Producing Quality Lucerne Hay

by Mary-Anne Lattimore

A guide for lucerne hay producers, across Australia.

This book provides practical management information to produce high quality and profitable lucerne hay.

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Foreword

Although there are various publications on hay and lucerne production available, there has not previously been one which has focussed on the lucerne hay industry. *Producing Quality Lucerne Hay* has been written for lucerne hay producers, contractors, advisers and other industry participants throughout Australia. The aim is to provide a tool to improve individual lucerne hay businesses and ultimately, to lift the profitability and sustainability of the industry. The book combines current scientific and technical knowledge with the experience of successful lucerne hay producers, in a comprehensive guide for the Australian lucerne hay industry.

The book is the result of a project which collected knowledge and best management practices (BMP) from lucerne hay producers in Australia and the USA who are achieving high levels of production and efficiency through good management and new technology. It is backed up with the 30 years of agronomic knowledge and experience of the author and strong links with the industry through the Australian Fodder Industry Association Inc.

The book highlights the benefits of lucerne hay to livestock, the importance of producing a high quality product and outlines the strategies used by successful lucerne hay producers. It includes best management practices and new technologies for growing, making and marketing lucerne hay, turning the art of lucerne hay production into a science.

It provides strategies to improve the efficiency, productivity, profitability and sustainability of lucerne hay production, so that producers can consistently meet the market requirements and environmental constraints. It covers both irrigated and dryland lucerne hay production.

Widespread adoption of practices outlined in this book should lead to better yields, quality and profitability for producers; a better supply of high quality hay for both the domestic and export markets; enhanced export market access; and a more profitable and stable lucerne hay industry.

This project was jointly funded by industry revenue, matched by funds provided by the Australian Government, and the NSW Department of Primary Industries.

This report, an addition to RIRDC's diverse range of over 1600 research publications, forms part of our Fodder R&D program, which aims to facilitate the development of a sustainable and profitable Australian fodder industry.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- www.rirdc.gov.au/fullreports/index.html for downloads
- www.rirdc.gov.au/eshop for purchases.

Peter O'Brien
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This book is a result of a project funded by the Rural Industries Research and Development Corporation (RIRDC) and New South Wales Department of Primary Industries (NSW DPI) to investigate the growing, making, processing and marketing of lucerne hay in Australia.

It is loosely based on an earlier regional publication—*Irrigated lucerne: a guide to profitable irrigated lucerne hay production in northern Victoria and southern NSW* (1998). (Eds S. Lolicato and M. Lattimore), NSW Agriculture, Department of Agriculture Victoria and Murray Darling Basin Commission. The book has been updated and the scope broadened to cover the whole Australian lucerne hay industry.

New information has been gathered from experienced growers, contractors, researchers, extension officers, industry representatives and others associated with the lucerne haymaking industry in both Australia and the USA, a leader in lucerne hay production. Farmer focus groups, interviews and a study tour were undertaken. Many comments and tips from growers and information from the study tour are included in the book. A separate report on the study tour to the USA is available from the author upon request.

This book also draws on, and refers the reader to, many excellent existing publications on lucerne and haymaking, and endeavours to provide the most up to date information available.

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Executive summary

Lucerne is a remarkably adaptable, productive and resilient crop-plant. However the potential for lucerne as a hay crop is often not achieved. This book has been written to help 'raise the bar' of productivity and profitability, and to realise the potential that exists within the Australian lucerne hay industry.

Lucerne hay is an important commodity in Australia, providing high quality feed for livestock. It promotes excellent liveweight gains and milk production and the crop helps to ensure farm sustainability, by serving as an important nitrogen-fixing rotation crop. Successful lucerne producers can achieve high returns with premium quality hay.

Australia produces about 1 million tonnes of lucerne hay each year with a value of at least $300 million (ABS 2003). Most of this is consumed domestically. There is a small export market of around 10,000 tonnes per year, but there is huge export potential to Asia and the Middle East.

Despite the value of lucerne hay as a commodity, the Australian lucerne hay industry does not have a highly organised domestic or export marketing system. There is generally a premium for high quality hay but there is limited value-adding and strategic marketing of hay products. Growers face highly volatile hay prices on the domestic market, driven by supply and demand. During drought periods the domestic price can far exceed that of export hay, while in favourable seasons it may be difficult to recover production costs.

Export markets demand a sizeable, stable supply of high quality lucerne hay at the right price, which may be below the domestic price during dry times. Export hay must also meet strict standards, especially in regard to chemical residues. Substantial markets exist, but the Australian industry cannot currently meet the quantity and quality required

The industry also currently faces problems with increased production costs and reduced availability of inputs such as water, and a host of environmental and other legislative requirements. In addition, many growers do not achieve the maximum potential yield or quality of lucerne hay through lack of knowledge and management skills.

Lucerne haymaking has traditionally involved hard work, long hours and sleepless nights. Many of the traditional practices and principles of lucerne haymaking have been handed down from father to son. While many of these still apply, new technological advances have made the task easier and less labour intensive. Research and development in haymaking machinery and irrigation technology has helped to turn the art of lucerne haymaking into a science. There is great potential to improve Australia's lucerne hay industry and its returns to growers through better production, storage and marketing of high quality hay.

This project examined the lucerne hay industry in both Australia and the USA, to determine best management strategies and new technologies that could be adopted to improve the profitability and sustainability of the industry. It involved a study tour of lucerne hay production in the USA and interaction with the Australian Fodder Industry Association, successful hay producers throughout Australia, as well as research and extension personnel of the various state Departments of Primary Industries and Agriculture.

Producing Quality Lucerne Hay provides guidelines for improving lucerne hay production, its efficiency and profitability. It combines scientific knowledge, new technology and valuable farmer expertise into a single resource that can be used by growers, contractors, advisers and other participants of the industry.

It provides an overview of the Australian lucerne hay industry, as well as the best management practices needed by Australian producers to grow make and market lucerne hay successfully. It includes detailed information and benchmarks on lucerne growing, haymaking and processing, feed quality and utilisation, marketing, a checklist for haymakers and a detailed reference and contact list for the industry.

Widespread adoption of practices outlined in *Producing Quality Lucerne Hay* will lead to improved yield, quality and profitability for producers, a more reliable supply of high quality hay for both the domestic and export markets, enhanced export market access, and a more profitable and stable lucerne hay industry. Small changes in practice can have an enormous impact on the lucerne hay industry.

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Chapter 1

Summary of best management practices for lucerne hay production

Targets

Quantity: 15–20 t/ha hay per season for a fully irrigated lucerne hay stand.

Quality: top quality lucerne hay should have at least 19% crude protein, 9 MJ/kg DM metabolisable energy and 65% digestibility.

Sustainability: lucerne stands should achieve high yields of good quality hay for 3–5 years (irrigated) or 4–7 years (dryland) if well managed.

Financial returns: reliable markets for all grades of hay are required to maximise financial returns.

Best management practices (BMPs) for lucerne hay production are the strategies used by successful growers to produce high yields of high quality lucerne hay, resulting in a profitable, sustainable business.

Successful lucerne growers set themselves benchmark targets, record their progress and continually fine tune their haymaking operation to improve their performance. Some targets and best management practices for lucerne growers are outlined in the following BMP summaries.

Summary of BMPs for growing lucerne

Aim to establish and maintain a dense, competitive lucerne stand.

Also see *Chapter 6*, *Chapter 7* and *Chapter 8*.

Factor	Key management practices
Paddock selection	Use the best paddock for lucerne growing available (e.g. soil type, infiltration, drainage, preparation). Ensure there are no hard pans to restrict lucerne growth.
Preparation	Rotate lucerne with other crops to prevent carry-over of disease and insects. Control weeds and insects in the year before sowing lucerne.
Soil type	Select the most suitable soil (chemistry & structure) with good moisture.
Soil nutrients	Do a soil test. Avoid or ameliorate acid or sodic soils. Ensure nutrients (especially P, S, Mo and K) are adequate at sowing. Do a nutrient budget and replace nutrients removed in hay with applied fertiliser.
Irrigation layout and drainage	Ensure adequate water supply. Test water to assess suitability. Ensure adequate water infiltration (at least 80–100 cm). Ensure adequate soil drainage to avoid waterlogging.
Irrigation management	Irrigate before cutting and allow paddock to dry enough for machinery access. *Spray irrigation:* ensure nozzles can deliver adequate water. *Flood irrigation:* drain within 8 hours to prevent plant death and ensure stand persistence. Do not flood irrigate straight after cutting. Avoid moisture stress by scheduling irrigations. Maintain all irrigation equipment.
Varieties	Select pest resistant varieties, adapted to your environment and management system. Use good quality, certified seed.
Inoculate seed	Use strain AL Rhizobium inoculant and make sure it is fresh. Do not expose inoculant or treated seed to heat before sowing.
Sowing time	Establish in autumn or spring to provide suitable growing conditions. Match variety with sowing time.
Seeding rate	*Irrigation:* 12–15 kg to achieve a plant population of 150–200 plants/m^2. *Dryland:* 1–3 kg/ha, depending on rainfall. Sow lucerne without a cover crop for best establishment.
Sowing depth	Less than 15 mm
Weed control	Assess weed potential and minimise competition from weeds. See *Summary of BMPs for managing weeds in lucerne,* following page.
Insect and disease control	Understand the risk of insect infestation and disease incidence. Control diseases and insects at establishment. Regularly monitor and manage insect populations. Monitor leaf disease and cut lucerne to remove diseased leaves, if necessary.
Stand management to maximise production and persistence	*Plant density:* at least 50 plants/m^2 for irrigated hay production. *Cutting height:* do not cut too low (5–7 cm minimum) to avoid crown damage. *Cutting frequency:* do not cut too often; allow regrowth to reach 20 cm height or at least 21–28 days, to replenish root reserves. *Grazing:* minimise grazing in hay stands; use rotational grazing.

Summary of BMPs for managing weeds in lucerne

Also see *Chapter 6* and *Chapter 7*.

Situation	Strategy
Before sowing	Choose a weed-free field and avoid introducing weed seeds via seed, machinery or vehicles. *Autumn sowing*: use a long fallow, cultivation and knockdown herbicides. *Spring sowing*: Reduce winter weeds by using spray-topping, heavy grazing or flaming. Pre-irrigate and cultivate or apply herbicide to control emerging weeds. Use pre-emergent herbicide.
Difficult summer weeds (e.g. couch grass)	Use winter-cropping for at least two seasons before sowing lucerne.
Where summer weeds are expected to be a problem	Sow a winter active lucerne variety in autumn to allow good lucerne growth before weeds germinate in spring. Early spring sowing of lucerne following a knockdown herbicide is an option if irrigation is available.
At sowing	Use weed-free seed. Use maximum sowing rate of lucerne for the situation. For grazed lucerne, companion planting with a cereal sown at low seed rate can suppress annual winter weeds—it is important that the companion crop does not out-compete the lucerne. Not a good option for lucerne targeted for hay production.
Establishing seedlings	Keep lucerne healthy and competitive by managing nutrition, diseases and insects. Control weeds when they are small to prevent them from setting seed. Monitor stands closely for emerging weeds. Use herbicides if necessary.
Salvage control for heavy infestations of tall weeds in lucerne	Mow young lucerne provided plants are well-anchored and at least 20 cm tall. Weeds are killed or suppressed and light penetration allows regrowing lucerne to compete better with surviving weeds. Allow time for the root reserves to regenerate after early cutting—delay the second cut.
Noxious weeds e.g. golden dodder, khaki burr	Monitor and map new infestations. Control new infestations by spot spraying and burning. Remove and dispose of weeds, particularly those with seed or fruit attached. Quarantine infested paddocks—no haymaking or grazing.
Organic lucerne	Use high lucerne seeding rates and manage nutrition, insects and diseases to maintain lucerne plant health. Grazing, light cultivation with narrow points or flame weeders during winter when lucerne is dormant can aid weed control when herbicides are not an option—resulting plant damage may reduce stand persistence.

Summary of BMPs for making lucerne hay

Also see *Chapter 9*.

Factor	Key management practices
Planning	Plan ahead, be prepared and do the job properly. Timeliness is critical.
Resources	Ensure adequate machinery and skilled labour for the job or availability of contractors. Maintain equipment. Cut what can be handled in one day and consider how to manage the risks associated with weather conditions.
Crop maturity	Cut at the correct growth stage to optimise quality, yield and stand persistence.
Moisture for haymaking	Rake and bale lucerne at the right moisture content. Rake lucerne when above 40% moisture. Bale lucerne when at 15–20% moisture, depending on bale size.
Technique	Handle hay gently and as little as possible during curing. Consider the weather conditions and use techniques to aid drying (e.g. conditioners, additives).
Lucerne stand care	Remove bales from paddock as soon as possible to allow regrowth of the lucerne crop. Keep wheel traffic of vehicles and machinery to a minimum in the lucerne paddock.
Storage	Store hay at the correct moisture in a covered shed. Monitor for heating regularly.
Transport	Transport hay efficiently and safely using industry recommended load restraints.
Viability	Keep up to date with technology and produce lucerne hay as efficiently as possible.

Summary of BMPs for marketing lucerne hay

Also see *Chapter 10* and *Chapter 11*.

Factor	Key management practices
Quality	Manage lucerne and make hay to produce a good quality product which consistently meets market specifications.
Value adding	Consider the potential for value-adding. Add value to hay by packaging and labelling or by finding a niche market.
Storage	Provide ample covered storage to maintain lucerne hay quality and to cope with seasonal price fluctuations. This assists with maintaining cash flow.
Markets	Update your marketing skills. Consider market location and organise a market before harvest. Be aware of customer requirements. Keep up to date with market prices. Advertise.
Hay grades	Tag and grade lucerne hay. Price grades accordingly and market each grade separately.
Quality assurance	Feed test all hay and make details available to the user. Keep accurate records of the hay produced and use vendor declaration forms to assure hay quality.
Communication	Form good relationships with customers and communicate with them frequently. Look after your customers.

Chapter 2
Lucerne hay in Australia

Lucerne is an extremely valuable plant to the fodder industry of Australia. It provides highly nutritious stockfeed and with the right growth conditions and careful management can be a highly productive and lucrative crop. Lucerne is grown for its perennial habit, adaptability and ability to survive in dry conditions, as well as its responsiveness to rainfall and irrigation and its role in soil improvement. Lucerne seed production can also be a valuable, sideline enterprise. Lucerne's versatility and resilience allows it to play an important role in the farming systems across Australia.

Lucerne is mainly grown in the temperate and sub-tropical regions of Australia, with average annual rainfall greater than 300 mm. With adequate water and warm temperatures lucerne forage production can be substantial, yielding up to 25 tonnes of hay per hectare. Its growth is limited by lack of water, extreme temperatures, acid soils, waterlogging, frost and various insect pests and diseases. Haymaking is limited by rainfall, high humidity and wet soils.

Soil type, warm temperatures and the availability of irrigation water are critical factors in achieving high lucerne yields. The best lucerne hay growing areas are on deep, well-drained alluvial soils, along coastal or inland river systems, in areas of low humidity.

The benefits of lucerne

Adaptability: highly adaptable and can be managed in different ways to produce different products.

Dry matter: produces more dry matter than most other pasture species.

Quality: superior quality feed value for livestock

Forage conservation: can be conserved as high quality hay or silage.

Grazing: perennial habit allows it to provide a stable basis for livestock grazing.

Growth: responds to rainfall and irrigation. Can produce opportunistic hay or feed and fill the autumn feed gap.

Seed production: Can produce high yields of high value seed.

Drought resistant: survives dry periods by using moisture from depth and by going dormant. Often the only green feed available during a drought.

Wool production: grass-free lucerne produces clean wool.

Break crop: provides an excellent break crop for weeds and diseases of cereal and oilseed crops.

Soil fertility: improves soil fertility by fixing nitrogen from the air and adding organic matter.

Soil structure: may improve soil structure, water infiltration and moisture extraction for subsequent crops by increasing organic matter and providing root channels.

Soil stability: can reduce soil erosion by providing year-round ground cover (although it can also result in reduced cover as the soil becomes bare between lucerne plants).

Soil moisture: can utilise subsoil moisture and rapidly use summer rainfall, so reduces the risk of waterlogging and soil salinity.

Weed competition: well established lucerne can inhibit summer weeds through competition for moisture.

Fire break: lush green lucerne can be a useful break for bushfires (although dry lucerne in extreme weather conditions can be flammable).

Australian lucerne hay production

About 3 million hectares of lucerne is grown in Australia. The majority of this area is used for extensive grazing. Around 7500 lucerne growers harvest about 200 000 ha annually for hay, producing about 1 million tonnes each year (Australian Bureau of Statistics). This represents about 25% of the country's total hay production from about 20% of the total hay area. Although the quantity is small relative to other types of conserved fodder, its value is significant. The estimated value of lucerne hay in 2001 was $181 million, while in the drier year of 2003 it was worth $336 million.

