Principles for integrating a perennial pasture into broadacre dryland farming systems
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Lucerne Guidelines for Western Australia

Principles for integrating a perennial pasture into broadacre dryland farming systems

Diana Fedorenko, Perry Dolling, Christopher Loo, Tom Bailey and Roy Latta
Department of Agriculture and Food, Western Australia
This publication is dedicated to Emeritus Professor Philip Stanley Cocks (Phil) for his outstanding contribution to making agriculture sustainable.

For more than a decade Phil was a strong advocate of lucerne as a tool to manage dryland salinity in the agricultural regions of southern Australia and a key player in attracting funding to support lucerne research and extension for this purpose.

Phil helped form Western Australian Lucerne Growers Inc., a farmers group that since 1998 has been committed to incorporating lucerne successfully into the wheatbelt’s farming systems.

In his position as Head of Crop and Pasture Science (now School of Plant Biology) at the University of Western Australia, Phil supervised many PhD students. He left behind a legacy of researchers who carry his ‘scientific genes’ and currently lead crop and pasture research in Australia and overseas.

Phil also led the working group that formed the Cooperative Research Centre for Plant-based Management of Dryland Salinity (now Future Farm Industries, FFI CRC). He was CEO from its inception in 2000 until his retirement in June 2004.

During his distinguished international career, Phil produced numerous scientific publications and received prestigious awards, the latest being the 2008 Farrer Memorial Medal.

In his retirement Phil continues to be a strong promoter of the important role that perennial pastures species like lucerne can play in managing environmental problems in agriculture.
Lucerne, often regarded as the queen of forages, has been used in agriculture for centuries. In Western Australia, however, its potential has never been fully realised despite its well-documented ability to dewater soils and reduce groundwater recharge. Over the years adoption has been limited by a range of factors including pests and diseases, soil acidity, grazing management and economics. During the last decade research has addressed these issues, paving the way for much greater impact at the farm and catchment level.

The funding contributions provided by the Department of Agriculture and Food Western Australia, the Grains Research and Development Corporation, the Future Farm Industries Co-operative Research Centre (previously CRC for Plant-based Management of Dryland Salinity) and the National Landcare Program were important for the development of this knowledge.

The Guidelines will be a valuable resource for farmers, agribusiness advisers, natural resource management groups, researchers and students alike who wish to learn more about lucerne and the role it can play in profitable and sustainable agricultural systems. Research managers, funding bodies and policymakers will also find this information useful for planning purposes.

Dr Clinton Revell  
Project Manager Pasture Science  
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1. An overview

Section 1 briefly describes the problem of dryland salinity and its impact on natural resources, agriculture and rural communities in the wheatbelt. It outlines the process undergone to develop a suitable tool to manage salinity in broadacre farming systems. It also states that a perennial pasture like lucerne can contribute to manage a suite of problems currently affecting grain and livestock industries.

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Plate 1.1 A property in York in summer shows salinity encroaching as a result of increased groundwater recharge under agricultural systems based on annual crops and pastures.

Description of the problem

The wheatbelt is one of Western Australia’s major export-earning regions

Western Australia’s wheatbelt has developed over the last century into one of the state’s major export-earning regions worth millions of dollars a year. However, clearing the perennial native vegetation to grow grains and pastures disrupted the balance of the hydrological cycle resulting in dryland salinity.19 Dryland salinity affects not only natural resources but people living on the farms and in towns throughout this vast region.

Recharge of underground waters increased steadily after clearing the native vegetation

After clearing, recharge of groundwater systems increased steadily as annual crops and pastures do not use as much rainfall as the native vegetation. As groundwater rises salts accumulated in the subsoil over thousands of years are mobilised and brought to the soil surface (Plate 1.1).

Dryland salinity affects natural resources, agricultural productivity and valuable infrastructure

The impact of dryland salinity is multi-faceted. Water seeps from aquifers have become visible in areas where none existed before and between 5–10 per cent of previously productive agricultural land has become saline and unsuitable for profitable grain industries. Eighty per cent of rivers, streams and wetlands are seriously degraded and extensive loss of unique flora and fauna habitat has occurred. Loss of remnant native vegetation is likely to continue mainly in lower parts of agricultural landscapes. Over half of the state’s divertible water is already saline, brackish or of marginal quality, affecting water supplies. High value infrastructure, such as buildings, houses, roads and railways, which make it possible for people to live in the wheatbelt and for agricultural industries to operate, is either now affected or threatened by salinity, including the ability to support new export industries.34, 75, 76, 79, 146, 152, 153

Government and community action

Coordinated government and community action is essential to manage dryland salinity and other environmental problems

Since 1980s State and Federal Government and the community have made some effort to combat dryland salinity and their impacts but it was not until 1996 that a comprehensive situation statement was published by the Government of Western Australia where existing information was integrated and updated. This document, besides describing the causes, effects and implications of salinity outlined ‘...the options and practices for controlling and adapting to salinity...’, which became the baseline of the Salinity Action Plan for Government and community action in Western Australia.153

At a national level collaborative research, development and extension investment on salinity was coordinated by the National Dryland Salinity Program (1993–2005) and the Future Farm Industries Co-operative Research Centre (FFI CRC) (2000–). Hence, some components of the state’s Salinity Action Plan became part of this collaborative effort.
Present groundwater trends

The area of land with shallow watertables could reach 15–25 per cent of the wheatbelt by 2100 if no significant action is taken.

Monitoring groundwater trends and assessing potential impact is an essential part of the Salinity Action Plan. Farm-scale studies using satellite techniques show that approximately 1.1 million ha of formerly arable land are severely affected by salinity. The area of land with shallow watertables and salinity could reach between 2.8 and 4.5 million ha (15–25 per cent of the wheatbelt) by 2100 if no action is taken.

These estimates are based on rainfall patterns and watertable trends monitored in over 1400 bores from 1975–2000. Analysis shows that prior to 2000 watertables across the region were rising or stable. Since 2000 water levels have begun to decline in the Northern and parts of the Central agricultural regions in response to drier conditions, while in the rest of the wheatbelt most continue to increase. The risk of salinity actually reaching the predicted area is largely dependent on future land use and rainfall patterns.

The risk of salinity reaching the predicted area depends on future land use and rainfall patterns.

Current situation and prospects

The extent and severity of salinity and other environmental problems can be mitigated if changes in current broadacre farming practices are adopted.

To restore previous levels of agricultural production, water quality or ecological diversity is not possible but the extent and severity of salinity can be mitigated if farmers deliberately use tools to manage excess water in agricultural systems. Modelling has shown that there is large variation in responses to different degrees of reduction in recharge rates within a catchment. However, forecasts of the impact of feasible management actions with given levels of adoption show that, if extensive changes in land use are implemented, it should be possible to recover 415 000 ha of saline land, to prevent or delay salinisation of a further 445 000 ha and to actively manage 750 000 ha of currently saline land using salt-tolerant species. It should also be possible to protect priority resources such as prime agricultural land, high value water resources, infrastructure and important natural habitats.
Using a perennial pasture in broadacre agriculture

Grain and livestock systems are required to incorporate deep-rooted perennial pastures to manage production and environmental problems more effectively.

Grain and livestock farming systems based solely on annual plants need to undergo significant changes to manage production and environmental problems more effectively. To address these problems in broadacre agriculture current farming practices need to incorporate deep-rooted perennial pastures (Plate 1.2). In the case of dryland salinity, water use of current agricultural systems needs to be increased to lower recharge of underground waters. Perennial pastures can use more water than annuals because of their longer growing season and deeper root systems. Persistence of plant activity throughout the year is the major determinant of annual evapotranspiration—water use—and rooting depth is a significant factor in extending the period of plant activity. Therefore, implementing this strategy in areas at risk can help manage recharge, prevent further land salinisation or even reverse it—increasing production potential of low productivity areas—and provide opportunities for income diversification through new farm industries.

Lucerne research

Lucerne was used to develop the technologies to fit perennial pastures into extensive agricultural systems.

Since mid-1990s researchers have focused on lucerne to develop the technologies to fit perennial pastures into broadacre farming systems. Lucerne, Medicago sativa L., is a herbaceous perennial medic originally from Eurasia. It is known as alfalfa in the Americas and Iberia and as lucerne in the rest of the world. Lucerne is the oldest, most important and most intensively studied fodder crop.

Early evidence from farmers attempting to manage waterlogging and salinity on their properties showed that lucerne could be used to lower shallow watertables.

Lucerne is the perennial pasture that best matches the wheatbelt’s soil and climate although these conditions are not the most appropriate for lucerne production.
In Western Australia, lucerne is the perennial pasture legume that best matches the wheatbelt’s soils and climate—although these conditions are not the most appropriate for lucerne to achieve potential production. Only 4 per cent of the wheatbelt is highly suitable and 42 per cent moderately suitable for dryland agriculture in general and for lucerne in particular (Plate 1.3). High–moderate suitability encompasses areas with soil pH in calcium chloride > 5.0, annual rainfall > 350 mm and very low waterlogging risk. Below these limits lucerne growth is constrained by soil acidity and drought in lower rainfall districts. Prolonged waterlogging and weed competition can kill lucerne in years with above average rainfall in higher rainfall districts.

Lucerne can still be grown in extensive conditions if suitable agronomic practices are implemented to overcome soil constraints.

Despite these limitations, lucerne can still be grown in extensive conditions if suitable agronomic practices are implemented to overcome soil constraints. Drought is inherent to dryland agriculture and the risk increases in areas of low–very low suitability (Plate 1.3). However lucerne has developed survival mechanisms that make it possible to avoid drought and resume growth when favourable conditions return.

A computer model was used to study the long-term functioning of systems with lucerne and current systems without lucerne.

Field research was undertaken throughout the wheatbelt from Buntine to Katanning to Esperance. A computer model was adapted to simulate lucerne growth and development in the context of Western Australian farming systems. Early field research was used to successfully develop and validate this tool, which allowed researchers to integrate data and study the long-term functioning of systems with lucerne in comparison with current systems. It also helped target research activities to gaps in knowledge and test the long-term viability of these systems under contrasting environmental conditions. The model saved considerable time and money that otherwise would have been required to generate information from field experiments—if at all possible.

Working with farmers to develop appropriate technologies

Research in partnership with farmers helped develop and adapt lucerne technologies to suit their systems and understand lucerne’s impact at a paddock, farm and landscape scale.

A large proportion of the research activities were conducted in partnership with farmers on their properties and with specialists of different disciplines who addressed specific issues as they emerged. For this technology to have a chance of being adopted lucerne had to lower watertables, be at least as profitable as current systems, compatible with existing practices and, as much as possible, suit farmers preferences and future plans. The participation of farmers was indispensable and invaluable as they brought together the awareness, practical knowledge and skills acquired by farming in the wheatbelt—and passed on through generations—experience that no university degree can provide.
Experiments at different scales and different levels of farmer-researcher participation helped farmers adapt this change to their own circumstances and researchers gain a better understanding of its implications from a farmer’s perspective.

To develop confidence in growing lucerne and in the transferability of the results, the scale of trials varied from small plots managed by researchers to large plots on paddocks established and managed in partnership with farmers. Small-scale experiments were conducted on experimental stations and farmers’ properties. Large-scale experiments on farmers’ properties were designed to use their equipment while still retaining scientific rigour. To represent larger areas sampling intensity had to be increased and funding made this possible. Some farmers were prepared to invest more time and their own resources to work out how this technology would fit into their farming system. The benefit of this research approach was for farmers to be able to adapt this change to their own circumstances and for researchers to develop a better understanding of its implications from a farmer’s perspective. It also allowed testing lucerne in extensive conditions, which in practical terms would have been impossible for researchers to reproduce. The availability of lucerne seed in commercial quantities enabled this strategy to be implemented.

Farmers and researchers realised very early on that fitting a perennial into the farming system was more complex than growing a new annual crop or pasture. This innovation would require adjusting practices at a whole-farm level—as well as changes in conventional thinking—to have the desired impact on long-term profitability and sustainability.

Lucerne’s contribution to farming systems

Dryland salinity and waterlogging associated with shallow watertables are not the only problems affecting agricultural systems in the wheatbelt. Farmers have to deal with soil acidity, soil erosion, poor soil structure, low nutrient levels, nutrient leaching, unreliable rainfall, feed gaps, high weed burdens, herbicide resistance and fluctuating markets, to name a few, to be able to maintain their farm businesses.

Lucerne can contribute to improve many aspects of broadacre grain and livestock production systems

Lucerne can contribute to improve many aspects of grain and livestock production systems. As research was being undertaken on farmers’ properties additional benefits from lucerne—besides lowering watertables—became evident and were recorded. These will be discussed throughout the document.
At this point it will be mentioned that incorporating lucerne into broadacre agricultural systems can:

- assist management of salinity-related land degradation through recharge control
- create new opportunities for livestock production by producing out-of-season pasture
- boost crop production by improving soil fertility and structure, decreasing weed burdens and providing more options to manage herbicide-resistant weeds
- contribute to decrease the rate of soil acidification and manage soil erosion.

The need for alternative perennial pastures

Research is undergoing to develop Profitable Perennials™ that will provide broadacre farm industries with tools to adapt and manage present and future challenges for food production and environment protection. Despite lucerne’s beneficial agronomic attributes and its ability to lower the watertable, alternative perennial pastures also need to be developed, as relying on one species is too risky. Collections of potential perennial pasture plants and their associated rhizobia—in the case of leguminous species—were carried out in Australia and other regions of the world that match the environmental conditions of southern Australia’s agricultural regions. This material, together with perennials native to Australia, form the primary genetic pool for intensive evaluation and breeding programs aiming to create both better-adapted lucerne varieties and new perennial pastures for areas unsuitable for lucerne. To date FFI CRC researchers have evaluated more than 1200 lines of diverse germplasm of which 70 per cent originated overseas and the rest in Australia. This strategy will provide broadacre farm industries with Profitable Perennials™ to adapt and manage present and future challenges for food production and environment protection.
Summary

- Dryland salinity is one of the most debilitating environmental problems facing farm industries in the wheatbelt.
- The present document sets out the knowledge acquired during the process of developing the technologies necessary to incorporate a perennial pasture into broadacre farming systems.
- Lucerne was used as the ‘model’ plant for developing perennial pastures as it was the species that best matched the wheatbelt’s soil and climate and the only one with seed available in commercial quantities.
- This document should also guide farmers in evaluating their own circumstances and determine where, when and how to apply best agronomic practices for lucerne.
- It should provide an understanding of how this tool functions and increase farmers’ confidence in applying it correctly.
- The issues discussed here will also be relevant to future alternative perennial pasture plants, although it is most likely that agronomic and whole-farm management may need to be adapted to suit each species’ particular requirements and development cycle.

Section 2 discusses the factors that influence lucerne’s ability to use water and produce dry matter in addition to the benefits that this perennial can bring to farming systems.
2. The role of lucerne in farming systems

This section examines the factors that influence lucerne production and water use and how this perennial pasture can contribute to protect the land resource and to improve livestock and crop production.

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Lucerne prevents land degradation

Lowering recharge in broadacre agricultural systems

Lucerne pastures can be used as a tool to manage recharge. Research has provided some clarity on how plant, soil, climate, landscape and management factors affect lucerne’s ability to use water and its effectiveness in dewatering soils.

Lucerne can increase the capacity of soils to store water because of its deep roots and perennial life-cycle

Lucerne uses more water than annual crops and pastures because of its deeper roots and perennial life-cycle. The deeper roots of lucerne dry out the soil profile over the summer and autumn, creating a soil water deficit similar to that under native vegetation. Lucerne densities of at least 5–8 plants/m$^2$ in areas of < 400 mm average annual rainfall (AAR) and > 15 plants/m$^2$ in wetter areas are necessary to maintain a larger soil water deficit than that found under annual crops and pastures. The difference between these two water deficits is known as ‘dry soil buffer’, which gives an indication of the maximum additional soil water storage capacity available after lucerne before leakage occurs, compared with an annual crop or pasture (Table 2.1).

Rooting depth of lucerne is constrained by poor soil structure, acidity, compaction, salinity and waterlogging

While lucerne roots are not likely to penetrate soils as deeply as those of native plants, studies have shown that an established lucerne pasture can dry out soils as much as native woodland, depending on the season and soil type. In Western Australia, lucerne rooting depths range from 1.5–6 m, taking up to two to three years to reach maximum depth (Plate 2.1). Rooting depth is reduced by soil constraints such as poor structure, acidity, compaction, salinity and waterlogging. Soil type also affects the size of the soil buffer. Buffer sizes are greatest in clays, less in red and red-brown earths, reducing still further in sandy duplex soils and least in deep sands.

