there are animals in the paddock to use the cut material. However, do not cut tagasaste when severe frosts or insect attack are expected. In fact, anything that causes defoliation of fresh regrowth in shrubs that are just recovering from compete defoliation may cause death.

Very large tagasaste shrubs (trees) can be cut to bring them back into production but care must be taken to avoid killing them. Large trees are cut in two passes. One side of the row is cut and left for about six months to allow new shoots to branch from the trunk. Once new branches have established then the other side is cut.

Tagasaste that is only grazed by sheep will need to be cut mechanically once each year to keep it under control. With cattle it is possible to graze the tagasaste so that it is kept short and never needs cutting, however this may not be the best management for either the cattle or for the whole farm feed supply.[437] The optimum management with cattle may result in the tagasaste requiring a 'hair cut' every few years.

Plantation versus alley farming

Fodder shrubs are established either in plantations or in 'alley farming' systems with wide spaces between rows. Tagasaste plantations generally have a row spacing of 6-12 m, which results in direct competition between the shrubs and the annual pasture growing between the rows.[434]

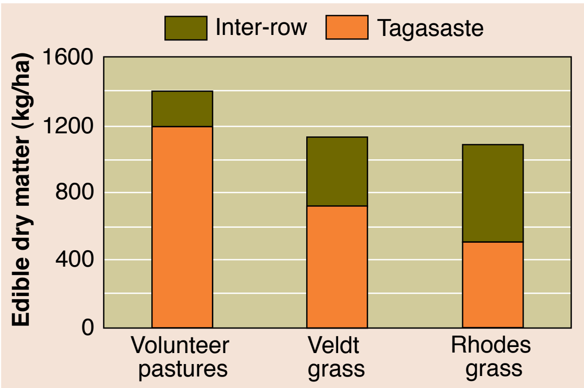


Figure 8.7 The effect of inter-row pasture on the total feed produced in a tagasaste plantation with 6 m spacing between the rows[439]

Increasing the production of inter-row pasture will often lead to a similar reduction in production from the fodder shrub, so there may be no net increase in feed from the paddock. When perennial grasses were established between rows of tagasaste at Dunmar the grasses competed directly with the fodder shrubs. In this example, there was a reduction in the total feed supply from the plantation when production from the inter-row increased (Figure 8.7). In plantations, paddock management should focus solely on the fodder shrub.

At wider row spacings (>12 m), or 'alley farming', the inter-row pasture is crucial to the production from the whole paddock, as it provides the majority of the feed. Management needs to focus on both the fodder shrub and the inter-row pasture, which can make management more complex. Compromises often have to be made, e.g. the tagasaste rows may need hard grazing in autumn to prevent them flowering later in the year, while the inter-row pasture should be rested to prevent erosion.

Maximising the feed production from all components in an alley farming systems is often difficult. It may be easier to move stock between paddocks with fodder shrub plantations and other feed sources rather than to have them growing together. With tagasaste most trials have failed to show any benefits to the grazing animals from having access to other feed in the inter-row. An exception was for blue lupins when they supplied lupin seed to sheep grazing tagasaste in autumn.[439]

Animal production

The liveweight gain of animals grazing tagasaste can vary significantly depending on the soil type, fertiliser applied, season and management factors.[100]

With tagasaste, liveweight gain can range from small losses in autumn to growth rates in winter and spring that are similar to other green feeds. During winter and spring cattle liveweight gains can be more than 1.5 kg/head/day. Animal growth rates decline progressively over summer. By autumn, animals may only be maintaining weight, or even slowly losing weight. The decline in animal production over summer is due to reduced feed intake caused by increasing levels of phenolics (tannin-like compounds). Supplementing animals on tagasaste in autumn with lupins will stimulate their feed intake and growth rates.[397]

The fertiliser experiment at Dunmar produced 386 kg liveweight gain/ha/year in a 450 mm rainfall zone or about 1 kg of liveweight gain for each millimetre of available rain (i.e. total rainfall – 100 mm). A similar result was achieved near Jurien Bay where the tagasaste produced 400-450 kg liveweight gain/ha/year over five years in a 600 mm rainfall zone.

Seed production

Tagasaste commences flowering in mid-winter and mature seed is shed in early December. Most of the pods shatter on the first hot day in December with a low relative humidity. Seed is collected by stripping pods from tagasaste plants by hand in late November to early December. The pods are then spread on a concrete floor, left to shatter and the seed is sieved from the pods.

Seed can also be gathered from underneath mature tagasaste plants by sieving the seed from the sand. This method results in lower quality seed than picking fresh seed by hand.

Tagasaste seed is very hard and must be treated to improve germination. Large quantities of seed can be scarified mechanically at seed works. Small amounts of seed can be scarified by scratching the surface with sandpaper or by using the 'hot water treatment' (i.e. seed is dropped into water that has just been boiled and left in the water until it has cooled).

Cultivars

Tagasaste is an out-crossing species so there will be a wide range of plant types within any plantation. Commercial tagasaste seed is a mix of many different forms of tagasaste.

'Cleavers Easy Graze'[ⓓ] was selected by a WA farmer for its prostrate or weeping form. These plants are shorter than conventional tagasaste and should require little or no mechanical cutting. However they are currently only available as potted seedlings and are therefore more expensive than direct seeded 'normal' tagasaste. It is still too early to determine if the weeping tagasaste is as productive as the normal sized plants.

8.2 Other fodder shrubs

Cattle grazing leucaena

Golden wreath wattle *(Acacia saligna)*

Acacia saligna is a leguminous shrub or small tree (2-8 m) native to WA. It grows on a wide range of soils from deep sands to clays. It is highly drought-tolerant and will persist and grow where the average annual rainfall is 250 mm, but prefers 350-600 mm. It has very good waterlogging tolerance and moderate salinity tolerance. It is also highly tolerant of low pH and high aluminium and will grow on the extremely acidic wodjil soils in the eastern wheatbelt. On these soils, tagasaste roots are restricted by soil acidity.

A. saligna is a productive shrub and once established it recovers well from hard grazing. With its wide adaptation to difficult soils and low rainfall *A. saligna* would seem to have considerable potential as a fodder shrub, however its low palatability limits its fodder value. At times livestock will readily eat *A. saligna* even in preference to other feeds, however at other times of the year the same plants can be totally unpalatable with animals starving rather than eating the leaves.

The low palatability is mainly attributed to the high levels (10.5-13.2%) of condensed tannins (CT) that reduce animal intake, feed digestibility and nitrogen retention in ruminants. The CT content of the leaves vary with the age of the plant, the age of the foliage, soil fertility, soil pH, high temperatures and other stresses on the plant.[190]

A. saligna is not a reliable, edible feed source and is no longer being sown as pure plantations solely for stock feed. It continues to have a role on farms for the landcare, stock shelter, wind break and wildlife habitat benefits. *A. saligna* has weed potential and is not recommended for growth beyond its native range.

Leucaena *(Leucaena leucocephala)*

Leucaena is a tropical legume fodder shrub from Mexico. In northern Australia it is grown mostly on loamy and clayey soils where the annual rainfall is above 600 mm. Leucaena is grown under irrigation in the Kimberley region. Under favourable conditions leucaena is very invasive and it is now a common weed of wetlands and riverine sites in the Kimberley and has been recorded from Pilbara south to Exmouth.[162]

Leucaena has had very limited testing in southern WA. Any role is likely to be restricted to frost-free areas with mild to warm climates, as leucaena is susceptible to light frosts and requires warm temperatures (25-30°C) for good growth.[382] It is reported to have low seedling vigour, which could affect the persistence of plants over the first summer.[382]

Leucaena has a highly specific *Rhizobium* requirement and requires inoculation with CB3060.

Leucaena management is very similar to that for tagasaste. It has been grazed mostly by cattle and will require mechanical cutting if the plants get too tall.

Leucaena contains an amino acid, 'mimosine', in the leaves and seeds that can be toxic to stock. This problem can be overcome by inoculating the animals with bacteria that break down the mimosine in the gut. Livestock only need to be inoculated once and the bacteria are readily passed on to any new animals that join the mob.

More information on leucaena is available from the Queensland Department of Primary Industry website or the FAO Grasslands Index website.

Chapter 9
Saltland pastures

Photographic credits:
Ed Barrett-Lennard and the late Clive Malcolm (DAFWA): pages 204, 205, 208, 210 (niche seeder), 211 (wavy-leaf saltbush), 212 (wavy-leaf saltbush), 216 (leaf), 217, 220, 224 (TWG rank); **DAFWA Image Resource Centre:** pages 206, 211 (old man and river saltbush), 212 (old man and river saltbush); **Simon Eyres (DAFWA Image Resource Centre):** page 226; **Sommer Jenkins (CRC Salinity):** page 218; **Peter Maloney (DAFWA Image Resource Centre):** pages 219, 222; **Geoff Moore (DAFWA):** pages 216 (plant), 221, 224 (TWG grazed), 225; **Hayley Norman (CSIRO):** page 209; **Pia Scanlon (DAFWA Image Resource Centre):** page 210 (saltbush seedlings); **Brett Ward (DAFWA):** page 215.