Most of Australia's lucerne hay is produced in NSW, Victoria and Queensland, mainly on irrigated enterprises but also on dryland farms. In areas with shorter haymaking seasons and a higher chance of moist conditions at harvest time, lucerne silage is also important form of conserved forage. In all of these areas lucerne is grazed as standing green feed or cut as green chop for direct feeding to livestock.

Much of the lucerne hay that is produced is consumed on farm. The majority of the traded lucerne hay is sold on the Australian domestic market which is subject to significant price fluctuations. The largest consumers of lucerne hay are the domestic horse (1.5 million horses), grazing and dairy industries. There is also growing interest in lucerne hay for new animal industries (e.g. deer, alpacas), stockfeed manufacturers and garden mulch. Most lucerne hay is sold as bales directly from the farm but some is processed into other products (e.g. meal and pellets) which adds value to the commodity.

Only a small proportion of Australia's hay and chaff is exported. Lucerne exports reached a peak of

"Top quality hay sells itself", Neil Natalier, Gatton, Qld.

17,349 tonnes in 1989–90 but have been 9,000–13,000 tonnes during the last 15 years (excluding severe drought periods). The main export markets are Japan and SE Asia (including Singapore, the Philippines, Hong Kong, Indonesia and Malaysia), where it is used predominantly for dairies and racehorses. Access to these markets is presently limited by price competition from the USA. Large potential markets exist in Korea and the Middle East. A small quantity of lucerne meal and pellets is also currently exported.

State lucerne hay production

Just under half of Australia's lucerne hay production (mainly irrigated) occurs in NSW (*Table 2.1*), accounting for 45% the total hay production of NSW. The main production areas in NSW are the slopes, tablelands and eastern plains, along the major inland river systems of the Peel, Macquarie, Hunter, Lachlan, Murray and Murrumbidgee Rivers.

Queensland and Victoria each produce about 20% of Australia's lucerne hay. In Victoria most of the lucerne hay is produced in the north central dairying region along the Murray, Goulburn and Lodden Rivers. Lucerne production in Queensland is confined to the south-eastern corner, as far north as Biloela, and includes the Moreton, Darling Downs, Wide Bay–Burnett and Fitzroy regions.

About 10% of Australia's lucerne hay comes from South Australia, mainly the south-eastern corner, with smaller amounts being produced in the Northern Territory, south-west Western Australia, Tasmania and the ACT. There are only a few growers in the Northern Territory but production is increasing.

Table 2.1 Australian lucerne hay production 2002.
Source: Australian Bureau of Statistics (2002).

State	Area (ha)	Production (t)	Average annual yield (t/ha)
NSW	94 390	389 981	4.1
Vic	39 124	215 607	5.5
Qld	25 196	193 713	7.7
SA	30 741	101 663	3.3
NT	8 000	36 000	4.5
WA	5 633	24 105	4.3
Tas	3 040	3 040	5.4
ACT	278	1 000	3.6
Australia	206 124	977 538	4.7

Dryland lucerne in Australia

Although most of the lucerne hay traded is sourced from irrigated production, dryland lucerne occupies a much larger area and is the basis of dryland livestock production in temperate Australia. Hay made from dryland lucerne stands is generally opportunistic, and depends on rainfall during the spring–autumn period.

Lucerne hay yields

The average yields of lucerne hay in Australia vary markedly depending upon location, rainfall or irrigation, management and the season. Generally, higher yields are achieved in the more northern locations due to longer lucerne growing and cutting seasons.

Successful irrigated growers could expect to produce between 15–25 t/ha lucerne hay per year from 5–7 cuts per year, while in dryland conditions up to 6–7 t/ha (1–2 cuts) could be produced in favourable years. In sub-tropical climates (e.g. Queensland) 8–10 hay cuts per year can be made, while in cool temperate regions or lower latitudes only 3–4 cuts may be possible. Yields of 40 t/ha have been achieved in Queensland but in most cases, yields are much lower than this, usually due to lack of water or poor management.

Lucerne hay yields vary from 1 to 4 t/ha per cut and usually decline with successive harvests. In summer, longer daylengths and warmer temperatures shorten the time to flowering and reduce the yield per cut. Although rapid regrowth occurs after harvest at 10–30°C, higher temperatures and increased moisture stress during mid-summer can reduce plant growth of lucerne, and may induce dormancy.

Chapter 3
Lucerne for livestock

Lucerne is considered a premium feed for livestock, providing higher quality feed than most other plant species, both as fresh and conserved fodder. Lucerne hay promotes high animal growth rates, milk production and reproduction. For these reasons it is highly sought after by livestock producers.

Most of Australia's lucerne hay and chaff is fed to horses and dairy cattle, which demand high quality feed. In the USA lucerne hay is the backbone of the dairy and beef cattle industries. It is also used in both countries for a range of other livestock, as fresh or conserved forage.

Both feed quality and animal requirements vary and should be matched for optimum animal production. Animal productivity is largely determined by feed availability, intake and the digestible energy gained from that feed. Feed requirements depend on the type, size and physiological stage of the animal. By understanding both feed quality and the feed requirements of animals, hay producers and their customers can select the right feed for their stock.

Feed quality, storage and feeding technique are all important to ensure good animal performance. Lucerne haymakers should always keep the end user in mind and aim to produce a high quality product which suits the customers' requirements.

Lucerne for horses

Horses are monogastric herbivores with a small stomach and bowel. They eat to meet their energy and gut fill requirements and feed frequently, up to 21 hours per day. They require a forage-based ration and must consume at least 1% of their body weight as roughage per day. Horses generally prefer lucerne to other types of hay.

The majority of digestion in horses occurs in the small intestine, with most of the energy coming from volatile fatty acids and fibre fermented in the hindgut. Lucerne hay is digested quickly and generally meets the horse's daily energy requirements.

Lucerne hay and lucerne chaff provide a highly nutritious feed for horses that is palatable, economical and practical. It contains high levels of protein, energy, calcium, magnesium, potassium, vitamins A and E, and the amino acid lysine, all important components of horse nutrition.

Phosphorus levels in lucerne may be low and supplements required.

High quality lucerne hay meets the calcium requirements of adult horses but young horses may need supplements. Excess calcium or magnesium intakes can lead to orthopaedic disease in young animals or enteroliths (bladder stones) forming.

Lucerne is less likely to cause laminitis (founder) than grazed cereals and is useful to help horses recover after laminitis or ulcers (*Table 3.7*).

Lucerne hay for horses must have a high leaf to stem ratio to aid digestion. It must be sweet smelling to improve palatability and free of dust to prevent asthma and lower airway disease. Hay must also be well cured and free of mould (toxins) or animal remains. Horses are very sensitive to dust or mould.

A. Manciagli © NSW DPI

Table 3.1 Lucerne hay requirements for different types of horses.
Source: Kohnke, *et al.* (1999).

Class of horse	Lucerne in a horse diet
Resting or idle (maintenance)	If pasture quality or quantity are limiting, lucerne hay can be used as a supplement. Feed hay at 1.75% body weight (3 small bale biscuits or 6–7 kg/day at night), and grass during the day. Only low protein hay (7-8%) is required.
Growing	Young horses require high protein (10-18%) and energy levels. Lucerne chaff is useful for young animals with high growth rates. A lucerne hay-based diet (plus oats) meets the high demand for energy, protein, lysine and digestibility. Because only about 20% of protein in lucerne hay is digested in the small intestine (the rest is digested in the large intestine) other supplements (e.g. soybean meal) may be required. Developmental orthopaedic disease can develop in foals on high energy diets.
Pregnant	Maintenance rations are required until the last three months of pregnancy, after which requirements increase but intake drops. Lucerne hay supplies adequate energy, protein and calcium, but phosphorus supplements may be needed.
Lactating	High protein and energy required, especially during early lactation. Lucerne hay plus oats needed, as well as a phosphorus supplement, to meet nutrient demand.
Working	Higher requirements than maintenance (similar to late lactation in mares or growing yearlings) depending on the level of work. Working, growing or exercising animals require 2% body weight of feed each day, half being hay (about 5–6 kg). Lucerne has only a slight advantage (higher ME) over grass for these animals. It can be used alone as a night ration for horses doing light work (0.5 kg/100 kg body weight). Lucerne hay provides adequate fibre and bulk, or it can be used (up to 1 kg) in a mixed ration for more advanced training.
Racing	High energy requirements mean race horses need to be fed 2.2–3% body weight each day. Hay intake must be kept to a minimum as hay absorbs moisture and adds weight to the horse (1 kg hay produces 4 kg hind gut weight). Lucerne provides high energy with a low volume of intake.

Lucerne hay should be weed-free, as 95% of ingested seed is passed in manure in a viable form within 4–5 days. Feeding horses hay that is contaminated with weed seed introduces and spreads weeds.

Most customers are prepared to pay a premium for high quality hay but tend to choose lucerne hay on subjective rather than objective parameters.

Matching feed to nutritional requirements

Lucerne hay and lucerne chaff form an important part of mixed rations for young, active, pregnant, lactating and stabled horses. The amount of lucerne hay required depends on the age, size and condition of the animal (*Table 3.1*). They are also useful as a supplement when pastures are short or of low quality. Although lucerne is often considered the best hay for horses, high quality lucerne hay may exceed the nutritional needs of some animals such as domestic horses or mares in early pregnancy. Problems can result from excess energy and protein in a lucerne diet. If lucerne hay is the sole diet, the high energy content can cause weight gain in resting horses or developmental orthopaedic disease in growing horses. This is more a function of the high quality of feed, rather than of lucerne *per se*. A lucerne/grass mix is preferable for these types of animals.

The high protein content of lucerne suits racehorses and young growing animals but may contribute to obesity in idle domestic horses if over fed. Excess protein (>16%) slows performance times for racehorses and increases the heat load during racing and endurance work. It also increases the amount of ammonia in the urine which can lead to dehydration in hot conditions, foul smelling droppings and lung irritation.

Hay or chaff for horses?

The length of the pieces of hay is important for horses. For adult horses long stems are needed to stimulate salivary flow and to maintain gut function but if lucerne is too stalky horses will not eat it. Hay needs to be 2–4 cm long to stimulate saliva production and ensure sufficient buffering time in the digestive system.

Lucerne chaff is a favourite of horse owners but may be unsuitable for some animals due to high quality.

Chaff, or finely chopped hay, moves quickly through the gut, reducing the amount of nutrients absorbed (60% may bypass digestion). Although useful for young foals there is no additional benefit in chopping good quality hay for adult horses. Chaff is useful to increase the bulk and fibre content of a grain-based racehorse ration. The ideal ration for these is 1:1 chaff:grain.

Feeding problems with horses

Lucerne hay does not hold water in the hind gut as well as cereal hay. It can cause wind and loose droppings. Excess sugar and starch can lead to nervous behaviour, diarrhoea and laminitis.

- If too much hay is fed, energy intake will be reduced, increasing the hindgut contents, resulting in messy droppings. Excess protein will pass to the hindgut and increase the heat load.
- If too little hay is fed (<0.5% body weight) growth will be limited. The gut will not be filled and horses will be hungry and chew at fences, etc.

Lucerne for ruminants

Ruminants have a different digestive system to monogastric animals which allows them to better utilise fibre in feed. Feed is initially stored in the rumen, regurgitated, chewed, re-swallowed and then digested by microbes in the rumen. Some is converted into microbial protein which is digested in the small intestine.

The nutrient requirements for ruminants are presented in *Table 3.2*. All ruminants need at least 15–20% effective fibre in their diet to supply nutrients and maintain digestive function. Effective fibre stimulates and cleans the rumen walls and promotes the release of digestive juices. A diet including 10–15% lucerne hay plus grain would meet this requirement.

Animals in feedlots perform well on high quality hay like lucerne (high protein, low fibre) which is digested quickly, so animals eat more and grow more quickly. Low quality forages (high fibre) take longer to digest, so stay in the rumen longer, reducing intake and production. Protein and minerals only become limiting when feed quality is low.

High quality lucerne hay with effective particle length (about 2 cm) also promotes salivary flow, which maintains the rumen pH, enhancing high feed intake. Lack of effective fibre lowers the pH of the rumen, leading to acidosis.

Silage and green chop

Silage and green chop can be used as part, or all of the roughage component of ruminant animal diets, especially in intensive dairy feedlots. They can be substituted for hay at the rate of 3–5 kg of silage or green chop per 1 kg hay, depending on moisture content. Note that silage quality can vary considerably.

High quality silage (at least 9.5 MJ/kg ME) can be substituted for some of the grain portion of the ration. It can produce liveweight gains of 0.8–1.0 kg/day in yearling-age cattle and 150–200 g/day in crossbred lambs when fed as chopped silage. For more information on silage see *Successful Silage,* Kaiser *et al*., 2000).

Lucerne silage can be stored in covered, above ground bunkers.

Table 3.2 Nutrient requirements for different classes of ruminants.

Source: adapted from Ball *et al*. (2001).

Class of ruminant	Lucerne in a ruminant diet
Maintenance	Energy is the most limiting factor to animal performance. The maintenance diet for adult animals should contain at least 5.5–7 MJ/kg ME and 8–10% CP, depending on the size and age of animal, assuming mineral supply is adequate. Most lucerne hay is suitable. Protein, vitamins and minerals can sometimes be limiting.
Growing	Young animals need high nutrition levels to produce muscle and bone, until they reach 50% adult body weight. Diets should begin with high protein (12–16% CP) and energy (9–11 MJ/kg ME) and gradually decrease to 10–12 % CP and 7–10 MJ/kg ME once 50% adult body weight is reached. After weaning, protein, calcium and/or phosphorus supplements may be required.
Fattening	High energy and lower protein, minerals and vitamins are required to fatten animals. Growth and fattening require 1.5–2 times maintenance levels. Aim for 8–10% CP and 12 MJ/kg ME in the diet.
Mating	More nutrients are required during the breeding season (e.g. 10–20% more energy and less fibre than maintenance) to enhance female fertility and male performance.
Pregnant	Nutritional requirements are low during the first two thirds of pregnancy (7–8% CP) and increase during the last third of pregnancy (8–12% CP). Even higher nutrition is required during the last 10% of pregnancy (at least 10–12% CP and 12 MJ/kg ME).
Lactating	Milk production requires high nutrition and demands the best quality feed for maximum production. High quality lucerne is an important feed component. Beef cattle and sheep need 2–2.5 times maintenance energy levels, while dairy cows, dairy ewes and dairy goats need up to 4–5 times maintenance. The diet of cows and sheep at peak lactation should contain 12–14% CP and 12 MJ/kg ME. High producing cows, ewes and goats should have 16–18% CP and 12 MJ/kg ME, plus high phosphorus and calcium. Fibre is important. Too much causes low feed intake. Too little reduces fat corrected milk, increases fattening of females, and increases digestive disorders. Fibre intake governs animal production, so feed quality must be high.

Lucerne for beef cattle

Cattle feed for about 13 hours each day, eating the equivalent of about 2–3% of their body weight as dry matter. They need high energy and protein levels in the diet with at least 17% effective fibre to maintain digestive function. Protein needs vary with the class and size of the animal. Two-thirds of the protein intake should be natural protein.

Lucerne hay results in excellent weight gain in cattle, so is preferred on farms for young or breeding stock. In Australian beef feedlots however, it is generally only used as a starter ration, the hay being gradually displaced by grain, a cheaper energy source. Lower quality roughages at about 20% of the diet are usually adequate in beef feedlots to accompany grain and other supplements.

Lucerne hay can cause bloating in cattle if fed alone. Ensure that lucerne comprises less than 40% of

the roughage portion of the ration to avoid bloat. However, this may limit production if the energy level is low and a high energy grain supplement may be required. Steers have higher protein and energy requirements for growth in feedlots than lactating cows. See *Table 3.3* for further information.

Table 3.3 Daily feed requirement of beef cattle.

Source: Agriculture Notes, Department of Primary Industries Victoria.

Class of beef cattle	Metabolisable energy requirement (MJ/day)	Minimum ME concentration (MJ/kg DM)	Crude protein of dietary dry matter (% DM)
Steer/heifer (300 kg live wt, 1 kg/day weight gain)	76	10–12	13
Dry, pregnant cow (500 kg)	61–74	5.7–6.9	8–10
Lactating cow (500 kg) with calf	90	8.4	10
Bull (600 kg, 0.5 kg weight gain per day)	95	8.1	11

Lucerne for dairy cows

High quality lucerne hay is especially useful for milk production. Lucerne promotes early growth of heifers so that they reach a suitable weight by joining time. It also helps to get cows back into calf quickly in subsequent years, and can be used to meet a milking cow's high protein and energy requirements.

Highly digestible feed like lucerne hay promotes high animal intake. Cows eat about 2.5% body weight per day of high quality lucerne hay but only 1.5% body weight of lucerne harvested at full bloom. High quality feed is more important to a high producing cow. Lower quality (higher fibre) feeds reduce milk production markedly in high producing herds. For poorer producers the loss is not as great. Mature lucerne with high fibre is not suitable for milk production.