Table 2.1 Comparative leakage rates, and maximum dry soil buffer [lucerne systems (Luc.), annual systems (Ann.)] and soil water deficit before starting the third growing season after sowing lucerne for different locations in the Western Australian wheatbelt

<table>
<thead>
<tr>
<th>Location</th>
<th>Region$^A$</th>
<th>AAR$^B$ (mm)</th>
<th>Leakage rate under rotation (mm/yr)</th>
<th>Dry soil buffer (Luc.–Ann.)</th>
<th>Soil water deficit 2 years after sowing lucerne (mm)</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Luc.</td>
<td>Ann.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 years after sowing lucerne</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Borden$^{167}$</td>
<td>SC</td>
<td>388</td>
<td>0.2$^C$</td>
<td>5.4$^C$</td>
<td>74</td>
</tr>
<tr>
<td>Katanning$^{164, 165}$</td>
<td>SW</td>
<td>488</td>
<td>17–27</td>
<td>45–79</td>
<td>60</td>
</tr>
<tr>
<td>Jerramungup$^{108}$</td>
<td>SC</td>
<td>429</td>
<td>1.1$^C$</td>
<td>9.9$^C$</td>
<td>55</td>
</tr>
<tr>
<td>Newdegate$^{108}$</td>
<td>SC</td>
<td>352</td>
<td>–</td>
<td>–</td>
<td>81</td>
</tr>
<tr>
<td>Corrigin$^{108}$</td>
<td>C</td>
<td>375</td>
<td>–</td>
<td>–</td>
<td>24</td>
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<tr>
<td>Meckering$^{11}$</td>
<td>C</td>
<td>325</td>
<td>1.6$^C$</td>
<td>10.4$^C$</td>
<td>50</td>
</tr>
<tr>
<td>Pingrup$^{11}$</td>
<td>SC</td>
<td>362</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Moora$^{41, 167}$</td>
<td>C</td>
<td>462</td>
<td>4.8$^C$</td>
<td>37.2$^C$</td>
<td>50</td>
</tr>
<tr>
<td>Wittenoom Hills$^{112}$</td>
<td>SC</td>
<td>387</td>
<td>–</td>
<td>–</td>
<td>42</td>
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<tr>
<td>Cascade$^{112}$</td>
<td>SC</td>
<td>396</td>
<td>–</td>
<td>–</td>
<td>39</td>
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<tr>
<td>Quairading$^{112}$</td>
<td>C</td>
<td>373</td>
<td>–</td>
<td>–</td>
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$^A$SW = South-west, SC = South Coast, C = Central. $^B$AAR = Average annual rainfall. $^C$Long-term leakage rates calculated using LeBuM model$^{161}$
The effectiveness of the dry soil buffer also depends on annual rainfall and type of farming system. In low rainfall environments, the dry soil buffer created by lucerne can store most—if not all—of the annual rainfall, mimicking the native vegetation. However, in environments with over 600 mm annual rainfall, lucerne systems cannot use all the water and drainage is more likely to occur (Figure 2.1).

The salinity level of groundwater affects lucerne’s ability to reduce recharge as lucerne does not tolerate salinity. Lucerne often grows close to the edge of salt-affected land where its roots encounter saline groundwater but this does not mean that lucerne can tolerate high levels of salinity (Plate 2.2). A recent study on lucerne dry matter production and water use in different saline environments confirmed that lucerne’s production decreases considerably, together with its ability to use groundwater, as salinity increases from 5 to 25 dS/m—a salt concentration equivalent to about 10 to 50 per cent of seawater. However, lucerne’s growth improved significantly after rainwater occupied newly dried soil.

Plate 2.1 Diagrammatic comparisons of rooting depth, leakage (vertical arrows) and recharge of current annual crop/pasture and lucerne systems

Plate 2.2 Lucerne tolerates transient waterlogging and very low soil salinity levels. However, it can be grown to restore areas that are too wet for cropping and show early evidence of salinity. Lucerne at I Wright’s New Norcia property in May 2000 (left) and lucerne regrowth 4 weeks after a 25 mm rainfall event at G Lang’s Wickepin property in April 2009 (right)
The type of groundwater flow system influences how quickly the watertable is lowered under lucerne pastures

The impact of lucerne on groundwater levels is influenced by the type of groundwater flow system. Most of the wheatbelt is characterised by local flow systems—hillsides. The groundwater levels in these systems conform to local topography and recharge areas are close to and upslope of the discharge sites. This causes water to move more rapidly and the watertable to drop more quickly when recharge is reduced or prevented. In contrast, in an intermediate groundwater flow system—a sedimentary valley—the difference in slope between recharge and discharge areas is smaller, therefore, water movement is slower and more time is required for lucerne to lower the watertable.68

A long-term study shows the impact of farming practices over a local flow system. After clearing, groundwater levels increased as a result of 30 years of consecutive cropping. At the time that lucerne was first incorporated into the system groundwater was 42 dS/m—a salt concentration equivalent to about 85 per cent of seawater—and close to the soil surface (Figure 2.2). Lucerne initially used rainfall captured above the saline watertable. As plant growth occurred, the dry soil buffer increased and roots grew in soil previously filled with saline water. As larger lucerne root systems intercepted more rainfall, the groundwater levels dropped under the entire hillside and rainfall had little impact on groundwater levels during the following cropping phase (Figure 2.2).67, 68

Growing lucerne anywhere in the landscape can reduce groundwater recharge regardless of the type of flow system

In most of the wheatbelt local and intermediate aquifers interact but managing recharge on hillsides will not significantly affect the impact of salinity on valleys at risk, as was initially thought.74 Therefore, it is important to understand that growing lucerne anywhere in the landscape will reduce groundwater recharge regardless of the type of groundwater flow system.64 Lucerne may even be effective in flat landscapes with a shallow watertable that recharges in winter and falls in summer. However, lucerne is less effective in intermediate, stagnant and shallow watertables.64, 68
Lucerne Guidelines for Western Australia

Lucerne improves livestock production

Lucerne improves livestock production

An established lucerne pasture provides an excellent alternative source of forage for animal production, especially outside the growing season of annual crops and pastures. Environmental, genetic and management conditions influence lucerne pastures’ productivity and longevity.

Lucerne production

Climatic, soil, genetic and management factors and their interactions influence lucerne production.

Temperature, day-length and soil moisture availability are the main environmental factors affecting growth rate of lucerne. APSIM (Agricultural Production Simulation Model) uses an optimal temperature range for growth of 8–25 °C. Outside this range lucerne growth rate is likely to decrease falling to zero when temperatures reach 0 or 32 °C. Lucerne’s efficiency in utilising radiation increased from 0.6 to 1.6 g DM/MJ when mean air temperature rose from 6 to 18 °C. Soil factors mentioned above also affect lucerne productivity and water use. Rainfall amount and distribution will determine seasonal and annual moisture availability and lucerne productivity.

All lucerne varieties can potentially grow in summer–autumn but only some types grow in winter.

All lucerne varieties can potentially grow in summer–autumn but winter growth (winter activity) varies widely. Winter-active varieties grow well during the growing season in Western Australia’s Mediterranean environment. These are genotypes selected for hay that produce 20 to 25 per cent of the annual yield in winter. In contrast, winter activity of lucerne varieties selected for grazing is very low or zero. In summer–autumn, established plants grow well independently of winter-activity rating if sufficient moisture is available and temperatures are adequate. If not, lucerne leaves are shed and plants become dormant as a strategy to survive drought and high temperature stresses which are not uncommon in the wheatbelt. Field observations have shown that 25–30 mm rainfall in a week can trigger significant growth (Plate 2.3).

Adequate plant density is critical to sustain productive lucerne pastures

Productivity of lucerne pastures also depends on plant density and this varies widely across wheatbelt’s soils and rainfall patterns (Plate 2.4). Lucerne pastures with > 15 plants/m² grown over a range of slightly acidic soils have achieved comparable or greater production than annual pastures in the South Coast and Central regions. Lucerne sowing rates of 2–3 kg/ha are sufficient for lower rainfall environments (325–450 mm AAR) and can achieve a density of 15–30 plants/m² after 6 months depending on good paddock preparation and sowing technique. In higher rainfall areas (> 450 mm AAR), where moisture is less limiting, 3–5 kg/ha should achieve 20–40 plants/m².

High seeding rates are wasteful in low rainfall areas as stands will almost certainly thin rapidly due to competition for water. Maintaining > 15 plants/m² will provide a productive and competitive lucerne pasture across the wheatbelt but higher rainfall environments can sustain higher plant numbers.

Plate 2.3 Lucerne leaves fall under drought and high temperature stresses (left, centre). When suitable environmental conditions return lucerne can rapidly resume growth (right).
Lucerne improves livestock production

Lucerne pastures produce more forage than annual pastures between late spring and early winter

An advantage of lucerne in relation to annual pastures is that available dry matter at the break of season is greater in established lucerne pastures than in recently sown or self-regenerating annual pastures. In addition, lucerne pastures can potentially grow in the summer–autumn period when most seeds of annual pastures are dormant. In winter, dry matter production can be bulked up if annual volunteer or sown pastures also grow with lucerne. As a general guideline, annual production of lucerne pastures can exceed that of annual pastures when out-of-season (Nov.–Apr.) rainfall is above average. In years with average or below average summer rainfall, lucerne production could be similar or less than annual pastures.61, 72, 105, 107

Rotational grazing improves pasture production, quality and persistence in comparison with set-stocking and helps manage livestock health problems

Pasture utilisation through grazing or harvesting affects stand persistence. Rotational grazing at high stocking rates for a short period followed by a resting period will improve pasture production, quality and persistence in comparison with continuous grazing. This system results in more uniform pasture utilisation as animals have less opportunity to be selective. It allows root and crown starch reserves required for lucerne regrowth to be restored more evenly compared with set-stocking, which leaves patches of grazed and ungrazed plants. A more uniform stand can also help manage bloating or scouring problems as livestock is exposed to regrowth of similar maturity. Resting and grazing periods need to be adjusted throughout the year depending on number of paddocks and environmental conditions to achieve potential production and nutritional quality but a 4–6 week resting period is essential.117, 139 Well-managed lucerne pastures can help reduce soil erosion when plant density is maintained in adequate numbers and overgrazing is prevented.

Long-term predictions show that lucerne pastures can produce on average 4–7 ton of dry matter in the wheatbelt environments

Long-term APSIM simulations for several locations of the wheatbelt have shown that well managed lucerne stands can produce on average 4–7 ton dry matter/ha/year (Table 2.2).
Lucerne improves livestock production

Table 2.2 Long-term (1955–2005) APSIM simulation of seasonal dry matter production in established lucerne pastures for a range of locations in Western Australia

<table>
<thead>
<tr>
<th>Location</th>
<th>Region</th>
<th>AAR (mm)</th>
<th>Average seasonal dry matter production (ton/ha)</th>
<th>Total production (ton/ha/yr)</th>
<th>AAR over summer (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>winter</td>
<td>spring</td>
<td>summer</td>
</tr>
<tr>
<td>Mingeneva</td>
<td>N</td>
<td>405</td>
<td>1.7–1.9</td>
<td>2.0–2.7</td>
<td>0.2–0.3</td>
</tr>
<tr>
<td>Cunderdin</td>
<td>C</td>
<td>377</td>
<td>1.4–1.4</td>
<td>3.9–3.1</td>
<td>0.3–0.7</td>
</tr>
<tr>
<td>Kojonup</td>
<td>SW</td>
<td>510</td>
<td>1.3–1.1</td>
<td>3.3–4.2</td>
<td>0.7–1.1</td>
</tr>
<tr>
<td>Jerramungup</td>
<td>SC</td>
<td>453</td>
<td>1.2</td>
<td>3.6</td>
<td>1.2</td>
</tr>
<tr>
<td>Borden</td>
<td>SC</td>
<td>338</td>
<td>1.1</td>
<td>4.4</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*Per cent of AAR over summer calculated from 21 Dec.–20 Mar. Range generated from two soil types*

Table 2.2 shows that lucerne can fill feed gaps in late spring and summer–autumn during an average rainfall year. This can potentially increase carrying capacity, reduce or eliminate the costs of supplementary feeding and increase whole-farm profitability.11

**Livestock production**

In Western Australia, joining and consequent ewe gestation often coincides with the traditional summer–autumn feed gap. Low quality feed intake during this period can result in loss of maternal live weight during pregnancy, which is associated with decreased clean fleece weight and staple strength, lower lamb birth weight and survival, and permanent changes to the wool follicle of the foetus.148 Therefore, adequate feed quantity and quality during summer–autumn needs to be offered to maintain ewe condition and ensure lamb survival and production.

Lucerne can provide inexpensive high quality feed at critical times during the reproductive cycle of livestock

To address these problems animal scientists have conceived Focus Feeding. This strategy consists of providing additional nutrients for short periods at critical times. For example, to increase productivity of the wheatbelt’s sheep enterprises, supplementary feeding is required to: 1) boost sperm production before mating, 2) maximise potential litter size (ovulation rate), 3) avoid early embryo loss, 4) program the future productivity of the developing foetus and 5) maximise postnatal survival and development (Figure 2.3).13

Figure 2.3 Focus Feeding model for small ruminants130

---

**Focus Feeding**

- Peri-conceptual programming?
- Sperm production
- Embryo survival
- Ovulation rate
- Foetus and placenta: foetal programming?
- Colostrum production
- Perinatal period: growth, maturation, puberty
- Postnatal and weaner nutrition: growth, maturation, puberty

**Timeline**

- Pregnancy
- Birth
- Lactation
- Weaning
- Mating
- Weeks: -8, 0, 6, 12, 18, 24, 30

---

Figure 2.3 Focus Feeding model for small ruminants130
Lucerne improves livestock production

Focusing on nutritional composition and duration of these supplementation periods can be cost-effective for broadacre livestock production systems. The points of focus may vary between environments and enterprises but it is useful to list the potential times during the reproductive process when additional nutrients can make a significant difference to production outcomes. Perennial pasture legumes like lucerne can play an important role as a source of inexpensive, high quality fodder that can be utilised through direct grazing or as conserved fodder when Focus Feeding.

Ewes grazing on lucerne pastures can produce more wool and more and heavier lambs than those on annual pastures and stubbles

Research in Western Australia has shown how lucerne can sustain or improve animal production all year-round and reduce the impact of the summer–autumn feed gap, especially when weather conditions are favourable. At Borden (Plate 2.5, left), a high rainfall area of the wheatbelt, pregnant ewes grazing rotationally on lucerne pastures without hand-feeding maintained or increased their live weight and produced more wool of similar quality to those on a system based on annual crop and pastures. This was achieved without detriment to meat production since they also produced more and heavier marked lambs. Annual rainfall was near average in the first year of this trial and below average in the second year. However, there was a 100 mm rainfall event in both summer (Dec.) and autumn (Apr.), which resulted in sustained high lucerne growth rates over a 12-month period.

Weaners on lucerne pastures can gain more weight and produce more and stronger wool than those on annual pastures and stubbles

In a drier environment (Meckering/Cunderdin) (Plate 2.5, right), two flocks of newly weaned ewes were grazed throughout summer–autumn–winter 2002–2003 (from weaning to shearing) one on lucerne and the other on a traditional system based on annual stubbles and pastures. The study was repeated in 2004–2005. At the end of the first summer–autumn gap, meat production on the system with lucerne was higher at lower costs as more than 90 per cent of the animals that grazed on lucerne without hand-feeding gained 13–22 kg, whereas 90 per cent of those on annual stubbles and pastures with hand-feeding gained 6–15 kg. The two flocks produced meat of very similar quality. Annual rainfall in 2003 was above average, with only two important rainfall events—41 mm (Feb.) and 47 mm (Apr.)—that triggered lucerne regrowth. During winter, animals in the annual system compensated weight, however at shearing the lucerne system showed greater meat and wool production and higher staple strength at lower costs (Table 2.3).

In contrast, during the summer–autumn gap 2004–2005 annual rainfall was below average, animals on lucerne without hand-feeding gained on average 9.3 kg/animal compared to 10.2 kg/animal by those on annual stubbles/pastures with hand-feeding.

Hand-feeding is less likely to be required in systems with lucerne
Lucerne Guidelines for Western Australia

Lucerne improves livestock production

Despite a dry summer–autumn period and no hand-feeding for the animals on lucerne, there were no differences in wool production and fibre diameter between systems, although the differences in live weight and staple strength were significant (Table 2.3).

Table 2.3 Meat and wool production and quality of ewe weaners under traditional annual stubbles/pastures v. lucerne in wet or dry summer–autumn seasons at a mixed farming enterprise in North Meckering/Cunderdin, Western Australia

<table>
<thead>
<tr>
<th>Variables</th>
<th>Units</th>
<th>Wet summer–autumn</th>
<th>Dry summer–autumn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Dec.–Jan. = 0 mm</td>
<td>Feb.–Apr. = 116 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May = 74 mm</td>
<td>May = 37 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lucerne</td>
<td>Annuals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>90</td>
<td>130</td>
</tr>
<tr>
<td>Mob size</td>
<td># sheep</td>
<td>90</td>
<td>130</td>
</tr>
<tr>
<td>Live weight gain^a</td>
<td>kg/sheep</td>
<td>33*</td>
<td>25*</td>
</tr>
<tr>
<td>Wool yield</td>
<td>%</td>
<td>62.2</td>
<td>67.7</td>
</tr>
<tr>
<td>Greasy fleece weight</td>
<td>kg/sheep</td>
<td>3.5*</td>
<td>3.8</td>
</tr>
<tr>
<td>Clean fleece weight</td>
<td>kg/sheep</td>
<td>2.2</td>
<td>2.6</td>
</tr>
<tr>
<td>Fibre diameter</td>
<td>micron</td>
<td>18.5</td>
<td>18.1</td>
</tr>
<tr>
<td>Staple strength</td>
<td>N/Ktex</td>
<td>31.2</td>
<td>36.3*</td>
</tr>
<tr>
<td>Hand feeding</td>
<td>$/animal</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Live weight gain^a</td>
<td>kg/ha</td>
<td>297</td>
<td>150</td>
</tr>
<tr>
<td>Stocking rate</td>
<td>sheep/ha</td>
<td>9</td>
<td>19.8</td>
</tr>
<tr>
<td>Greasy fleece weight</td>
<td>kg/ha</td>
<td>31.5</td>
<td>22.8</td>
</tr>
<tr>
<td>Clean fleece weight</td>
<td>kg/ha</td>
<td>19.8</td>
<td>15.6</td>
</tr>
<tr>
<td>Gross margin</td>
<td>$/pasture ha</td>
<td>454</td>
<td>226</td>
</tr>
<tr>
<td>Gross margin</td>
<td>$/DSE</td>
<td>50.5</td>
<td>38.3</td>
</tr>
</tbody>
</table>

Source^4  *Weaning (Dec.) to shearing (Sep.).  *Significant differences (P < 0.05) between systems within seasons

Table 2.3 also shows that in both seasons the lucerne system was more profitable than the traditional system, in the wetter summer–autumn years as a result of more production and lower costs, and in the drier years because of savings in hand-feeding costs.

