Chapter 3
Herbaceous perennial legumes

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89, 91, 92; Pia Scanlon (DAFWA Image Resource Centre):
page 54 (flowers, foliage), 59 (leaflets), 78 (flower, leaflets);
Jonathan Warden (UWA): page 54 (plant).
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** \( \text{Ca} \): 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:

<table>
<thead>
<tr>
<th>Tolerance Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low drought tolerance</td>
<td>typically requires a growing season length &gt;8 months to persist</td>
</tr>
<tr>
<td>Moderate drought tolerance</td>
<td>typically requires a growing season length &gt;6.5 months to persist</td>
</tr>
<tr>
<td>High drought tolerance</td>
<td>typically requires annual rainfall &gt;450 mm and/or growing season length &gt;5.5 months to persist</td>
</tr>
<tr>
<td>Very high drought tolerance</td>
<td>can persist where annual rainfall &gt;325 mm</td>
</tr>
<tr>
<td>Extremely drought tolerant</td>
<td>can persist when annual rainfall &gt;250 mm</td>
</tr>
</tbody>
</table>

### Frost tolerance:

<table>
<thead>
<tr>
<th>Tolerance Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitive to frosts</td>
<td>extensively damaged by light frosts, with some plant deaths</td>
</tr>
<tr>
<td>Low frost tolerance</td>
<td>typically green-leaf is killed by mild frosts with occasional plant deaths</td>
</tr>
<tr>
<td>Moderate frost tolerance</td>
<td>withstands mild frosts, leaf damage when frosts less than –3°C</td>
</tr>
<tr>
<td>High frost tolerance</td>
<td>usually minimal damage to foliage from frosts</td>
</tr>
</tbody>
</table>

### Waterlogging tolerance:

<table>
<thead>
<tr>
<th>Tolerance Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nil waterlogging tolerance</td>
<td>only persists on well drained sites</td>
</tr>
<tr>
<td>Low waterlogging tolerance</td>
<td>persists on moderately well drained sites (perched watertable within 30 cm for 1-3 weeks depending on the season)</td>
</tr>
<tr>
<td>Moderate waterlogging tolerance</td>
<td>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)</td>
</tr>
<tr>
<td>High waterlogging tolerance</td>
<td>persists on poorly drained sites (perched watertable within 30 cm of the surface for more than 10 weeks in an average season)</td>
</tr>
<tr>
<td>Very high waterlogging tolerance</td>
<td>persists on very poorly drained sites, where the soil is inundated or the profile is saturated for more than 3 months in most years</td>
</tr>
</tbody>
</table>

### Salt tolerance:

<table>
<thead>
<tr>
<th>Tolerance Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nil salt tolerance</td>
<td>only grows on non-saline soils (EC(_e) &lt;2 dS/m)</td>
</tr>
<tr>
<td>Slight salt tolerance</td>
<td>can grow on soils with an EC(_e) 2-4 dS/m</td>
</tr>
<tr>
<td>Moderately low salt tolerance</td>
<td>can grow on soils with an EC(_e) 4-8 dS/m</td>
</tr>
<tr>
<td>Moderate salt tolerance</td>
<td>can grow on soils with an EC(_e) 8-16 dS/m</td>
</tr>
<tr>
<td>Highly salt tolerant</td>
<td>halophytes which can grow on soils with an EC(_e) &gt;16 dS/m</td>
</tr>
</tbody>
</table>
**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. 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. 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 \( \text{Ca} < 4.8 \)), 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.
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. It is a long day plant and requires day lengths of more than 16 hours to flower profusely.

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.