Saltland pastures

Ed Barrett-Lennard and Geoff Moore

In Western Australia there are between 1.0 and 1.2 million hectares of severely salinised land and between 2.8 and 4.4 million hectares of land with a high risk of secondary salinity.[11] Saltland pastures have been planted and grazed in WA since at least the late 19th century and their use has been promoted actively since the 1940s.[387, 398]

About half of WA's saltland is suited to various kinds of saltland pasture.[26] The remainder is too saline and should be fenced to allow it to revegetate naturally with samphire (*Halosarcia* species) and salt- and waterlogging-tolerant trees like swamp sheoak (*Casuarina obesa*).

The key saltland pasture types are:

- halophytic shrubs, especially river saltbush (*Atriplex amnicola*), old man saltbush (*A. nummularia*), wavy-leaf saltbush (*A. undulata*) and small leaf bluebush (*Maireana brevifolia*)
- halophytic perennial grasses, especially puccinellia (*Puccinellia ciliata*) and tall wheat grass (*Thinopyrum ponticum*)
- mildly salt and waterlogging tolerant annual legumes such as balansa clover (*Trifolium michelianum*), Persian clover (*Trifolium resupinatum*) and burr medic (*Medicago polymorpha*) and more tolerant annual grasses such as annual ryegrass (*Lolium rigidum*).

This chapter focuses on the halophytic shrubs and perennial grasses that are currently available. The CRC for Plant-based Management of Dryland Salinity is currently developing new, improved fodder species for revegetating saltland.[331]

A recent survey of old trial sites has demonstrated that long-term, sustainable, productive reclamation of saltland is achievable in many areas in the WA wheatbelt using a combination of halophytic shrubs and understorey plants.[232] Many plantings of halophytic shrubs in the wheatbelt remain productive after 40-50 years so must have reached equilibrium in terms of their salt and water balance.[232]

Salinity, waterlogging and inundation

Saltland is not all equally productive. Saltland plants occur in a range of ecological zones of differing productivity created by variations in the severity of salinity, waterlogging and inundation. Waterlogging and inundation are different stresses, although they may occur in close proximity.

Removing stock or controlling grazing to allow an area to recover naturally, can have a dramatic effect at a low cost

Salinity

Saline soils affect the growth of plants mainly because of high concentrations of dissolved sodium and chloride ions in the soil. They may also contain significant concentrations of magnesium, sulphate, carbonate, bicarbonate and boron. The salts in WA soils are commonly in similar proportions to the salt in seawater with sodium chloride making up about 75%. In saline soils sodium and magnesium replace calcium to varying degrees in the exchange complex on the clay and cause the soils to be dispersive and poorly structured.

Salinity can affect plants in a number of ways:[131]

- Salinity makes it difficult for the roots to take up water due to the decreased osmotic potential. Plants may have difficulty withdrawing water from what appear to be moist soils.
- A build-up of salt in the leaves, especially old leaves, can lead to necrosis. The overall

effect on the plant depends on the rate of new growth compared with the rate of leaf necrosis.

- High sodium and chloride concentrations in the soil can affect the uptake of other nutrients, e.g. potassium, magnesium, nitrogen and phosphorus, which are essential for plant growth.

The most common way of assessing the salinity of a soil is to extract the salt in water and measure its electrical conductivity (EC). Salt solutions are conductive because of the electrical charges on the ions. For most practical purposes, the conductivity of soil extracts is proportional to their salt concentration. The electrical conductivity of soil extracts is most commonly reported in deci-siemens per metre (abbreviated dS/m). In the past, micro (μ) siemens per centimetre (μS/cm) or parts per million (ppm) were used. Conversions for sodium chloride solutions can be made between units on the basis that:

1 dS/m = 1,000 μS/cm = 584 ppm.

Plants can be divided broadly into three groups according to their growth response to salinity (Figure 9.1).

(a) *Halophytes* ('salt plants'). Halophytes actually grow faster in mildly saline soils than non-saline soils, but have reduced growth at high salt concentrations. River saltbush (*Atriplex amnicola*) is a typical example; it has a 10% increase in shoot dry weight at 5 dS/m (a salt concentration equivalent to about ~9% of seawater), a 50% decrease in growth at 40 dS/m (equivalent to ~70% of seawater), and is still alive at 75 dS/m (equivalent to ~140% of seawater).

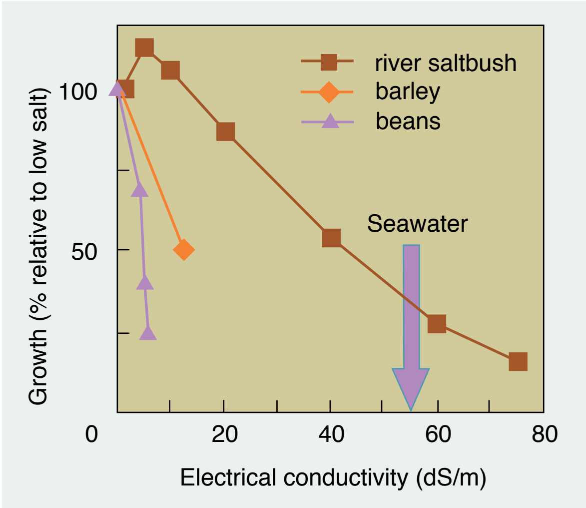


Figure 9.1 Growth response of three plant species to salinity; barley and beans are typical non-halophytes, while river saltbush is a typical halophyte[15, 98, 124, 130]

(b) *Salt-tolerant non-halophytes.* These plants will grow at low salt concentrations, but have decreased growth at higher concentrations. Barley is a typical example; it has a 50% reduction in shoot growth at 13 dS/m (equivalent to ~20% of seawater).

(c) *Salt sensitive non-halophytes.* The growth of these plants is sensitive to even low concentrations of salt. Beans (*Phaseolus vulgaris*) are typical, with a 50% decrease in growth at salt concentrations of 5 dS/m (equivalent to ~9% of seawater).

Severely saline areas prone to flooding should be left to revegetate naturally with plants like samphire (above)

Waterlogging

Waterlogging refers to the saturation of the root zone by excess water. This inhibits gaseous exchange between the soil and atmosphere, leading to a dramatic decrease in the concentration of oxygen in the soil and an accumulation of ethylene and various products of anaerobic metabolism such as carbon dioxide and ethanol.[90] Roots normally require oxygen for the optimal production of energy from sugars. Waterlogging therefore causes: (i) an immediate decline in root growth followed by a subsequent decline in shoot growth; (ii) rapid death of root tips followed by the death of previously developed roots; and (iii) decreased activity of all processes associated with active ion transport across membranes (such as the uptake of inorganic nutrients).

Most importantly, under saline conditions, waterlogging causes plants to increase their rate of salt uptake, increasing the concentrations of salt in the shoots and jeopardising growth and survival.[23]

Much of WA's saltland is also subject to waterlogging because of the presence of shallow groundwater and/or shallow duplex soils with impermeable clay subsoils. The importance of waterlogging is often underestimated, since it is usually not visible at the soil surface and can be ephemeral.[249]

Waterlogging varies in duration and intensity (depth to watertable) and can have a more adverse effect on plants when they are growing actively. For instance, cereals are more tolerant of waterlogging in mid-winter when temperatures and transpiration rates are low than in mid- to late-spring when temperatures and transpiration rates are higher.[250]

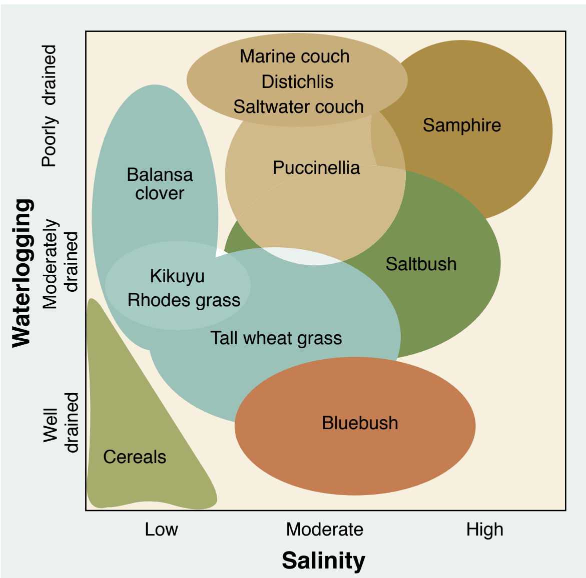
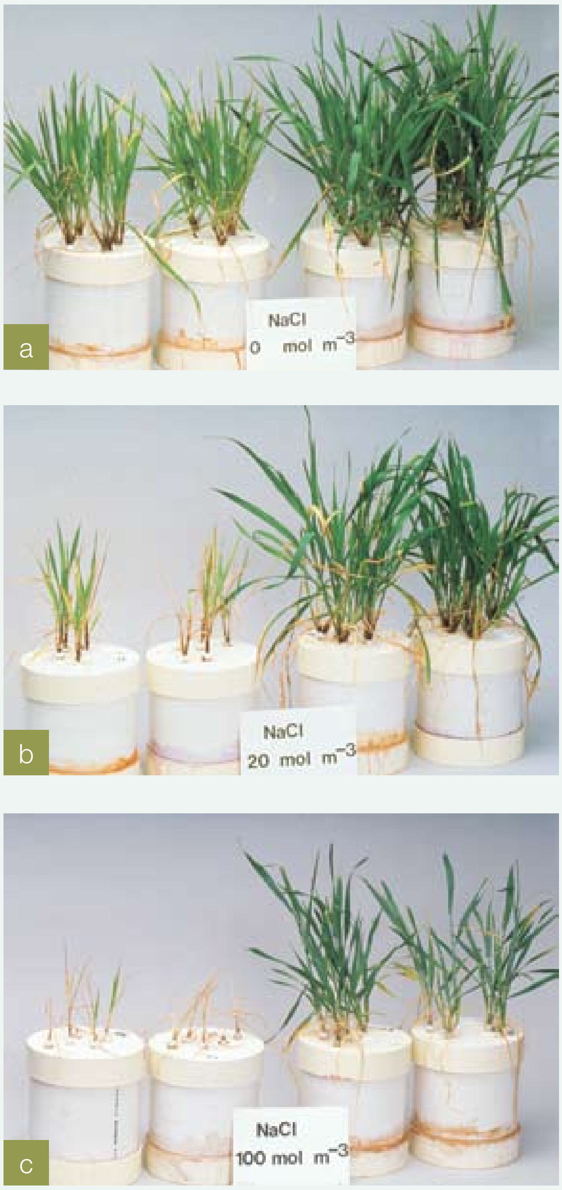