Lucerne also boosted meat production in Wickepin (Central region) after wethers were weaned onto a lucerne pasture in spring 2000 when the annual pasture was starting to die off as a result of drought.

Live weights recorded fortnightly over a 10-wk period showed that the animals grazing lucerne in a rotational system consistently gained weight despite the absence of rainfall during this period. Annual rainfall in 2000 was 280 mm, well below the long-term average (400 mm) for Wickepin.

The additional benefits of lucerne-based pastures on animal production in Western Australia are consistent with those found in other regions of southern Australia.
Lucerne enhances crop production

Improving soil fertility and structure
Lucerne pastures provide a sustainable and economic approach to improve soil fertility and structure. The study of nutrient dynamics in crop rotations helped gain some understanding of how and when such changes in soil attributes can have an impact on production and quality of annual crops and pastures.

Lucerne pastures capture atmospheric nitrogen and produce organic nitrogen fertiliser
Lucerne can capture atmospheric nitrogen and incorporate it into the soil through the legume-*Rhizobium* symbiosis. The amount of nitrogen fixed depends on dry matter production. A healthy stand (Plate 2.6) can add between 10–20 kg N/ton of above-ground dry matter (≈ 50–90 kg N/ha) annually.\(^{22, 107, 123, 137}\)

Lucerne’s nitrogen is released after stands are terminated
The amount of nitrogen fixed annually and the timing of its release vary according to rainfall and agronomic management. Lucerne stands can potentially fix more nitrogen than annual legumes if there is sufficient rainfall or stored soil water for plants to grow over the summer–autumn period.\(^{136}\) However, lucerne’s nitrogen is released after the plants are removed or die, which is not every year like in annual legumes.

The soil around lucerne roots is often low in nitrogen

The processes of nitrogen fixation and utilisation are very dynamic in lucerne pastures. The soils around lucerne roots will often be low in nitrogen as the living portion of the stand quickly takes up decaying residue. In infertile soils, lucerne fixes and uses its own nitrogen with little excess released into the soil nitrogen pool. As soil nitrogen increases, plants preferentially use this source only reverting back to fixing nitrogen when the pool is depleted.\(^{123}\)

Lucerne roots create ‘biopores’ that carry air and nutrients through deeper soil layers
Lucerne pastures develop extensive root systems that improve soil structure due to increased porosity of the profile (See Plate 2.1). Lucerne roots can also access nutrients leached below the root zone of annuals. The ‘biological drilling’ effect of lucerne roots creates stable ‘biopores’ which, after lucerne removal and subsequent root decay, allow the passage of air and water through the soil profile, improving drainage, aeration and diffusion of nutrients through the root zone.\(^{122, 135, 155}\)

The improved porosity of the soil after a lucerne phase enables subsequent crops to access water and nutrients from a deeper soil profile than after an annual pasture and can enhance crop yields. Several trials have demonstrated that crops grown immediately after lucerne can extract more water from a larger and deeper soil profile than crops grown in a conventional annual cropping rotation.\(^{3, 107, 141, 165}\)

Crop production
Lucerne can improve crop total biomass, grain yield and grain protein
Crops following a lucerne pasture will benefit in terms of biomass production, and grain yield and protein (Table 2.4).\(^{39, 107, 112}\) How soon this advantage is expressed depends on the rate of nitrogen mineralisation after lucerne dies off, that is, how quickly organic nitrogen is converted into inorganic forms (nitrate and ammonium), which plants can utilise. The mineralisation process is regulated in part by microbial activity, site fertility, soil moisture and temperature.\(^{1, 90}\) It is slow in the first year after lucerne removal because nitrogen is tied up in the soil by the large amounts of carbon present in decaying residues. Early removal of lucerne prior to sowing a crop increases the likelihood of soils refilling with...
Lucerne enhances crop production

moisture, which will enhance the decay of plant residue and nitrogen release to the benefit of subsequent crops. In waterlogging-prone soils, however, the drier soil profile created by lucerne can delay the onset of waterlogging and as a result enhance crop yields.

Table 2.4 Wheat yield and protein and soil nitrogen in a lucerne phase compared with an annual pasture phase in above or below average seasonal conditions in the wheatbelt of Western Australia

<table>
<thead>
<tr>
<th>Location</th>
<th>Region</th>
<th>Year</th>
<th>Rainfall in cropping year in relation to AAR</th>
<th>Annual system (AAWW)</th>
<th>Lucerne system (LLWW)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yield (ton/ha)</td>
<td>Protein (%)</td>
</tr>
<tr>
<td>Borden107</td>
<td>SC</td>
<td>1998</td>
<td>Above 4.0</td>
<td>4.0</td>
<td>9.3</td>
</tr>
<tr>
<td>Pingrup107</td>
<td>SC</td>
<td>1998</td>
<td>Below 2.0</td>
<td>2.0</td>
<td>12.0</td>
</tr>
<tr>
<td>Cascade112</td>
<td>SC</td>
<td>2000</td>
<td>Below 1.2</td>
<td>1.2</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2001</td>
<td>Above 2.9</td>
<td>2.9</td>
<td>8.5</td>
</tr>
<tr>
<td>Wittenoom Hills112</td>
<td>SC</td>
<td>2000</td>
<td>Below 0.9</td>
<td>0.9</td>
<td>8.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2001</td>
<td>Above 1.8</td>
<td>1.8</td>
<td>8.8</td>
</tr>
<tr>
<td>Quairading112</td>
<td>C</td>
<td>2000</td>
<td>Below 0.7</td>
<td>0.7</td>
<td>15.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2001</td>
<td>Above 1.3</td>
<td>1.3</td>
<td>11.8</td>
</tr>
<tr>
<td>Meckering/Cunderdin</td>
<td>C</td>
<td>200419</td>
<td>Below 2.6</td>
<td>2.6</td>
<td>11.917</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200519</td>
<td>Below 1.7</td>
<td>1.7</td>
<td>12.1</td>
</tr>
</tbody>
</table>

AAR = average annual rainfall. AAWW = 2-yr subclover pasture followed by 2-yr wheat. LLWW = 2-yr lucerne pasture followed by 2-yr wheat

Opening new options for weed management

Lucerne can compete strongly and lower weed burdens

Well-established lucerne stands compete strongly against weeds. For this reason paddocks with lucerne have lower weed burdens compared with those with annual pastures if best-practices for lucerne management are implemented (Plate 2.7). As a result, the use of chemicals for weed control in the following crop phase is likely to decrease.

Herbicide resistance can be managed using selective herbicides on lucerne pastures

Plate 2.7 A successfully established lucerne pasture competes strongly against weeds (left). CR Butterly on an experiment to evaluate herbicide options to reduce weed burdens and manage herbicide resistance in a commercial lucerne stand at Buntine in 2000 (right)
Lucerne enhances crop production

In the seedling and mature stage lucerne is relatively tolerant of some selective herbicides. This attribute opens opportunities to use a diverse range of strategies to help manage herbicide resistance, an issue particularly important to farmers who crop continuously. A range of herbicides can be used in lucerne for winter cleaning and this practice can reduce annual weed density without loss in total pasture production when lucerne density is $>15$ plants/m$^2$.\textsuperscript{108}

**Breaking disease and pest cycles**

Crop rotation is essential to reduce disease and pest populations that may build up in continually cropped paddocks. Cereals and grass weeds (for example, wheat, barley, silvergrass and ryegrass) are hosts to take all, cereal rusts, viruses and nematodes. Rotation with a lucerne pasture gives the opportunity to break pest and disease cycles, providing there is good grass control during the lucerne phase.

The risk of lucerne acting as a ‘green bridge’ is low in most years under current and forecast wheatbelt’s climate

On the other hand, perennial pastures can be a host of virus, fungal and nematode diseases than can affect annual crops and pastures. The actual risk of a ‘green bridge’ for pests and diseases carried through foliage is low in most years in Western Australia. The pronounced seasonality of rainfall in most of the wheatbelt makes it rare to have green foliage all through the dry season.\textsuperscript{39, 101, 149, 170, 171}

The most cost-effective strategy for managing most potential problems due to pests and diseases in agricultural systems is to use preventative measures under a carefully-thought integrated pest management system. New lucerne stands should be sown with disease-free seed stocks to prevent lucerne pests and diseases that can affect annual grain and pasture crops. To achieve this, a lucerne seed industry would need to be developed in south-western Australia to satisfy local demand. In parallel, the importation into Western Australia of seed infected beyond economic thresholds would have to be banned.\textsuperscript{100, 101, 156}
Perennial pastures like lucerne can help minimise land degradation and manage the impact of climatic variation on agricultural production.

Some additional benefits of summer-active perennial pastures, which can potentially have a favourable impact on crop production and environment protection, are:

- reduced accumulation of nitrate—from the breakdown of annuals over summer—as the nitrate is taken up by the plant’s active biomass, therefore,
  - lower rate of soil acidification and
  - reduced nitrate leaching—after opening rains and before annuals develop an active root system—compared with continuous cropping
- reduced soil erosion by wind and water as a result of increased plant cover with upright type perennials—in particular species with dense fibrous roots near the soil surface
- more strategies for agricultural systems to cope with climatic variation.

These issues may warrant further research in systems with lucerne under the conditions of the Western Australian wheatbelt.
Summary

- Landscape, soil, plant, animal, climatic and management-related factors and their interactions influence lucerne’s productivity and its potential role in agricultural systems.
- Understanding lucerne’s responses to variations in these factors, and knowing the limits within which this perennial can function effectively, will help make informed decisions and create realistic expectations of benefits and awareness of risks.
- Lucerne’s long-term potential benefits include:
  - preventing land resource degradation due to waterlogging and salinity by managing underground water recharge
  - opening new opportunities for livestock production by producing pasture any time in the year that climatic conditions are favourable
  - increasing crop production by improving soil fertility and structure, decreasing weed burdens, providing more options for pest management, lowering the rates of soil acidification and erosion.
- The additional benefits that systems with lucerne can bring about to manage current agronomic and environmental problems could be an incentive for implementation beyond areas threatened by rising groundwater and salinity.

Section 3 discusses how to integrate lucerne into farming systems and compares the long-term impact on production and leakage between systems with lucerne and traditional annual systems.
This section discusses how lucerne can be fitted into farming systems. Phase farming and pasture cropping are the two agricultural systems used to integrate herbaceous perennial pastures into broadacre farming systems. These systems introduce additional knowledge into cropping systems based solely on annual crops and pastures. Therefore, learning and implementing these key concepts is very important to obtain the long-term production and environmental benefits lucerne can potentially deliver into crop and livestock farm businesses.

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Phase farming involves alternating pasture and crop phases

In phase farming systems, pastures and crops are grown in rotation. A pasture phase follows a crop phase and the length of each phase can vary from three to six years. The separation of pasture and crop phases facilitates agronomic management and crop and livestock production (Figure 3.1).

**Keys to unlock phase farming potential benefits**

**Successful pasture establishment and management**

Meeting lucerne’s requirements is essential to obtain its production and environmental benefits

Best agronomic practices for Western Australian conditions will be discussed in Section 4 in the context of costs of lucerne pastures. At this point it will only be stated that applying these agronomic practices to meet lucerne’s requirements is essential for profitable and sustainable production. Poor management will most likely result in low plant densities, low productivity and short stand longevity. Plate 3.1 shows two excellent examples of successful lucerne stands.

**Optimal phase length**

Optimal phase length depends on site-specific environmental and management factors

Optimal phase length will vary according to environmental conditions. In general, where the risk of leakage is high (> 450 mm average annual rainfall, AAR) the lucerne phase should be longer than the crop phase—for instance, 4 years of lucerne followed by 2–3 years of crop. In these areas the environmental and economic benefits from using lucerne are greater. In contrast, where the risk of leakage is lower (< 450 mm AAR) and also the production benefits of lucerne, the crop phase can equal or exceed the length of the lucerne phase—for example, 3 years of lucerne followed by 3–5 years of crop. In areas known to have very high recharge rates, the lucerne phase should alternate with a minimal number of crop years such as 5 years of lucerne followed by 2 years of crop. In any case, the maximum hydrological benefits will be achieved if the lucerne phase is 4–5 years, 3 years is too short in some circumstances and year 6 will have little or no hydrological impact.

---

Figure 3.1 An example of phase farming with lucerne

The pasture is removed by a combination of grazing and well-timed chemical application

The pasture can be established under a crop in the final year of the crop phase

After 84 canola lupin barley lucerne wheat
While these figures represent a general guideline in relation to rainfall, phase length should be adapted to specific circumstances at each site. Factors like site hydrology, soil type, crop rotation history, water use by local native vegetation and purpose for growing lucerne will have an impact on phase length. Strategically located observation wells to measure watertable depths are a practical way to help make decisions about when to change phases (see Section 2, Figure 2.2).

**Timing of pasture removal**

Timing of lucerne removal involves trade-offs between production and environmental benefits:

All lucerne plants need to be killed at the end of the pasture phase to avoid competition with the crop (Plate 3.2). The timing of removal is a critical factor as this will have an effect on recharge management and the nitrogen mineralisation process. Lucerne may be removed early in the spring (Oct.–Nov.) or late in the autumn (Mar.–May) prior to cropping. In early removal, crop production can achieve full potential in the first year of the crop phase but at the expense of producing less lucerne dry matter and risking recharge over summer–autumn if rainfall occurs. An advantage of early lucerne removal is that most out-of-season rain will benefit the crop in terms of moisture and plant-available nitrogen. In contrast, with late removal the conditions are set to produce quality forage if out-of-rainfall occurs as lucerne continues to use soil water but at the expense of water and nitrogen for the crop.12, 32

In general, low rainfall or dry summer–autumn environments have reduced risk of leakage so spring removal is more likely to result in higher crop yields in the first year of the cropping phase, especially if rainfall is below average. In this case increased leakage is likely to occur if more rain than the soil can store falls subsequently (Figure 3.2). In contrast, in higher rainfall or wet summer–autumn environments with increased risk of leakage, autumn removal will have minimal impact on yield and leakage and waterlogging can be greatly reduced (Figure 3.2).

Length of the lucerne phase affects size and duration of the soil buffer.
The duration of the dry soil buffer—the time taken after lucerne removal for leakage to return to levels found under continuous cropping systems—varies between environments, seasons, management practices and soil types. Field experiments and APSIM modelling have shown that a suitable soil buffer can be created by a 2–3 year lucerne phase (see Section 2, Table 2.1). The actual benefit of a lucerne phase > 3 years is to prolong the duration of the soil buffer—and reduce the risk of leakage—rather than a major increase in the size of the buffer. At Katanning, leakage rates after removal of a 3-yr lucerne phase take on average only 1–2 years to return to those found under continuous cropping but at Cunderdin this takes on average 2–3 years (Figure 3.2). Long-term modelling has also shown that in low rainfall environments with heavy soils, the duration of the soil buffer before leakage returns to continuous cropping rates can be substantial (> 5 years).

**Crop selection**

Any crop species can be sown after a lucerne phase. Any crop is suitable for sowing after a lucerne phase. However, a short-season crop will pay better in low rainfall environments if there is insufficient moisture. Sowing a low establishment cost, dual-purpose crop is another alternative which can be grazed and produce grain if the season is favourable or either green forage or hay if unfavourable. In high rainfall environments the risk of crop failure after lucerne is lower, so the most profitable crop option can be chosen.

---

Figure 3.2 Predicted long-term effect of early (Oct.–Nov., spring) or late (Mar.–May, autumn) lucerne removal on A) grain yield and B) leakage of successive wheat crops following a lucerne phase v. continuous cropping in Cunderdin (AAR 377 mm) and Katanning (AAR 488 mm). APSIM modelling using seasons 1957–2003.
‘Intercropping’ is a term used widely throughout the world to describe an agricultural system in which two or more different crops are grown simultaneously on the same area of land.6,169 ‘Pasture cropping’ is a type of intercropping system practised for several decades in eastern Australia to produce a crop over native perennial grasses.6,17 In the last decade the term ‘companion cropping’ was used in southern Australia to refer to farming systems in which lucerne is grown with a companion crop. It has been referred to as ‘cover-cropping’ when the lucerne is established using a grain crop54,106 and as ‘over-cropping’ when the crop is direct-drilled into an established lucerne stand.87,144

Pasture cropping combines grain crops and perennial pastures with complementary life-cycles growing simultaneously in the same area of land. Since 2008 researchers have adopted the term ‘pasture cropping’ throughout Australia to refer to developing grain and livestock production systems that combine annual crops and perennial plants with complementary growth and development cycles. The concept includes grain crops and introduced or native perennial plants. Essential considerations in the design of these new systems are the sustained rational use of resources and the capacity to generate profit, recover from severe disturbance and adapt to changing climatic conditions. Future farming systems with these features are more likely to meet increasing demands for food production. For the sake of consistency the current term ‘pasture cropping’ is used in this document to show lessons learnt from systems including grain crops and lucerne pastures.