Dairy cows fed on pure lucerne may need phosphorus supplements to make up for the low levels in lucerne (*Table 3.4*).

In the USA, lucerne hay is used to complement corn silage as a basis for dairy feedlot rations. The higher the feed value of the lucerne hay, the higher the price paid by dairymen in order to achieve top production. Australian dairy feedlots are beginning to use these principles.

Lucerne for sheep production

Sheep are the most efficient utilisers of forage of all ruminant animals. Their nutrient requirements vary widely depending on breed, class and size of the sheep (*Table 3.5*). Digestibility is directly related to the energy content of the feed, which in turn is linked to the protein content. A feed with high digestibility will have high energy and protein levels capable of supporting high levels of sheep performance. Energy and protein must be in balance for efficient feed utilisation. For example, feed with

Table 3.4 Daily feed requirement of dairy cattle.

Source: FeedTest, Victoria.

Class of dairy cattle	Metabolisable energy requirement (MJ/day)	Crude protein of dietary dry matter (% DM)
Milk fed calf (40 kg, 0.5 kg/day weight gain)	13	19
Heifer (200 kg, grazing, 0.5 kg/day weight/gain)	43	17
Dry pregnant cow (450 kg, grazing, 1 kg weight gain/day)	146	10
Friesian cow (450 kg, early lactation)	163	15
Jersey cow (450 kg, early lactation)	147	15

Table 3.5 Daily feed requirement of sheep.

Source: NSW Department of Primary Industries.

Class of sheep	Metabolisable energy requirement (MJ/day)	Crude protein of dietary dry matter (% DM)
Weaner (50 g/day weight gain)	6–8	10
Dry ewe (40 kg) maintenance	6.5	8
Ewe (40 kg), late pregnancy	9.5	8–10
Lactating ewe (40 kg) with lamb	15.5	12–13
Lactating ewe (40 kg) with twin lambs	24.5	12–13

13 MJ/kg ME must be matched with 16% protein, while feed with 8 MJ/kg ME needs 10% protein. If either protein or energy is limiting, the sheep will not be able to utilise all of the other components of the feed.

Digestibility also affects a sheep's daily feed intake. A digestible feed like lucerne hay spends less time in the stomach, encouraging the animal to eat more to satisfy its appetite. The more nutrients consumed, the closer a sheep will come to achieving its genetic potential for growth or wool production. Sheep are unable to consume enough feed for maintenance if the energy content in the feed is below 7.5 MJ/kg ME.

Lucerne hay is often used as a drought feed with 3 kg hay being equivalent to about 1 kg grain. Pregnant or lactating ewes and weaners should receive a minimum of 20% high quality hay in their diet to improve milk production, lamb survival and early growth. High rates of lucerne hay or silage are generally used within the starter ration in lamb feedlot programs. Finisher rations incorporate less high quality fibre such as lucerne hay, meeting fibre requirements through lower quality hay and straw. Feed requirements for sheep increase markedly during cold conditions. Good quality hay is the best source of feed to maintain growth in this situation.

J. Gasparotto © NSW DPI

Lucerne for other animals

Lucerne is used to feed other domestic animals, such as poultry, ostriches, pigs, alpacas, guinea pigs, rabbits and zoo animals. Lucerne pellets produce the highest animal weight gains. Ground lucerne in pellets has lower fibre content so more protein will be consumed than for an equivalent weight of lucerne hay.

Grazing lucerne

Lucerne can be damaged by over-grazing, so it must be managed well to ensure stand persistence. In irrigated lucerne, grazing is not desirable as it can cause 'pugging' and compaction on wet soils. Limited grazing in dry conditions in winter may assist with control of annual winter weeds with minimal crop damage. Grazing damages lucerne plants more than haymaking, but growers may be willing to trade-off some stand persistence for grazing and weed control in the hay stand.

Where livestock production takes priority over hay production, lucerne can produce some hay, as well as high quality green feed. The lucerne takes

G. Duddy © NSW DPI

A. Bowcher

Lucerne is a high quality feed supplement for domestic animals such as rabbits or for use in intensive livestock industries.

Table 3.6 Carrying capacity of grazed dryland lucerne at different locations in NSW.

Source: NSW Department of Primary Industries.

Location	Median rainfall (mm)	Carrying capacity (DSE)
Trangie, NSW plains	468	12.5
Wagga, NSW slopes	575	15
Canberra, NSW tablelands	623	20

advantage of any summer rains, filling summer and autumn feed gaps, fattening spring-born weaners and boosting the fertility of females prior to joining.

Rotational grazing is recommended to maintain stand density and viability. Small paddocks or electric fencing allow short periods (1–2 weeks) of intensive grazing at the bud stage (when new crown shoots are 2–5 cm long), until most of the herbage taller than 5–7 cm is eaten. If the stand is to be grazed again, allow a 4–6 week rest period (depending on the season) to let the stand recover.

With high stocking rates, monitor the lucerne plants closely to ensure that animals do not remove the new shoots at the crown or base. Remove animals during and after irrigating or rain until the field dries out, to avoid plant damage and soil compaction. There are some animal health problems associated with grazing pure stands of lucerne or being fed lucerne hay (*Table 3.7*).

Carrying capacity of lucerne in the field

The livestock carrying capacity of a farm can be increased significantly by including irrigated lucerne. Stocking rates of 40 lambs/ha (60–70 DSE/ha) over summer have been achieved on irrigated lucerne at Kerang (Department of Primary Industries Victoria). Highly winter active lucerne varieties can support animal production during the winter months. Dryland lucerne stocking rates (rotational systems) should be based on the median rainfall of the area and the corresponding amount of feed available. Drier environments will carry fewer livestock.

Animal health for livestock feeding on lucerne

Table 3.7 Animal health issues for livestock feeding on lucerne, including grazing fresh stands, hay and silage. Livestock should be managed accordingly.

Condition	Description	Management
Asthma and lower airway disease	Results from dusty hay. Horses are very susceptible.	Feed high quality hay, free from dust to prevent problems.
Bloat	A potentially serious problem for cattle grazing lush, leafy, actively growing lucerne, especially after irrigation or rainfall. Animals fill up with gas and usually die unless treated quickly. Sheep are less susceptible.	Do not introduce hungry stock to lucerne. Feed hay to reduce the risk. Observe stock frequently and remove at first sign of bloat. Use high stocking rates and small paddocks or strip graze with electric fencing to force stock to eat more mature parts of the plant. Anti-bloat veterinary medications are available, but regular, accurate dosages are important. Direct application of medication (e.g. slow release, orally-administered capsules), or an oil drench is more effective than adding anti-bloating agents to drinking water or oil/fat sprayed on the stand before grazing.
Botulism	A bacterial disease resulting from dead animals contaminating hay or silage. Bacteria produce toxins which can cause rapid death of livestock.	Remove dead animals from the field before making hay or silage.
Colic	Stomach pain in horses caused by gas in the digestive system due to overeating or a sudden change to a high legume diet.	Change the diet gradually and carefully, monitoring the condition of animals.
Developmental orthopaedic disease	Joint and limb abnormalities in foals due to high energy intakes and deficiencies or imbalances of calcium, phosphorus and other minerals. Not necessarily linked to lucerne but over feeding can play a part.	Ensure animals are not over fed and balance the lucerne in the diet with grasses to reduce high energy intake.
Laminitis or founder	Lameness in horses, cattle and sheep after grazing lush pastures or a sudden change to a high legume diet. An overload of starch and sugar in the hindgut results in acidosis. This leads to the death of microbes and the release of toxins that affect the tissues in the hooves.	Change the diet gradually, monitoring the condition of animals.
Listeriosis	A bacterial infection that can cause abortions, brain damage and death in ruminants, especially sheep. Caused by aerobic conditions in poorly compacted and sealed silage. Often in the surface layer of bunkers or wrapped bales.	Seal silage well and avoid feeding spoilt forage to animals.
Mould	Mould in poorly produced or stored hay/silage can produce toxins which can kill livestock. Mould spores inhaled can induce respiratory irritations or asthma, especially in horses.	Feed hay made at correct moisture content. Seal silage well.
Pulpy kidney or enterotoxaemia (*Clostridium perfringens* type D)	Occurs in sheep, especially lambs, grazing lush pastures and actively growing lucerne.	Do not introduce hungry sheep to lucerne. Vaccinate livestock at least 14–21 days before introduction to lucerne (the commonly-used '5 in 1' vaccine includes pulpy kidney protection).
Pizzle rot (sheath rot or balanoposthitis)	Occurs in wethers grazing good quality legumes. Rams are less susceptible to pizzle rot.	Provide additional low quality roughage. Remove wool from around the pizzle and treat wethers with testosterone before grazing lucerne. Testosterone can only be used with written advice from a veterinary surgeon.
Red gut	Twisted intestines in sheep grazing pure stands of lucerne in warm dry conditions, often following light rain in autumn. (Similar weather conditions to those causing bloat). The main symptom is sudden death.	Feed pasture hay and alternate grazing lucerne with lower quality feed. Remove affected flocks from the lucerne paddock immediately.

Chapter 4
Importance of lucerne hay quality

Although generally considered a high quality fodder, lucerne hay quality varies widely depending on:

- the health and growth stage of the lucerne plants when cut
- grass or weed contamination
- weather damage
- how the hay is made and stored.

The use of best practice management is critical to produce high quality lucerne hay.

High feed quality is important for optimum animal performance. Hay must be extremely palatable, digestible and nutritious to promote high levels of animal intake and growth, as well as having no detrimental factors such as mould. Problems with quality can reduce animal performance and profit.

High quality lucerne hay means different things to different people. The *indicative* nutritive value of lucerne hay can be determined *subjectively*, by considering its colour, texture, smell and composition. Usually high quality lucerne hay is green, leafy, soft, sweet-smelling and pure, without any mould, dust, weeds, chemical residues or other foreign material.

The *real* nutritive value should be measured *objectively* by laboratory analysis.

For effective, profitable marketing of hay producers need to understand the real feed value of their product and the factors that affect it, so that they can match it to the requirements of their own or customers' livestock.

Combined or bulked hay core samples ready for testing.

Measuring feed value

In Australia the major feed quality parameters are protein, energy and digestibility. Neutral detergent fibre (NDF) is also important for ruminants as it influences hay intake. The measure of NDF holds greater importance in the USA.

High quality lucerne hay has higher palatability, digestibility and protein than hay made from many other species. Its high energy level and low fibre (*Table 4.1*) also promote high animal intake, rapid digestion and excellent animal production.

Traditionally, feed value of hay or silage has been measured by standard chemical digestion tests which are time consuming and expensive. NIR (near infra-red reflectance spectroscopy) analysis is now more commonly used, offering a much quicker, cheaper and accessible method.

Standard laboratory techniques have been developed by the Australian Fodder Industry Association Inc. (AFIA) to provide a common language of feed quality for the industry. Reputable feed testing laboratories are located in most Australian states and are routinely checked by AFIA to ensure accuracy of results. USA analysis systems are sometimes used in Australia, especially with feedlots. Current research is working towards developing internationally accepted feed analysis standards.

Table 4.1 Typical nutritive values of high quality lucerne hay.

Characteristic	Value
Digestibility (%)	≥ 65
Metabolisable energy (ME) (MJ/kg DM)	9
Crude protein (% DM)	≥ 19
Acid detergent fibre (ADF) (%)	30
Neutral detergent fibre (NDF) (%)	40

Objective measures of hay and silage quality

Moisture content

The moisture content of hay affects how well it stores and how much an animal will eat. It must be taken into account when assessing nutrient content and the price of the hay. Moisture content is expressed as a percentage. Lucerne hay is usually less than 15% moisture for large bales and less than 20% moisture for small bales, but must be as low as 12% for export markets (*Table 4.2*). Lucerne silage has much higher moisture content than hay, ideally 60–65%.

Dry Matter (DM)

Dry matter (DM) content is the amount of dry material in the feed when all moisture is removed. DM content is expressed as a proportion (percentage) of total hay weight.

It is important to know the dry matter percentage to be able to calculate the real feed value of the hay.

Dry matter content (%) = 100 – moisture content (%)

Total dry matter (t) = weight of hay (t) x dry matter content (%)

Example 1:

20 t lucerne hay at 80% DM content contains
16 t dry matter (20 x 0.80 = 16 t DM)

Example 2:

20 t lucerne silage at 35% DM content contains only
7 t of dry matter (20 x 0.35 = 7 t DM)

Digestibility or digestible dry matter (DDM)

Digestible dry matter (DDM) is the amount of feed that can be digested by animals. A feed's digestibility is the DDM expressed as a percentage. Lucerne hay is highly digestible (typically 65% DDM) compared to other types of hay (*Table 4.3*). If the digestibility of hay is less than 55% it is too low to maintain animal liveweight, even if the hay supply is unlimited.

Metabolisable energy (ME)

Metabolisable energy (ME) describes the energy value of the feed and is calculated from DDM. It is expressed in megajoules of energy per kg of dry matter (MJ/kg DM). Animals eat to satisfy their energy requirement, so feeds must contain sufficient energy for maintenance or production. A one unit increase in ME can make a considerable difference to animal production.

Table 4.2 Critical moisture levels for lucerne hay and silage.

Moisture (%)	Requirement or effect
Hay	
12	Export hay
15	Large bales
18-20	Small bales
>20	Browning of hay can occur
>25	High risk of hay spontaneous combustion
Silage	
<45	Low moisture silage–can lead to heat damage
60-65	Ideal moisture for silage
>70	High moisture silage–can result in poor fermentation, effluent production and potential intake problems with livestock

Crude protein (CP)

Crude protein (CP) includes protein (amino acids) and non-protein nitrogen which can be converted to protein by microbes in ruminants. CP is expressed as a percentage of the total dry matter (DM) and is calculated by multiplying the nitrogen content of the feed by 6.25. Lucerne has the highest CP value of most types of hay (typically 15–20%) which makes it an excellent feed for growing and lactating livestock (*Table 4.3*).

Calculating feed value

Feed value from a laboratory analysis is expressed on a dry matter basis. With hay typically at 85% DM and silage at 35% DM, this means that the feed analysis values must be converted to an 'as fed' basis to be able to formulate rations accurately.

For example, if lucerne hay is 85% DM, 20% CP and 9 MJ/kg ME, each kilogram of hay fed actually contains:

CP = 0.85 x 0.20 = 0.17 or 17% crude protein

ME = 0.85 x 9 = 7.65 MJ energy/kg hay fed

Sampling for laboratory analysis

Laboratory feed analysis is a very accurate measurement of feed value but results are only as good as the samples that are submitted and analysed. Take care when sampling lucerne hay or silage to ensure that the sample is representative of the 'hay lot' and that it does not deteriorate before analysis. A 'lot' is defined as hay or silage taken from the same cutting, at the same stage of maturity, the same species (pure or mixed) and variety, the same paddock and harvested within 48 hours. Other factors influencing the definition of a 'lot' include rain damage, weed content, soil type, treatment after cutting and storage effects. A 'lot' of baled hay should not exceed 200 tonnes. Store hay in 'lots' and sample each 'lot' separately as there can be great variation in feed value within one hay cut due to differences across a paddock.

Gary McDougall, Inglewood Qld using a corer attached to an electric drill to sample lucerne hay.

How to take samples

The Australian feed testing laboratories have special packaging (often with reply paid mailing) and instructions on sampling and sending samples. Always contact the laboratory before sampling any forage.

It is important to take a one sample from at least 10% of the 'lot' of bales. These should be selected at random from each lot.

Sample hay bales with a corer that can penetrate at least 30 cm into the bale. This can be pushed or screwed in manually or by using a sharpened steel attachment on an electric drill.

Example of a corer tip used to sample lucerne hay bales.

Sample of lucerne hay from a single core.

Handling samples

Collect at least 500 g DM and place in an air-tight container and submit for analysis as soon as possible. Treat samples gently to avoid leaf loss and degradation of the sample due to heating. Collect samples just prior to mailing them to minimise the time between sampling and analysis. Mail early in the week to avoid delivery and analysis delays over the weekend. Silage should be frozen between sampling and mailing so that it remains stable during delivery.

Australian feed testing laboratories

See *Appendix B: References and information sources.*

Table 4.3 The nutritive value of lucerne hay compared to other hay types (mean values and range of tests conducted in 2005-6).

Source: FeedTest, Department of Primary Industries Victoria, Hamilton, Victoria.