Figure 9.2 Relative rankings of different saltland pasture species in the salinity/waterlogging matrix[29]



Effects of waterlogging on wheat grown with (a) zero salinity, (b) 2 dS/m (equivalent to 4% seawater), and (c) 10 dS/m (equivalent to 18% seawater). Plants on the left were grown in nitrogen bubbled nutrient solutions (simulating waterlogged soils) for 33 days. Plants on the right were grown in aerated nutrient solutions (simulating drained soils)

For saltland pastures, one of the keys to profitability is to grow the right plant in the right place. Waterlogging will affect the growth of all but the most tolerant plants on saltland. The matrix in Figure 9.2 shows where different plants have a competitive advantage in soils of increasing salinity and waterlogging.

Inundation

Inundation refers to water ponding on the soil surface. The effect on plants is severe because inundated leaves cannot photosynthesise and few plants survive if they are completely submerged. Flooding is similar, but refers to water flowing outside its usual channel, such as a river or a small drainage line.

As salinity in valley floors increases because of shallow watertables, inundation and flooding will become more severe.[49] In effect, less rainfall can infiltrate into the soil, so more becomes available for run-off. Even brief periods of inundation appear to be highly damaging to plants and the environment. There is only limited anecdotal evidence of the tolerance of different plants to inundation. One mechanism by which plants avoid inundation is to grow quickly so that total immersion in water is avoided.[29]

Implications for drainage

Understanding the interactions between waterlogging, inundation and salinity can help with the debate about design criteria for drainage.

The level of drainage required to decrease soil salinity can be substantial. Depending on soil texture and rainfall the watertable may need to be drawn-down to 'critical depths', e.g. greater than 2 m from the surface.[289] However, studies of the interaction between waterlogging and salinity show that substantial improvements in plant growth can be possible with even slight decreases in waterlogging. These kinds of changes may be achievable with relatively cheap structures that improve the control of surface water, for example, grade banks that intercept surface water run-off further up the landscape and redirect it away from low lying waterlogged areas and surface drains like W-drains or raised beds. Such measures should be used to alleviate surface waterlogging before saltland pastures are established. Further lowering of the watertable may then be possible through the use of shallow groundwater by these salt-tolerant plants.

Developing a revegetation strategy

Saltland is usually highly variable spatially, especially in terms of the degree of salinity and waterlogging. As a result, evaluating a site's potential for revegetation options may not be straightforward. For example, a site with moderate salinity in summer may also be subject to prolonged waterlogging in winter. The combination of waterlogging and salinity may adversely affect plant establishment, depending on the degree of leaching in early winter (which in turn is related to the soil texture). As discussed previously, reducing waterlogging (e.g. raised beds, W-drains, surface drains) will often increase the revegetation options. Figure 9.3 outlines the steps in developing a revegetation strategy for saltland.

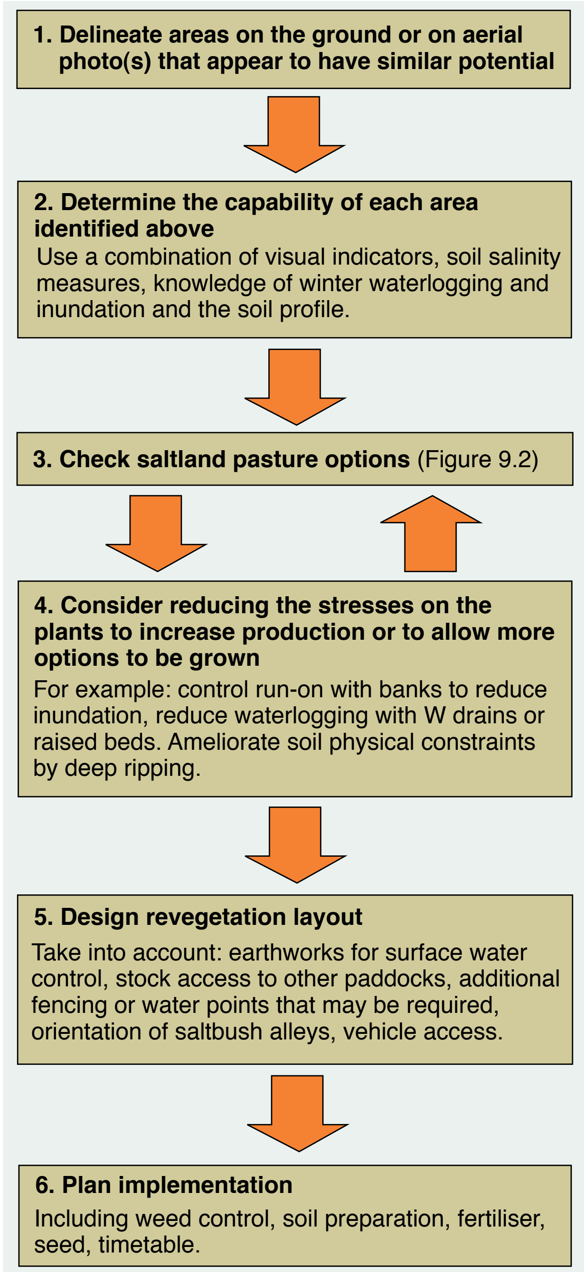


Figure 9.3 A schematic diagram of the steps involved in developing a revegetation strategy for saltland. For further information consult the second edition of 'Saltland Pastures in Australia: a Practical Guide'[29]

9.1 Halophytic shrubs

The benefits of growing halophytic shrubs include:

- increased production on moderately salt-affected and waterlogged land
- high protein forage available to meet the 'autumn feed gap' and provides a source of vitamin E
- increased evapotranspiration, so recharge and saline groundwater are used. This makes productive use of as much water as possible and can lower the watertable, so that understorey species of higher productivity and nutritive value can be grown
- sequestration of CO_2
- control of wind and water erosion
- shelter for stock in severe weather conditions
- reduced shedding of water, salt, soil and nutrients
- improved sustainability in the long-term
- increased biodiversity and improved wildlife habitat.

The importance of mixtures

Good animal production requires fodders that contain high concentrations of metabolisable energy, moderate to high concentrations of crude protein, adequate vitamin levels and relatively low concentrations of salt. In general, saltbushes have a reasonable metabolisable energy concentration when expressed as a proportion of the organic material in the plant. They also have high crude protein, vitamin E and high salt concentrations.[239, 285] High salt concentration is a major limitation to feed intake, as grazing animals are unable to eat sufficient saltbush to grow. Animals grazed on pastures containing saltbush alone will gain weight briefly (due to additional fluid retention), but will not thrive in the longer-term.[268, 416] Saltbush leaf on its own is at best a maintenance diet for sheep.

Saltbush alleys in a farming system. The saltbush maintains the groundwater at depth allowing an understorey of productive, annual pastures with lower salt tolerance

The key to the use of saltbush fodder is to mix it with feeds with complementary characteristics such as stubble. The potential of this approach is clear from a pen-feeding trial in which sheep were fed diets of 100% low quality hay (dry matter digestibility 57%), 100% leaves of wavy-leaf saltbush, or a 50:50 mixture of hay and saltbush (Figure 9.4a, b)[418]. Sheep fed the saltbush or the hay alone had low feed intakes and lost liveweight. However, when saltbush leaf was mixed with hay, feed intake doubled and the sheep gained liveweight at about 70 g/day (Figure 9.4).

Achieving mixtures in the field

The field strategies required to optimise mixed saltland pasture diets are the subject of research in the Sustainable Grazing on Saline Lands (SGSL) initiative. Nevertheless, at this stage, there seem to be two major options:

(a) On moderately saline and waterlogged land, grow fairly dense stands of shrubs and provide a supplement to grazing animals of hay or small amounts of grain, or provide the animals with simultaneous access to cereal stubbles.