In pasture cropping grain can be produced without having to remove and re-establish the perennial pasture.

Figure 3.3 An example of pasture cropping with lucerneAfter 84

[wheat 
lupin 
lucerne 
barley 
lucerne canola 
lucerne 
lucerne 
lucerne 
]
Pasture cropping can also be seen as a modified phase farming system that allows inserting a cropping year into an otherwise long-term lucerne phase (Figure 3.3). Grains are produced without having to deal with the risks and costs of lucerne termination and re-establishment while maintaining the watertable low\(^{138, 162, 163}\) (Plate 3.3). Rainfall utilisation is more efficient and total biomass production is greater under pasture cropping than either lucerne or crop in monoculture.\(^85\) In the Western Australian wheatbelt’s mediterranean environment most annual biomass of grain crops is produced between late winter and mid-spring, while most growth in lucerne occurs between early to mid-spring and autumn if moisture is available during this period.

Pasture cropping can be managed tactically fitting in with seasons, markets and personal preferences. Pasture cropping can be managed opportunistically, fitting in with seasons, market prospects and personal preferences while keeping the watertable low.\(^{138}\) In higher rainfall areas the impact of competition on production is expected to be low and waterlogging problems should lessen. Maintaining lucerne pastures throughout the wheatbelt in parts of the landscape at risk of salinisation can prevent long-term loss of productivity.

Pasture cropping benefits crop and livestock production and the land resource. Any crop, including wheat, barley, oats, canola, lupin and field peas, can be used in pasture cropping with lucerne. After harvest, the combination of stubble, lucerne and leftover grain can provide a diet high in protein and carbohydrates. The increased dry roughage can also contribute to the prevention of scouring in animals grazing tender pasture regrowth. When over-cropping with a cereal, the paddock can be grazed in mid-winter and either lucerne-cereal hay produced in early spring or grain harvested later in the season. The increased groundcover pasture cropping provides can also help reduce soil erosion in the summer-autumn period if overgrazing is prevented.

**Keys to unlock pasture cropping potential benefits**

Pasture cropping can be more profitable than phase farming if plant competition is managed appropriately. Pasture cropping can be more profitable than phase farming but managing competition for water and other nutrients is the most important challenge for potential benefits to be achieved.\(^{13, 86}\) Some management strategies to reduce competition and maintain the watertable low are briefly discussed below.

Cover-cropping generates income in the establishment year and protects lucerne seedlings from wind and sandblasting.
Establishing the pasture with a companion crop
Sowing a companion crop—cover-cropping—is a strategy sometimes used by farmers to establish lucerne (Figure 3.3). The advantages are that the crop can generate income in the establishment year and protect lucerne seedlings from wind and sandblasting. 25, 106, 117

Farmers have developed different ways of cover-cropping varying spatial arrangements and sowing times of the crop and perennial pasture

Some farmers have sown the pasture following the crop when their equipment does not permit to sow both at the same time. They sow the rows of the perennial across or between the crop rows. This alternative doubles the costs of establishment and is less likely to achieve good results—especially in lower rainfall areas—as controlling sowing depth of lucerne is difficult and competition with the crop is stronger.

Deferred sowing of the perennial can improve in-crop weed control
The companion crop and lucerne can also be sown at different times using a controlled traffic or satellite navigation system. The crop is sown at the break of season, leaving free the lucerne rows (at about 1-m apart) (Plate 3.5). 25 This enables better control of broad-leaved weeds—particularly wild radish—early in the season. Lucerne is sown from mid- to late-winter if the weeds were successfully controlled and moisture is available. This practice is risky and could fail if these conditions do not occur before the crop is too high.

Sowing lucerne as monoculture is an option many farmers prefer to cover-cropping.
Pasture cropping

Sowing lucerne as monoculture is an option many farmers prefer, especially in lower rainfall areas. This option allows more control of the conditions for establishment. Lucerne is sown soon after the annual cropping program is completed or between the end of winter (late Aug.) and early spring (15 Sep.). Independently of the cover-cropping technique used, the success of lucerne establishment is assessed at the end of the summer–autumn period by counting plants per area.\textsuperscript{40}

**Pasture suppression**

Chemical suppression of lucerne reduces the impact of competition on crop yield. Chemical suppression of lucerne is most commonly practised when inserting a cropping year into a lucerne phase (Figure 3.3). After grazing in summer–autumn, lucerne is suppressed by applying a knockdown to kill annual weeds prior to sowing the crop. The crop can be directly drilled into the lucerne pasture immediately after the break of season to minimise early competition for water. Coupling chemical suppression of lucerne with the control of wild radish about 4–5 weeks after seeding the crop is possible, although the presence of lucerne limits chemical options for control of broad-leaved weeds.\textsuperscript{59}

Yield increase from a second pasture suppression depends on rainfall after anthesis.

**Table 3.1 Effect of lucerne suppression on crop yield in pasture cropping (PC) systems**

<table>
<thead>
<tr>
<th>Location</th>
<th>Region\textsuperscript{a}</th>
<th>AAR\textsuperscript{b} (mm)</th>
<th>Treatment</th>
<th>Crop yield (t/ha)</th>
<th>% yield loss compared to monoculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pingrup\textsuperscript{33}</td>
<td>SC</td>
<td>362</td>
<td>Crop monoculture</td>
<td>3.9</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PC – no suppression</td>
<td>1.9</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PC – 1 suppression</td>
<td>2.1</td>
<td>46</td>
</tr>
<tr>
<td>Katanning\textsuperscript{32}</td>
<td>SW</td>
<td>488</td>
<td>Crop monoculture</td>
<td>3.3</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PC – 1 suppression</td>
<td>2.4</td>
<td>27</td>
</tr>
<tr>
<td>Meckering\textsuperscript{31}</td>
<td>C</td>
<td>325</td>
<td>Crop monoculture</td>
<td>1.7</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PC – no suppression</td>
<td>1.1</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PC – 1 suppression</td>
<td>1.3</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PC – 2 suppressions</td>
<td>1.7</td>
<td>3</td>
</tr>
</tbody>
</table>

\textsuperscript{a}SC = South Coast, SW = South-west, C = Central. \textsuperscript{b}AAR = average annual rainfall

Plate 3.5 Sowing cereals at the beginning of the growing season leaving rows at about 1-m spacing to sow lucerne later in the season. N Diamond of Latham applying this method in 2001 using a satellite navigation system.
A second suppression of lucerne is possible when the crop is at flag-leaf stage. This may increase grain yield (Table 3.1) but the extent to which this occurs depends on the rainfall after anthesis. To reduce management costs, the second suppression can be done at the same time as the fungicide application if there is a need to control crop diseases (Plate 3.6). An additional benefit of suppressing lucerne late in the season is reduced contamination of cereal grain with lucerne pods and flowers because lucerne growth and development is delayed. Chemical suppression of lucerne can increase crop biomass compared with no suppression but it does not necessarily result in a significant increase in grain yield unless sufficient water is available during the reproductive phase. It can also decrease lucerne biomass production at later stages due to whole plant or stem losses.

Nitrogen fertilisation

Nitrogen fertilisation before tillering can increase grain yield if moisture is not limiting late in the season

Applying nitrogen in pasture cropping has the potential to increase grain yield when the nitrogen is applied before tillering and moisture is not limiting late in the growing season. Increments in cereal crop biomass, lower harvest index, and higher grain protein and screenings were observed after nitrogen fertilisation (in either pasture cropping or monoculture) when there was a dry finish to the growing season. APSIM modelling has shown that under Western Australian conditions nitrogen fertilisation could increase grain yield by 35–40 per cent. However, crop responses to nitrogen do not always result in higher grain yield if the nitrogen is not available for plant uptake at the appropriate time. Further investigation is required regarding the interaction between moisture availability and the timing of fertilisation to determine how nitrogen is allocated between lucerne and the crop, and between different plant organs.

Pasture termination or re-establishment

Pasture termination or re-establishment will depend on site-specific circumstances and farmer’s plans

Lucerne plant density tends to decline with time. The decision to either re-establish the pasture to restore productivity or remove it in preparation for one or more years of crop monoculture will depend on site-specific circumstances and farmer’s plans. Over-cropping when pasture density is low provides an opportunity to produce a grain crop with reasonable yields and increase total biomass production (Figure 3.3). If competition for water is expected to be high the use of dual-purpose crops is a good alternative to consider. As with phase farming, the decision to remove the pasture in spring or in autumn will involve trade-offs between production and environmental benefits.
Long-term production and leakage

The long-term impact of lucerne on production and leakage varies considerably between regions, depending on rainfall and type of farming system. A computer model adapted to Western Australian soils and climate was used to study this variation. Production and leakage were simulated under continuous cropping and under four possible systems with lucerne: continuous lucerne, continuous phase farming, continuous pasture cropping and tactical pasture cropping. These systems were run for nearly 50 years in two contrasting wheatbelt environments using actual long-term climatic records. Figure 3.4 shows the average production and leakage for the five systems over that period (Figure 3.4).

In the long term, leakage is lower and total production is higher in systems with lucerne than under continuous cropping with annual crops and pastures. Comparisons of long-term production and leakage between these five farming systems show on average:

- greater leakage under continuous cropping than under systems with lucerne in higher and lower rainfall environments
- more dry matter production and similar grain yield in farming systems with lucerne than under continuous cropping in higher and lower rainfall environments
- greater leakage, grain yield and lucerne production in higher compared with lower rainfall environments
- lower leakage under continuous lucerne or pasture cropping than under phase farming.

Figure 3.4 Long-term average production and leakage of a traditional annual cropping system and four farming systems with lucerne at Cunderdin (AAR 377 mm, left) and Kojonup (AAR 510 mm, right). Continuous phase farming alternates 3-yr wheat and 3-yr lucerne and tactical pasture cropping produces a grain crop in years with higher rainfall. APSIM simulations were run using climatic records from 1957–2003.
• Lucerne can be integrated into current farming systems using phase farming or pasture cropping, or a combination of both systems.
• Systems with lucerne are more complex than systems based solely on annual crops and pastures.
• Farmer-researcher partnerships made it possible to develop an understanding of systems with lucerne in extensive conditions.
• Farmers experimenting on their properties using their equipment revealed what can be done in practical terms to adapt or make these systems work at a commercial scale.
• Modelling has shown that long-term agricultural production is greater and leakage is lower in broadacre farming systems with lucerne in comparison with current systems.

Section 4 shows the principles of managing the costs of lucerne pastures, and the factors that influence profitability and operations of farming systems with lucerne in Western Australia.
4. Management and economics of systems with lucerne

Section 4 discusses the most appropriate practices for lucerne establishment and management in Western Australia. It addresses management issues that affect costs of lucerne pastures and factors that influence whole-farm profitability of systems with lucerne. It also summarises the expected changes in crop and livestock production practices, farm economics and health of natural resources as a result of incorporating lucerne into broadacre farming systems.

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Managing costs of lucerne pastures

Costs of lucerne pastures are directly linked to the principles that rule how lucerne functions and responds to changes in environmental conditions. These principles underpin essential agro-ecological requirements that need to be met to grow lucerne successfully. The agronomic practices presented here are targeted to meet these requirements under the soil and climate of Western Australia’s wheatbelt. Their implementation will ensure that the conditions are set for lucerne potential production providing favourable weather and no major pest outbreaks occur.

Learning principles—rather than recipes—empowers farmers to evaluate existing circumstances and to target agronomic practices to meet lucerne’s requirements

Learning principles—rather than recipes—allows a better understanding of the role that lucerne can play on each farming system and empowers farmers to evaluate existing circumstances, make informed decisions and target practices to meet nutrient and management requirements. The decision to implement or not each practice depends on previous paddock management, the purpose for growing lucerne and current seasonal conditions. It will almost certainly vary from one paddock or season to another.

Lucerne establishment

Table 4.1 links principles, agro-ecological requirements and agronomic practices to establish lucerne pastures in the conditions of the wheatbelt and broadacre farming systems of Western Australia. The proportion of total costs involved in each practice is based on past experiences and will vary according to the cost of products at the time of purchase. Following these guidelines will help target agronomic practices to meet lucerne demands for successful establishment and will save costs where practices are not necessary. This is important because under certain circumstances, reducing costs of lucerne establishment by 50 per cent can have a bigger influence on profitability than, for example, increasing winter productivity by 50 per cent.

Failure to establish lucerne is more often than not due to preventable causes

Partial or total failure to establish lucerne is often related to causes that can be rectified with appropriate agronomic management rather than to factors that are out of control like drought. The most common causes are: inappropriate site selection (Plate 4.1) and ineffective pest management, including weeds.

Lucerne is not adapted to either waterlogging or salinity

Plate 4.2 illustrates that lucerne should be grown on well-drained and non-saline mid-slope soils as lucerne does not tolerate waterlogging and is not adapted to salinity. In lower rainfall districts farmers have grown lucerne in non-saline low-lying areas that become waterlogged for short periods or in fresh water seeps higher in the landscape. In higher rainfall districts—especially in years with above-average rainfall—weed competition and waterlogging can kill lucerne. Therefore, planning is essential to minimise the risk of failure. The software package Saltland Genie™ (www.saltlandgenie.org.au) is an excellent tool to support decisions about plant options for productive use of waterlogged and saline areas.
### Table 4.1 Principles, agro-ecological requirements and agronomic practices for establishing lucerne in the wheatbelt of Western Australia

<table>
<thead>
<tr>
<th>Principles for lucerne establishment</th>
<th>Agro-ecological requirements</th>
<th>Agronomic practices</th>
<th>Total costs (%)&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
</table>
| Learning correct technical information to grow lucerne and thinking in advance about the purpose for growing it, appropriate varieties, possible paddocks, likely rotations and forms of utilisation, will enable farmers to succeed in developing profitable, sustainable and resilient agricultural systems | A year or two in advance | Planning systems with lucerne |  |}
| Lucerne is not adapted to waterlogging and salinity. Both lucerne production and ability to use water decrease significantly as salinity increases and plants can die if exposed to waterlogging for only a couple of days<sup>56</sup> | Well-drained, mid-slope and higher areas EC < 2 dS/m (Figure 4.1) | Positioning lucerne in the landscape |  |}
| Lucerne is unlikely to grow well in problem paddocks where a crop cannot grow. However, it can be sown around saline areas to use excess water and restore those that have become too wet for cropping, and to help manage weed problems | Suitable for cropping | Selecting appropriate paddocks |  |}
| Lucerne can grow in soil types where most annual crops and pastures are productive but is better adapted to duplex soils containing clay. It is preferable to avoid deep sandy soils | Mid- to fine- textured or duplex soils | Selecting suitable soil types |  |}
| Soil acidity is common in the wheatbelt. Lucerne is a perennial medic better adapted to slightly acidic–alkaline soils. At pH ≤ 4.5 aluminium becomes soluble and toxicity occurs in lucerne if free Al > 2 mg/kg. High Al inhibits root elongation, which compromises lucerne’s establishment, production and ability to use water. It can also cause phosphate deficiency. Lime alleviates the impact of high Al and its interactions with other nutrients. Lucerne growth and nodulation improve significantly with lime applications<sup>69, 130-133</sup> | Apply 1–2 ton lime/ha 1–2 years in advance if pH<sub>ca</sub> in the top 30 cm < 5 | Checking and adjusting soil pH | ≈ 15 |
| Nutrients need to be added for cropping to be profitable as most wheatbelt soils are nutrient-deficient. Adequate soil or tissue tests help identify significant nutrient deficiencies. Technical advice is essential to determine most suitable fertiliser types, rates, and time of application for each particular crop and paddock<sup>20, 40, 83</sup> | P 20–40 mg/kg  K 100–200 mg/kg  S > 10 mg/kg  trace elements (Cu, Zn, Mo) | Targeting fertilisation to meet crop nutritional demands | ≈ 40 |
| Lucerne is not a good competitor during early life stages because perennials grow more slowly than annual weeds. Accurate weed identification and good records in years prior to lucerne will help select the correct herbicide—in particular pre-emergent chemicals—and the appropriate application rate. Plant-back periods for lucerne are close to one year, especially for Group B herbicides like Glean®, Ally®, Logran®, and Lontrel® a group I herbicide<sup>177</sup> | Monitor and control weeds starting 1–2 years before sowing lucerne. Apply two knockdowns before seeding if weeds are still abundant | Managing weeds effectively | ≈ 15 |
Managing costs of lucerne pastures