Type of hay	Crude protein (CP) (% DM)		Metabolisable energy (ME) MJ/kg DM		Digestible dry matter (DDM) (%)		Neutral detergent fibre (NDF) (%)	
	Average	Range	Average	Range	Average	Range	Average	Range
Lucerne	20.2	6.1–28.1	9.5	5.0–12.0	65	38–79	43	31–68
Clover	15.8	7.0–24.3	9.1	7.1–11.4	62	41–76	50	32–68
Cereal	7.0	1.2–26.9	8.9	5.5–11.3	60	34–86	59	34–82
Grass	10.6	3.9–19.3	8.7	6.5–10.4	60	47–70	64	48–74

Neutral detergent fibre (NDF)

Neutral detergent fibre (NDF) is the total amount of fibre (cell wall constituents) in the feed. NDF is expressed as a percentage of total dry matter (DM). The lower the fibre (NDF) the more the animal will eat. Lucerne's low NDF (40–45%) compared to other types of hay (*Table 4.3*) promotes high animal intake, but as lucerne matures, the NDF value increases, and the feed quality and intake decline.

Acid detergent fibre (ADF)

Acid detergent fibre (ADF) is the amount of indigestible fibre in the feed (part of NDF). It is expressed as a percentage of total dry matter (DM) and is sometimes used to calculate DDM and ME. The lower the ADF, the better the feed quality. Lucerne is low in ADF (30–35%) compared to other types of hay.

Other nutrients

Lucerne contains a range of minerals including calcium (Ca), magnesium (Mg), phosphorus (P), potassium (K), sodium (Na), sulphur (S), iron (Fe), copper (Cu), zinc (Zn), manganese (Mn) and molybdenum (Mo) (*Table 4.4*). Calcium in lucerne is usually adequate for animal diets but phosphorus can be low and may require supplementation. Lucerne is also high in vitamins A and E and the amino acid lysine, which are important for horses.

Predicting lucerne feed value

TopFodder and NSW Department of Primary Industries tools

There are various tools available on the internet to help predict the feed value of lucerne and to show the importance of high feed quality. The NSW Department of Primary Industries website (www.dpi.nsw.gov.au) has a database of feed tests and can provide typical ranges of feed values for different feeds. NSW Department of Primary Industries' Feed Cost Calculator can also be used to compare the value of feeds on an energy and crude protein basis in order to calculate the best value feed (see *Chapter 12 Economics of lucerne hay production*). The TopFodder website (www.topfodder.com.au) has various 'mini-calculators' which are also helpful in calculating the value of feeds.

Table 4.4 Important nutrients in lucerne.

Source: Kohnke *et al.* (1999), complied from Australian and USA research data.

	Lucerne growth stage	Ca (g/kg)	P (g/kg)	K (g/kg)	Cu (g/kg)	Zn (mg/kg)	Mn (mg/kg)	Vit A (iu/kg)	Lysine (g/kg)
Fresh lucerne (26% DM)	**Pre-bloom**	4.4	0.7	4.4	2.2	9.5	8.3	41 900	2.6
	Mid-bloom	4.0	0.6	8.0	4.4	9.1	7.1	33 000	2.9
	Full bloom	2.8	0.6	8.6	3.6	8.5	24.6	-	2.8
Lucerne hay (90% DM)	**Pre-bloom**	13.4	3.0	22.5	10.2	33.5	42.2	-	-
	Mid-bloom	11.8	2.0	15.1	16.1	28.1	32.8	55 000	8.0
	Full bloom	10.8	2.2	14.2	9.0	23.7	55.1	9 850	7.9

Subjective quality parameters for lucerne hay

Colour

Green hay is usually leafy and nutritious. However colour does not necessarily indicate the true nutritive value of the feed. Paler hay can be just as nutritious as green hay. Weeds can make a poor sample appear green. A beige colour can be sun-bleached, over-mature or rain-damaged hay. Brown/black indicates heating and/or moisture damage and should be avoided. Aphid infected hay can also appear black due to a sooty mould that grows on sugars exuded by aphids. This hay may be higher in plant oestrogens which may have undesirable effects on livestock. Covered storage helps to maintain good colour of hay.

Leafiness

A leafy lucerne crop is generally high in protein, energy and nutrients. Lucerne leaves contain 21–24% protein while stems have 10–14%. Older stems have the lowest protein content. Leafiness can vary with variety but the season and maturity have much more effect on leafiness. Leaves can also be lost if the hay is raked too much when the leaves are dry.

Stem thickness

Lucerne stem thickness is influenced by variety, stand density and crop maturity. Finer stems are generally more digestible than thicker ones but some customers prefer thicker stems for maintenance rations. Conditioned hay has crimped or flattened stems which can make it softer and more palatable for livestock.

Palatability

Palatability–the smell, feel and taste of the feed–is affected by a range of factors. These include: texture, leafiness or moisture content of the hay, fertilisers used, dung or urine contamination, pests or disease infestations, or the presence of compounds that make it taste sweet, sour or salty. Younger lucerne or early spring growth is generally highly palatable. Mouldy, musty or rotten hay will have low palatability and nutritive value and may contain toxins that can cause illness or death in livestock.

Dust

Lucerne hay that is harvested when it is too dry can be powdery or dusty due to leaf shatter. This can result in respiratory problems for livestock that are fed the dusty hay.

Foreign material

Contaminants in lucerne hay can include sticks, stones, poisonous weeds, moulds, dust, insects and dead animals. These affect the commercial value, the palatability and the nutritive value of the hay. Health risks to livestock that are fed the lucerne hay are increased by the presence of contaminants, so ensure that contamination is minimised.

Bale appearance and weight

Lucerne bales should be well-presented, with a consistent weight, shape and density. Some customers may prefer small sliced bales. Plastic wrapping of bales, individually or in bulk on pallets, enhances their presentation for certain markets. Lucerne pellets, cubes and chaff are bagged for high value markets.

Poor lucerne agronomy and haymaking techniques can lead to inconsistent quality of bales. Aphids can increase bale weight markedly due to excreted sugars that stick the hay together and discolour the hay. Super-conditioners can leave large bales soft and loose. Loose hay bales are difficult to transport and store.

Quality standards for lucerne

Objective feed measurements allow both the producer and customer know exactly how the feed will perform in terms of animal production. They can be used to accurately match the feed to their livestock requirements.

AFIA grades

The Australian Fodder industry Association Inc. (AFIA) has devised a set of national hay grading standards to help standardise fodder grades and quality across the industry. These are recognised by the National Agricultural Commodity Marketing Association (NACMA). AFIA has also established common quality testing standards for laboratories to help standardise quality assessment across the industry.

The AFIA grades (*Tables 4.5* and *4.6*) are based on objective quality measures of digestibility, energy and protein and relate directly to livestock performance. There are grades for legumes (*Table 4.5*) and cereals (*Table 4.6*) which can be used for both hay and silage. Digestibility and energy are similar for both legumes and cereals. Legumes, including lucerne, have superior protein levels compared to cereals.

Quality assurance (QA)

Quality assurance for lucerne hay production can be summed up simply as follows:

'Say what you do, do what you say and prove it!'

It involves:

- Record keeping–records prove that the hay has been grown and made in accordance with best practice and is free of contaminants
- Quality descriptors, such as chemical analysis, or physical descriptors: these are determined to suit the customer.

QA helps to ensure the delivery of a consistent, high quality product, and benefits both the producer and customer.

Table 4.5 AFIA grades for legume and pasture hay and silage.

Source: AFIA, www.afia.org.au

DDM %	ME (MJ/kg DM)	Crude protein %			
		>19	14–19	8–13	<8
>66	>9.5	A1	A2	A3	A4
60–66	8.7–9.5	B1	B2	B3	B4
53–59	7.4–8.4	C1	C2	C3	C4
<53	<7.4	D1	D2	D3	D4
DDM–digestible dry matter, ME–metabolisable energy, DM–dry matter					

Table 4.6 AFIA grades for cereal hay and silage.

Source: AFIA, www.afia.org.au

DDM %	ME (MJ/kg DM)	Crude protein %			
		>10	8–10	4–7	<4
>66	>9.5	A1	A2	A3	A4
60–66	8.7–9.5	B1	B2	B3	B4
53–59	7.4–8.4	C1	C2	C3	C4
<53	<7.4	D1	D2	D3	D4
DDM–digestible dry matter, ME–metabolisable energy, DM–dry matter					

Chemical residues

Chemical residues are of particular concern to lucerne hay producers, as these chemicals can be transferred along the food chain. Unacceptable levels of chemical residues in any agricultural product can lead to market closures and multi-million dollar costs to primary producers and agribusiness.

Chemicals must be applied following the label directions. Withholding periods must be observed and accurate records of chemical use must be kept. Off label chemicals should not be used. Note that endosulfan can no longer be used on lucerne or other crops used in the crop rotation.

Lucerne hay that is destined for the export market, especially to Japan, requires proof of its quality and safety. Japan imposes tight minimum residue limits (MRLs) on foods, including hay, that are different to Australian levels. Producers of export lucerne hay need to be aware of the different export standards for their products.

Residue testing

Lucerne hay samples can be tested for specific chemical residues used during its production, harvesting, processing, storage and transport. A list of accredited testing laboratories is available from the National Association of Testing Authorities, Australia (NATA) (www.nata.asn.au).

National Commodity Vendor Declarations

Vendor declaration forms are available to hay producers to show that their hay is free of known unacceptable chemical residues and is suitable for the intended purpose (i.e. to feed animals). The vendor declaration forms are available from the Meat and Livestock Australia (www.mla.com.au), AFIA (www.afia.org.au) or *Appendix D*.

Pastures and fodder crops which may be contaminated with endosulfan spray drift should not be fed to livestock within 42 days of slaughter. Any detectable level of endosulfan may breach fodder supply contracts and result in rejection of the fodder by the customer.

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USA hay quality descriptors

Australian laboratories do not use USA hay quality descriptors. Feed descriptors used in the USA are included here because some Australian producers, especially feedlots and dairies, use the USA laboratories. These provide a simpler system but do not give a full description of the real feed value to livestock. There are three main systems used.

Total digestible nutrients (TDN)

TDN is used in California. It provides a single figure value to describe the nutritional value of feed. TDN is the sum of crude protein, fat, carbohydrates and digestible NDF. Lucerne with a TDN ≥ 55 is considered excellent quality feed for high production dairy cows.

Relative feed value (RFV)

RFV is used in the Midwest USA. It is calculated from feed intake and digestible energy but does not take the protein into account. It compares a feed's value to that of lucerne at full bloom (RFV 100, NDF 53% and ADF 41%). RFV values increase with increasing quality and prime quality lucerne has an RFV of >151. Hays with identical RFV scores do not necessarily produce the same production responses in ruminants.

Relative feed quality (RFQ)

RFQ is a new measure of feed value, based on intake and TDN which takes digestibility into account. It uses a similar scale and numbers to RFV and is designed to bring quality standards across the USA into line. On average, lucerne will have the same scores as RFV but individual samples may differ by up to 50 points. RFQ more accurately reflects the forage's true value.

Predicting milk production from feed analysis

Equations are available in the USA to estimate the potential milk production from a particular feed (milk per ton index). MILK2000 provides a forage quality index based on energy and intake of the feed, which can estimate milk production per ton of dry matter or per acre (see: www.uwex.edu/ces/forage/pubs/milk2000.htm).

USA hay grades

The USA hay grading systems use a simple scale of a single predicted value of feed quality (e.g. TDN , RFV or RFQ). Hay pricing relates directly to the feed value, particularly in the dairy industry. Each point increase on the scale represents more money for the grower. These systems are generally not used by Australia as our descriptors (digestibility, protein and energy) provide more accurate information about the feed value. The USA hay grades are included here for growers that have dealings with USA producers.

Table 4.7 USA hay quality standards for lucerne.

Source: Undersander *et al.* (2000).

Grade	Flower	Growth stage	CP (%)	ADF (%)	NDF (%)	RFV	TDN	OMD (%)
Prime	Pre-flower	Bud	>19	<31	<40	>151	62–65	>65
1	10%	Early bloom	17–19	31–35	40–60	125–151	58	62–65
2	50%	Mid bloom	14–16	36–40	47–53	103–124	56	58–61
3	100%	Full bloom	11–13	41–42	54–60	87–102	54	56–57
4	100%	Post-bloom	8–10	46–45	61–65	78–86	52	54–55
5	Non lucerne	Post-bloom, weathered	<8	>45	>65	<75		>55

CP–crude protein; ADF–acid detergent fibre; NDF–neutral detergent fibre; RFV–relative feed value; TDN–total digestible nutrients; OMD–organic matter digestibility.

Chapter 5
Characteristics of a successful lucerne hay producer

Successful lucerne hay production is not straight forward. The rewards from lucerne are worthwhile for those that take it seriously and are committed to producing the best quality product possible. Leading lucerne producers believe that successful lucerne haymaking requires certain qualities, as well as plenty of experience and learning. These growers have adjusted their lifestyle to the pattern of the crop and do what they can to produce the best product possible. The overall goal of hay production is to do everything in a timely manner when the lucerne crop is ready and with the end user firmly in mind. The rewards are a stable return from the lucerne enterprise and a profitable, sustainable farming business.

Essential skills and qualities for successful hay growers

Qualities

Lucerne growing is a lifestyle, not just a job. Growers must possess certain traits to make them successful. Good haymakers must have common sense, open-mindedness, good organisational and communication skills, patience, motivation and commitment to doing the job properly. Growers must also be prepared to work hard and to operate at night at critical times.

Focus Groups: experienced lucerne growers were questioned about their haymaking experience.

Grower tips

'To make a good bale requires brains, experience and good advice'. *Matt Oxenford, Inglewood, Qld.*

'Make mistakes; they may be costly but that is how you will learn'. *Donald Barwick, Tamworth, NSW.*

Don Barwick, Tamworth, NSW.

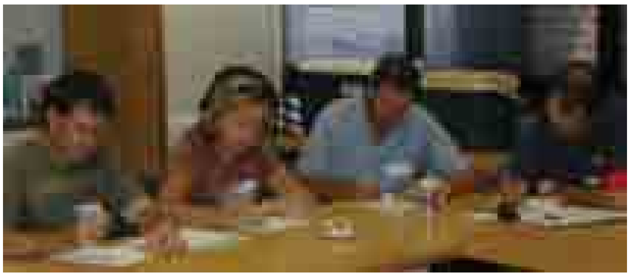
'The only way you will get experience is to stick at it'. *Claude Robinson, Forbes NSW.*

Claude Robinson, Forbes, NSW.

Focus Group recommendations

Use experienced people and learn from experience.

Haymaking requires skill and experience—if you have no experience, use a contractor.



Focus groups: information was gathered from growers about lucerne haymaking.

Experience

Most haymakers learn by many years of personal and practical experience or knowledge passed on from their fathers, contractors and neighbours. Some of that experience has been captured through Focus Groups and interviews with leading growers, and is included in this book.

Grower tips

'You have to like making hay; be prepared for long hours; always make top quality hay (or silage); always inspect paddocks'. *Tony Kurtz, Coolah, NSW.*

'Lucerne growing and haymaking is a seven day a week commitment'. *Lance Pollock, Gatton, Qld.*

'Be prepared to nurture it like a baby; you may have to work at night to let it "make", but the return is worth it'. *Damien Moss, Gundagai, NSW.*

'Have patience with clients and the haymaking'. *Tricia Kiddle, Coolah, NSW.*

'There are no short-cuts when making quality hay'. *Lloyd Rossington, Musswellbrook, NSW.*

'Be prepared to have interrupted sleep and social life to be a successful lucerne grower'. *Neil Natalier, Gatton, Qld.*

Learning

Good haymakers and business people must ask questions and be open to new ideas. They should seek advice from knowledgeable sources and pursue learning opportunities when they arise to complement their skills and experience. Many growers have attended field days, seminars, short courses and study tours to improve their knowledge about lucerne haymaking.

Grower tips

'Seek the help of experienced neighbours who make good hay'. *John Bruce, Forbes NSW* and *Alan Moss, Tamworth, NSW.*

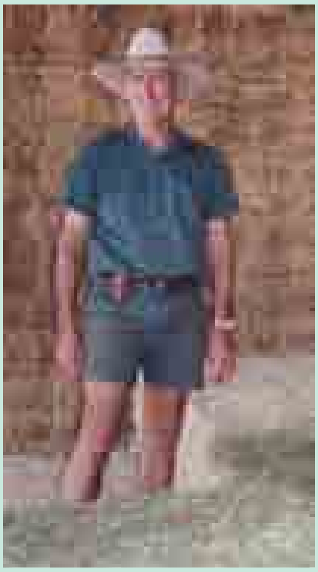
'You are always learning'. *Tracey Ghent, Cassilis, NSW.*

'Do research on growing lucerne before you start'. *Lindsay Hogg, Kerang, Vic.*

'Ask lots of questions'. *Wayne Klepzig, Tamworth, NSW.*

'Talk to the Department of Agriculture extension officers & attend field days'. *Sam Flaherty, Scone, NSW; Lawrie Ayres, Denman, NSW;* and *Wallace Knodler, Musswellbrook, NSW.*

'Do a lucerne course'. *Jamie Semmler, Kerang, Vic.*



Left: Alan Moss, Tamworth, NSW.