(b) On mildly salt-affected land, grow rows of shrubs at wider spacings with an understorey of tolerant annual legumes and perennial grasses (e.g. tall wheat grass, puccinellia) and intensify

Saltbush is a high protein forage which can be used to meet the 'autumn feed gap'

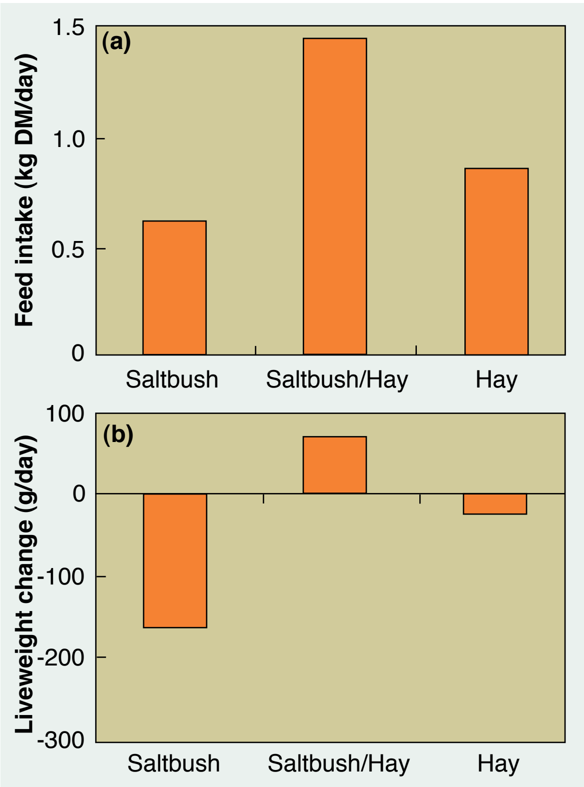


Figure 9.4 Effects of mixtures of leaves of wavy-leaf saltbush (Atriplex undulata) *and oaten hay on the performance of sheep: (a) feed intake; and (b) liveweight change*[418]

the grazing so that the palatable and less palatable components of the feed-on-offer are consumed simultaneously.

The optimum shrub density for a particular farm varies with the area of saltland relative to other feed. The higher the proportion of saltland on a farm the more important it is to increase the alley spacing and grow more understorey.

Economic value

Current economic analyses suggest that the main value of saltland pastures is in providing a source of feed in autumn. A recent analysis of a 2000 ha property on the south coast of WA, suggested that revegetating 2.5% of the farm to saltbush could increase the profitability of the whole farm by 5%.[291] The analysis also showed that profit could be further improved if both the nutritive value and production of the saltland pasture were increased.

Establishing shrubs

There are two methods for establishing shrubs.

Niche seeding

Seeds on saltland germinate naturally in protected 'niches' such as in debris lying on the soil surface where they remain protected from drying winds. Niche seeders attempt to reproduce such protected sites. Niche seeders deposit fruits of saltbush or bluebush and a covering of vermiculite at 1-3 m intervals on a raised M-shaped mound. The shape of the mound promotes leaching of salt from the seed bed, while the vermiculite acts like mulch by retaining moisture around the fruits and reducing the movement of salt into the seed bed by capillarity. The elevation of the seed bed above the surrounding soil reduces waterlogging.

The keys to successful niche seeding are:

- Good site selection. Best results have been achieved in WA on sandy and deeper duplex soils.[407] Avoid grey clays and sites that grow samphire (too saline/waterlogged) or that grow subterranean clover and capeweed (low salinity allows growth of weeds).

Mound and mulch left by niche seeder

Planting saltbush seedlings

- Good weed control. Spray-top in the year before establishment, graze hard and use knockdown herbicides before seeding.
- Reduce waterlogging and inundation. Reduce overland flow onto saltland by using seepage interceptors and grade banks further up the landscape to direct excess water away. Remove surface water from saltland using W-drains. Plan niche seeding so that mounds and furrows direct water into surface drains.
- Use seeding rates appropriate for the seed quality. Fruit quality can be highly variable, as seed fill is often less than 20%. Seed should be sown at sufficiently high rates to have 50 germinable seeds per placement.[408]
- Control insects. The use of systemic insecticides is essential to control redlegged earth mite and other insects during establishment.
- Good timing. Sow sufficiently late to avoid winter waterlogging, but sufficiently early to avoid the drying conditions of late spring.
- Control grazing until plants are well established. This varies with seasonal conditions but may mean deferring grazing until after the second summer.

Planting nursery-raised seedlings

Nursery-raised seedlings can be planted using commercial tree planters. This technique is generally more reliable than direct seeding, especially into clayey soils.[27] However, the use of seedlings is relatively expensive as nurseries sell saltbushes for ~25 cents each. On this basis a stand of 1000 plants/ha would cost $250/ha, plus transport, site preparation and planting costs.

Bare-rooted seedlings, i.e. seedlings with no soil around the root, can be raised on the farm at low cost. This method can give good results when used on non-saline soils, however on saline soils it has had limited success. This is probably due to damage to the roots during planting and 'osmotic shock' from a lack of salt hardening.[29]

Natural establishment

The cheapest way to establish halophytic shrubs is to fence off an area to control grazing and allow the site to regenerate naturally. This is particularly appropriate for bare areas affected by severe valley floor salinity and waterlogging, where protection can promote the natural establishment of samphire (*Halosarcia* species) and swamp sheoak (*Casuarina obesa*). On moderately saline, non-waterlogged soils, controlled grazing will promote the establishment of small leaf bluebush (*Maireana brevifolia*) if wind-borne seed is available from nearby plants.

9.2 Saltbush *(Atriplex* species)

River saltbush flowers

River saltbush fruit

Old man saltbush leaf

Typical curling leaves of wavy-leaf saltbush

Features

- halophytic shrubs, many species native to WA
- long-term survival and production on moderately saline and waterlogged soils
- drought tolerant
- can be used as plant-based 'water pumps' to maintain saline watertables below critical depths
- best used in conjunction with other feeds because they have:
  - high protein concentrations
  - adequate metabolisable energy
  - high salt concentrations
  - limited edible dry matter
  - moderate oxalate concentrations.

Saltbush is the common name for plants from the genus *Atriplex*. The three main commercial species in WA are river saltbush (*Atriplex amnicola*), old man saltbush (*A. nummularia*) and wavy-leaf saltbush (*A. undulata*). Other species that have been used are creeping saltbush (*A. semibaccata*), grey saltbush (*A. cinerea*) and quailbush (*A. lentiformis*).

Saltbushes have dimorphic flowering systems and many of them are dioecious, i.e. having male and female flowers on separate bushes.[105] This reproductive strategy produces high levels of genetic variation within populations. Female plants produce a fruit that contains a single seed, but fruits will be empty if they develop without a nearby source of pollen.[373]

River saltbush (*Atriplex amnicola*) comes from the floodplains of the Murchison and Gascoyne Rivers of WA where the plant's growth habit can vary from prostrate to erect and individual plants vary in size from 1 m by 1 m to 4 m across and 2.5 m high. Stems touching the ground can form roots.[336] Established plants have good waterlogging tolerance and can survive partial inundation in winter.

River saltbush has excellent long-term survival, recovers well from grazing and has high palatability.[233] It has been widely

Description

- halophytic shrubs are perennial except for creeping saltbush, which is biennial
- prostrate to erect growth habits with woody stems
- grey-green leaves with bladder cells on the leaves
- mostly dimorphic flowers, many dioecious (i.e. female and male flowers on separate plants)
- fruits mature between February and April
- usually a single seed is contained between two bracts, but not all fruits form seeds.

Wavy-leaf saltbush has a relatively prostrate growth habit

Old man saltbush

grown in mixed plantings in the WA wheatbelt. Establishment from seed can be difficult, especially if correct establishment procedures are not followed. Germination is improved by exposure to light, hence the need for shallow sowing.[407]

Two ecotypes, 'Meeberrie' and 'Rivermor', which are both public varieties, were selected for their colonising ability, which is related to ease of establishment.

Old man saltbush (*A. nummularia*) is Australia's iconic saltbush species. It is native to the semi-arid and arid zone of southern and central Australia. It grows well on saline and rangeland soils and is deeper-rooted (down to ~4 m) than many other saltbushes.[182] Given its deeper root system it can be sensitive to waterlogging, particularly at high temperatures. Symptoms of waterlogging damage include bleaching of the leaves.[29]

Old man saltbush has a relatively poor ability to produce volunteer seedlings. Its main disadvantages as a fodder are its erect growth habit (up to 2 m high) and lower palatability than other saltbushes and bluebush. It has been advocated as a drought reserve in NSW and has shown good survival after severe frosts.

In South Australia, a cloned variety 'Eyres Green'[Φ] has been selected for its low growth habit and palatability. It is propagated vegetatively.

Wavy-leaf saltbush (*A. undulata*) comes from the semi-arid rangelands of central Argentina and as the name suggests, the leaves are crinkly or wavy. Established plants can reach 1 m high and 2 m across and stems touching the ground can form roots. It establishes readily from seed using the niche seeder. It appears to have lower waterlogging tolerance than river saltbush.

River saltbush erect type

River saltbush prostrate type

Soil–climate adaptation

Rainfall: 250-450 mm

Drought tolerance: Extreme (once established)

Frost tolerance: High

Soil type: Moderately saline and waterlogged soils with best growth on deeper sand over clay soils. Poor growth on massive grey clays

Soil fertility requirements: Low, Generally well adapted to soils deficient in N and P. At Tammin, application of P had no effect on the growth of river saltbush. Applications of N (60 kg/ha) doubled shoot volumes after three months, but after two years plants with added N were only 12% larger than non-treated plants[121]

Soil pH_{Ca}: 4-8.5[233]
Old man saltbush does not survive as well on shallow acid (pH 3.4) groundwater[24]

Aluminium tolerance: Unknown

Waterlogging tolerance: Moderate (old man saltbush), moderate to high (river saltbush) (Figure 9.2).[120] When waterlogged, saltbush develops increased salt concentrations in the leaves, which has an adverse effect on feed quality, while plant growth and survival may also be affected[29]

Salt tolerance: Moderate to high (Figure 9.2). Optimal growth occurs at EC_e values of 25 dS/m,[25] however species will survive irrigation with seawater (~55 dS/m)[14, 421]

Nutritive value

Being a shrub, nutritive value is strongly affected by the tissue sampled. Twigs should not be regarded as forage. Dry matter digestibility (DMD) values are meaningless and should not be quoted for these plants, due to the high concentrations of salt that can accumulate in the leaves (see below).