### Principles for lucerne establishment

<table>
<thead>
<tr>
<th>Pests are widespread in cropping areas and can kill a young lucerne crop overnight or cause irrecoverable losses. Preventing infestations of red-legged earth mites, lucerne flea, cutworms, wingless grasshopper and others is crucial as insect feeding on lucerne can cause total establishment failure(^{67, 125}).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Agro-ecological requirements</strong></td>
</tr>
<tr>
<td>Apply a bare-earth chemical at seeding prior to infestation, and promptly if an attack occurs</td>
</tr>
<tr>
<td><strong>Agronomic practices</strong></td>
</tr>
<tr>
<td>Preventing insect attack effectively</td>
</tr>
<tr>
<td><strong>Total costs (%)(^a)</strong></td>
</tr>
<tr>
<td>&lt; 5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>All lucerne varieties grow in summer (summer-active) if soil moisture and temperatures are adequate but there is wide variation in winter growth (winter activity(^b)). Highly winter-active varieties (8–10) are adequate for cropping rotations. Winter active (6–7) and semi-winter dormant (4–5) varieties are generally for longer term pastures (the latter up to 8 years) due to better grazing tolerance. Pest- and weed-free seed must be acquired of varieties resistant to pests and diseases and tolerant to soil acidity(^{40}).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Decide on one or more varieties to meet production goals and order seed a year in advance</strong></td>
</tr>
<tr>
<td><strong>Selecting appropriate lucerne varieties</strong></td>
</tr>
<tr>
<td>≈ 25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Achieving adequate plant density at establishment is essential to ensure a productive lucerne phase. Sowing lucerne is similar to canola in that seed is small and low sowing rates of 2–3 kg bare seed/ha contain enough seed to give satisfactory plant density. Sowing rate can be increased to 4–5 kg/ha in higher rainfall areas or 8–10 kg/ha under irrigation. These rates need to be increased by at least a third when acquiring seed already inoculated and lime-coated(^{40}).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>30–40 plants/m(^2) or more at 6 months and &gt; 15–20 plants/m(^2) over the pasture phase</strong></td>
</tr>
<tr>
<td><strong>Using sowing rates for profitable production</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Matching lucerne with its specific rhizobium is critical to ensure good nodulation and further nitrogen fixation. Onset of nodulation is delayed and its effectiveness reduced with increasing soil acidity. Hence, providing an alkaline pH around the seed is vital for the establishment of the symbiosis. New lucerne varieties and rhizobium strains have increased tolerance to soil acidity, but this does not replace lime coating(^{24}).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inoculate seed with latest AL strain and lime coat</strong></td>
</tr>
<tr>
<td><strong>Preparing seed adequately</strong></td>
</tr>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Using the correct seeding technique is essential for adequate seedling emergence and establishment and overall pasture production. As lucerne seed is small it needs to be placed near the surface (preferably 2–5 mm(^{46}) into moist soil with good soil-seed contact. If establishing lucerne with a companion crop, sowing depth must be adjusted to suit lucerne. Lucerne and the companion crop should be sown in alternate rows to reduce competition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seed placed at &lt; 10 mm depth in moist soil followed by press-wheels. In alternate rows if cover-cropping</strong></td>
</tr>
<tr>
<td><strong>Adjusting seeding technique to suit lucerne</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inspecting lucerne paddocks can help prevent many potential pest problems and allow timely action if they occur(^{9, 115, 145}).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>More regularly during stand establishment</strong></td>
</tr>
<tr>
<td><strong>Monitoring lucerne pastures</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>It is essential to allow time for newly sown pastures to develop a strong root system. Grazing too early could hinder overall pasture production, water use and longevity(^{26}).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Do not graze in the first 6 months, or use very low stocking rates</strong></td>
</tr>
<tr>
<td><strong>Limiting utilisation in establishment year</strong></td>
</tr>
</tbody>
</table>

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\(^a\)Proportion of costs of inputs for all establishment practices without operation costs. 

\(^b\)Winter-activity rating varies from 0 (winter dormant) to 10 (highly winter active)
Managing costs of lucerne pastures

Most wheatbelt soils are poor and nutrients must be added to meet crop demands. The use of nitrogen to establish lucerne, in particular, has been a controversial issue world-wide and has not been investigated under the wheatbelt conditions. However, when lucerne was established in partnership with farmers, a starter application of nitrogen fertiliser was often used according to the farmers’ knowledge of their soils.

A review of the literature on this subject showed that there is a significant response to nitrogen fertilisation (10–60 kg/ha) at lucerne establishment when soils are low in nitrogen (< 15 ppm soil nitrate) or organic matter (< 1.5 per cent), when the conditions for effective nodulation (soil pH from 6.2 to 7.5 and high populations of *Rhizobium meliloti*) are not present, or the soils are low in nitrogen and also remain relatively cool (< 15 °C) for several weeks after sowing. These conditions are not uncommon in the wheatbelt’s environment and this topic may warrant further investigation.

**Lucerne management**

Young lucerne seedlings compete poorly with weeds but adult plants are strong competitors

Successfully established plants have a moderate to high tolerance to frost and drought, which are not uncommon events in some areas of the wheatbelt (Plate 4.3). It is essential therefore to maintain healthy and strong lucerne plants that can compete with annual weeds, cope with environmental stresses and fulfil their role in the farming system. Table 4.2 links principles, agro-ecological requirements and agronomic practices to successfully manage lucerne pastures in the context of Western Australian broadacre farming systems.

Plate 4.3 Strong and healthy lucerne plants can cope with drought and frost. An excellent lucerne pasture at I Wright’s New Norcia property in 2000
Managing costs of lucerne pastures

Table 4.2 Principles, agro-ecological requirements and agronomic practices for managing lucerne pastures in the wheatbelt of Western Australia

| Principles for lucerne management | Agro-ecological requirements | Agronomic practices | Total costs (%)  
|-----------------------------------|-----------------------------|---------------------|-----------------|
| Maintaining adequate soil nutrient levels is critical for profitable production in any crop, including lucerne. Macronutrients need to be replenished annually. Soil and tissue testing is recommended every 3–4 years to monitor pH and every 6–10 years for trace elements. | P if < 20 mg/kg  
K if < 100 mg/kg  
S if ≤ 10 mg/kg  
Cu if < 0.8 mg/kg  
Zn if < 20 mg/kg  
Mo if < 0.05 mg/kg | Replenishing nutrients to meet crop requirements | ≈ 40  
| Controlling weeds is essential to sustain pasture production and quality, especially if lucerne will be conserved and marketed. A range of chemicals not suitable for grain crops can be used on lucerne to help manage herbicide resistance. Strategic grazing management and cultural practices can help prevent contamination of clean paddocks, deplete weed seed bank and reduce the use of chemicals. | Implementing an integrated pest management program | Managing weeds and herbicide resistance effectively | ≈ 30  
| Preventing pest infestations is crucial as pests like red-legged earth mites, lucerne flea, locusts and others can cause significant production and quality losses, and shorten stand longevity. Insect feeding can slow down phenological development, delay maturity, alter harvest or grazing schedules and disrupt regeneration of root reserves. Good grazing management as part of an integrated pest management program can help reduce the impact of pests and dependency on chemicals. | Implementing an integrated pest management program | Preventing and controlling pests | ≈ 10  
| Utilising and resting lucerne pastures appropriately is essential to sustain pasture production, quality and longevity. The length of resting period between grazing periods is a critical factor. This will vary with seasonal conditions, winter-activity rating and age of the stand. Shorter than required resting periods will shorten pasture longevity and lower production. Unnecessary longer resting periods will decrease pasture quality and annual production. Risk of bloat may be reduced by waiting until the dew is off the lucerne and risk of scouring by avoiding grazing tender shoots. | First grazing at 10 % flowering and resting 4–6 weeks after grazing periods. Remove stock when < 300 kg dry matter/ha | Managing lucerne utilisation |  
| Lucerne needs to be harvested regularly to maintain a productive pasture. If there is no livestock in the system, lucerne hay, silage or pellets can be produced and marketed. Lucerne is one of the best and most valuable conserved fodders for the dairy, horse, beef, alpaca, ostrich, emu and sheep industries because of its high nutritional quality. It is also a popular garden mulch. Allowing lucerne to flower at least twice a year will improve its persistence | Cutting at 10–20 % flowering and resting until flowering again | Conserving lucerne and marketing as hay, silage or pellets |  

Table 4.2 continues on next page
Managing costs of lucerne pastures

<table>
<thead>
<tr>
<th>Principles for lucerne management</th>
<th>Agro-ecological requirements</th>
<th>Agronomic practices</th>
<th>Total costs (%)&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminating a lucerne pasture is necessary to avoid competition between lucerne and crop in the following cropping phase. The timing of removal will be influenced by region and plans for crop and livestock production after lucerne. Successful removal is based on depleting carbohydrates reserves followed by the interruption of vital physiological processes. This is attained by sustaining high stocking rates for long periods and applying Grazon® + glyphosate (only registered option) or 2,4-D amine + glyphosate to young regrowth. It is important to select a product with plant-back periods suitable for future cropping plans&lt;sup&gt;40&lt;/sup&gt;</td>
<td>All plants killed in spring or autumn prior to commencing a cropping phase</td>
<td>Removing lucerne</td>
<td>≈ 20</td>
</tr>
</tbody>
</table>

Source<sup>40, 104, 117</sup> Proportion of costs of inputs for all maintenance and termination practices without operation costs

All principles in Table 4.2 are important and implementing associated practices is essential to manage lucerne pastures productively. Important issues regarding pest management, in particular, are briefly addressed below due to the current emphasis on protecting natural resources by using more environment-friendly technologies in agricultural systems.

IPM is the most cost-effective approach to manage weeds, pests and diseases with little detrimental effect on beneficial populations and the environment.

Many pests such as plant pathogens, insects, weeds and others, are widespread in cropping areas and are common inhabitants of an agricultural system. Some have little or no detrimental impact on crops and pastures of economic significance but others have the potential to cause extensive production and quality losses. Implementing an integrated pest management (IPM) program is the best tactic to manage these problems successfully. An IPM program can be more cost-effective for preventing rather than treating outbreaks and for dealing with multiple issues at once. IPM is also less aggressive and cleaner in environmental terms as it uses alternative methods, instead of relying solely on chemicals.<sup>102, 106</sup>

Host-plant resistance is the primary and most effective control method of an IPM program

Host-plant resistance is the primary control method of an IPM program and is the most effective means of minimising crop losses due to pests and diseases. In Australia and abroad lucerne has traditionally been bred for high rainfall or irrigation areas. Breeders have succeeded in developing highly productive varieties with resistance to many pests and diseases of economic significance.<sup>98, 102</sup> Over the last two decades lucerne breeding objectives have been broaden to include tolerance to grazing, soil acidity, salinity and waterlogging in order to use lucerne to address land degradation and future environmental challenges in southern Australian cropping systems. This needs to be achieved while retaining tolerance to pests and diseases and feeding value, and lowering anti-nutritional factors. Progress has been made but there are still many aspects of this research that remain a challenge, especially in relation to adaptation to waterlogging and salinity.<sup>81, 92–94, 96, 102, 147</sup>
Managing costs of lucerne pastures

Cultural control involves preventative practices using a good deal of common sense

Cultural control as part of an IPM program involves preventative practices involving a good deal of common sense. For instance, working—planting, spraying, harvesting, grazing—on pest-free areas prior to problem paddocks can prevent dispersal of weeds and diseases. Cleaning soil and plant residues from equipment before entering a different paddock also reduces the likelihood of contamination. Preventing the importation into Western Australia of commercial seed stocks contaminated with weeds and seed-borne diseases decreases risk of dissemination. Sowing weed-free and disease-free seed minimises the incidence and dispersal of weeds and seed-borne diseases. Modifying habitat by strip- or border-cutting, removal of hay for greenchop, silage, pelleting or dehydration rather than field curing for bailing helps prevent pest proliferation. Good grazing management maintains potential pests and diseases below economic thresholds—in particular foliar pests. Crop rotation mitigates the impact of some nematode species and reduces the incidence of many root diseases.\textsuperscript{101, 156} Delaying lucerne sowing until the end of the seeding program in lower rainfall areas or sowing from end of winter to mid-spring in higher rainfall regions allows grazing of volunteer annual pasture or time for a double knockdown with pre-emergent herbicides, which are less expensive.

A goal of IPM is to minimise the use of chemicals but they still play an important role in pest and disease management

A goal of IPM is to minimise the use of chemicals but these still play an important role in pest and disease management. Successful establishment of lucerne pastures would not be possible if a bare-earth insecticide were not applied to control red-legged earth mites or lucerne flea. Good weed control is also essential for successful lucerne establishment as perennials grow more slowly than annuals. A well-established and healthy lucerne pasture offers the opportunity to use selective herbicides—other than those used in the crop phase—for control of herbicide-resistant weeds.

Good records—including accurate weed identification and their abundance, and developmental stage of both weeds and lucerne—are essential to determine the most appropriate solution. Adhering to economic thresholds, selective herbicides when possible, and recommended timing, method and rate of application will minimise the negative impact of chemicals—this is, the disruption of natural enemy populations and development of herbicide resistance.\textsuperscript{101, 156}

Computer software can help improve management of pests and diseases

The use of some computer programs can help improve management of pests and diseases, especially when chemicals are involved. For instance, Timerite\textsuperscript{\textregistered} (www.timerite.com.au) is a simple tool for the effective control of red-legged earth mite (RLEM) infestations. The program links knowledge of the insect’s life cycle with climatic data to predict the time of the year when the insect is most susceptible. Spraying at this time will deplete insect populations the following autumn and minimise the damage to pastures. The program only requires entering each paddock’s geographical position. Herbiguide\textsuperscript{\textregistered} (www.herbiguide.com.au) is another example of a computer program that provides information on pests and diseases—including weeds—in crops and pastures to help with crop protection decisions. It includes data on hundreds of species with solutions drawn from numerous products and active ingredients. The program also provides basic information and descriptions of species and suggestions for their control or eradication.

An IPM can reduce the incidence of pests and diseases and costs at a whole-farm

The expected outcome of managing pests and diseases effectively in lucerne pastures is less weed burdens—including herbicide-resistant weeds—lower incidence of pests and diseases, and improved overall productivity, sustainability and resilience of farming systems. This can eventually contribute to reduce costs at a whole-farm level and increase gross margins.
Managing costs of lucerne pastures

Costs of lucerne pastures depend on whole-farm management practices

From the above, it is reasonable to suggest that costs of lucerne pastures greatly depend on whole-farm management practices. They are also about planning, acquiring correct knowledge, adapting this information to particular circumstances, making informed decisions and responding promptly as problems arise. When considering growing lucerne it is important to take into account the interactions of lucerne with other components of the farming system. For instance, the cost of some agronomic practices for lucerne, like liming, needs to be distributed among other crops as the benefit lasts for several years and vice versa.

Perennial pastures can build the capacity of agricultural systems to adapt to change and recover from stressful events

Some benefits of lucerne are more difficult to express in economic terms than others. However, evidence suggests that the result of having perennials like lucerne in the system will be improved and sustained crop and livestock production, less costs at a whole-farm level, and a greater in-built capacity to adapt to change and recover from environmental stresses.

Plate 4.4 Opportunistic lucerne hay production in spring (left) and green feed in summer at Meckering in 2002 (right)
In order to assess the financial implications of incorporating lucerne into wheatbelt farming systems, economists used MIDAS (Model of an Integrated Dryland Agricultural System) and STEP (Simulated Transitional Economic Planning), two whole-farm modelling tools. Both models integrate important biological and economic aspects of agricultural enterprises. However, MIDAS aims at maximising profit depending on management, resource and environmental constraints and STEP focuses on the financial implications at a whole-farm level of the transition to integrate a new practice.

Factors affecting long-term profit

Whole-farm profit increases after incorporating lucerne

Using MIDAS for a hypothetical mixed farm representative of each wheatbelt region in an average rainfall season shows that whole-farm profitability increases after incorporating lucerne. Lucerne offers the greatest environmental and economic advantage in the South Coast region due to the amount and distribution of rainfall, particularly in the summer–autumn period.

The greater the annual rainfall the larger the optimum area of lucerne and its economic benefits

The optimum area of lucerne, in economic terms, varies between 10–30 per cent of the farm depending on the environment. Properties in higher rainfall areas benefit more from having lucerne in a larger proportion of the farm than those in lower rainfall areas (Table 4.3). The marginal return becomes negative at greater proportions of lucerne but the overall profitability does not change greatly around the optimum.

The impact of changes in commodity prices on the optimum area of lucerne is different on each region

Fluctuations in commodity prices affect the optimum area of lucerne in each region. In general, changes in commodity prices have low impact in the South Coast and South-west regions but for the Central region the area of lucerne increases considerably with increasing sheep and wool prices, and drops sharply with increasing grain prices.