Below: John Bruce, Forbes, NSW.

Focus Group recommendations

Continue to educate yourself as a grower or buyer.

Learn from experienced people, other farmers and agronomists, field days, etc.

Keep up to date with latest technology.

Chapter 6
Growing a lucerne crop

Lucerne that is to be established to produce hay should be grown in a favourable environment with access to water, transport and markets. Many lucerne hay producers in Australia are located along river systems, close to markets or major transport routes.

A successful lucerne crop relies on:

- planning and preparation of paddocks
- successful plant establishment
- vigilant early crop management and
- continued maintenance of established, mature crops.

Grower tips

'Prepare your paddock properly before you sow. If you don't establish the stand to be the best possible, it won't improve'. *Darryl Cleeve, Inglewood, Qld.*

'Don't take short-cuts on seed bed preparation and stand establishment'. *Andrew Oxley, Inglewood, Qld.*

'Research soil preparation and establishment of lucerne before attempting to sow the stand'. *Deid Schlitz, Kerang, Vic.*

Ron and Deid Schlitz, Kerang, Victoria.

'Use your best paddock. Don't short-change the crop by cutting corners'. *John Hewitt, Kerang, Vic.*

Focus Group recommendations

Identify the paddock limitations.

Ensure paddocks are relatively weed-free, with few trees and no rocks.

Ensure that paddock terrain and proximity to rivers will not affect haymaking.

Planning and preparing for lucerne hay

Establishing a high density, even lucerne stand is critical for good hay production in subsequent years. Planning ahead is crucial for successful lucerne establishment. Growers need to consider:

- paddock selection
- soil and water characteristics
- irrigation systems
- paddock rotations

Paddock selection

Paddock selection affects the future success of any management and agronomic decisions that are made.

Soil and water characteristics

The chemical and physical properties of both the soil and irrigation water affect the growth of lucerne (*Table 6.1*). Nutrients in irrigation water can affect plant growth, soil characteristics and irrigation equipment.

Regular tests and well kept records are important to detect any problems (*Table 6.2*). Lucerne hay production removes large quantities of nutrients from the soil. Knowledge of soil and water properties is needed to ensure that the correct amount of fertiliser can be applied. Cutting and removing the lucerne hay from the paddock also contributes to soil acidification.

Grower tips

'Use the best soils for the best quality hay to suit the market. For new lucerne paddocks, dig a soil pit to check soil structure and presence of any soil constraints (e.g. soil pH). If unsuitable, choose another paddock'. *Greg Pickering, Kerang, Vic.*

Focus Group recommendations

Know your soils; identify different soil types.

Choose your best paddock, and best soil—deep river soils are often ideal for lucerne.

Choose well-drained paddocks with a flat even grade.

Table 6.1 **Summary of soil and water properties that should be tested for lucerne production.**

Physical or chemical property		Testing procedure
Soil	**pH**	Simple field test and/or laboratory test.
	sodicity (ESP)	
	salinity (ECe)	
	nutrient levels - aluminium (Al), phosphorus (P), sulphur (S), potassium (K), molybdenum (Mo) and zinc (Zn)	Laboratory analysis of the topsoil, sub-soil, leaf tissue and irrigation water. Leaf tissue tests can indicate any potential trace element imbalances.
Water	**pH**	Simple field test and/or laboratory test
	sodicity (SAR)	
	salinity (ECw)	
	bicarbonates	Laboratory analysis of the topsoil, sub-soil, leaf tissue and irrigation water. Leaf tissue tests can indicate any potential trace element imbalances.

Table 6.2 **Summary of soil and water limits for lucerne.**

Soil properties		Water properties	
Characteristic	**Limit**	**Characteristic**	**Limit**
pH_{CaCl_2}	5.0–7.5	**pH_{water}**	5.8–8.2
soil salinity (ECe)	<2 dS/m	**salinity (ECw)–seedling lucerne**	<0.8 dS/m
aluminium (KCl)	<15 mg/kg	**salinity (ECw)–established lucerne**	<2.3 dS/m
exchangeable Al	<3%	**sodium (SAR)**	<3
phosphorus (Olsen test)	15–20 mg/kg	**chloride**	<350 mg/L
phosphorus (Colwell test)	25–35 mg/kg	**bicarbonates**	<335 mg/L
potassium (Skene test)	>160 mg/kg		
sodium (ESP)	<6%		
Ca/Mg ratio	>2		
sulphur (KCl test)	>10		

Simple soil tests can be done in the field to assess suitability for lucerne and irrigation. Water infiltration (left) and soil texture (right) tests.

Soil type

Soil type determines how the lucerne plant will grow, and how quickly the paddock is trafficable after rain or irrigation. Selecting the paddocks with the best soils is therefore important for profitable lucerne hay production.

Lucerne will grow well on a range of soils from sands to clays. It is short-lived on acid soils and where drainage is poor. Lucerne thrives on deep sandy loams and alluvial soils that have good water infiltration and internal drainage. It can also be grown on heavier clay soils if infiltration, drainage and irrigation design are adequate, and there are no hard pans below.

Good drainage is critical for lucerne to avoid waterlogging. Lucerne paddocks require natural slopes or higher elevations. Flood irrigated lucerne paddocks can be landformed to provide an even grade with no hills or hollows and the bay size should allow good water infiltration and surface drainage.

Soils should be tested before sowing to ensure there are no problems that would impede lucerne root growth such as a hard pan below the surface. If problems exist, ameliorate the soil if possible or find an alternative paddock.

Soil pH

Lucerne prefers neutral to slightly alkaline soils (i.e. pH_{CaCl_2} 6.0–7.5).

Soil pH affects the availability of nutrients to plants and the growth of rhizobia on lucerne roots. Acidity, ties up important nutrients such as molybdenum (Mo) and phosphorus (P), and releases others from the soil, such as aluminium (Al) and manganese (Mn) which can be toxic to lucerne at high levels. Both plant growth and rhizobia are inhibited by low pH and high Al levels.

Lucerne will not grow in strongly acidic soils but can tolerate moderately acid topsoils (> pH 5.0), as long as the exchangeable aluminium in the soil is < 3%. In strongly acidic soils (pH<4.8), Al can become toxic. At high pH (>8.5) soil structural problems may occur if irrigating with sodic/saline water.

Important notes about pH

Laboratory analysis determines the soil pH in a solution of $CaCl_2$ (i.e. pH_{CaCl_2}).

A field test kit measures pH in water.

pH_{water} is 0.8 units higher than pH_{CaCl_2} for the same soil acidity level.

One unit drop in pH represents a tenfold increase in acidity.

pH can vary widely within a paddock, so identify different soil types and test these separately. EM instruments mounted on a quad bike and linked to a GPS allow easy mapping of soil pH.

Soil pH can be assessed in the field using a simple kit.

Further acidification can occur on sandy soils due to high rates of product removal with intensive hay production. Lime applications are needed to counteract further long-term pH decline.

Liming acid soils

Harvesting high yields of lucerne removes large quantities of soil nutrients which can result in high soil acidification rates. Acid soils can be neutralised by adding lime ($CaCO_3$)–1 tonne hay will require 70 kg lime to neutralise the acidity. Lime does not move readily through the soil, so needs to be well incorporated by tillage before sowing. Amelioration is not possible once the lucerne is growing.

If the pH in the topsoil is <5.2, incorporate lime at least three to six months before sowing to allow time for it to act. Lime on soils above this pH can improve lucerne plant growth but is not usually considered economically viable in Australia.

Soils with acid sub-soils or high levels of sub-soil aluminium are not suitable for lucerne because lime will not move downward below the cultivated layer.

When liming, aim to raise the pH_{CaCl_2} to at least 5.2 for lucerne growing. The amount of lime required depends on the CEC (cation exchange capacity) of the soil, obtained from a soil test. Clay soils need more lime than sandy soils to raise the pH to the same level. Very acid soils (e.g. pH 4.5) may require at least 1 t/ha of lime. If the pH is less than 5.0 lucerne seed should also be lime-coated (or pre-coated seed can be used) to provide a favourable micro-environment for the germinating seed.

Soil sodicity

Sodic clay soils have a very unstable structure and can be a problem for lucerne under irrigation. When low salinity water is added to these soils surface crusting and poor water infiltration result which can limit the establishment and growth of lucerne.

Sodic soils have a high proportion of sodium ions (Na^+) attached to the clay particles which bind the clay particles together. When low salinity water is applied, the water is attracted to the sodium ions. This pushes the clay particles apart (dispersion) destroying the soil structure. Compacted layers can form on the surface and within the soil profile which restrict movement of air, water and plant roots.

Managing sodic soils

If soil is sodic, minimise cultivation and try to retain organic matter to prevent structural problems. Gypsum ($CaSO_4$) can also be applied to counteract soil sodicity problems (*Table 6.3*). In contrast to lime, gypsum moves through the soil quickly, so it can be applied at any time, depending on the needs of the soil. The effects can be both short and long term.

Gypsum, once dissolved in water, works on the soil in two ways. The first is an immediate electrolyte effect. Gypsum is a salt and any increase in salt concentration in the soil solution will cause clay particles to aggregate. This provides only a short term improvement in soil structure, because gypsum is slightly soluble and the free ions (salt) are slowly leached lower down the profile.

The second effect is related to calcium. Over time, the calcium in gypsum displaces sodium from the exchange sites on soil particles. The sodium is then slowly leached deeper in the profile, improving water penetration, drainage and root growth. This is a slower process and has a longer lasting effect.

Using sodic water (SAR>3) can increase the risk of sodicity, especially on poorly drained soils. Note that irrigating with bore water that is saline can mask the effects of sodic soils, as the clay particles are flocculated by the salt in the water. Reintroducing fresh water can cause dispersion of the clay soil and waterlogging.

Table 6.3 Gypsum rates and application timing.

Rate of gypsum	Typical gypsum rates for dispersive clay soils are 2.5–5 t/ha (for ESP 6–10) or greater than 5 t/ha (for ESP>10). Lower rates can be applied in irrigation water with special mixing machinery. Discuss the suitability and quality of gypsum with your local agronomist.
Application well before sowing (6-12 months prior)	High rates of gypsum (3.0–7.5 t/ha, depending on the soil test results) incorporated into the soil will provide a long-term effect. Gypsum moves down into the soil profile to improve water penetration, crop rooting depth and internal soil drainage. Deep ripping may be needed to break hard layers in the sub-soil and to increase gypsum penetration, but this is often not cost effective. As gypsum is leached with time, the soil requirement must be re-assessed and gypsum re-applied every 1–2 years.
Application close to sowing	Light rates (2.5 t/ha) left on or close to the surface can prevent soil surface crusting and improve water penetration in the short-term to aid seedling emergence.

Salinity

The effect of salts present in irrigation water on plants depends on the tolerance of the plant species (*Table 6.4*), the stage of plant growth, the climate, the irrigation method and the soil type. Lucerne seedlings are very susceptible to salt damage, but mature plants are moderately tolerant.

Lucerne yield losses due to soil salinity on well-drained soils can be 10% with soil salinity (ECe) of 2 dS/m, up to 30% with 2–6 dS/m ECe and even greater with >6 dS/m ECe. On less well-drained soils the salt tolerance limit of lucerne plants is lower. The effects of salinity on lucerne growing on well-drained soils are temporary, as the salts may be leached out of the soil. When lucerne is growing on poorly drained soils the salts may accumulate in the soil and this increases the effects of salinity on plant growth.

Assessing the need for gypsum

Clay dispersion test (quick field test)

Take a few 3–5 mm crumbs of air-dried soil and cover them with rain water (not tap water) in small, clean dishes. Leave undisturbed for two hours and if the soil disperses through the water in milky clouds, the soil will require gypsum.

Sodicity or Exchangeable Sodium Percentage (ESP) test (laboratory test)

This test measures the amount of sodium (Na) attached to the clay. A soil is sodic if ESP>6. Dispersion and sodicity often increase with depth, so check a number of depths in the soil profile (e.g. 0–10, 10–30, 30–50 cm). The topsoil may not need gypsum, but the subsoil may.

Gypsum test strips

Apply gypsum to the soil at rates of 0, 2.5, 5 and 7.5 t/ha and observe the response in plant growth.

Managing salinity

Although mature lucerne is moderately tolerant of salt, it will only achieve high yields on the best soils. Before establishing lucerne, salt in saline soils should be leached out by growing an irrigated annual salt tolerant crop such as millet, followed by an application of gypsum.

In saline situations, test the soil salinity levels at different depths before sowing lucerne, since lucerne roots can penetrate to depth. Fertiliser and gypsum should not be applied before taking soil samples because they will affect the measured salt levels. If fertiliser or gypsum has been applied, test for chloride salts when the ECe >1.5 dS/m to determine salinity.

Using saline water

Groundwater or re-use water must be tested for salinity before being used on lucerne (*Table 6.5*). Use only low salinity irrigation water (<0.8 dS/m ECw) to establish lucerne and do not use water of >2.0 dS/m ECw undiluted to prevent damage to plants. ECw can be assessed in the field with a hand-held salinity meter available from NSW Department of Primary Industries (Salt Bag).

Note that interactions occur between sodic soil and saline water (i.e. SAR>3) which can lead to soil structural problems (dispersion, slaking and crusting). See *Chapter 8 Irrigation for hay production: irrigation with sodic or saline water.*

Table 6.4 Salt tolerance of mature lucerne relative to other pasture and crop species.

	Species	Soil salinity limit * (dS/m)
Most tolerant	puccinellia	16.0
↑	saltbush	12.0
	barley	8.0
	canola	6.5
	wheat, millet, berseem clover	6.0
	Perennial ryegrass	5.6
	strawberry clover	2.7
	lucerne, paspalum, soybeans	2.0
↓ Least tolerant	subterranean clover, white clover	1.2

* Salinity limit in the root zone causing 10% yield loss.

Table 6.5 Water and soil salinity limits for irrigated lucerne.

Situation	Salinity limit	
	ECw (dS/m) causing 10% yield loss	ECw (dS/m) causing 25% yield loss
Water on well-drained soil (<30% clay)	2.0	5.4
Water on moderately-drained soil (30–40% clay)	1.3	3.5
Soil in root zone	2.0	5.4

Table 6.6 Using ground-water on lucerne.

Ground water properties	Effects on lucerne, soil or irrigation pipes
pH less than 6	Corrosion of irrigation pipes
pH less than 4	Reduced plant growth
pH greater than 8	Bicarbonates and sodium may cause encrustation of pipes with calcium carbonate
Sodium	Reduced crop growth but damage is usually masked by salt damage
Chloride	Leaf burning, if lucerne is spray irrigated with water containing high levels
Bicarbonates	Cause hardness in water and can also cause Ca and Mg in the soil to precipitate, leaving Na behind and increasing sodicity
Iron (Fe)	If Fe >1 mg/L, ferric oxide may precipitate which blocks irrigation pipes and nozzles
Sediments	Reduced photosynthesis at high sediment levels (>5 mg/L for spray irrigation and >10 mg/L for flood)
Nitrates	Not generally a problem in ground water in Australia

Testing groundwater

Groundwater should be tested by a NATA accredited analysis laboratory every 2 years. Apart from ECw and SAR, other water properties can also sometimes cause problems if irrigating lucerne (*Table 6.6*).

Focus Group recommendations

Test soil for pH, P, Mo, K and Zn.

Know the nutrient content of the soil and fertiliser.

Use lime to increase the soil pH.

Apply gypsum and potash where necessary.

Apply P as superphosphate at sowing and by topdressing.

Nutrients

Apart from lime and gypsum, several other nutrients are important for lucerne growth including: phosphorus (P), sulphur (S), potassium (K), calcium (Ca), molybdenum (Mo), boron (B) and zinc (Zn).

Harvesting high yields of lucerne removes large quantities of soil nutrients (*Table 6.8*). Since Australian soils are often deficient in one or more

Lucerne roots explore well suited soil to great depth, extracting water and nutrients.

Table 6.7 Lucerne nutrient requirements.