Metabolisable energy: 7.1-7.6 MJ[285]

Crude protein: 7-17% (in summer/autumn), 17-23% (in winter)[284]

In halophyte tissues, nitrogen can also be in the form of nitrate (up to an equivalent of 2-3% crude protein) and small molecular weight amino acids like glycine betaine (up to an equivalent of 4% crude protein). These may be incorporated into microbial protein in the rumen if animals have sufficient metabolisable energy in the diet[239]

Ash: 15-39% (average 23%) – the ash is about 75% sodium chloride[29]

The salt concentration in the leaves affects feed quality. This is affected by growing conditions (levels of salinity and waterlogging), leaf age (recently formed or old), and by inherent differences between plants within populations.[29] We estimate:

less than 20% ash in leaves grown under non-saline (e.g. rangeland) conditions

~20% ash in leaves grown under saline conditions in winter

~30% ash in leaves grown under saline conditions in summer/autumn

Environmental implications

Groundwater recharge control: Saltbush can probably use groundwater at salinities up to that of seawater. Use of groundwater with EC values of ~20-30 dS/m has been reported at Kellerberrin[26, 234]

Ability to spread: Wavy-leaf saltbush is an introduced species and has shown limited spread to unsown areas. River saltbush is from low rainfall regions and some ecotypes have spread downstream of plantings. Old man saltbush has a very low tendency to spread by seed.

There are differences between saltbush species in cold tolerance. River saltbush is a sub-tropical species and while it grows well in the central and southern wheatbelt, it is best suited to the northern agricultural areas. In cooler areas wavy-leaf saltbush is preferred.[147]

Seasonal growth pattern

Saltbushes are warm season (C4) plants and as a result they generally grow slowly in winter because of the cool temperatures. They grow actively from early to mid-spring and into early summer. Summer and autumn growth depends on access to moisture from rainfall, stored soil water and from groundwater (depends on depth to watertable, salt concentration, pH and presence of other dissolved toxic ions).

Saltbushes often grow rapidly over the first and second summer as they use the water stored in the soil profile. However, in the longer term their growth rate slows down as they become more reliant on rainfall.

Establishment

Saltbush should be established using a niche seeder or nursery raised seedlings planted with a tree planter as described previously.

Livestock disorders

There are upper limits to the amount of salt that sheep can consume; for a 50 kg sheep, this limit is about 100-120 g/day provided there is a plentiful supply of non-saline water available.[239, 418] As a result, saltbush intake can be limited by the salt concentration in the feed, the amount of alternative feeds available and the salinity of the drinking water.[239]

Saltbush can contain 3-6% of oxalate.[234] Poisoning in sheep and cattle has been reported when pastures contain 7-8% oxalate.[161] Saltbush can contain iron (Fe) levels above the suggested maximum tolerable concentration for sheep of 500 mg/kg DM.[287] However, these levels of oxalates and iron present no problems if the saltbush is fed with other feeds of lower oxalate/iron content.

Management

Grazing management for saltbush aims to mix the saltbush leaf, which contains high concentrations of crude protein and salt, with other plant material of lower salt concentration.

Animals grazing saltbush need to have access to a good quality (non-saline) water supply. They will also drink a large amount of water, e.g. sheep on saltbush drink 6-9 L/day compared with 2 L/day on a low salt feed.

Saltbush plants are usually ready to be grazed after 9-12 months. Early grazing is important to increase the number of stems and reduce the development of wood. The first grazing needs to be managed carefully to ensure that the plants are quickly defoliated and there is no damage to the main stems. Aim to leave about 15% of the foliage to ensure good recovery after grazing.

Established saltbush can withstand hard grazing (complete defoliation back to bare branches) once per year. However they do not tolerate long-term continuous grazing and need to be allowed to recover after grazing. Short grazing periods (<21 days) are preferable to ensure that the regrowth is not grazed. When grazing near the start of winter, ensure that at least 10% of foliage remains after grazing.

If cereal grain supplements are fed to sheep on saltbush, then additional calcium should be considered, as the oxalate in saltbush leaves may make the low concentrations of calcium in the grain even less available.[239]

Recovery of river saltbush from simulated grazing: (a) 8 month old plant, (b) simulated grazing, (c) recovery 3 months later

9.3 Small leaf bluebush *(Maireana brevifolia)*

Small leaf bluebush

Bluebush leaf

Features

- halophytic shrub native to the eastern wheatbelt
- suited to moderately to highly saline and moderately to well drained soils
- best used in conjunction with other feeds, because of:
  - high protein concentrations
  - high salt concentrations
  - high oxalate concentrations
  - limited edible dry matter.

Small leaf bluebush is the other major halophytic shrub used in WA. It is native to the wheatbelt and is common on soils near salt lakes where the native vegetation was 'morrel' (*Eucalyptus longicornis*).

Bluebush occurs at slightly higher elevations in saline landscapes than the saltbushes. It differs from the saltbushes in having a lower tolerance to waterlogging and flooding, but has similar feed value.

The distinctive fruit consists of a woody structure (5 mm) surrounded by a papery wing up to 20 mm in diameter. Bluebush is shorter lived than some of the saltbush species, but it can maintain stand density because of its excellent seedling recruitment. It is an early coloniser of disturbed lands.

Seasonal growth pattern

Bluebush is a warm season (C4) plant which is dormant or grows only slowly in winter and then grows actively from early to mid-spring through to early summer. Growth over the summer to early autumn period depends on moisture availability, i.e. on rainfall, stored soil water and the accessibility of groundwater (which is affected by its depth and salinity). Production from bluebush is well correlated with the rainfall for the two previous years.[231]

Description

- deep-rooted perennial shrub up to 1 m high and 1 m wide
- habit is upright to semi-erect
- leaves are short (2-5 mm), fleshy and dark bluish-green
- flowers are bisexual and occur in leaf axils
- flowers from late November to July, with most seed in February and March[336]
- winged seeds scattered by the wind.

Soil–climate adaptation

Rainfall: 250-400 mm

Drought tolerance: Extreme

Frost tolerance: High
(In NSW, severe frosts killed plants back to the ground but most recovered well.)

Soil type: Medium- and fine-textured with low to high salinity (not waterlogged)

Soil fertility requirements: Fertiliser response unknown

Soil pH_{Ca}: Unknown, but commonly occurs on soils with pH_{Ca} 6-8.5 which may contain lime in the profile

Aluminium tolerance: Unknown

Waterlogging tolerance: Low (Figure 9.2)[233]

Salt tolerance: Moderate to high (Figure 9.2)

Nutritive value

Being a shrub, nutritive value is strongly affected by the tissue sampled. Twigs should not be regarded as forage. Dry matter digestibility (DMD) values are meaningless for these plants and should not be quoted, due to the high concentration of salt that can accumulate in the leaves – see below.

Metabolisable energy: 7-8 MJ[285]

Crude protein: 10-14% (in summer/autumn), 21-22% (in winter)[284]

Ash: 22-30%[417]

Environmental implications

Groundwater recharge control: As with saltbush, bluebush plants can probably use groundwater at salinities up to that of seawater. At Lake Jilakin, bluebush grew over summer using groundwater of EC 60 dS/m.[231] Observations of a bluebush stand at Jilakin indicate sustainability of grazed stands for up to 50 years.

Ability to spread: As an endemic species it is unlikely to pose serious environmental risks.

Ripe seed shed by small leaf bluebush

Establishment

If there is a nearby stand of bluebush, fencing and protecting an adjacent area for two to three years will lead to colonisation – the lowest cost establishment strategy. Alternatively, bluebush can be introduced into an area by sowing with a niche seeder, or less reliably by spreading seed onto cultivated soil. Only recently collected seed should be sown as seeds lose their viability within a year when stored at ambient temperature and relative humidity.

Livestock disorders

Bluebush can contain high concentrations (9-12%) of oxalate. Hungry sheep should not be introduced to bluebush unless other feed is also available. It should be fed with other pasture, stubble or hay.

Bluebush can also accumulate nitrates (1,000-3,000 mg N/kg DM).[239]

Management

Farmers often use bluebush in summer to late autumn with stubble or pasture as discussed above. Bluebush can be grazed hard in autumn, but it should be grazed for short periods (two to three weeks) and then allowed to recover.

Cultivars

There are no commercial cultivars, but there are distinct ecotypes in the agricultural area.[229]

9.4 Halophytic grasses

The major salt-tolerant grasses used in Australia are puccinellia (*Puccinellia ciliata*) and tall wheat grass (*Thinopyrum ponticum*). Many saline sites are a mosaic of severely and moderately saline/waterlogged land. In these cases, sowing a mixture of tall wheat grass and puccinellia results in the puccinellia colonising the more waterlogged/saline bare land where it has a competitive advantage and tall wheat grass establishing in the less waterlogged/saline areas.