Table 4.3 Expected profit from incorporating lucerne in optimal area of a typical sheep/wheat farm in three regions of the Western Australian wheatbelt

<table>
<thead>
<tr>
<th>Location</th>
<th>Region</th>
<th>AAR (mm)</th>
<th>Farm size (ha)</th>
<th>Optimal area of lucerne</th>
<th>Increase in profit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ha</td>
<td>% of whole farm</td>
</tr>
<tr>
<td>Meckering</td>
<td>C</td>
<td>325</td>
<td>1800</td>
<td>234</td>
<td>14</td>
</tr>
<tr>
<td>Borden</td>
<td>SC</td>
<td>388</td>
<td>2500</td>
<td>525</td>
<td>21</td>
</tr>
<tr>
<td>Kojonup</td>
<td>SW</td>
<td>510</td>
<td>1000</td>
<td>289</td>
<td>29</td>
</tr>
</tbody>
</table>

Source: Data derived from whole-farm analyses. C = Central, SC = South Coast, SW = South-west. AAR = average annual rainfall

Table 4.4 Expected profit from three livestock production enterprises under optimal area of lucerne in three regions of the Western Australian wheatbelt

<table>
<thead>
<tr>
<th>Location</th>
<th>Region</th>
<th>AAR (mm)</th>
<th>Wool only</th>
<th>Wool &amp; prime lamb</th>
<th>Prime lamb only</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Profit ($/ha)</td>
<td>Optimal lucerne area (%)</td>
<td>Profit ($/ha)</td>
</tr>
<tr>
<td>Meckering</td>
<td>C</td>
<td>325</td>
<td>0–2</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Borden</td>
<td>SC</td>
<td>388</td>
<td>7</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>Kojonup</td>
<td>SW</td>
<td>510</td>
<td>15</td>
<td>15</td>
<td>85</td>
</tr>
</tbody>
</table>

Source: SW = South West, SC = South Coast, C = Central. AAR = average annual rainfall
Impact of lucerne on whole-farm profitability

Profit of systems with lucerne increases as livestock production shifts towards meat

Type of livestock enterprise is another factor that influences the profitability of systems with lucerne (Table 4.4). Under current market circumstances, wool is the least profitable enterprise across regions but profit increases as meat production is incorporated into the sheep enterprise, reaching its highest when meat production is the main focus compared with wool.143

Changes in crop rotations at a whole-farm level can influence the profitability of systems with lucerne

Changing crop rotations in areas of the farm where lucerne is not being grown can result in a further increase in profit. Farmers do not need to make changes at this scale when introducing a new crop or another annual practice but having a perennial as a component of broadacre farming systems is different. Management changes at a whole-farm level will influence profitability when incorporating lucerne into the system.72

Long-term financial implications of the transition

Management decisions during the transition to incorporate lucerne can impact long-term profitability

STEP was run in collaboration with several farmers across the wheatbelt.15 Each property had paddocks where cropping was no longer possible due to salinity, crop productivity was low and remnant vegetation had been lost. Each case study used the actual farm’s economic and management data to study changes in practices that farmers considered to be feasible.25 While the results were only applicable to each farm in particular, they revealed how decisions farmers make during the transition can affect long-term profitability.

Financial provision needs to be made to go through the transition until the system with lucerne in optimal proportion is fully developed and functioning

A system in transition needs to bear some cash flow and management changes before the full benefits of lucerne in optimum proportions are realised. Awareness of these changes for each particular set of circumstances will help farmers have realistic expectations and make provision to get through the transition. It is important not to get discouraged or give up on this practice change before the system including lucerne is developed and implemented to its full extent.

The proportion of the farm required to include lucerne has an impact on the transition costs. The upfront costs and the impact on short-term profitability increase as the optimum area of lucerne increases. Farmers making changes to large areas may need to make the transition over a longer period.15

The optimal length of the transition period for maximum long-term profit depends on the profitability of the system with lucerne, its costs of implementation and the capacity of the farm business to absorb change.
The optimal transition period for maximum long-term profit is influenced mainly by the profitability of the new system and the costs of implementation. However, it is also necessary to consider the variation in income distribution between transition periods when deciding how long to take to incorporate lucerne (Figure 4.1). Larger fluctuations in annual income, associated with shorter transition periods, may involve greater risks, so the length of the transition period could be determined by the enterprise’s capacity to absorb changes at each particular time.\textsuperscript{15}

If loss of productivity due to salinity is ignored, the current annual crop and pasture system is more profitable than the system with lucerne (Table 4.5) but this scenario is unrealistic. To quantify production losses under the current system yield penalties of 1, 3 or 5 per cent for each year not planted to lucerne were investigated for different transition periods. For this particular exercise, the farm has eight paddocks threatened by salinity, so the maximum transition period is eight years if lucerne is incorporated on one paddock a year (Table 4.5).\textsuperscript{15}

If no changes are introduced to reduce recharge, the profitability of the current system will fall rapidly as crop productivity decreases due to salinity (Table 4.5). Production penalties of as little as 1 per cent justify a change in practice. Under this scenario making the transition in six or eight years is more profitable than the current system and in four years only slightly less profitable. The longer the incorporation of lucerne is delayed the greater the long-term cumulative loss in whole-farm profitability (Figure 4.1).\textsuperscript{15}

The greater the production penalties under the current system the shorter the optimal transition period to the new system

Often the optimal transition shifts towards a shorter period as production penalties increase. In the example of Table 4.5, the 6-year transition has the highest net present value independently of the magnitude of the production losses. This is due to a trade-off between losing the profitability of the current system by making a transition too quickly and the loss of production due to salinity from delaying the transition.\textsuperscript{15}

Long-term profitability of systems with lucerne is greater than that of current systems

It is clear from studies at another property in the Central region, that when seasonal variation is included in the analyses, the long-term profitability of the system with lucerne is greater than that of the current system in all seasonal conditions. This difference in profit is larger if rainfall is above average and smaller if below (Table 4.6).\textsuperscript{14}

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|}
\hline
Production period (years) & 4 & 6 & 8 & No transition \\
\hline
0 & $1.69 & $1.73 & $1.77 & $1.83 \\
1 & $1.68 & $1.71 & $1.70 & $1.68 \\
3 & $1.66 & $1.68 & $1.65 & $1.38 \\
5 & $1.65 & $1.65 & $1.60 & $1.09 \\
\hline
\end{tabular}
\caption{Interaction between length of the transition period and production losses due to salinity and its impact on whole-farm profitability in a wheat/sheep farming system in the Central wheatbelt. Figures represent net present values in million dollars at a discount rate of 10 per cent.}
\end{table}

Table 4.5

Table 4.6 The impact of seasonal variation on whole-farm profitability of a farming system with lucerne for salinity management compared with a system without lucerne

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|c|c|}
\hline
Profit at full equity ($/ha/yr) & 25\textsuperscript{th} percentile & Average & 75\textsuperscript{th} percentile & Farm area (ha) & Proportion of farm on lucerne phase system (%) \\
\hline
without & with & without & with & without & with & \\
\hline
42.8 & 44.9 & 81.7 & 83.4 & 141.2 & 143.3 & 3621 & 14 \\
\hline
\end{tabular}
\caption{The impact of seasonal variation on whole-farm profitability of a farming system with lucerne for salinity management compared with a system without lucerne.}
\end{table}

Source: Note: variation in income distribution for 1 per cent production penalty shown in Figure 4.1

Lucerne Guidelines for Western Australia
Expected changes from using a perennial pasture

A perennial pasture like lucerne introduces important changes into grain and livestock production practices. Many are the factors that need to be considered to reap the environmental, biological and economic benefits of broadacre farming systems with lucerne. Table 4.7 summarises important changes in crop and livestock production practices farmers need to deal with if they integrate a perennial like lucerne into a farming system based on annual crops and pastures.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Farming system</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without lucerne</td>
</tr>
<tr>
<td><strong>Cropping operations</strong></td>
<td></td>
</tr>
<tr>
<td>Flexibility</td>
<td>Paddocks with annual crops and pastures free to crop annually</td>
</tr>
<tr>
<td>Pasture establishment</td>
<td>Lower costs if adequate soil seedbank is present</td>
</tr>
<tr>
<td>Pasture termination</td>
<td>Less costly</td>
</tr>
<tr>
<td>Grain yield</td>
<td>Variable depending on rainfall</td>
</tr>
<tr>
<td>Weed burdens</td>
<td>Higher, more chemical inputs</td>
</tr>
<tr>
<td>In-crop weed control</td>
<td>More herbicide-resistant weeds</td>
</tr>
<tr>
<td><strong>Livestock operations</strong></td>
<td></td>
</tr>
<tr>
<td>Stocking rates</td>
<td>Lower stocking rates especially in drier environments</td>
</tr>
<tr>
<td>Grazing system</td>
<td>Set-stocking</td>
</tr>
<tr>
<td>Grazing period</td>
<td>Limited to growing season</td>
</tr>
<tr>
<td>Condition score</td>
<td>More variable</td>
</tr>
<tr>
<td>Staple strength</td>
<td>Lower</td>
</tr>
<tr>
<td>Joining management</td>
<td>Reliant on lupins for ‘flushing’</td>
</tr>
<tr>
<td>Joining dates</td>
<td>Early–mid-summer</td>
</tr>
<tr>
<td>Lambing dates</td>
<td>Autumn–winter</td>
</tr>
<tr>
<td>Weaning dates</td>
<td>Early–mid-winter</td>
</tr>
<tr>
<td>Health disturbances</td>
<td>Depending on weather and management</td>
</tr>
<tr>
<td>Supplementary feeding</td>
<td>More summer–autumn hand-feeding. Requires vitamin E</td>
</tr>
</tbody>
</table>

Source: After 84
### Table 4.8 Expected changes in farm economics and health of natural resources as a result of incorporating lucerne into broadacre grain and livestock farming systems

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Farming system</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without lucerne</td>
</tr>
<tr>
<td><strong>Farming system</strong></td>
<td></td>
</tr>
<tr>
<td>Livestock returns</td>
<td>Lower. Lambs ready when market is saturated</td>
</tr>
<tr>
<td>Cropping returns</td>
<td>Depends on the run of seasons</td>
</tr>
<tr>
<td>Whole-farm returns</td>
<td>Lower in the long term</td>
</tr>
<tr>
<td><strong>Natural resource health</strong></td>
<td></td>
</tr>
<tr>
<td>Soil fertility</td>
<td>More dependent on chemical inputs if no annual legumes in the system</td>
</tr>
<tr>
<td>Recharge rate</td>
<td>Higher</td>
</tr>
<tr>
<td>Waterlogging</td>
<td>More likely to occur</td>
</tr>
<tr>
<td>Land salinisation</td>
<td>Further degradation</td>
</tr>
<tr>
<td>Soil acidification</td>
<td>Higher</td>
</tr>
<tr>
<td>Soil erosion</td>
<td>Higher</td>
</tr>
<tr>
<td>Climatic variation</td>
<td>Dependent on favourable conditions during the annual growth cycle</td>
</tr>
<tr>
<td>Native flora and fauna</td>
<td>Higher rate of loss, decrease in biodiversity</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Further deterioration</td>
</tr>
</tbody>
</table>

Source: After 84
Expected changes from using a perennial pasture

Broadacre dryland farming systems are complex in structure and functioning

The changes listed in Tables 4.7 and 4.8 illustrate some of the complexity of broadacre farming systems. These systems are complex in structure and functioning. They contain systems within systems and at the same time are components of larger systems. Their output depends on inputs plus the interactions between their components, and between these and the environment in which they are placed. Uncertainty is inherent to these systems as farmers have no control over some on-farm and off-farm factors that are likely to impact on their system.

Farming is an interdisciplinary profession

Thinking of farming as an interdisciplinary profession helps view these systems from a different angle. It includes relationships in soils, plants, animals, humans and the environment plus their interactions. It involves disciplines like chemistry, physics, mathematics, geology, ecology, physiology, genetics, climatology, mechanical engineering, marketing and sociology, accounting and finance, to name a few.

Working with farmers helps researchers integrate specialised knowledge

Researchers from different disciplines are increasingly working in partnership with farmers to help integrate specialised knowledge and improve their understanding of the feasibility and impact of new changes at a systems level. They put together their knowledge—and intuition—to understand how these systems function under present and future scenarios. On this basis they design strategies and practices that can build the systems’ capacity to cope with change.

Changing creates new opportunities to improve

Designing practices like the discussed in this bulletin is of little or no use if they are not implemented. Changing conventional farming practices is the way to bring about new opportunities to improve food production and protect natural resources.

Complex changes need to be supported by appropriate training and extension programs and policies

Changes of this magnitude take time, create uncertainty, and are difficult to bring about. Therefore, they need to be supported by appropriate training and extension programs and policies that go beyond political boundaries and terms.
Summary

- Costs of lucerne pastures depend on whole-farm management practices. They are also about good planning, decision-making based on correct knowledge and adaptation of this information to particular circumstances.
- Changes at a whole-farm level are required to reap the economic benefits of farming systems with lucerne.
- Planning the transition from an existing system to one that includes lucerne and making financial provision to go through it are important requirements to integrate lucerne successfully and in the most profitable way.
- Systems with lucerne improve sustainability, profitability and resilience of agricultural enterprises in a way that no farming system based on annual crops and pastures can.
- Broadacre grain and livestock agricultural systems are required to include a diversity of strategies to build their capacity to function under changing climatic conditions and meet future demands for food production.
- Complex changes need to be supported by training and extension programs and policies that transcend political boundaries and terms.

The following and last section presents farmers’ experiences of systems with lucerne at a commercial level and briefly discusses progress in adoption of lucerne.
5. The farmer experience

This section contains the results of a social science survey of lucerne growers in the wheatbelt of Western Australia. It brings together the knowledge of 25 farmers who have been growing lucerne for an average of 13 years. It discusses why, how and where they have fitted lucerne into the farming system and presents useful hints for its establishment and management.

The last part uses information from several sources, including this survey and another of consultants, to briefly discuss the progress made with adoption of systems with lucerne.

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Diana Fedorenko and Perry Dolling, DAFWA

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Survey of lucerne growers

Farm characteristics

The farms are located in the wheatbelt’s low to medium rainfall zone from Buntine to Kojonup to Borden to Ravensthorpe. The arable area indicates that the farms are extensive in size with slightly smaller farms located in the southern region (Table 5.1).

The survey covered the low to medium rainfall zones, ranging from 325 to 510 mm annual rainfall. The summer or non-growing season (Nov.–Apr. inclusive) rainfall was on average 30 per cent of the total rainfall with more summer rain occurring on the south relative to the two other regions. On average during summer period 50 per cent of the years had at least one month with at least 50 mm rain varying from one third of the years in the central wheatbelt to two thirds in the south (Table 5.1). The farmers indicated that on average 19 per cent of the arable land was at risk of rising groundwater and salinity with a range of 2 to 67 per cent.

On average every year 50 per cent of the wheatbelt’s arable land is on crops and 50 per cent on pastures

Cropping and livestock are important industries for all farms in the study with cropping and pasture occupying on average similar amount of land, although in the lower rainfall Central region cropping occupies nearly two thirds of the arable area (Table 5.1). Fifteen of the 25 interviewed farmers indicated that both crop and livestock had similar importance to their enterprise with five listing crop as the main focus and five listing livestock.

On average wool and meat contribute 50 per cent each to the livestock profitability

Wool and meat on average contributed 50 per cent each to the livestock profitability. Twenty of the farmers used merino sheep with varying proportion mated to terminal sires to provide wool and meat. Only a small number had cattle or meat sheep only. Most farmers sold lambs (< 12 months old) and also important were ‘shippers’ which are male sheep aged > 12 months for the live sheep trade. Three farmers had a merino stud but only for one farmer was it a significant income source. Most farmers aim to lamb onto green pastures during winter although a smaller proportion also lambed earlier mostly to turn off crossbred lambs by the end of the growing season.

The area sown to lucerne was related to the region. Farmers in the Great Southern region had three times the amount of lucerne on average than farmers in the Northern/Central region. Farmers in the South Coast region had 75 per cent more lucerne on average

Table 5.1 Average farm characteristics for three regions of the Western Australian wheatbelt

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Units</th>
<th>Region</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Northern/ Central</td>
</tr>
<tr>
<td>Farmers</td>
<td>No.</td>
<td>7</td>
</tr>
<tr>
<td>Arable area</td>
<td>ha</td>
<td>3865</td>
</tr>
<tr>
<td>Crop</td>
<td>% of arable</td>
<td>62</td>
</tr>
<tr>
<td>Annual rainfall</td>
<td>mm</td>
<td>360</td>
</tr>
<tr>
<td>Nov.–Apr. rainfall</td>
<td>mm</td>
<td>97</td>
</tr>
<tr>
<td>Summer rain frequencyA</td>
<td>%</td>
<td>35</td>
</tr>
<tr>
<td>Lucerne area</td>
<td>ha</td>
<td>129</td>
</tr>
<tr>
<td>Lucerne area</td>
<td>% of arable</td>
<td>4</td>
</tr>
<tr>
<td>Lucerne area</td>
<td>% of pasture</td>
<td>11</td>
</tr>
<tr>
<td>Lucerne area range</td>
<td>ha</td>
<td>0–280</td>
</tr>
<tr>
<td>Years growing lucerne</td>
<td>#</td>
<td>11</td>
</tr>
</tbody>
</table>

*AProportion of years with at least one month during Nov.–Apr. period with at least 50 mm of rain*
than the farmers in the Great Southern region (Table 5.1). The data do not include the area in crop after a lucerne phase. On average the farmers first started growing lucerne in 1995 but this varied from 1970 to 2001. The farmers in the south were generally the first to start growing lucerne (Table 5.1).