Nutrient	Comments
Macro nutrients	
Nitrogen (N)	Lucerne is a legume and so fixes its nitrogen requirement from the air, provided it has plenty of healthy root nodules. N fertilisers are not necessary on lucerne unless poor nodulation occurs. High soil N levels resulting from a long legume history or applied N fertilisers will delay or inhibit nodulation and promote greater weed competition.
Phosphorus (P)	P is critical for early growth and production of lucerne. Since it is low in most Australian soils and large amounts of P are removed in lucerne hay, P fertiliser is needed both at sowing and during the life of the stand to maintain high lucerne production. Irrigated lucerne usually requires 20–30 kg P/ha at sowing (equivalent to 250–340 kg/ha single superphosphate), preferably banded 2–3 cm below the seed. The lower end of this range can be used if there are high residual levels of P in the soil (e.g. >30 ppm using Colwell test, or >18 ppm using Olsen test). More may be required in areas where topsoil has been removed during laser levelling. Dryland lucerne, with a lower potential yield, requires at least 125 kg/ha superphosphate. Do a soil test to determine its P status. Superphosphate supplies the three major elements required by lucerne (i.e. 9% P, 11% S and 22% Ca). Manures can supply these and other nutrients but high quantities are required. They should be well composted to prevent weed infestation and an analysis is required to know what you are adding.
Calcium (Ca)	Large quantities of Ca are removed in lucerne hay. However, Ca deficiency symptoms are unlikely, since natural Ca reserves in Australian soils are high and because it is a high component of most phosphate fertilisers.
Sulphur (S)	Sulphur is important for protein synthesis and is required in large amounts. It is usually supplied as superphosphate (11% S) but can be supplied as gypsum, if P is not limiting. High analysis phosphate fertilisers (e.g. double super, triple super) contain inadequate sulphur and should be used only in conjunction with gypsum (15% S) or other high-S fertilisers. Sulphur status of the soil can be monitored with soil tests or with plant tissue analysis at flowering.
Potassium (K)	K is removed in large amounts in lucerne hay. Although there is generally adequate natural K in clay soils for intensive lucerne hay production, deficiencies can occur on deep, sandy or alluvial soils. If a deficiency is suspected, use fertiliser test strips, leaf tissue analysis at flowering, or soil tests to verify the need for fertiliser. If soils are deficient, muriate of potash applied at 250–375 kg/ha will generally be adequate. Annual applications of 125–375 kg/ha K can substantially raise lucerne yields in deficient soils.
Trace elements	
Molybdenum (Mo)	Mo is essential for effective growth of rhizobia in root nodules. It is unavailable to plants in acid soil (pH_{CaCl_2} <5.2) and can also be removed in topsoil with landforming. In acid soils lime applications will increase the availability of soil Mo and seed should also be lime coated. Mo is usually only applied once as Mo-superphosphate at sowing but if inadequate lime or Mo have been applied at sowing, Mo foliar sprays (up to 50–60 g/ha Mo) can be used. An additional application of Mo may be required after about 4 years. However, too much Mo may cause copper deficiency in ruminant animals, so base application rates at this time on tissue tests of lucerne plants at flowering.
Boron (Bo)	More Bo is needed for lucerne than most crop and pasture plants. Deficiency can occur in sandy soils and tableland areas but is uncommon in the clay soils of northern Victoria and southern NSW. Apply fertiliser at 1–2 kg/ha Bo but no more than this, as there is only a small safety margin.
Zinc (Zn)	Zn deficiency can occur in high pH soils in northern NSW. It may also be needed where topsoil has been removed with landforming or on some sandy soils. Apply with phosphate fertiliser or as a foliar spray. Test strips with 20–25 kg/ha zinc sulphate can indicate whether a response is likely.

of these nutrients some of them may be rapidly depleted to levels that will limit high production.

Soil nutrient problems must be corrected before sowing lucerne and adequate levels of fertiliser must be applied to balance the rate of nutrient removal. The removal rate of nutrients can be used to calculate the fertiliser inputs required to maintain long-term production. The calculated fertiliser requirement should be regarded as a minimum, to allow for losses due to other factors, such as drainage water.

While soil tests can detect major nutrient deficiencies, they are not reliable for identifying deficiencies in trace elements. Once plants are growing, deficiency symptoms in plants (*Table 7.10*) and plant tissue tests can indicate deficiencies.

Tools for monitoring lucerne nutrition

Visual observation of crop plants (see *Table 7.10 Symptoms of nutrient imbalances*).

Fertiliser test strips.

Laboratory plant tissue tests.

Laboratory soil tests.

Irrigation systems

Lucerne production is substantially improved with the use of irrigation. For optimal production the irrigation system must match the soil type and the layout must allow efficient delivery of adequate quantities of water, good infiltration and good surface drainage. Poor irrigation management and subsequent poor drainage can cause lucerne to be damaged by waterlogging and scald. See *Chapter 8 Irrigation for hay production* for further information.

Table 6.8 Soil nutrients removed in 1 tonne of lucerne hay.

Nutrient	Nutrient removed (kg/tonne)
Nitrogen (N)	20–30
Phosphorus (P)	2–3
Sulphur (S)	2–4
Potassium (K)	15–20
Calcium (Ca)	13–17

Planning rotations

Rotating lucerne with other crops for two to three years helps to break weed, insect and disease cycles. These rotation crops will also use the nitrogen reserves that are present in the soil from previous lucerne crops.

A range of crop species can be chosen. Sowing a completely different type of plant (e.g. cereal) improves paddock management options (e.g. pest or weed control, herbicide choice). A one year break from lucerne is generally not long enough to break lucerne insect and disease cycles. (See *Cropping after lucerne* at the end of this chapter for further information).

Focus Group recommendations

Rotate lucerne with other crops for at least two years to break weed, insect and disease cycles. Crop stubble can be incorporated to increase organic matter.

Establish a well-managed rotation (i.e. choice of crops, sequence and timing).

Include rotation crops such as maize, sorghum, soybean, faba beans, canola, cereals (oats, barley, wheat, millet), onions, potatoes or fallow, depending on location.

Establishing lucerne

Establishment is the key to successful lucerne hay production. It is often said that with lucerne crops, 'What you see is what you get.' A dense, even, competitive stand provides the basis for high yields and profitability. A sparse, patchy non-competitive crop will provide little return on investment. Lucerne crops thin with age and generally cannot be thickened up later.

The establishment phase includes germination and survival of seedlings through the first year. A new lucerne stand takes at least one year to become fully established. Although establishment of lucerne is expensive, the cost can be spread over the productive life of the stand.

Lucerne is often perceived as being difficult to establish but this is not really true. Planning and management before and during establishment are important for growing a successful haymaking crop. It is essential to plan and manage the following to be successful:

- seedbed preparation
- weed control
- irrigation at establishment
- variety selection
- seed selection and treatment
- sowing time
- seeding rate
- sowing technique
- potential companion crops

Grower tips

'Make sure you do everything right for good lucerne establishment if you want to get a good return for the next five years'. *Deid Schlitz, Kerang, Vic.*

'Ensure good paddock preparation, use appropriate varieties and excellent weed, disease and insect pest management'. *Brett Wesley* and *Bryan Mathews, Coolah, NSW.*

'Good establishment requires fine tilth, high seeding rate and water'. *Greg Finlay, Texas, Qld.*

'Continually monitor crop for pests, diseases and moisture stress. Monitor soil chemical condition and fertiliser status and correct if necessary'. *Ernie Idiens, Cowra, NSW.*

A healthy, well established lucerne seedling.

Seedbed preparation

Seedbed preparation must start in the previous year to allow effective weed control, break-down of organic matter, the incorporation of nutrients and development of a fine tilth. Sticks and stones must be removed from the paddock first to avoid problems with haymaking.

Focus Group recommendations

Use good ground preparation and sowing technique.

Ensure good soil moisture—if possible sow after rainfall.

Poor establishment is often caused by inadequate seedbed preparation. The ground must be uniform, level, firm and weed-free. The seedbed must be fine and slightly crumbly, but not powdery, and soil moisture must be adequate. Be careful not to overwork the soil to prevent the seed from being buried or the soil crusting.

In areas where water tables are close to the surface, long summer fallows should be avoided as salt can be brought to the surface via the capillary rise of saline groundwater in clay soils and high evaporation from bare ground.

Weed control when establishing lucerne

Weeds in lucerne reduce establishment, the quality and quantity of hay, and the productive life of the stand. See *Chapter 7 Lucerne pests, diseases and disorders* and *Chapter 1 Summary of BMPs for managing weeds in lucerne* for further information.

Weed management from the outset is critical. Lucerne seedlings are tiny and do not compete well with weeds. Weeds in seedling lucerne result in a thin, weak lucerne stand. Future weed control in non-vigorous crops is difficult, as the wheel traffic will cause further damage to the lucerne plants.

Weed control must begin in the year before lucerne establishment. This reduces the incidence and seed-set of potential weeds and allows the lucerne to be sown into a clean seedbed. Lucerne should not be established in weedy paddocks, especially if competitive weeds such as wireweed, khaki weed or silverleaf nightshade are present. Subsequent weed management strategies depend on the weed species and population, the season and the availability of irrigation water.

> **Focus Group recommendations**
>
> Be well-prepared and ensure the paddock is weed free before sowing.
>
> Pre-sowing and early post-emergent weed control are critical.
>
> Incorporate pre-emergent herbicides well (work in twice).
>
> Use post-emergent herbicides if necessary.
>
> Use registered products at the right growth stage of both the lucerne and weeds.

A healthy, weed free established lucerne stand.

Herbicides for seedling lucerne

Herbicides options for seedling lucerne are limited (*Table 6.9*). There is no herbicide that will control the whole spectrum of weeds, so weed identification is important.

The herbicides must be applied at the correct stage of growth for both the lucerne and the weeds to maximum impact on the target weeds without damaging the lucerne. Some chemicals registered for lucerne cannot be used during the first 12 months of crop growth. Herbicides should be used in conjunction with other good weed management practices.

Consult your agronomist or current chemical weed control books for more details.

Table 6.9 Herbicide options for seedling lucerne.

Type of chemical	Comments
Knockdown herbicides (e.g. glyphosate)	Useful before sowing but only control the weeds present at spraying.
Pre-emergent herbicides for germinating winter weeds e.g. grasses and wireweed (hogweed)	Apply at least 6 days before sowing and incorporate well into the soil for good weed control. They may also render lucerne seedlings more susceptible to pythium disease (damping off) so seed should be treated with fungicide to prevent seedling death. Post-sowing pre-emergent herbicides are also available.
Post-emergent herbicides for emerging grasses and broadleaf weeds	Limited options on young lucerne. Different herbicides can be used at different stages, so it is critical to identify the lucerne plant growth stages. Note that some selective herbicides have specific temperature requirements; others must not be used until the lucerne is 12 months old; while some cause bleaching or set-backs to the young lucerne.

Using herbicides safely and effectively

Identify problem weeds correctly.

Consider alternative methods.

Consult weed control handbooks, agronomists or chemical supplier to select most appropriate herbicide.

Only use products registered for lucerne.

Apply at the correct weed and crop stage.

Always read the label thoroughly and follow application and safety directions.

Observe withholding and plant back periods.

Rotate chemical groups to avoid herbicide resistance.

Keep records of weed infestations and all chemical applications.

Note that herbicide registrations and formulations change frequently. See current State Department of Agriculture/Primary Industries publications on weed identification and herbicides available for lucerne.

Irrigating for crop establishment

Irrigating to establishment lucerne can occur either before or after sowing. Note that if using sub-surface drip irrigation (SDI), a separate irrigation source (or timely rainfall) is usually required to establish lucerne because the water emitted from the drippers in the soil does not usually reach the soil surface. See *Chapter 8 Irrigation for hay production* for further information.

Lucerne varieties

It is difficult to define what makes a good lucerne hay variety. Haymakers usually require a productive, leafy variety with good leaf retention, fine stems and good palatability. However, most of these characteristics are not clearly defined, and location and management strongly influence the final product. Growers often learn by experience which varieties make good quality hay in their situation.

When selecting varieties, select the right characteristics for the environment and management system and have a clear plan for the use of the crop. The aim is to ensure that the stand produces well for as long as it is needed.

Lucerne breeding programs strive to improve yield, persistence and quality of lucerne. An extensive range of varieties is available commercially in Australia (see *Appendix C: Australian lucerne varieties*). Updates are available from various State Government Departments of Primary Industries and Agriculture (see *Appendix B: References and information sources*). Most current varieties have high yield potential, but vary significantly in their resistance to insects and diseases, and their late autumn–winter growth.

Insect and disease resistance of the varieties

Insect and disease resistance are the most important selection criteria for lucerne (*Table 6.10*). The proportion of resistant or tolerant plants varies between varieties, and seedlings of resistant varieties may still be susceptible to some pests and diseases.

Lucerne breeding programs produce more productive and better adapted varieties.

Grower tip

'Don't rush in; take time to select varieties that suit your lucerne operation'. *Paul Jones, Gundagai, NSW.*

Focus Group recommendations

Use productive varieties that are adapted to your region (i.e. soils, known pests).

Choose varieties to suit your management, the purpose of operation and the market.

Select varieties for persistence.

Select varieties for quality factors such as fine stems, high leaf retention and high leaf to stem ratio.

Select varieties with the help of local knowledge, word of mouth, local trials.

Keep up to date with local variety evaluation results. See current variety listings for your state and region.

Table 6.10 Importance of insect and disease resistance in lucerne varieties.

See *Chapter 7 Lucerne pests, diseases and disorders* for further information.

Insect resistance	Comments
Lucerne aphids	The old variety Hunter River is highly susceptible to lucerne aphids. Most current varieties in Australia have some resistance to the spotted alfalfa and blue-green aphids but seedlings of all lucerne varieties can be killed by aphids. Mature plants have varying levels of resistance and those with low resistance are more likely to be damaged and to increase the insect pressure on neighbouring resistant crops.
Other insects	There is currently little resistance available to other important insect pests such as spotted clover aphid, redlegged earth mite, blue oat mite, lucerne flea, white-fringed weevil and sitona weevil. (See insect section for more details).
Disease resistance	**Comments**
Phytophthora root rot	Essential for establishment and high lucerne production under surface flood irrigation, especially on clay soils.
Crown rots	Required in dense stands that are frequently cut and irrigated. These conditions create ideal conditions for a number of crown rots.
Anthracnose (colletotrichum crown rot)	Important in humid locations or under spray irrigation.
Leaf diseases	Limited leaf disease resistance is available. Highly winter active varieties tend to be more susceptible than winter dormant varieties.
Bacterial wilt	Important in some areas, such as Victoria and southern NSW.
Stem nematode	Important along inland river systems.

Root and crown rots are the most common problems for haymakers. Resistant lucerne varieties are required if these diseases occur in your area or if growing conditions favour disease. See *Chapter 7 Lucerne pests, diseases and disorders* for further information.

Growth and dormancy of lucerne varieties

The dormancy of a lucerne variety and where it is being grown determine the length of the growing season. Lucerne grows all year round, with high growth rates in spring and summer (up to 100 kg DM/ha/day) and slower growth during autumn and winter (*Figure 6.4*). In Queensland lucerne hay can be made all year round with winter active varieties, while in cooler areas winter dormancy may be needed for winter survival.

Lucerne varieties vary significantly in their late autumn to winter growth or dormancy rating:

- winter dormant (3)–no growth from autumn to spring
- semi-dormant (5–6)–slow growth from early autumn to spring
- winter active (non-dormant) (7–8)–a longer growing season with active growth during winter
- highly winter active (9–10)–active growth throughout the year

Semi-dormant to highly winter active varieties are usually grown for hay production in Australia. Winter dormant varieties suit cold locations (high latitudes or elevations) where they survive better in severe cold, wet winter conditions.

Winter dormancy is a response to both day length and cold temperatures. All lucerne varieties grow well during the warmer months but highly winter active varieties produce about 20% of their annual

Growth of a winter dormant variety (left) is less during winter than a winter active variety (right).

growth in winter (April–August), while winter dormant varieties produce only about 5%. Winter active varieties stop growing actively later in autumn and start earlier in spring than more dormant varieties.

The utilisation of winter growth for hay and grazing will depend on the climate. Warmer, drier climates normally have longer haymaking seasons and could be expected to produce more hay with irrigation from winter-active lucerne than in cooler, wetter areas.

Persistence and dormancy of varieties

Select varieties on how long you want them to last. Dormant and semi-dormant varieties generally persist longer than winter-active ones, though there can be exceptions. The lower crowns and slow growth in winter help them to survive better in cold conditions. Winter-active and semi-dormant varieties should be managed differently in order to maintain stand life.

Special characteristics

Some lucerne varieties are selected for special characteristics that may improve adaptability to acid soils, salinity or grazing. Newer breeding goals include greater leaf area, improved digestibility, increased root growth, better nitrogen fixation, persistence under heavy traffic and herbicide resistance, but few commercial varieties in Australia currently have these traits.

Multi-leaf varieties (with five or more leaflets instead of three) and varieties bred for higher digestibility (labelled 'High quality' or HQ) are now available in Australia.

Roundup Ready® lucerne, released in the USA in 2005, can be sprayed with Roundup® herbicide to kill young weeds without affecting the lucerne. This improves the establishment and competitiveness of the stand, and potentially reduces the need for further herbicide applications. At the time of writing Roundup Ready® and other genetically modified lucerne varieties are not available in Australia.

Multi-leaf lucerne varieties are being bred to improve feed value.

Lucerne parent plants are grown and hand crossed in pots in the glasshouse.

Lucerne breeding lines are assessed in field plots for several years before commercial release.