Two other grasses of interest for WA are distichlis (*Distichlis spicata*) and saltwater couch (*Paspalum vaginatum*). These grasses are highly waterlogging and salt-tolerant and are propagated vegetatively. The warm season (C4) grasses Rhodes grass, kikuyu and bambatsi panic are reported to have some salt tolerance and may have a role on marginally saline soils (Chapter 5).

Establishment

The keys to successful establishment of salt-tolerant grasses are similar to those for the establishment of shrubs. Sites for puccinellia and tall wheat grass should receive more than 350 mm of annual rainfall and should be dry at the surface in summer.

- Site preparation. It is essential to get good control of sea barley grass (*Hordeum marinum*), which is the major grass competitor. Sea barley grass possesses little or no dormancy and does not persist in the soil. More than 99% of the seed will germinate in the first few weeks after the autumn rains. Germination is not stimulated by tillage.[300] Sea barley grass can be readily controlled if a combination of strategies are used. In the year before seeding, graze hard then spray-top in spring. Then burn off the dry grass in the autumn and use a knockdown before seeding.
- Extended surface ponding inhibits germination, so construct surface water control structures such as W-drains to decrease inundation and waterlogging of the surface soil. Cultivate the area roughly before the break of the season, to provide a variety of micro-sites in which seed can lodge and germinate.
- Timing of seeding. If there is an early break, wait for the sea barley grass to germinate (two to four weeks), then spray with a knockdown herbicide and sow. When there is a late break, wait two weeks before applying a knockdown spray and then seed immediately.
- It is essential that seed is fresh since germination declines rapidly if the seed is more than two years old.[278, 279] Apply superphosphate (50-100 kg/ha), but no nitrogen at seeding.
- Grazing. Prevent uncontrolled grazing of young plants. Protect stands from heavy grazing for at least 18 months (two winters).

Saltland pasture showing zonation between puccinellia (foreground) and tall wheat grass

9.5 Puccinellia *(Puccinellia ciliata)*

Puccinellia seed head

Features

- moderately salt-tolerant and moderate to highly waterlogging tolerant perennial grass
- suitable for winter wet, summer dry saline sites
- tolerates partial inundation over winter
- 'resurrection grass' – green in winter, dry in summer
- often used as pioneer species on bare saltland
- prefers neutral to alkaline, calcareous soils
- responsive to nitrogen fertiliser.

Puccinellia was introduced into WA by CSIRO in the early 1960s as a pioneer plant for revegetating saltland.[326] It has been widely sown in WA, but most stands are poorly managed. On the other hand, in South Australia puccinellia is one of the great saltland pasture success stories. Puccinellia is grown extensively on the low-moderately saline, but highly waterlogged soils of the Eyre Peninsula and the Upper South East. It is used to fill the autumn feed gap, with carrying capacities up to 32 DSE/ha for three months. An export seed industry has also been established in the region.

The relative failure of puccinellia to thrive on WA soils may be due to the combination of low pH and low availability of calcium. Recent research has shown that puccinellia appears to prefer alkaline, calcareous soils.[167] The benefits of lime and/or gypsum have yet to be assessed for WA soils.

Puccinellia is well suited to winter waterlogged, saline sites with a patchy cover of sea barley grass (*Hordeum marinum*) or bare ground. On non-saline soils it usually behaves as a low productive annual grass and is out-competed.[293] Puccinellia is best used to meet the autumn feed gap reducing the reliance on supplementary feeding.

Seasonal growth pattern

Puccinellia is a 'resurrection grass', as the plants hay-off in late-spring and remain dormant over summer. They shoot vigorously from the tiller bases after the opening rains and heavy dews in mid-autumn, and then have good winter production. The stand can be thickened by allowing it to set seed. Seed will not germinate on summer rain as it is inhibited by high temperatures (>30°C).[273, 326]

Description

- densely tufted, perennial bunch grass up to 40 cm high and wide
- long, thin (1-4 mm), greyish-green leaves
- seed head is an open, panicle (35-40 cm high)
- flowers in September, with seed ripe by December.

Puccinellia is tolerant of waterlogging and inundation

Establishment

Successful establishment requires excellent weed control as puccinellia seedlings compete poorly with annual weeds, in particular sea barley grass (refer to 'establishment of halophytic grasses' in the previous section). The suggested seeding rate is 2-4 kg/ha when sown alone, or 1-3 kg/ha when sown in a mixture with tall wheat grass.

In general, puccinellia should be sown before the end of June while the conditions are still mild. Puccinellia has a very small seed (6.6 million/kg) and needs to be sown shallow (<5 mm) or broadcast on the surface. Covering harrows are not recommended for puccinellia because of its small seed. The seedlings are slow to establish, however very small plants can persist through the first summer.[293]

Puccinellia normally takes at least a year to become well established. It should not be grazed in the first year as sheep can uproot the plants. Light grazing is possible in the second year.

Soil–climate adaptation

Rainfall: >350 mm

Drought tolerance: Very high

Frost tolerance: High

Soil type: Moderately saline, highly waterlogged soils; prefers calcareous soils

Soil fertility requirements: Requires both N and P to thrive

Soil pH_{Ca}: 5.5-8.0

Aluminium tolerance: Unknown

Waterlogging tolerance: High to very high (Figure 9.2). Also tolerates partial inundation[326]

Salt tolerance: Moderate to high. Occurs in the field over an EC_e range of 5-40 dS/m, with best growth at 16-32 dS/m[140, 353]

Nutritive value

The grazing value of puccinellia depends on its growth stage. It has good feed quality during winter and early spring, but declines with flowering and as the leaves dry off[149, 150, 269]

DMD: 60-78% (in winter and early spring), <50% (in summer)

Crude protein: 10-18% (in winter and early spring), <5% (in summer)

Ash: ~10%[363]

Environmental implications

Soil erosion control: Often sown as a pioneer plant on eroded saltland where the topsoil has been lost.

Puccinellia grows actively from late autumn to spring (left), but is dormant in summer (right)

Puccinellia often colonises waterlogged-saline bare ground

Seed ripens by December and can be harvested at any time during the summer with little risk of shedding. The seed is difficult to harvest because it is small and light. A conventional closed-front cereal harvester can be used with some adjustment. Use the maximum drum speed with a drum clearance of 1.5 mm front and rear. Cut off the air blast completely by loosening belts and covering vents. Use a wheat riddle on top, a lupin screen fitted to the rear and a canola screen on the bottom. The puccinellia seed is taken off into the seconds box.[347]

Livestock disorders

None reported.

Management

Established stands are tolerant of heavy grazing as the growing points are embedded in the base. Puccinellia can be grazed hard in autumn and winter, provided the soils are not too wet (avoid pugging) or there is a possibility of inundation, as immersion can kill plants. A lower grazing pressure in spring is recommended, so that a dense plant cover reduces salt accumulation at the surface. Dry material grazed in late summer is palatable, but of low quality and may not be sufficient for maintenance.

Growth is highly responsive to applications of nitrogen in late winter. In one trial in SA, a split application of 65 kg N/ha (25% in June, 75% in August) increased dry matter production from 2.2 to 7.8 t/ha. There were similar relative benefits for seed production.[242] Anecdotal evidence also suggests that puccinellia is responsive to N-fertiliser on WA soils.[275]

Companion species

Puccinellia is often sown in a mixture with tall wheat grass. However, they have different growth patterns and may require different grazing management. Puccinellia grows actively from late autumn to mid-spring, while tall wheat grass grows actively from spring through to autumn.

Cultivars

'Menemen' (public variety) is the only cultivar. It was originally collected from the west coast of Turkey in 1951 from a village near the town of Menemen, hence the name.[293] It is marketed in South Australia as 'Restora sweet grass'.

9.6 Tall wheat grass *(Thinopyrum ponticum)*

Features

- tall, summer-active, temperate perennial bunch grass
- moderate salt tolerance; low to moderate waterlogging tolerance
- slow to establish
- grazing management is critical for feed quality
- useful alternative on non-saline soils.

Tall wheat grass (formerly *T. elongatum*, *Agropyron elongatum*, *Elymus elongatus*) comes from the Balkans, Asia Minor and southern Russia. The tall wheat grass grown in Australia was originally collected by the American 'Westover-Enlow' expedition near Bandirma in northern Turkey in 1934. The plant was bulked up and released in 1937 by the United States Department of Agriculture as the cultivar Largo. After introduction to Australia, selection pressure changed the genetic constitution of the line, and it was renamed Tyrell after a salt-affected parish and salt lake in Victoria.[141, 293, 362] Tall wheat grass has been grown on saltland in WA since at least the mid-1940s.[387]

Tall wheat grass is now widely grown on summer-moist soils of low to moderate salinity which were previously dominated by sea barley grass.[140, 278, 353] It does not persist on soils that are waterlogged over spring and into summer. Tall wheat grass can be a productive option on non-saline soils.

Tall wheat grass can lower shallow water-tables and decrease soil salinity, providing an opportunity to promote the growth of companion annual legumes. Stands of tall wheat grass can use up to 4 mm/day of groundwater in summer.[43] There are reports of surface soil salinities (EC_e values in the upper 10 cm of the soil profile) declining from 5 to 1 dS/m in four years.[279]

Many old stands of tall wheat grass have been poorly managed, giving it a reputation as producing low quality feed. When under-grazed it becomes coarse, unpalatable and is a low quality feed. Good grazing management is critical to maintain feed quality and palatability, as the quality drops markedly as the plant matures. On the other hand, when well managed the dry matter production and feed quality of tall wheat grass were similar to tall fescue and perennial ryegrass on a non-saline soil in Victoria.[364]

Description

- tussock-forming temperate (C3) perennial grass up to 1 m tall (seed heads to 1.6 m)
- leaves are greyish or bluish-green, up to 30 cm long, 4-8 mm wide with thick veins
- leaves are rough on the upper surface and margins
- seed head is an erect spike 10-30 cm long
- good seed yields, although mature spikes shatter easily.