Establishment
Birdsfoot trefoil requires careful management for successful establishment because of its small seed size (0.8 x 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. 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.
Herbaceous perennial legumes

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).
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. 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.
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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.20 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

Soil–climate adaptation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall</td>
<td>&gt;600 mm (&gt;500 mm south coast)</td>
</tr>
<tr>
<td>Season length</td>
<td>&gt;7.5 months</td>
</tr>
<tr>
<td>Drought tolerance</td>
<td>Low</td>
</tr>
<tr>
<td>Frost tolerance</td>
<td>High</td>
</tr>
<tr>
<td>Soil type</td>
<td>Range including sandy duplex, medium- and fine-textured soils</td>
</tr>
<tr>
<td>Soil fertility requirements</td>
<td>Low to medium, efficient at extracting P due to extensive lateral root system</td>
</tr>
<tr>
<td>Soil pH&lt;sub&gt;c&lt;/sub&gt;</td>
<td>&gt;4.0</td>
</tr>
<tr>
<td>Aluminium tolerance</td>
<td>Moderate to high350</td>
</tr>
<tr>
<td>Waterlogging tolerance</td>
<td>Very high</td>
</tr>
<tr>
<td>Salt tolerance</td>
<td>Nil350</td>
</tr>
<tr>
<td>DMD</td>
<td>75% (young growth) to 65% or less in old growth</td>
</tr>
<tr>
<td>Crude protein</td>
<td>20%</td>
</tr>
</tbody>
</table>

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<sub>c</sub>: >4.0
Aluminium tolerance: Moderate to high350
Waterlogging tolerance: Very high
Salt tolerance: Nil350
DMD: 75% (young growth) to 65% or less in old growth
Crude protein: 20%
**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. It is a highly palatable pasture with similar feed quality to lucerne and is grown in sub-tropical environments including coastal Queensland and Uruguay. 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 9ºC. 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.

**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.
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Lotononis can be sown from late winter to early spring providing there is excellent weed control. It has small seeds (3 x 10⁶ 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. 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.

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.

Establishment
Lotononis can be sown from late winter to early spring providing there is excellent weed control. It has small seeds (3 x 10⁶ 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.

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Lotononis must be inoculated with specific Rhizobium (CB 376) and lime coated. 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.

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.

Establishment
Lotononis can be sown from late winter to early spring providing there is excellent weed control. It has small seeds (3 x 10⁶ 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.

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

**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.

**Cultivars**

There are two cultivars of lotononis, ‘Miles’ (public variety) and ‘INIA Glencoe’.

Miles was released in Queensland in 1966 after extensive agronomic evaluation in Australia. 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.
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<sub>Ca</sub> > 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. 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. 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.

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. 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;
- increased water use and pasture biomass than an annual pasture-crop rotation;
- increased animal production in terms of liveweight and wool quality;
- 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;
- provision of a disease break compared with continuous cropping;
- the ability to control weeds using non-selective chemicals, thereby providing another option to prevent or control herbicide resistant weeds. Good weed management will, in turn, increase the legume component and nitrogen accumulation for subsequent rotations.

**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...
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. 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.

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

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**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**

- Gravel
- Yellow sand
- White sand
- Duplex soil

*Lucerne*  
*Serradella pasture*
Herbaceous perennial legumes

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.38

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.
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.25

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. Trifuralin 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

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
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. 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/m² 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.

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. 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). 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. 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.
Establishing new lucerne is also an opportunity to apply the minor trace elements like copper, zinc and molybdenum, if tissue tests identify a deficiency. 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. 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. 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.

**Cover-cropping**

Cover-cropping (or companion cropping) refers to sowing lucerne with an annual crop such as wheat, barley, canola or oats. 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 3.1 Advantages and disadvantages of early, mid- and late sowing of lucerne

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

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

**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.
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 CaCO₃ 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
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. 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.

Stem nematode, root-knot nematode and lesion nematodes can damage lucerne and infect a subsequent crop. 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.

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.

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. 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. 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.

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. 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. 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).

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.

Bloat is the main health issue for cattle grazed on lucerne, but is less of a problem for sheep. 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.

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. 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.

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.

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:

- **Grazing 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.

- **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.