Broad characteristics of lucerne varieties

Winter dormant varieties

Slow growth during winter, fast growth in spring and summer.
High leaf to stem ratio–more leaves and branched stems.
Broad, low crowns–tolerant of grazing and low-cutting.
Persistent under non-ideal conditions, especially long periods of very cold temperatures.
More resistant to leaf diseases than winter active varieties.
More time at harvest before quality declines than winter active varieties.
Well suited to long-term irrigated or dryland production.

Winter active (or non-dormant) varieties

Active growth throughout the year, especially in late autumn–early spring.
Vigorous seedlings and quick establishment.
Narrow, high crowns and few tillers.
Higher annual production in the first three years than dormant varieties.
Fast recovery after cutting or grazing.
Can be sown in late autumn or winter.
More susceptible to cold.
May not persist as long as dormant varieties.
Suitable for: sowing in late autumn or winter; short-term irrigated stands; a region with a long hay-making season; some winter grazing; a component of an annual winter pasture mix; or in cereal crop rotations where high nitrogen inputs are required.

Seed selection and treatment

When purchasing lucerne seed, choose a suitable variety from certified seed source. Certified seed should have good germination and contain low weed numbers.

Inoculation

Lucerne must be inoculated with the correct strain of viable rhizobium inoculant (i.e. 'Lucerne' or Group AL). The rhizobia form nodules (bacterial colonies) on lucerne roots and fix nitrogen from the air for use by the host plant. Well-nodulated lucerne can produce enough nitrogen to sustain the high nitrogen removal rates of hay stands. Without healthy root nodules, lucerne will suffer from nitrogen deficiency and appear pale.

Focus Group recommendations

Sow quality seed.

Inoculate seed or buy pre-pelleted seed, coated with inoculant, fungicide and insecticide.

Choose seed that has a firm round coat and no dust.

Ensure pre-coated seed is fresh, or treat your own and sow within 24 hours.

Healthy nodules are pink inside and can be found just below the soil surface on seedlings (or deeper on fine lateral roots of older plants). Good nodulation is critical for lucerne hay production, so always inoculate seed, even if re-sowing an old lucerne paddock. Newer rhizobium strains are more effective than older ones that may have survived in the soil from previous lucerne.

Lucerne can be inoculated by lime pelleting or slurry techniques, either on a tarpaulin or in a cement mixer. Directions are included in each commercial packet of inoculant. Take care not to use excess lime or insufficient glue, as free lime will block the seed distributors of a seeder. Pre-inoculated seed is also available.

Table 6.11 Rhizobium inoculant for lucerne seed.

Product	Comments
Peat inoculant	A live, perishable product. Store in a refrigerator before and after sale. Do not use if the expiry date has passed. Mix with cold water to treat seed.
Inoculated seed	Do not leave in the sun (hot, dry conditions). Sow within 24 hours. Do not allow it to come into contact with fertiliser, as rhizobium strains are very susceptible to acid soil conditions.
Pre-inoculated seed	Available commercially. Inoculant has a long shelf-life. Keep in cool conditions before sowing. Sow promptly to ensure that the rhizobium remain viable. Keep a seed sample and store in a cool place in case of nodulation failure.

Seed dressings

Chemical seed coatings can reduce damage to establishing lucerne seedlings from insects and damping-off disease (pythium). Fungicide seed dressing for damping-off is important when sowing lucerne on clay soils or under flood irrigation and can be most useful when sowing into cold, moist soil (less than 10°C). It is also useful when using pre-emergent herbicides.

Seed dressings can interfere with rhizobia if they are used incorrectly, so read and follow the directions on the chemical labels and only use products registered for these purposes. Pre-treated seed including inoculant, fungicides, insecticides and wetting agents is available commercially.

Lucerne seed (left) and commercially coated lucerne seed (right).

Focus Group recommendations

Plant a new stand every season.

Sow at the right time for temperature and moisture (autumn or spring).

Sow before rain for an even germination.

Sowing time

Lucerne should be sown during mild conditions, as this favours its germination, establishment and growth and so assists with weed management.

Temperature

The optimum temperature for lucerne establishment is between 15 and 25°C. Germination of lucerne can occur between 5 and 37°C, but seedling growth is very slow at the extremes. A period of mild temperatures favours strong plant growth before the onset of low temperatures and frosts in winter, or hot weather in late spring–summer.

Soil moisture

Germination and establishment is generally more successful after rainfall than after irrigation, so sow when there is a high likelihood of effective rain and a low likelihood of the soil drying out. Permanent spray irrigation allows greater flexibility with sowing time, since water may be applied as required. Monitor the stand carefully to ensure germinating seedlings do not dry out before the roots are established.

Nitrogen fixation in lucerne

Lucerne fixes nitrogen from the air to sustain its nutrient requirements. The amount fixed in the plant is proportional to its growth (i.e. the more leaf the crop produces, the more nitrogen is fixed). A dense, vigorous, irrigated stand will fix more nitrogen than a thin dryland one. Generally, about 20 kg/ha shoot nitrogen is fixed for each tonne of dry matter produced (Peoples and Baldock, 2001). For a yield of 20 t/ha hay per year (i.e. 16 t/ha DM at 20% moisture content) this is equivalent to about 685 kg urea.

A similar amount of nitrogen is stored in the root system. About 20 kg/ha nitrogen is fixed in the soil for every tonne of dry matter produced.

The nitrogen in the soil organic matter is released as the roots and nodules break off, or the stand is terminated by spraying or cultivation.

Nitrogen from lucerne is slowly released into the soil over 3–5 years, especially in dryland conditions. About half of the nitrogen is available to plants in the first year following lucerne, with smaller amounts being released in subsequent years. This slow release effect is ideal for cropping rotations.

Mineralisation of nitrogen is related to soil moisture. Dry soil conditions during summer slow the rate of organic matter break-down, so that very little nitrogen is released into the soil. Wet summers and autumns promote decomposition of the organic matter and release of nitrogen. Research indicates that in dryland cropping rotations, the optimum time to terminate a lucerne stand to maximise soil moisture and nitrogen for the subsequent crop is in early spring (Dear *et al*., 2004).

Weeds
Weed competition must be limited to assist vigorous lucerne seedling growth. Paddocks with a history of summer weeds should be sown in autumn. Paddocks with a history of winter weeds should be sown in late winter to early spring.

The ideal sowing times are usually in autumn or late winter–early spring but will depend on the climate in each area. Areas with high annual rainfall, long wet cold winters and a long growing season in spring, are more suited to early spring sowing. Those with lower annual rainfall and mild winters favour autumn sowing. Winter sowing is possible in Queensland, but dry winds may dry seedlings out, reducing establishment.

Autumn sowing
All varieties can be sown during March–April; winter active varieties can also be sown in May–June. Early autumn sown crops can produce an extra one or two harvests over spring sown crops in the first season.

During winter, newly-sown lucerne is less competitive than many annual winter-growing weeds. The seedlings are also more prone to damage from insects, disease and waterlogging. Winter-dormant varieties should not be sown during winter, as their poor seedling growth and vigour may reduce their chances of survival.

Autumn sowing may also help to reduce the risk of seedling damage where sand blast due to strong winds in spring is likely.

Early spring sowing
All varieties can be sown in early spring (mid August–mid September) if soil moisture is sufficient, and rainfall is likely or irrigation is available.

Later spring sowing is risky and often produces a poorly established crop. Increasing temperatures and declining rainfall may cause seedlings to dry out and die before the roots reach moisture while summer weeds may become a problem.

Seeding rate

Lucerne crops thin with age so a suitable, even initial plant population is important to ensure a dense, even, productive stand. Ensure that the plant population matches the amount of moisture available to prevent competition between plants in dry times.

Irrigated lucerne crops: High plant densities produce high yields and provide good weed control in the first year, as well as finer stems. The target initial plant density for an irrigated lucerne crop in Australia should be 150–200 plants/m^2. This can be achieved with a seeding rate of at least 12–15 kg/ha. The number of lucerne seedlings surviving the first year is often only 25–50% of the seed sown due to the effects of moisture stress, weed competition, insects, waterlogging, disease and a host of other causes. Growers must manage the stand to maximise plant survival.

Some irrigated lucerne growers use seeding rates of up to 20 kg/ha to help ensure adequate establishment. Organic growers may use even higher rates to provide vigorous competition against weeds. However, very high seeding rates are expensive and lower rates may be adequate if the crop is managed well.

Focus Group recommendations
Establish a suitable plant population.

Dryland crops require a low seeding rate to guarantee plant survival (1–8 kg/ha, depending on rainfall).

Irrigated crops require high seeding rates to guarantee optimum hay production levels (seed rates range from 9–20 kg/ha).

Dryland lucerne crops: Low seeding rates (1–3 kg/ha) are usually adequate for dryland grazing stands. A seeding rate of 1 kg/ha provides about 44 seeds/m^2. With 30–50% seedling establishment, this results in a plant population of 12–22 plants/m^2 and

this will thin further over time, depending on the available rainfall; 5–8 plants may be adequate in a 350–400 mm rainfall area. High sowing rates in a low rainfall zone could mean total failure of a new stand in dry years due to competition between lucerne plants for moisture.

At low lucerne populations, other species become important in maintaining the groundcover and any dryland lucerne hay will generally be a mixture of species.

Sowing depth

Lucerne seed is small, so a shallow sowing depth is critical. It should be sown on, or very close to the surface–no more than 10–15 mm deep. Deeper sowing reduces the germination of lucerne significantly.

Focus Group recommendation
Use a shallow sowing depth. It is important to sow lucerne seed on or just below the surface and harrow lightly to cover.

Sowing technique

Lucerne can be sown with a pasture seeder or a small seeds box on a combine seeder. Broadcast the seed onto a smooth, cultivated surface and cover very lightly by trailing light harrows or mesh. The seedbed should be levelled with a levelling bar behind the cultivating tines and in front of the down-tubes from a small seeds box to prevent some seed falling into the furrows and being buried too deeply.

Focus Group recommendations
Use a small seeds box on a combine or broadcast seed with a fertiliser spreader.

Band seeders work well for lucerne.

Aim for a total sward with no lines by dropping seed onto a splash plate, lightly harrowing and then rolling.

Roll with a rubber-tyred roller after sowing to improve soil/seed contact.

Double sow on headlands and sow on check banks.

Sow across the paddock to prevent washout in flood irrigation.

Re-sow only when plants are young if establishment is patchy.

A band seed with narrow row spacing provides a good plant population.

A disc seeder can be used successfully to sow lucerne.

Direct drilling lucerne is possible if the seed bed is uniformly flat, soil structure is good, weed burdens are likely to be low and surface trash levels are low (usually after a winter crop). Direct drilling must follow a period of cropping and chemical fallow. Direct drilling and band seeders also achieve good results because they provide accurate seeding depth. On low-moisture sandy or light, fluffy, non-crusting soils, a rubber-tyred roller or press wheels can improve seed-soil contact to assist germination.

For dryland establishment, sowing into small furrows with press wheels to firm down the soil can help attract moisture to assist establishment on lighter soils.

When lucerne seed is sown in rows, the crop is sometimes sown in two directions (half rate in each direction) to increase plant density and weed suppression. However, this exercise is costly and may bury some seed too deeply. Sowing once with narrow row spacing may produce the same or a better result.

Companion crops

Cover crops

Dryland lucerne is often sown with a cereal cover crop to offset the cost of establishment. While this can result in extra income during lucerne establishment, the results are rarely as good as sowing a pure sward of lucerne and in dry years may lead to complete failure of the lucerne. The cover crop reduces lucerne seedling vigour and just like weeds, competes against the lucerne for moisture, light and nutrients.

> **Focus Group recommendations**
>
> Sowing with cover crops reduces lucerne establishment.
>
> Sow without a cover crop for hay.
>
> Sow dryland lucerne under cover crops only if cover crop seeding rates are reduced.

If using cover crops for dryland lucerne:

- choose a short-strawed, low-tillering species such as barley
- use a low cereal seeding rate (20 kg/ha)
- sow as early as possible to ensure that the lucerne will establish well.

Sowing lucerne and cover crops in alternate rows can also be successful.

Some growers maintain that sowing 1 kg lucerne with their cereals into the same paddock each year maintains a good lucerne population and improves the value of their cereal hay. This is highly dependent on a relatively thin population of existing lucerne plants, low cereal rates and adequate rainfall to support the new plants.

Dryland lucerne can be established with a cereal cover crop, provided the crop is not too competitive and conditions are favourable.

Nurse crops

In some situations companion crops can be used in irrigated lucerne as 'nurse crops'. These crops are sown to control weeds in place of herbicides, or to prevent wind blast of lucerne seedlings or soil erosion. In this case, the cover crop grows more quickly than the lucerne and provides protection to the seedlings or soil. It must not be sown at a density that allows it to compete against the lucerne seedlings for moisture, light and nutrients.

In California under irrigation, oats sown at rates of 9–18 kg/ha provides the right balance for lucerne sown at 22–28 kg/ha (Canevari *et al.*, 2000). The oats are usually sown first, with the lucerne broadcast or drilled immediately afterwards. Berseem clover sown at 7–9 kg/ha can also be sown in place of oats. In both cases, reasonable quality hay can still be made and the cover crop is eventually removed leaving a competitive lucerne crop.

Managing the young stand

Once lucerne seedlings have germinated they must be managed carefully through the first season. Seedlings face many limiting factors at the early stages of growth. A lucerne crop takes a year to fully establish.

Insect control

Lucerne seedlings are very susceptible to insect damage. Mites and aphids can damage or kill small seedlings in a short time reducing lucerne establishment. The establishing lucerne crop needs to be monitored for insects every day until the plants have two to three trifoliate leaves. Monitoring can then occur weekly for the next few weeks, to detect any rapid increase in insect populations.

Mite control in the previous year reduces the size of the mite population that may attack autumn sown lucerne. Timerite®, an insect prediction program for redlegged earth mite control, can help determine the most effective time to spray mite populations to prevent their build up. (See www.timerite.com.au)

High mite populations should be controlled with timely insecticide applications when necessary.

Grower tip
'Be aware of insects, especially in young freshly germinated lucerne'. *Paul Jones, Gundagai, NSW.*

Focus Group recommendations
Use resistant varieties and good rotations, and spray only when needed.

Avoid plant stress, as pests generally attack stressed plants.

Control insects (e.g. lucerne flea and RLEM) with appropriate insecticide sprays when necessary (especially dryland).

Preventative bare earth sprays around the perimeter or across the whole paddock should be applied immediately after sowing if high mite populations are likely. Paddock edges should be checked at least twice a week for mites migrating from neighbouring paddocks. Systemic insecticide should be applied if there are 1–2 mites per plant.

Seedling lucerne should be monitored regularly to assess populations of other insects such as lucerne flea, sitona weevil and whitefringed weevil, and determine whether chemical control is necessary. See *Chapter 7 Lucerne pests, diseases and disorders* for further information.

Irrigating seedling lucerne
Irrigation of germinating seedlings must occur before the soil dries out and the seedlings wilt. The timing of the irrigation will depend on the weather, soil type and method of irrigation. See *Chapter 8 Irrigation for hay production* for further information.

Cutting young lucerne
Young lucerne crops should be at least 15–20 cm high and preferably flowering before the first cut or grazing. Delaying cutting or grazing until this time allows adequate root reserves to be stored after cutting. This then encourages strong regrowth and reduces damage to the new shoots and crowns. Lucerne must not be cut lower than 8–10 cm on the first cut to avoid crown damage and to allow rapid regrowth from the stem shoots.

Poor nodulation
Occasionally lucerne fails to nodulate due to problems with the inoculant or poor management of treated seed. The lucerne plants turn yellow as they develop a nitrogen deficiency.

This problem can be overcome successfully in some instances by adding inoculum to the irrigation water. If paddocks are flood irrigated, bags of peat inoculant can be suspended in a fine nylon mesh bag at the water outlet, so that the inoculum can reach and infect the deficient plants. Inoculant may also be tank mixed in water and sprayed onto a lucerne crop or applied through a spray irrigator. The peat carrier must be filtered out or it will cause blockages to the irrigation nozzles.

Re-sowing lucerne after poor establishment
Re-sowing may be possible after poor crop establishment but it is essential that the reason for the failure is first identified and eliminated. Successful re-sowing can only occur when the lucerne plants are very young.

Thickening up thinly established crops is not generally successful once the lucerne plants are well established. The seedbed is no longer ideal

Poorly nodulated lucerne is yellow-green, lacks vigour and is poorly competitive, allowing weeds to establish and set large amounts of seed.

and existing lucerne plants compete for light and moisture. Established plants are also thought to exude allelopathic chemicals that may suppress the germination and growth of re-sown lucerne seedlings. Re-sowing will physically damage existing plants and leave them susceptible to infection by insects and diseases.

If re-sowing is undertaken, a disc seeder or narrow points should be used to reduce the disturbance to the soil and existing plants.