Table 5.2 Farmers’ reasons to initially grow and expand lucerne areas in broadacre farming systems

<table>
<thead>
<tr>
<th>Reasons</th>
<th>No. farmers</th>
<th>Example of farmers’ comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>To try lucerne for the first time:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To control excess water—this includes reducing groundwater rise and decreasing waterlogging and salinity</td>
<td>19</td>
<td>‘Controlling waterlogging, that’s why I was first attracted to it’</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[Referring to the first paddock] ‘That was where one of the hillside seeps was. I decided to fence it off and try lucerne. I don’t know really why I tried lucerne. We did put tree belts in the area and lucerne in between. I guess salt was the main driver but why lucerne I don’t know. Sheep feed being a sheep cocky’</td>
</tr>
<tr>
<td>To improve pasture and crop productivity</td>
<td>5</td>
<td>‘Salt wasn’t the major issue behind sowing lucerne at the start. High protein green feed over summer is the main reason I grow it’</td>
</tr>
<tr>
<td>To control herbicide-resistant weeds</td>
<td>1</td>
<td>‘Driving factors [for growing lucerne] were herbicide resistance, also being able to put a perennial into the landscape for more water usage. There were three driving factors. Probably diversity, having a more diverse system, having a rotational advantage’</td>
</tr>
<tr>
<td><strong>For expanding the area of lucerne:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observing that lucerne had greater water use than annual pasture and crops....</td>
<td>17</td>
<td>‘Saw trees [which were being affected by salinity] in the paddock pick up because of the lucerne’</td>
</tr>
<tr>
<td>.... Initially without observing greater water use, but on the knowledge that it was [expected], and later they observed the greater water use</td>
<td>A portion of the 17</td>
<td>‘We felt we needed more of the place in perennials. We could have lost two dams. Not only did it stop that but the salt patch is now completely fresh’</td>
</tr>
<tr>
<td>Observing increased pasture production....</td>
<td>14</td>
<td>[Referring to the first paddock] ‘we were impressed, we had a lot of rain in November and it went mad’</td>
</tr>
<tr>
<td>.... and specifically mentioned increased summer production</td>
<td>12 of the 14</td>
<td>‘It just seemed to work. We were getting fabulous year-round production. Total feed was way in front of annuals less in winter’</td>
</tr>
<tr>
<td>Increased crop production....</td>
<td>5</td>
<td>‘After 6 months the paddock becomes a good pasture paddock and within a few years a good cropping paddock’</td>
</tr>
<tr>
<td>.... and effective weed control</td>
<td>2 of the 5</td>
<td>‘First year I got a lot of grazing out of the lucerne and cut some hay. I had an 11-year rotation planned with 3 years of lucerne. The three years of lucerne allowed me sufficient time for weed control’</td>
</tr>
</tbody>
</table>
‘Controlling waterlogging, that’s why I was first attracted to lucerne’

All farmers targeted paddocks which had the problem that they wanted to overcome to test its performance. For five farmers their first paddock of lucerne failed or partially failed but they all tried again and eventually successfully established lucerne.

‘Salt wasn’t the major issue behind sowing lucerne at the start. High protein green feed over summer is the main reason I grow lucerne’

The farmers were asked the prime reason they were growing lucerne (Table 5.3)—as distinct from the reason to first try lucerne. Most of the farmers mentioning production increases as the prime reason for growing lucerne or of equal importance to excess water control were in the South Coast region with eight out of nine farmers compared to two out of seven in Northern/Central region and three out of nine farmers in the Great Southern region. Production increases include greater pasture productivity and quality and cropping benefits such as increased soil fertility and weed control.

Table 5.3 Prime reason farmers are growing lucerne

<table>
<thead>
<tr>
<th>Reasons</th>
<th>No. farmers</th>
<th>Example of farmers’ comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controlling excess water</td>
<td>12</td>
<td>‘Number one, to use water, lower the watertable in strategic areas of the farm’</td>
</tr>
<tr>
<td></td>
<td></td>
<td>‘Controlling watertables is the biggest one’</td>
</tr>
<tr>
<td>Production increases</td>
<td>9</td>
<td>‘Key benefit for us is filling feed gaps. It’s the first pasture you can graze in autumn’</td>
</tr>
<tr>
<td></td>
<td></td>
<td>‘Single biggest advantage is opportunity, out of season rain, graze or cut silage or hay cheaply’</td>
</tr>
<tr>
<td>Excess water control and production increases equally important</td>
<td>4</td>
<td>‘Wool, meat and N, drying out soil profiles … soil structure and opening up hard pans’</td>
</tr>
</tbody>
</table>

Uses or benefits of lucerne

The farmers were asked what they used lucerne for—as distinct from the prime reason—and they can be grouped into four broad areas:

Supplying feed for livestock

The opportunity for out-of-season (summer–autumn) grazing and/or hay production is seen as an advantage for all farmers (Table 5.4) even though it does not occur regularly. The out-of-season lucerne production was then used by the farmers to reduce the amount of supplementary feeding, mate on green feed, lamb earlier, turn off lambs, shippers and cattle, grow replacement sheep or produce quality wool with low vegetable matter (Table 5.4).

The quality of the feed especially in a mixed pasture is seen as an advantage in every season even if there is minimal rain during the non-growing season, as a small amount of green feed can improve the health of livestock. The ability to graze early in the growing season (early grazing in Table 5.4) is seen as an advantage as it allows annual pastures to be deferred while they germinate and other paddocks go into crop. Production at the end of the growing season is also of value as the annual pastures die and crop harvest has not commenced so stubble is not available (late grazing, Table 5.4).
Survey of lucerne growers

Table 5.4 Uses or benefits farmers get of lucerne

<table>
<thead>
<tr>
<th>No. Farmers</th>
<th>Use or benefit of lucerne</th>
</tr>
</thead>
<tbody>
<tr>
<td>24–25</td>
<td>Opportunistic grazing, increased water use</td>
</tr>
<tr>
<td>21–22</td>
<td>General grazing*, reduce supplementary feeding</td>
</tr>
<tr>
<td>18–20</td>
<td>Weaners*, soil fertility, weed control</td>
</tr>
<tr>
<td>16–17</td>
<td>Lamb turnoff, late grazing</td>
</tr>
<tr>
<td>14–15</td>
<td>Shipper/cattle turnoff, early grazing</td>
</tr>
<tr>
<td>12–13</td>
<td>Increased crop yield, waterlogging control, improved soil structure</td>
</tr>
<tr>
<td>10–11</td>
<td>Joining, opportunistic hay/silage, feel good</td>
</tr>
<tr>
<td>7–8</td>
<td>Poor performing paddocks*, rams, medicinalD</td>
</tr>
<tr>
<td>4–6</td>
<td>Opportunistic harvesting of seed, increased stocking rate, pasture or pasture cropping (Plate 5.1)</td>
</tr>
<tr>
<td>3</td>
<td>Increase lambing percentage, reduce frost risk, reduction in erosion</td>
</tr>
<tr>
<td>1</td>
<td>Reduce impact of water repellence</td>
</tr>
</tbody>
</table>

*This includes ewes with lambs, cows and calves. *Young sheep (< 12 months old). *Poor-performing paddocks is a broad term which includes low pasture legume content, high weed content, high herbicide-resistant weed content, frost-prone paddocks, waterlogging. *To improve low condition animals or to supply vitamin E

**Increased water use relative to annual crops and pastures**

Nearly all of the farmers used lucerne to increase water use (Table 5.4) which reduced the spread of salinity and/or decreased the depth to the groundwater. In addition, about one-half of the farmers used lucerne to reduce waterlogging.

**Reduced waterlogging and salinity in cropping areas**

All of the farmers believed that after growing lucerne the problems associated with excess water had stabilised or had decreased. There were 10 farmers who believed the problem was stable and 15 who believed that the problem was decreasing. However, several farmers mentioned that they had been through a drying phase and they realise this may have also contributed to a reduction in the excess water problems.

The farmers formed their understanding about the impact of lucerne on excess water from measurements and observations. Ten farmers out of 22 (three farmers’ thoughts were not recorded) use piezometers to measure the groundwater and have measured either stable or declining levels.

Plate 5.1 Pasture cropping lucerne and wheat at Buntine (left) and Borden (right)
‘We put 20 ha of trees in there [the first lucerne paddock] and they were looking sick after a few years. They were salt-tolerant eucalypts. They went in about 1991. We planted lucerne in the other 50 ha and the trees picked up. We needed something to cover the whole landscape that was going to use water’

Many of these farmers have also made observations about the land, dams or crop after lucerne. Twelve farmers and many of the farmers using piezometers have based their understanding on observations (Plate 5.2).

‘We’ve seen country with patchy crop [due to salinity] across the flat and after three years of lucerne we’ve had crops that are wall-to-wall. We were still driving over grey clay flats in May 2005 when everyone else was getting bogged. We can always drive on lucerne flats without bogging. We had 3–4 inches in a week in May 2005’

Visual observations were for example decreased area of salt scald, reduction in waterlogged areas, dams or lakes have become less salty, crops could be grown after the lucerne where before they were patchy. One farmer had some trees die because of the extra water used by lucerne, one farmer dug a hole to measure the groundwater and found that it was never full after lucerne but before it was, and one farmer had his soak dry up. Another farmer had some soil measurements taken and the soil under lucerne was drier than under annual species.

Crop phase uses

Most farmers use lucerne to improve soil fertility as lucerne can increase nitrogen status, break hard pans and recycle nutrients from the subsoil to the surface

Most of the farmers used lucerne to increase the soil fertility which can benefit pasture and crops after the lucerne is removed (Table 5.4). The increased soil fertility is due to improved nitrogen status of the soil due to nitrogen fixation by lucerne. Many farmers also valued the ability of lucerne to break up hard pans or to create pathways in the soil to benefit crop roots and improve soil structure. Some farmers also value the ability of lucerne to recycle nutrients from the subsoil to the surface soil and to reduce the risk of frost affecting production. There were also some farmers who pasture crop lucerne (Table 5.4).

Most farmers also use lucerne to control herbicide-resistant weeds during summer and growing season because they can use a wider range of herbicide options relative to annual pasture legumes

Most farmers also used lucerne to control weeds (Table 5.4) especially herbicide-resistant weeds. They used lucerne to control weeds (summer and growing season weeds) because it allowed them a wider range of herbicide options relative to annual pasture legumes. The lucerne is very competitive against weeds and the pasture phase is longer giving more opportunities to control weeds.

Other benefits

‘Lucerne looks good in summer when the other pasture is dry but lucerne is still green, it does not burn and it is a robust perennial legume, which can be hard to kill’
Other benefits mentioned by farmers included that it looks good in summer when all the other pasture is dead and dry but lucerne is still green, it does not burn, it is a robust perennial legume which can be very hard to kill (Table 5.4, Plate 5.3).

Lucerne coexists well with annual pastures and withstands false breaks. It is relatively tolerant of insects, you do not have to re-sow it every year, it stops wind erosion on sandy soils if not over-grazed and lucerne and medics co-exist very well as sheep stir the bare soil in between lucerne clumps and the medic seed gets cover. It also withstands false breaks whereas subterranean clover density can be reduced by false breaks. For one farmer, the lucerne improved water infiltration into the soil.

Disadvantages of lucerne
All of the farmers said that the advantages outweighed the disadvantages and the disadvantages could be managed. However, they are issues that farmers need to be aware of.

Establishment costs
Most farmers consider the costs of lucerne establishment to be high but similar to those of annual pastures. The cost of establishment is considered to be high but similar to the cost of establishing annual pasture legumes. There is also an opportunity cost as production is low until the second year unless out-of-season rain occurs. As a consequence some farmers establish lucerne under a cover crop but they realise that this increases the risk of establishment failure or part failure if there is a dry spring or early summer.

Farmers know that establishing lucerne with a cover crop can generate a greater return but also increases the risk of failure. The farmers also point out that cover-cropping allows a greater area to be sown to lucerne due to the greater return. Most of the farmers thought that lucerne can be difficult to establish. Cover-cropping increases risk of establishment failure and requires greater management intensity to achieve success. The farmers find that lucerne seedlings do not compete well with weeds and are vulnerable to insects. For some soil types under lucerne the soil is vulnerable to wind erosion and lucerne is susceptible to dry finishes or waterlogging events. In addition most farmers at the end of the cropping program are looking for a break from seeding but lucerne extends this period.

Soil issues
Lucerne paddocks are prone to erosion in dry summers if overgrazed.
On sandy soils farmers find that there is the potential for wind erosion in dry summers as sheep walk between rows and the paddock can become bare, especially if overgrazed, if there is no annual pasture residue and if the density has thinned. Farmers find that lucerne does not hold the soil together like grasses do. There is also a risk of soil compaction especially heavy soils when wet resulting in increased run off. The third soil issue is that it cannot tolerate waterlogging (Plate 5.4).

**Crop phase issues**

Farmers find that to grow lucerne they have to rethink the cropping program and it is not as flexible as with annuals

Farmers find that removing established lucerne is difficult, you need to plan to get good removal, you need more chemical and it is more expensive compared to removing annual pasture. Lucerne can make the soil very dry and if there is insufficient rain after removal combined with a dry season then it can reduce grain yield. The benefits of lucerne to cropping (such as nitrogen input) rely on good seasons after the lucerne phase. The third issue is that the farmers find that they have to rethink the cropping program, ‘it is not as flexible as you cannot crop when you want to crop and you have to leave lucerne in for at least three years to get a return on investment’.

**Livestock and grazing issues**

Farmers believe that there is greater management intensity with lucerne-based pastures.

In general the farmers believe there is greater management intensity with lucerne-based pastures. Lucerne can cause livestock disorders including red gut and scouring, there is a lack of winter production unless you’ve got a good mix and it can out compete other species. Sometimes the risk of overgrazing and killing the plants restricts when the farmers want to graze and they cannot set stock. Often there is not enough production (or insufficient area) in summer so the animals cannot stay on an even nutritional level and there is limited grazing over summer.

**Performance of lucerne pastures depends on management but this is not different to annual pastures**

The farmers find that performance of a lucerne pasture depends on management but they believe it is no different to annual pastures. Another disadvantage is that the profitability of lucerne depends on the profitability of livestock. Some farmers find that when the lucerne has dried the soil after a couple of years then it responds slowly at the start of the growing season especially if the opening rains are light and it also does not allow other plants to germinate.

**Other disadvantages**

Other disadvantages the farmers find with lucerne include it can be an insect breeding ground and can be affected by insects so it needs extra monitoring and they may have to use more chemicals. There is limited tolerance to herbicides for broad-leaved species. Other systems are just as profitable or more, this particularly refers to annual pasture paddocks with good legume base.

**Lucerne establishment and management**

**Establishment**

**Choice of paddocks for lucerne**

The paddocks chosen for growing lucerne were mostly lower in the landscape (Table 5.5). The reason why the farmers chose the lower to mid-slopes is because they were focusing on controlling the groundwater or salinity which was generally expressed in this part of the landscape. On the valley floors many farmers grew the lucerne either directly around the problem areas or the paddock up slope of the problem area (Table 5.5). In some cases farmers fenced off areas to grow lucerne adjacent to the areas of salinity or at risk of salinity which can result in small paddocks.
Table 5.5 Choice of paddocks for lucerne

<table>
<thead>
<tr>
<th>Where lucerne is grown</th>
<th>No. farmers</th>
<th>Example of farmers’ comments</th>
</tr>
</thead>
</table>
| Lower slopes or valley floors                         | 11          | ‘I grow lucerne on smaller, awkward, non-cropping paddocks around salt flats’  
 ‘Break of slope we have 1800 ha of this type of country where crop does not perform it gets frosted or it needs the watertable reduced, every paddock that seems a bit sparse we whip some lucerne in it’ |
| Lower to mid-slope because they had a large area of this country | 2           | [The lucerne is grown]  
‘only on one soil type, sand over white clay at the bottom of the valley, next to salt lakes’  
‘I have grown [lucerne] over all soils, I could really plant over the whole lot except the deeper sands which occur on the tops of hills, mainly a wind erosion issue. I’m concentrating now on the gully and river systems, which takes in most of the farm’ |
| Mid-slope                                              | 4           | ‘We are generally growing it in areas where we need to lower the watertable…..Areas that get wet in winter when other areas are trafficable, we start to think they are problem areas or if there is a salt scald’ |
| Anywhere in the landscape                              | 8           | ‘We’ve gone from the deep sands to the red loams, we’ve done everything. Different soils work better in different years’  
‘My first idea was growing small amounts around the salt problems. It didn’t take me long to realise it wasn’t going to work…But I looked at the whole farm benefits of lucerne so I did it over the whole farm’  
‘The paddocks we select for lucerne normally have a waterlogging issue or poor fertility or weeds….. There is always a paddock that is not performing. The bar keeps rising’ |

‘Break of slope we have 1800 ha of this type of country where crop does not perform it gets frosted or it needs the watertable reduced, every paddock that seems a bit sparse we whip some lucerne in it’

Choosing the paddocks to grow the lucerne for excess water control was mainly based on observations of the land and some data collection. For example, observing increasing salinity in dams, waterlogged patches and salinity patches and measurements of the depth of groundwater using piezometers.

There were some farmers who did not grow lucerne on any specific landscape position but chose paddocks coming out of crop or problem paddocks to grow lucerne (Table 5.5). Problem paddocks consisted of two or more reasons for growing lucerne. It could include paddocks with low pasture legume content, high weed content, high herbicide-resistant weed content, or requiring waterlogging or groundwater control.
Survey of lucerne growers

Sowing method

Most farmers establish lucerne as monoculture

Most farmers use the more reliable practice of establishing lucerne by sowing as a monoculture (spraying out the existing pasture/weeds and seeding with lucerne only) with 17 farmers choosing this technique, two farmers sowed lucerne with other perennials. In addition another four farmers use both monoculture and cover-cropping. Only four farmers use cover-cropping as the only technique to establish lucerne. This is a more risky way of establishing lucerne because of the competitive effect of the crop and the variable climate. However, cover-cropping does allow the costs of establishment to be offset by a greater amount by the sale of grain compared to monoculture which relies on grazing for the return.