- **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.
Herbaceous perennial legumes

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. Lucerne can also be grown with temperate perennial grasses like tall fescue and cocksfoot.

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.

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.

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

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).

![Figure 3.4 Starch levels in lucerne after cutting or grazing (adapted from Boschma and Williams, unpublished)](image-url)
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.
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. 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. 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.
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.

**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.
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 shows that ‘shaded’ varieties are commercially available in WA.

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74 Perennial pastures for Western Australia
### Table 3.3 (continued)

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WAR – Winter-activity rating where 10 is very high to 1 is low (winter-dormant).
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.²⁴

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.
Perennial pastures for Western Australia

Herbaceous perennial legumes

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.

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.

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: >5.0
Aluminium tolerance: Medium to high350
Waterlogging tolerance: Moderate to high
Salt tolerance: Moderately low
Nutritive value
DMD: 60-68%
Crude protein: 19-22%

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 subtropical 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.\(^\text{101, 355}\) 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.\(^\text{360, 383}\) 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.\(^\text{71}\)

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.\(^\text{449}\)

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.
Perennial pastures for Western Australia

Herbaceous perennial legumes

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.

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.

‘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.

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.

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

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

Soil fertility requirements: High phosphorus and potassium are beneficial

Soil pH\textsubscript{\text{cr}}: >4.5-8.0

Waterlogging tolerance: Low

Salt tolerance: Moderately low

Nutritive value

DMD: 60% (seasonal range 55-64%)

Crude protein: 15%

Siratro dominant pasture

Good establishment of siratro in the northern agricultural region

Siratro dominant pasture

Siratro dominant pasture
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 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<sub>6.5</sub>: >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.

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. Susceptible to redlegged earth mite and root-knot nematodes (Meloidogyne spp.).

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’ 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. 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
- 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.
Herbaceous perennial legumes

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

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
Soil fertility requirements: Moderate to high
Soil pH: >5.0-5.5
Prefers neutral to alkaline, especially highly calcareous soils, however will tolerate slightly acid soils providing the fertility is good
Aluminium tolerance: Unknown
Waterlogging tolerance: Low to moderate
Salt tolerance: Nil
Ability to spread naturally: Moderate from seed (variable)

Nutritive value
DMD: 60-70%
ME: Approximately 12 MJ
Crude protein: 18-21%

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)
Herbaceous perennial legumes

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

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.

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.

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%. 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.

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. Research in Italy suggests that reducing seed-set in the first year may reduce plant death during summer and increase stand persistence.

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, redlegged earth mite 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.

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.
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 swath in windows 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. The proportion of hard seed at harvest is usually high (70-80%), particularly if there is dry hot weather during seed-ripening. 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.

‘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.

‘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’ 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’ 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’ 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.\(^{205}\) 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.
Perennial pastures for Western Australia

Herbaceous perennial legumes

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.

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.

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*ₜₚ: >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)²²³

Nutritive value

DMD: 64-82%¹⁷

Crude protein: 12-27%¹⁷

White clover-kikuyu pasture on the Swan Coastal Plain
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. All varieties have low concentrations of oestrogen.

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.
## Herbaceous perennial legumes

Table 3.4 Summary of white clover varieties (adapted from\textsuperscript{293, 447} and PBR database)