Tall wheat grass can also be planted in hedge-rows about 1 m wide for shelter in maternity paddocks to improve lamb survival. The grass in the hedge-rows is allowed to become tall and rank, so it is unpalatable and stock do not eat it.

Seasonal growth pattern

Tall wheat grass has slow winter growth with most growth occurring from spring onwards. Subsoil moisture or rain over summer is necessary for good production. It sets seed from January to March.

The growth pattern is typical for many species coming from regions with cold winters. As a summer-active perennial, tall wheat grass is more productive in areas with moist summers and autumns.

Establishment

Good weed control is a prerequisite for successful establishment as tall wheat grass does not compete strongly with annual weeds (refer to 'establishment of halophytic grasses' in the section above). Preferably, tall wheat grass should be sown under mild conditions, either after the break of season in May-early June or in late July to mid-August as the soil temperatures increase. In low rainfall areas only early seeding is recommended, as the plants need to be well established before summer.

The suggested seeding rate is 10 kg/ha when sown alone, or 4-10 kg/ha when sown in a mixture. The seed should be sown at a depth of 5-20 mm with good seed to soil contact.

Tall wheat grass has a large seed (130,000-150,000/kg) and germinates well, but seedling growth is comparatively slow. It should not be grazed during the first year, unless the seasonal conditions are favourable, the crown is well developed and the plants are strongly anchored.

Livestock disorders

None reported.

Soil–climate adaptation

Rainfall: >375 mm (>350 mm south coast)

Drought tolerance: High to very high

Frost tolerance: High

Soil type: Wide range from acid, sandy duplex, to alkaline medium- to fine-textured soils, including saline soils which dry out in summer to form a hard crust

Soil fertility requirements: Growth, palatability and feed quality all respond to N

Soil pH_{Ca}: 4.5-8.5

Aluminium tolerance: Unknown

Waterlogging tolerance: Moderate (Figure 9.2)

Salt tolerance: Moderate
Occurs over an EC_e range in the field of 5-40 dS/m, with best growth at 16-32 dS/m[140, 353]

Nutritive value

DMD: 54% (summer) to 80% (spring)[50]

Crude protein: 7% (summer) to 27% (spring)[50]

Ash: ~7%[417]

Environmental benefits

Groundwater recharge control: Tall wheat grass lowered the watertable and reduced winter waterlogging compared with the volunteer pasture at a site in the Great Southern[325]

Management

The quality of tall wheat grass declines rapidly with maturity, so it is important to graze the pasture before the stems are fully mature. Heavy crash grazing encourages leafiness and helps maintain feed quality.[364]

When tall wheat grass is planted with balansa clover, grazing in spring should be regulated to allow the balansa to flower and set seed.[278, 279] Balansa clover requires grazing in winter to control weeds, but avoid grazing waterlogged soils to prevent pugging of the soil surface. Grazing needs to stop when the balansa clover starts flowering (usually in September) and can recommence when the balansa seed has matured (usually in November-December). Tall wheat grass is most palatable in January and can be grazed heavily over summer. The pasture should consist of a uniform stubble 3-5 cm high by the end of summer to prevent clumps becoming rank. Stock should be removed in late autumn to allow the tall wheat grass to develop seed heads and for the balansa clover to regenerate.[279]

Recent research has shown that tall wheat grass is susceptible to stripe rust of wheat (*Puccinia striiformis* f.sp. *tritici*). Maintain grazing pressure in years with summer rain to minimise the 'green bridge' effect.[228]

Fertilise with nitrogen in late winter (to 50 kg N/ha) and graze the following summer/early autumn. Nitrogen application is particularly worthwhile if harvesting seed during the following summer. Seed can be harvested in early autumn by cutting and swathing the grass two to three (but not more than four) weeks after flowering, then picking up the material about five days later with an open front header.[347]

Companion species

Tall wheat grass can be grown as a companion species to legumes (balansa clover, strawberry clover and Persian clover) and other perennial grasses (puccinellia, phalaris and tall fescue) depending on site conditions.

Cultivars

There are two cultivars available in Australia.

The most widely used is 'Tyrell' (public variety), which originated from seed imported into Australia from the US as the variety Largo.[293]

'Dundas'⁽ᵠ⁾ was released by Agriculture Victoria in 1999. It was selected from Tyrell for enhanced leafiness and improved feed quality and disease resistance.

Tall wheat grass should be grazed hard in late summer (bottom) to prevent it from going rank (top)

9.7 Other species

Distichlis *(Distichlis spicata)*

Distichlis comes from the coastal areas of North and South America. It occurs in brackish to saline marshes and on beaches and salt flats, usually above the high tide-line, but occasionally in the upper inter-tidal zone.[451]

Distichlis is a warm season (C4) grass that has high waterlogging tolerance, some tolerance to inundation and moderate to high salinity tolerance (Figure 9.2). The roots form aerenchyma (air channels), which enable gas exchange with the atmosphere under waterlogged conditions. Optimum growth for distichlis is 7-28 dS/m, but it will survive at 80 dS/m (equivalent to 150% of seawater).[207] The leaves have highly efficient salt glands, so salt concentrations in the leaves are likely to be lower than other forages grown under similar conditions of salinity and waterlogging.

Description

- low, creeping perennial grass with both stolons (runners) and shallow rhizomes
- leaves are borne on erect culms arising from the stolons and rhizomes
- leaf blades, are pointed, stiff and covered with microscopic salt glands
- the NyPa Forage™ type produces no seed and is propagated vegetatively.

The following comments focus on the use and value of a selection of distichlis marketed as NyPa Forage™, which is a male clone and is vegetatively propagated. It is still being assessed for WA conditions. Only the sterile NyPa Forage™ clones are permitted in WA.

Establishment

Establishment is currently difficult and time consuming as vegetative propagation relies on transplanting established root material. One farmer has established 1-2 ha/day on a 1x1 m grid using a broccoli planter to plant harvested tillers about 5 cm into the soil.

Nutritive value

Sheep and cattle have been observed grazing distichlis. Limited measurements of young growth (10-15 cm) gave the following results: crude protein 10-17%, dry matter digestibility 55-60% and ash 6.5-11.7%.[207]

Environmental implications

Distichlis has the ability to control erosion on bare saline soils. Its ability to spread and weed potential are unknown.

Management

Distichlis is tolerant of heavy grazing due to its rhizomatous growth habit. There is limited information on fertiliser response and animal performance.

Distichlis showing rhizomatous growth habit

Distichlis is a highly salt-tolerant warm season (C4) grass

Salt water couch *(Paspalum vaginatum)*

Salt water couch (seashore paspalum) is a warm season (C4) creeping grass with both rhizomes and stolons. It comes from the coastal areas of southern and eastern Africa. It has been widely distributed throughout the world, firstly because it was used as bedding in slave ships and secondly as a salt-tolerant forage. It occurs naturally on sandy beaches, banks of estuaries, saline swamps and areas which are frequently inundated with salt water.[29]

Salt water couch has high tolerance to waterlogging and moderate to high tolerance to salinity (Figure 9.2). It is also tolerant to inundation and has been observed growing in shallow standing water lower in the landscape than puccinellia. It was one of the first saltland reclamation species used in WA.[54] Salt water couch performed well on a range of saline sites in NSW, (pH_w 5.0-8.8 and 4-52 dS/m).[353] It can also be used as a lawn grass using fresh or saline irrigation water but has low drought tolerance. It can be an invasive weed of wetlands.

Description

- low, creeping perennial grass with both stolons and deep rhizomes
- bright green foliage, with hairless leaves 40-90 mm long and 2-3 mm wide
- leaf blades taper and roll inwards towards the point
- inflorescence is a pair of spike-like racemes which are at first erect but spread with maturity to form a flat V-shape.

Establishment

Seed production is unreliable, so the species is vegetatively propagated.

Nutritive value

No information is available on grazing value, but the species persists with heavy grazing and is palatable.

Environmental implications

Salt water couch controls erosion in seepages and gullies, but may build up the surface level and cause run-off to divert. It has become an invasive weed in areas such as the shores of Wilson Inlet.

Salt water couch

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APPENDIX 1 Summary of soil and climate tolerances for perennial pasture species

Appendix 1.1 Herbaceous legumes

Please refer to the key for definitions of each category. Where there are major differences between ‘types’ or varieties these are noted in the table, otherwise the rating is for the species as a whole.