Sowing time

Most farmers establish lucerne after their cropping program from mid-winter into early-spring

When establishing as a monoculture 18 farmers established lucerne after their cropping program from mid-winter into early-spring as they have more time to get the establishment right. Other reasons for establishing lucerne later in the season are that it allows good weed control before sowing and grazing before establishment and waterlogging risk is reduced. The four farmers using cover-cropping established lucerne early in the season from May to mid-June. There were three farmers who established lucerne opportunistically, which may occur at any stage in the growing season.

Management

Pasture composition

Most farmers would have a mixed lucerne pasture consisting of annual legumes, grasses and other broad-leaved species

Most farmers would have a mixed lucerne pasture (Plate 5.5) once established with 16 farmers out of 25 plus another nine farmers having both mixed and pure stands. The mix would consist of annual legumes, grasses and other broad-leaved species. The reason for farmers preferring a mix is to increase growing season productivity, particularly winter production, and reduce erosion in summer. Another reason is that the lucerne plant density declines with time so the preference by the farmers is to allow annual legumes to fill in the spaces in between.

A pure lucerne stand maximises lucerne productivity, which can benefit livestock and the following crop after lucerne is removed

A pure stand maximises lucerne productivity which can benefit livestock as well as the following crop, after the lucerne has been removed but it requires at least 30 plants per square meter to allow optimal production. Most of the farmers applied some herbicide to their lucerne stands to control weeds, mainly grasses, and this is often applied late in the season to prevent seed set. The farmers with pure stands used more herbicide to keep the stand free of weeds.

Plate 5.5 R Wilkinson and P Dolling showing mixed pastures with lucerne and volunteer annuals
**Phase length**

The average length of the lucerne phase was 4–6 years and of the crop phase 3–4 years.

The average length of the lucerne stand was 4–6 years with some farmers leaving paddocks under lucerne for 12–13 years. The shorter crop phase compared to the pasture phase is an indication that most farmers use lucerne in a targeted way revolving around excess water control. Once in crop some farmers monitor the groundwater depth to determine when to go back to lucerne. If the groundwater rises and reaches a critical depth they would then return to lucerne.

Lucerne plant density declines with time but some farmers will keep it longer than 4–6 years.

After 4–6 years (3–4 years in the Central region) of lucerne the plant density does decline and therefore production of lucerne decreases. It is generally sufficient time for the lucerne to dry the soil, control weeds and build up soil nitrogen to benefit the crop. Farmers will let the stand go longer than 4–6 years if the paddocks are less suitable for cropping, if they are still getting production or if annual legumes have compensated for the declining lucerne plant density.

**Plant density**

‘Lucerne density declines to a number of plants per square meter equivalent to the average rainfall measured in inches’

What constituted a successful stand varied from farmer to farmer and there was generally a large range in tolerance. Most farmers had an understanding of plants per square meter (psm). All of the farmers realise that establishment counts are often very high > 50 psm but by the end of the first summer they will have declined and will continue to decline with time. Several farmers go by the saying that ‘the lucerne density declines to a plants per square meter density equivalent to the average rainfall measured in inches’, for example, 16 inch rainfall area (400 mm) will result in 16 psm.

Lucerne plant density is one of several indicators farmers use to judge successful establishment and there is wide variation in range

Most farmers think that having 20 and 40 psm 6 months after establishment was a success. Some farmers considered success having around 10–20 psm. Some farmers judge success on how it looks, how well it is growing, whether it is free of disease, has nodules and some judge success on its impact such as lowering the groundwater or seeing clovers come back.

Most farmers believe a pasture with a low plant density (1–3 psm) is still of value especially if clovers are part of the mix. For some farmers having part of the paddock with lucerne was difficult to manage. One farmer mentioned that on his sandier soils if the density is 2–3 psm then he limits grazing over summer due to risk of wind erosion. If the farmers had an establishment failure then they would tend to crop the following year, work out what went wrong and try again in the future.
Survey of lucerne growers

Farmers’ hints for lucerne establishment and management

The first 6–8 weeks after sowing is the most critical period as lucerne is a poor competitor at seedling stage. Many farmers said that growing lucerne is like growing canola and many of the establishment tips are similar. The first 6–8 weeks after sowing is the most critical period, weeds and insects are the biggest challenges as lucerne is a poor competitor. To maximise the density the farmers make the suggestions presented in Tables 5.6.

Table 5.6 Farmers’ hints for lucerne establishment in broadacre farming systems of Western Australia

<table>
<thead>
<tr>
<th>Establishment practices</th>
<th>Farmers’ hints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weed control</td>
<td>Good weed control before establishing lucerne is critical. If sowing early weed control must start the year before and if sowing late more than one herbicide application is suggested before sowing lucerne. It is an advantage if weeds are killed at the same time as the cropping program and 4–6 weeks later spray again if needed before sowing. A long fallow also builds up moisture.</td>
</tr>
<tr>
<td>Soil types</td>
<td>Do not choose paddocks with deep sands, subsoils with aluminium, salt scalds or severely waterlogging sites. Know the history of the paddock for example if it has got herbicide resistant weeds.</td>
</tr>
<tr>
<td>Sowing time</td>
<td>Do not sow too late as there needs to be sufficient time for the plant to develop before summer. Sowing after the cropping program allows more time to be put into establishing the lucerne, greater time to control weeds as well obtaining good moisture conditions.</td>
</tr>
<tr>
<td>Seeding technique</td>
<td>Seed placement and seeding conditions are important and this includes sowing no deeper than 1 cm, sowing into moist soil, ensuring good seed to soil contact using press wheels, or broadcast and harrow or roll. Sow into short stubble so it doesn’t come up ‘cloddy’, sow slower than for normal crop to get better seed placement and sow after waterlogging events. Seeding machinery is not critical so long as shallow seed placement is achieved. Sow after a cereal crop to get fewer bugs, more friable soil and better seeding depth control while the stubble gives wind protection and phosphorus levels have increased. Sow perpendicular to damaging winds.</td>
</tr>
<tr>
<td>Seeding rate</td>
<td>Not too thin or too thick, the rate varies from farmer to farmer ranging from 1.5–5 kg/ha, with most between 3–5 kg/ha.</td>
</tr>
<tr>
<td>Fertility and inoculation</td>
<td>If soil pH is low use lime at least a year before sowing, the soil needs to be reasonably fertile so fertilise with phosphorus and potash if required and inoculate the seed. Check the flow of lime pelleted seed as it can cause distribution problems due to the build up of lime. A farmer used a small amount of starter nitrogen fertilizer to get the seedlings going while nodules develop.</td>
</tr>
<tr>
<td>Insect control</td>
<td>Controlling insects is also another critical aspect in getting a successful stand. Red-legged earth mite is the most important insect to control as they can kill plants within hours. All farmers use at least one application of insecticide to prevent damage. Other insects can also be a problem so this needs regular monitoring and insecticide application if required.</td>
</tr>
<tr>
<td>First grazing</td>
<td>For the first grazing don’t graze too early, the plant needs to be established so that it cannot be pulled out, it is best to wait until 10 per cent flower before grazing as it gives time for the roots to bulk up and get the stock out quickly once the dry matter has been consumed. If radish is present then use a light grazing to remove the flowers and green seed.</td>
</tr>
</tbody>
</table>
Table 5.7 shows a number of practical ideas from interviewed farmers make for successful lucerne management.

### Table 5.7 Farmers’ hints for lucerne management in broadacre farming systems of Western Australia

<table>
<thead>
<tr>
<th>Management practices</th>
<th>Farmers’ hints</th>
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</thead>
</table>
| **Grazing**          | The main management hint is about good grazing management. The key point is to let the lucerne get to 10 per cent flowering at least once a year before grazing as it builds up reserves in the root which allows the plant to withstand stresses especially water stress. It is also important to rest the stand when it is dormant during summer as the plants can be overgrazed.  
Rotational grazing is preferred and the more paddocks on lucerne the easier it is to rotationally graze. If not possible to graze rotationally give lucerne a rest once or twice a year. During the growing season it is difficult to graze rotationally because the paddocks available have been reduced due to crop and the sheep are difficult to move because they are lambing. Rainfall influences how much rest you should give, the harder the year the less the rest you are able to give it. However, rest lucerne usually around harvest as there is plenty of stubble and the lucerne has stopped growing. As one farmer said ‘I look at it in terms of how much pressure you’re putting it under and then give it a spell, let the plant build up energy reserves in its root’  
Set stock only for a couple of months especially in winter but don’t continuously graze for long periods or eat crowns down to the ground as it will kill the plants or cause erosion. Try not to graze until 10 per cent flower to maximize production  
At the other end of the scale do not undergraze. Try to graze before it’s in full flower so it doesn’t go woody or rank, if it is too tall they just pluck the leaves off  
The animals need diversity in their fodder so allow access to grass or give them hay especially if the plants are actively growing as they are low in fibre. With a pure stand watch that the sheep are gaining weight. With young stock allow it to get to the woody stage (10 per cent flowering)  
It is helpful to have a good companion. Allow annuals to come through such as subterranean clover and ryegrass to increase diversity and production during winter  
Have plenty of watering points  
If there is summer rain take the sheep off for a couple of days to let the new growth get going  
Make it earn its keep; keep the stock up to it even in the tough years | |
| **Weed control**     | To get more production from lucerne keep it fairly clean but at minimum reduce the weeds. Prevent barley grass, geranium, capeweed and ryegrass being major competitors. Use chemicals and grazing to keep weeds in check |
Progress with adoption of lucerne

The area of lucerne in 1995 was 5 000 ha and by 2001 this had reached 170 000 ha. This increase in area was most likely due to the intensive focus on lucerne research and development of those years together with the successful extension and communication strategies implemented by Western Australian Lucerne Growers Inc. (WALG) technicians with the support of state and national stakeholders.

WALG’s one-to-one assistance package is an example of a successful extension method

WALG was formed in 1998 to bring researchers and experienced lucerne growers together to share research results and practical experiences in using lucerne as a tool to manage rising watertables (Plate 5.8). They used a one-to-one assistance package to deliver to new growers correct advice on lucerne establishment and management. By 2004 more than 500 farmers had grown lucerne on their properties using WALG’s assistance package.

Unfortunately, the area of lucerne actually grown was not investigated in the 2006 census but by late 2009 WALG technicians had delivered technical assistance to nearly 900 farmers. This does not necessarily mean that all farmers were growing lucerne at that time but it is a possibility.

According to WALG, adoption of systems with lucerne has been slow due to the perception that lucerne is a difficult plant to establish and hard to remove. Failures have caused some potential users to have a negative view of lucerne but WALG technicians diagnosed that in each case failure was due to causes that can be rectified if appropriate agronomic practices are implemented.

The formal survey of farmers presented above was carried out as part of a recent FFI CRC project that investigated lucerne adoption. The survey confirmed most of the lucerne knowledge developed through the research activities presented in these Guidelines. It has also provided a formal evaluation of farmers’ current lucerne knowledge, perceptions and practices.

There is potential for lucerne adoption at a landscape scale despite being considered a complex technology

For some farmers the potential for lucerne adoption at landscape scale is high despite being a particularly complex technology. These farmers are more likely to be those either with strong environmental goals, have a large proportion of their farm at risk of dryland salinity, have livestock as a significant component—especially for meat production—or farm in areas with more probability of out-of-season rainfall.

There is potential for lucerne adoption as a niche technology limiting its use to problem areas

The survey also indicated that some farmers use lucerne as a niche. These farmers are likely to limit the use of lucerne to areas at immediate risk to salinity. This highlights that a complex technology can be used in a less complex way.

A recent survey of private consultants showed that they perceive the potential for wide-scale adoption of lucerne by their farmers is low although there is a place for lucerne in the farming system.

Plate 5.8 Discussing lucerne with farmers and technicians. L-J Blacklow from WALG at Katanning in 2000 (left) and D Fedorenko from DAFWA at Latham in 2001 (right)
Progress with adoption of lucerne

In 2008 WALG and EF joined forces to continue to assist farmers in developing agricultural systems that include perennials.

In 2008 WALG joined forces with Evergreen Farming (EF), a growers’ group with a strong focus on subtropical perennial grasses. This new body will continue to promote the use of perennial pastures and fodder shrubs to assist farmers in developing profitable and sustainable farming systems. They recently published a back pocket guide for lucerne establishment and management and an A4 card summarising some practical key points contained in this bulletin (Plate 5.9). These were designed as quick reference resources to inform experienced and new lucerne growers on best management practices for lucerne production in Western Australia. Another useful resource with nation-wide application was published in 2002 by DPI Queensland and GRDC in the form of a ute guide to assist in the diagnosis of lucerne pests and disorders (Plate 5.9). The book Perennial Pastures for Western Australia is also a very valuable resource for lucerne and developing perennial pastures. These resources, including these Guidelines, contain technical information that can be used as components of extension programs to deliver correct information on lucerne.

Plate 5.9 Resources for lucerne establishment and management in Western Australia and for the diagnosis of lucerne pests and disorders
Summary

- Cropping and livestock are important industries for all farms with crops and pastures occupying at least half of the farm area each in most of the wheatbelt.
- All farmers tested lucerne performance by first growing it on paddocks which had the problem they wanted to overcome.
- The prime reason farmers are growing lucerne was greater productivity and quality, and cropping benefits as increased soil fertility and weed control. For most of them controlling excess water was of equal importance.
- All farmers see the opportunities lucerne brings to improve overall performance of broadacre crop and livestock farm businesses, an advantage that farming systems based on annual crop and pasture species cannot offer.
- The aspects of lucerne that farmers see as a disadvantage are related to changing conventional practices and adapting to different ways of practising agriculture.
- There is scope for increasing the area of lucerne in Western Australia if establishment and management practices are implemented to meet lucerne’s requirements for production and persistence in the environment of the wheatbelt.
Integrating a perennial pasture like lucerne as a new component of broadacre farming systems was suggested by the Government of Western Australia in early 1990s as a tool to halt salinity. At that time some leading farmers were already experimenting with lucerne to manage shallow watertables as lucerne was then—and still is—the best-bet perennial pasture for the wheatbelt with seed readily available in commercial quantities.

As a result of this early evidence, several stakeholders initiated an intensive phase of lucerne research and development, led at a national level by the Future Farm Industries CRC (then CRC Salinity), to find solutions to this problem. Research aimed to investigate the adaptation of lucerne to a range of soils and climate throughout the wheatbelt of southern Australia and its ability to reduce recharge. Simultaneously a search for germplasm of alternative perennials for areas less suitable for lucerne was undertaken. Collaboration between leading farmers and researchers was critically important to successfully develop an understanding of the role of lucerne in farming systems, its contribution to whole-farm profitability and its implications at different scales. The findings were published and shared with different audiences as they became available.

These Guidelines have put together such knowledge and shows that agricultural systems with lucerne can be more robust in productive and environmental terms than existing systems. In the long term, systems with lucerne are more profitable, can prevent further degradation of land and water resources, reduce economic and financial losses as a result of waterlogging and salinity and offer opportunities to manage other agronomic and environmental problems in agriculture.

To date a small proportion of farmers has adopted lucerne despite being the only herbaceous perennial legume for broadacre agriculture. Inaccurate or incomplete early messages may have contributed to misconceptions being formed about lucerne, so this technology is perceived by some stakeholders as inappropriate, complex or too risky.

In order to reap the production and environmental benefits of systems with lucerne it is essential to learn the principles that underpin how and within what limits lucerne functions. This information coupled with farmers’ local knowledge will help determine the appropriate agronomic practices to meet the agro-ecological requirements for lucerne establishment and management. The use of lucerne at a paddock, farm or catchment level and the need to be used in combination with other practices will have to be determined according to site-specific circumstances and each farmer’s short- and long-term goals.

Land salinisation is one of the highest priority environmental problems in Western Australia together with salinisation of inland waters, climate change, weeds and others. Over the past decade further deterioration due to salinity has occurred in the south-western corner of the state and this trend is predicted to continue. Therefore, significant land use changes are still required.

To the best of our knowledge, systems with lucerne directly address these problems and others considered second priority like soil erosion, loss or degradation of native vegetation and third priority like soil acidification. Lucerne can contribute to manage these problems effectively if adopted by farmers. Degradation is expected to continue with current farming practices based on annual crops and pastures if no change is made in areas at risk. This trend can be changed and the impact of such environmental problems mitigated if new practices are adopted.

DAFWA and FFI CRC are dedicated, in collaboration with farmers, to designing appropriate technologies and developing more diverse farming systems with an in-built capacity to function under present and future environmental and production challenges.

The release of alternative perennial pastures will, without any doubt, provide new opportunities for improving profitability, sustainability and resilience of broadacre grain and livestock farming systems in a way no system based on annuals can.

To support these changes sustained research funding is required and user-friendly decision tools need to be developed for farmers to assess their options for best managing the transition to systems with perennial pastures, as well as suitable extension strategies and policies that transcend political boundaries and terms.
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