<table>
<thead>
<tr>
<th>Variety</th>
<th>Leaf size</th>
<th>Stolon density</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aran (public variety)</td>
<td>Large</td>
<td>Low</td>
<td>Winter-active, late flowering, suited to irrigated dairy pastures</td>
</tr>
<tr>
<td>Grasslands Kopu (public variety)</td>
<td>Large</td>
<td>Low</td>
<td>Suited to irrigated dairy pastures</td>
</tr>
<tr>
<td>Haifa (public variety)</td>
<td>Large</td>
<td>Low</td>
<td>Broad adaptation and winter-activity</td>
</tr>
<tr>
<td>Ladino (public variety)</td>
<td>Large</td>
<td>Low</td>
<td>Widely used in the US. It has good early growth, but is a short-lived forage type which requires irrigation to persist over summer</td>
</tr>
<tr>
<td>Super Haifa\textsuperscript{a}</td>
<td>Large</td>
<td>Low</td>
<td>Selection from Haifa</td>
</tr>
<tr>
<td>Super Ladino\textsuperscript{a}</td>
<td>Large</td>
<td>Low</td>
<td>Selection from Ladino</td>
</tr>
<tr>
<td>Waverley\textsuperscript{a}</td>
<td>Large</td>
<td>Low</td>
<td>Winter-active, with good spring, early summer production</td>
</tr>
<tr>
<td>Will Ladino (public variety)</td>
<td>Large</td>
<td>Low</td>
<td>Erect variety with good spring, summer production</td>
</tr>
<tr>
<td>Grasslands Challenge\textsuperscript{a}</td>
<td>Medium-large</td>
<td>Medium</td>
<td>Good autumn, winter production suitable for rotational grazing with cattle</td>
</tr>
<tr>
<td>Grasslands Nusiral\textsuperscript{a}</td>
<td>Medium-large</td>
<td>High</td>
<td>Alternative to Haifa with good cool season growth</td>
</tr>
<tr>
<td>Tribute\textsuperscript{a}</td>
<td>Medium-large</td>
<td>Medium</td>
<td>Good autumn, winter growth</td>
</tr>
<tr>
<td>Grasslands Sustain\textsuperscript{a}</td>
<td>Medium-large</td>
<td>High</td>
<td>Good autumn, winter, spring production suitable for rotational grazing</td>
</tr>
<tr>
<td>Grasslands Bounty\textsuperscript{a}</td>
<td>Medium</td>
<td>Medium</td>
<td>Good autumn production</td>
</tr>
<tr>
<td>Grasslands Huia (public variety)</td>
<td>Medium</td>
<td>Medium</td>
<td>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</td>
</tr>
<tr>
<td>Mink\textsuperscript{a}</td>
<td>Medium</td>
<td>Medium</td>
<td>Selection from long-term pastures previously sown to Irrigation</td>
</tr>
<tr>
<td>Super Huia\textsuperscript{a}</td>
<td>Medium</td>
<td>Medium</td>
<td>Selection from Huia</td>
</tr>
<tr>
<td>Tribute\textsuperscript{a}</td>
<td>Medium</td>
<td>Medium</td>
<td>Good autumn, winter growth and foliar disease resistance</td>
</tr>
<tr>
<td>Grasslands Demand\textsuperscript{a}</td>
<td>Medium-small</td>
<td>Medium</td>
<td>High persistence and suited to set-stocking with sheep. Good spring, summer production</td>
</tr>
<tr>
<td>Grasslands Prestige\textsuperscript{a}</td>
<td>Medium-small</td>
<td>Medium</td>
<td>Good winter, spring, summer production with good pest and disease resistance</td>
</tr>
<tr>
<td>Grasslands Tahora\textsuperscript{a}</td>
<td>Small</td>
<td>Medium</td>
<td>Dense prostrate growth habit suitable for close grazing by sheep. Low winter-activity</td>
</tr>
<tr>
<td>Prop (public variety)</td>
<td>Small</td>
<td>Medium</td>
<td>Very early flowering, behaves as an annual pasture under dry conditions</td>
</tr>
</tbody>
</table>
3.10 Future perennial legumes
Geoff Moore

The following perennial legumes are considered to have potential for southern Australia. 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.

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. 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 has fair to moderate feed quality (DMD 49-73%, CP 5-13%). 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.

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. 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. Lespedeza seedlings had slow
growth at 20/15°C and moderate growth at 24/20°C. 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 (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. 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.\textsuperscript{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.\textsuperscript{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).\textsuperscript{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).\textsuperscript{293} Seed is currently not available, but SARDI is working on this species.