Common name (Species)	Main varieties	Cool season growth	Frost tolerance	Drought tolerance	Opportunistic summer growth	Acid soil tolerance (pH_{Ca})	Waterlogging tolerance	Inundation tolerance	Salt tolerance
Birdsfoot trefoil (*Lotus corniculatus*)	Goldie	Good	High	Moderate	Slow to responsive	>4.5	Moderate	Low	Nil
Greater lotus (*Lotus uliginosus*)	Maku, Sharnae	Good	High	Low	Slow to responsive	>4.0	Very high	High	Nil
Lotononis (*Lotononis bainesii*)	Miles	Dormant to slow	Low to moderate	Moderate	Highly responsive	>4.0	Moderate to high	Moderate	Nil
Lucerne (*Medicago sativa*)	Various (vary in their winter activity)	Moderate to good (winter-active) dormant to slow (winter-dormant)	High	Very high	Highly responsive	>4.8	Low	Nil	Slight to mod. low, if not waterlogged
Narrow-leaf trefoil (*Lotus glaber*)	Not yet commercial	Good	High	Moderate	Slow to responsive	>5.0	Moderate to high	Low	Slight to mod. low
Siratro (*Macroptyllium atropurpureum*)	Siratro, Aztec atro	Dormant	Sensitive	Moderate to high	Highly responsive	>4.5	Low	Nil	Slight to mod. low, if not waterlogged
Strawberry clover (*Trifolium fragiferum*)	Palestine	Moderate to good	High	Low to moderate	Slow	>4.8-5.5	High (at low salinity)	Moderate	Slight to mod. low
Sulla (*Hedysarum coronarium*)	Various	Good to very good (in second year)	Moderate to high	High	Summer-dormant to slow	>5.0-5.5	Low	Nil	Nil
White clover (*Trifolium repens*)	Various	Good	High	Low	Slow	>5.0	Moderate to high	Low	Nil to slight

Appendix 1.2 Temperate grasses

Refer to the key for definitions of each category. Where there are major differences between ‘types’ or varieties these are noted in the table, otherwise the rating is for the species as a whole.

Common name (Species)	Main varieties	Cool season growth	Frost tolerance	Drought tolerance	Opportunistic summer growth	Acid soil tolerance (pH_{Ca})	Waterlogging tolerance	Inundation tolerance	Salt tolerance
Cocksfoot (*Dactylis glomerata*)	Currie, Porto	Good	Moderate to high	High	Slow to responsive	>4.0	Low	Nil	Nil
Perennial ryegrass (*Lolium perenne*)	Various	Very good	High	Low	Slow to responsive	>4.5	Low to moderate	Low	Nil to slight
Perennial veldt grass (*Ehrharta calycina*)	Mission	Good	Moderate	Very high	Slow to responsive	>4.0	Low	Nil	Nil (?)
Phalaris (*Phalaris aquatica*)	Various	Very good	High	High	Summer-dormant to slow	>4.7	Moderate	Low	Slight
Puccinellia (*Puccinellia ciliata*)	Menemen	Good	High	Very high	Summer-dormant	>5.5 (will persist at lower pH)	Very high	Moderate	Moderate to high
Tall fescue (*Festuca arundinacea*)	Summer–active	Moderate	High	Moderate	Responsive	>4.3	High	High	Slight
Tall fescue (*Festuca arundinacea*)	Winter-active, summer-dormant	Very good	High	Moderate to high	Summer-dormant	>4.3	High	High	Slight
Tall wheat grass (*Thinopyrum elongatum*)	Tyrell, Dundas	Slow to moderate	High	High to very high	Responsive	>4.5	Moderate	Low	Moderate

Appendix 1.3 Sub-tropical grasses

Refer to the key for definitions of each category. Where there are major differences between 'types' or varieties these are noted in the table, otherwise the rating is for the species as a whole.

Common name (Species)	Main varieties	Cool season growth	Frost tolerance	Drought tolerance	Opportunistic summer growth	Acid soil tolerance (pH_{Ca})	Waterlogging tolerance	Inundation tolerance	Salt tolerance
Bambatsi panic (*Panicum coloratum*)	Bambatsi	Dormant	Low	High to very high	Highly responsive	>5.0 (est.)	Moderate	Moderate	Moderately low if not waterlogged
Consol lovegrass (*Eragrostis curvula*)	Consol lovegrass	Dormant to slow	Moderate	High to very high	Highly responsive	>4.0 (est.)	Low to moderate	Nil	Slight
Digit grass (*Digitaria eriantha*)	Premier digit grass	Dormant	Low to moderate	Moderate to high	Highly responsive	>4.2 (est.)	Low	Nil	Nil
Kikuyu (*Pennisetum clandestinum*)	Whittet	Dormant to slow	Moderate	Moderate to high	Highly responsive	>4.0	Moderate	Low	Slight to mod. low if not waterlogged
Panic grasses (*Megathyrsus maximus*)	Green panic Gatton panic	Dormant to slow	Sensitive to low	Moderate to high	Highly responsive	>4.3 (est.)	Low	Nil	Nil
Paspalum (*Paspalum dilatatum*)	Common	Dormant	Moderate	Moderate	Highly responsive	>4.3 (est.)	Moderate to high	Low to moderate	Nil
Rhodes grass (*Chloris gayana*)	Main differences between diploid and tetraploid varieties are noted	Dormant to slow	Low	High (diploid) Moderate (tetraploid)	Highly responsive	>4.3	Moderate	Low	Mod. low (diploid) if not waterlogged Slight (tetraploid)
Setaria (*Setaria sphacelata*)	Various	Dormant to slow	Sensitive to moderate	Moderate	Highly responsive	>5. (est.)	Moderate	Low to moderate	Nil
Signal grass (*Urochloa decumbens*)	Basilisk	Dormant	Sensitive	Moderate	Highly responsive	>4.0 (est.)	Low to moderate	Low	Nil

Appendix 1.4 Shrubs and herbs

Refer to the key for definitions of each category. Where there are major differences between 'types' or varieties these are noted in the table, otherwise the rating is for the species as a whole.

Common name (Species)	Main varieties	Cool season growth	Frost tolerance	Drought tolerance	Opportunistic summer growth	Acid soil tolerance (pH_{Ca})	Waterlogging tolerance	Inundation tolerance	Salt tolerance
Bluebush (*Maireana brevifolia*)	Local collected seed	Slow to moderate	High	Extreme	Responsive	Unknown	Low	Low	Moderate to high
Chicory (*Cichorium intybus*)	Various	Slow	Moderate	Moderate to high	Highly responsive	>4.3	Low	Nil	Slight
Golden wreath wattle (*Acacia saligna*)	Local collected seed	Good	High	Very high	Responsive	>4.0 (est.)	High	Moderate	Moderate
Plantain (*Plantago lanceolata*)	Lancelot, Tonic	Moderate	Moderate	Moderate	Slow to responsive	4.2-7.8	Low to moderate	Nil	Nil
Saltbush (*Atriplex* spp.)	Local collected seed	Slow to moderate	High	Extreme	Responsive	4-8.5	Moderate to high	Moderate	Moderate to high
Tagasaste (*Chamaecytisus palmensis*)	Local collected seed	Good	Moderate	High	Responsive	4.0-7.5	Nil to low	Nil	Nil

KEY:

Cool season growth

Dormant in cool season	–	typically requires temperatures above 20°C/15°C (day/night) for growth
Slow growth in cool season	–	typically growth is restricted by temperatures <18°C/13°C
Moderate cool season growth	–	typically growth is restricted by temperatures <15°C/10°C
Good cool season growth	–	typically growth restricted by day temperatures <12°C
Very good cool season growth	–	typically growth restricted by day temperatures <9°C

Frost tolerance

Sensitive to frosts	–	extensively damaged by light frosts, with some plant deaths
Low frost tolerance	–	typically green-leaf is killed by mild frosts with occasional plant deaths
Moderate frost tolerance	–	withstands mild frosts, leaf damage when frosts less than -3°C
High frost tolerance	–	usually minimal damage to foliage from frosts

Drought tolerance

Low drought tolerance	–	typically requires a growing season length >8 months to persist
Moderate drought tolerance	–	typically requires a growing season length >6.5 months to persist
High drought tolerance	–	typically requires annual rainfall >450 mm and/or growing season length >5.5 months to persist
Very high drought tolerance	–	can persist where annual rainfall >325 mm
Extremely drought tolerant	–	can persist when annual rainfall >250 mm

Waterlogging tolerance

Nil waterlogging tolerance	–	only persists on well drained sites
Low waterlogging tolerance	–	persists on moderately well drained sites (perched watertable within 30 cm for 1-3 weeks depending on the season)
Moderate waterlogging tolerance	–	persists on imperfectly drained sites (perched watertable within 30 cm of the surface for 3-6 weeks in an average season, longer in a wet season)
High waterlogging tolerance	–	persists on poorly drained sites (perched watertable within 30 cm of the surface for more than 10 weeks in an average season)
Very high waterlogging tolerance	–	persists on very poorly drained sites, where the soil is inundated or the profile is saturated for more than 3 months in most years

Inundation tolerance

Nil	–	killed by inundation of more than 1 day
Low	–	tolerates short periods of inundation (<1 week)
Moderate	–	tolerates inundation for 2-4 weeks
High	–	tolerates extended periods of inundation (1-3 months)

Salt tolerance

Nil salt tolerance	–	only grows on non-saline soils (EC_e <2 dS/m)
Slight salt tolerance	–	can grows on soils with an EC_e 2-4 dS/m
Moderately low salt tolerance	–	can grow on soils with an EC_e 4-8 dS/m
Moderate salt tolerance	–	can grow on soils with an EC_e 8-16 dS/m
Highly salt tolerant	–	halophytes which can grows on soils with an EC_e >16 dS/m

Opportunistic summer growth (refers to response to summer rain events greater than 10-15 mm)

Summer dormant	–	negligible summer growth
Slow summer growth	–	often a delayed response with low biomass production
Responsive	–	grows actively in response to summer rain
Highly responsive	–	grows rapidly in response to summer rain

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