Maintaining the lucerne crop

The yield, persistence and quality of a mature lucerne hay stand depend on how well it is managed. A dense, vigorous stand can outcompete weeds and produce good yields of top quality hay. It is important to monitor the stand closely to ensure that any impediments to production are identified and rectified promptly. Best management practices are needed to ensure that the stand performs to its potential.

In crop fertilisers

Phosphorus

With high lucerne hay yields, soil nutrient levels, especially P and K, can be reduced over time. Annual topdressing with superphosphate replaces the P removed in hay and also keeps S and Ca at adequate levels. Dense irrigated lucerne hay crops that yield 12–15 t/ha/year require an application of 36–45 kg P/ha/year (i.e. 400–500 kg superphosphate/ha/year). Phosphorus is especially important after landforming where topsoil has been removed. In this case very high rates of P (50–60 kg P/ha) should be applied for a few years to build up the soil reserves.

> **Grower tips**
>
> 'Keep your nutrition up. Don't let paddocks rundown'. *Robyn Brosnan, Inglewood, Qld.*
>
> 'The greater the input, the higher the return'. *Sam Flaherty, Muswellbrook, NSW.*

Superphosphate is best applied in spring, before the main growing period. Some growers apply smaller amounts of superphosphate after each cut throughout the season. This is an expensive practice and there is no evidence that it benefits production any more than a single application of superphosphate.

Freshly broadcast P fertilisers are susceptible to large losses in water run-off. Fertiliser should be applied before a light rainfall if possible so that it washes into the soil. This also ensures that there is no fertiliser run-off after the first irrigation. Once in the soil, P remains immobile as it becomes bound to the clay particles. The availability of P to plants is reduced in acid soils. The P levels in the soil should be monitored with laboratory soil tests.

Other nutrients

Nutrients important for lucerne growth such as potassium and molybdenum can be deficient. If lucerne leaf symptoms or tissue tests indicate deficiencies, apply fertilisers as required. See *Chapter 7 Lucerne pests, diseases and disorders* for further information.

Lucerne pests, diseases and disorders

There are a number of pests, diseases and disorders that can severely reduce the growth and survival of lucerne. See *Chapter 7 Lucerne pests, diseases and disorders* for further information. Managing these is essential to achieve a vigorous, persistent lucerne crop that produces excellent hay yields.

Weed management strategies for established lucerne

Successful weed management in lucerne involves promoting a healthy, vigorous, competitive crop to provide competition against weeds. An integrated approach should be used including strategies such as rotation, cultivation, grazing and herbicides.

Weed control in mature lucerne depends on the health and density of the lucerne, the weed species and population, the season and the availability of irrigation water.

Actively growing, well-established lucerne is a strong competitor for light and moisture, so ensure that plant number is maximised and manage the stand well to provide good competition against weeds. Large gaps between the plants will promote weeds, so avoid anything that may thin out the stand. This includes slow irrigation and drainage, low fertility, frequent cutting, disease and insects. Frequent irrigations, with shallow water penetration also favour many summer weeds.

When weeds invade, early control is more effective and less costly. A number of herbicides are registered for use in established lucerne that cannot be used on younger stands. However, do not substitute herbicides for good management. Herbicides can be expensive and can sometimes suppress lucerne growth.

When lucerne is growing slowly during winter it is less likely to be damaged by herbicides or other weed control practices. Careful grazing or flame weed control can remove weeds from established stands during winter, without causing too much damage to the lucerne. Light cultivation with narrow points can provide weed control but care is needed not to damage existing plants and this practice is a last resort.

Winter management

In an established stand, winter management influences both persistence and hay quality in the first and last cuts of the season.

During winter, limited growth occurs in winter dormant and semi-dormant lucerne varieties. The lucerne plant draws on its root reserves for survival. Energy reserves in the lucerne roots will replenish if the plants are allowed to reach full flower before the last cut of the season. This will maximise lucerne plant survival over winter.

Winter active and highly winter active varieties keep growing during the colder months and can be grazed during winter. Winter grazing may reduce hay yields in spring and cause increased crown damage and disease infection. Many growers graze instead of cutting in late autumn. If lucerne is cut at this time it often contains a high proportion of weeds, and is difficult to cure for hay. Turning it into silage may be a better option.

Grazing in winter and then removing livestock for a short time allows winter weeds to regrow. This practice exposes weeds for better herbicide control in late winter–early spring. A range of herbicides can be used in winter to remove or suppress annual weeds. See *Appendix B: References and information sources* for resources on weed control.

Damage to winter-grazed lucerne from crown and root disease infections can be minimised by removing livestock in wet conditions to avoid pugging the soil. A strict rotational grazing program must be maintained during winter to ensure lucerne persistence.

Irrigated lucerne can be damaged by a frost that occurs after a flush of growth in spring. Younger, more exposed leaves become bleached and die. In extreme cases whole plants can be killed.

Lucerne persistence

Lucerne can survive for many years if conditions are favourable and it is managed well. The productive life of the stand usually depends more on its purpose and how it fits into the farm business. It

Lucerne stands thin after a number of years and productivity drops dramatically.

Focus Group recommendations

Lucerne stand life varies (3–6 years). Older stands thin out, lose vigour and weeds encroach.

Most farmers rotate with a range of crops for one to two years for good weed control, especially of grasses.

For old stands, direct drill with oats for hay in the last year or so, to extend the stand life.

is a compromise between the production required, how long it is needed and whether the enterprise is economical. An irrigated lucerne hay crop usually remains productive for 3–4 years, while a grazing stand may last 3–6 years.

Lucerne crops become thin and less vigorous as they age and decline in hay yield and quality. A less competitive lucerne crop provides increased opportunity for weed invasion. This further reduces the yield and quality of the crop. The rate of decline will depend upon the soil type, the variety, its management (cutting, grazing, irrigation, weeds and fertiliser) and any problems that may occur (e.g. insects, diseases, waterlogging).

Renovating old lucerne crops

The old practice of renovating lucerne crops by cultivation is not considered good practice. The benefits of cultivation are generally short-lived. Subsequent crown damage and increased incidence of disease lead to plant death. Some growers still renovate their lucerne crop using narrow-tined points to minimise plant damage.

Lucerne seed is sometimes direct-drilled into an existing old lucerne stand in an attempt to improve plant density. This practice usually has limited success as the seed bed is not ideal for establishment; existing plants compete for light and moisture; and there can be high levels of weeds, insects and diseases. Seedlings which do survive are generally poor competitors and do not contribute significantly to production.

D. Holding

Thinning dryland lucerne stand oversown with perennial ryegrass to extend stand life and maintain grazing productivity.

Focus Group recommendations

Renovating lucerne can help with water infiltration.

Renovation can cause lucerne plant damage and create disease problems.

If renovating lucerne stands use narrow points to reduce plant damage.

Over-sowing old lucerne crops

The productive life of thinning lucerne crops can be extended by over-sowing with another species such as a winter cereal, perennial grass or another legume, which can be grazed or cut for hay. This practice provides good yields of high quality feed and provides weed control for the lucerne stand. This is typically done in the last year of the rotation but can be done for a number of years if necessary.

Focus Group recommendations

Sow oats or ryegrass during the last few years of old lucerne stands to improve hay production.

Crops such as chickpeas or field peas can be sown into lucerne.

Over-sowing winter cereals into lucerne can increase yield, especially in a 3rd or 4th year stand. If done too early it can damage the lucerne, but this depends on the machinery used.

The over-sown crop should be sown at a rate and time to optimise the new crop. Resulting hay will be of lower quality than a pure stand but is likely to have a higher yield and quality than from thin weedy lucerne.

Terminating lucerne crops

Eventually the lucerne crop will become too thin and weedy to be economically viable. Lucerne should then be rotated with other crops to provide a break from weeds, diseases and insects. These crops are able to use the soil nitrogen that has been fixed by the lucerne.

Focus Group recommendations

Remove stands when plant population thins out.

Don't let the stand get too old–watch for weeds, low yield and thick stems.

Ensure population is good for 2.5 tonne/ha (1 t/acre) production.

To remove lucerne, graze with lambs, plough or spray out.

The decision to terminate a lucerne hay crop can be difficult and depends on a host of factors including the season and the markets. Growers will often delay terminating the lucerne because it looks productive, even though yield and quality may have dropped significantly. For hay production it is important to know when a lucerne crop has reached its economic threshold. It is therefore important to record the production from each harvest and calculate the costs. When the returns from the hay are no longer economic, the stand should be terminated.

The economics of all options must be considered before terminating a lucerne crop. Grazing for one or two years with limited inputs may be an alternative option. If cereal crops are used in the rotation, a deteriorating, grass dominated lucerne-based pasture should not be kept in the rotation. This pasture would provide little benefit to the following cereal grain crop.

Potential crop yield can be determined in the field by assessing the size and number of lucerne plants or by counting the number of stems. It is also important to check the crowns and roots of lucerne plants for signs of insect or disease damage. Large numbers of damaged plants indicates that the stand is declining rapidly. Similarly, a large number of gaps between plants and/or high weed populations would indicate that the stand is at the end of its productive life.

Monitoring lucerne plant stands

Irrigated lucerne

Even though Australian growing conditions differ to those in the USA, data from the US provides a benchmark to monitor the productivity of irrigated lucerne stands over time (*Table 6.12*).

An irrigated lucerne hay stand is unlikely to produce high yields with less than 40 plants/m^2. Once it reaches this stage, monitor the yields and consider the economics of maintaining the stand.

Stem numbers can also be used as an indicator. In the USA crops are said to be productive if they have more than 600 stems/m^2. Some yield reduction is expected at 420–600 stems/m^2, and when the stem count reaches 400 stems/m^2, consider replacing the stand (Undersander *et al.*, 2000).

Dryland lucerne

Dryland lucerne crops are established with a low plant density (20–100 plants/m^2) depending upon on the likely rainfall (*Table 6.13*). Plant density decreases with time due to moisture availability, diseases, insects and grazing pressure. Final

Monitoring lucerne plant population

Lay a small square or grid of weldmesh on the ground in a lucerne stand with a few days of regrowth after cutting and count the plants.

Mark the spot with a small stake and revisit the same area to repeat counts. Observe how the plant numbers change with time.

Plant numbers will decline over time but the remaining plants will expand in diameter.

Table 6.12 Recommended minimum stand density to maintain lucerne hay production in an irrigated lucerne stand at varying ages of the stand in the USA.

Source: Canevari *et al*. (2000).

Production year	Stand density (plants/m²)	Comments
New seedling stand	> 270	Dense initial population
End of 1st year	160–270	Stand produces well
End of 2nd year	108–160	Stand thinning but still viable
3rd–4th years	64–108	Consider over-sowing
Later years	32–54	Replace stand or over-sow

lucerne plant populations can range from 1 to 20 plants /m^2. At low densities the lucerne crop will have a high proportion of other grass and legume species, and any hay made is likely to have a lower feed value than a pure lucerne stand.

Dryland lucerne uses moisture from deep in the soil profile which has implications for the following rotation crops and weed control. The amount of nitrogen fixed in the soil also depends on the density of the stand.

Cropping after lucerne

Once the decision to plant a new crop has been made the best practice is to completely remove the old lucerne plants and sow a different type of crop such as a cereal. A broadleaf crop sown after lucerne may act as a disease host for future lucerne crops. Lucerne is susceptible to some common broadleaf crop diseases such as sclerotinia.

Wait at least two years before re-establishing lucerne in the same paddock. Sowing lucerne straight after lucerne is not good practice, since existing weeds, pests and diseases can infect the new plants, and the remaining nitrogen in the soil will encourage grasses and thistles. Old plants will compete for light and moisture and there may be some allelopathic effect from remaining old lucerne plants which can reduce germination and growth of young seedlings.

Table 6.13 Dryland lucerne densities, production and nitrogen fixation at two locations in NSW.

Source: Mark Peoples, CSIRO Canberra.

Location	Median annual rainfall (mm)	Plants (number/m²)	DM (t/h)	N fixed (kg/ha)
Trangie	468	1.1	0.70	11
		3.5	1.47	24
		6.5	2.63	52
Wagga	552	5.0	2.17	64
		10.0	3.09	88
		20.0	4.02	117

Removing lucerne before cropping

An understanding of the growth cycle of the lucerne plant can help growers to remove it effectively. An integrated approach involving grazing, chemicals and cultivation is required (Davies *et al.*, 2006).

Focus Group recommendation

Herbicides and/or cultivation can be used to remove lucerne, after first running down the plant's root reserves

It is important to first deplete the root reserves and weaken the plant. This can be achieved by frequent cutting or heavy grazing and then allowing active regrowth for about two to three weeks to utilise root reserves. Herbicides are most effective when they are applied to active regrowth. In actively growing plants carbohydrates begin to be stored in the root system about two to three weeks after cutting. Herbicide applied at this stage will be translocated into the root system and will finally kill the plant.

It is important to choose the most appropriate herbicide to kill lucerne. There are several herbicides registered. Consult your agronomist for the most current recommendations.

Chapter 7
Lucerne pests, diseases and disorders

There are a number of insect pests, weeds, diseases and disorders that can severely reduce the ability of lucerne to germinate, establish and grow. They may include:

- insect pests
- fungal diseases, including: root, stem, crown and leaf diseases
- stem nematodes
- bacterial diseases
- viral diseases
- nutrient disorders, including: deficiency or toxicity of nutrients
- other disorders, including: waterlogging, scald, frost, herbicide damage
- weeds.

Managing these problems is essential to achieving a vigorous, persistent lucerne crop that produces excellent hay yields.

Insect pests

Insects can significantly reduce the yield and persistence of lucerne in Australia. Insects that cause damage to lucerne in Australia include aphids, mites, lucerne fleas, weevils, caterpillars, crown borers, leaf hoppers, green vegetable bugs, thrips, lucerne seed wasps, web moths and grasshoppers.

Chewing insects such as crickets and weevils, and mice can also cause damage to sub-surface irrigation systems. Lucerne stands should be checked regularly to ensure that prompt action can be taken when necessary.

A sweep-net is used to monitor insect numbers on an uncut strip of lucerne.

There are several major insect pests of lucerne (e.g. alfalfa weevil, glassy-winged sharpshooter) not yet in Australia. Biosecurity measures are important to keep these out of the country. Vigilance is important to ensure that any new pest is reported, identified and eradicated as soon as it is discovered.

There is also a host of beneficial insects in Australia that can keep pests under control. It is important to be able to identify and manage the insect populations using a range of methods including resistant varieties to keep costs low, avoid insecticide resistance and maintain the beneficial insect populations.

Aphids

Aphids are the most damaging insect pest of lucerne in Australia. They are very mobile and can substantially reduce production or rapidly kill plants of susceptible varieties. The types of aphids, symptoms and management are found in *Table 7.1*.

Aphid enemies

Populations of natural enemies build up in fields infested with aphids and should be encouraged to help to keep the aphid numbers in check. There is usually a lag time in the population peaks of aphids and predators, so there will often be substantial lucerne damage before the populations come into equilibrium.

Insect predators (e.g. ladybirds, hover flies, lacewings) often feed on aphids and their presence indicates that aphid numbers are high. Parasitic wasps are also extremely important, their presence indicated by the mummified remains of aphids on leaves. A fungus disease of aphids produces similar grey or light brown "mummies" stuck to leaves in humid conditions. Note that beneficial insects are also susceptible to insecticides, so careful management is needed to maintain them. Beneficial insect numbers can also be allowed to build up in uncut borders or strips of lucerne to re-infect new growth after cutting the field.

Mites

Although mites are tiny, they often occur in such high numbers that they can devastate establishing lucerne stands, especially young seedlings (*Table 7.2*).

Lucerne flea

Lucerne fleas can kill seedling lucerne stands and severely reduce the yields of older ones. They are wingless, with pale or light green globular bodies about 3 mm long, and hop when disturbed. They feed on leaves, leaving membranous 'windows' or large holes. Lucerne fleas hatch on the first autumn rain and produce several generations in winter and spring, before laying over-summering eggs. They can be managed by clean fallowing, liming before sowing, treating seed with insecticide and using foliar sprays.

Weevils

Adult weevils chew leaf margins and stems of plants and can kill seedling stands or defoliate established ones (*Table 7.3*). Larvae (the immature stage grubs) feed on roots and root nodules, often killing seedlings.

Caterpillars

A range of caterpillars can damage lucerne stands, reducing both hay yield and quality (*Table 7.4*). They occur in spring, summer and autumn, especially when lucerne is moisture stressed in hot, dry weather.

Avoid plant moisture stress. Monitor stands regularly and if numbers are high, spray while caterpillars are small, or use strategic cutting or grazing. Early detection is essential.

Lucerne flea leaf damage.

Lucerne flea.

Insect predators which feed on aphids (top L to R) brown lacewing, lacewing larva, hoverfly, (bottom L to R) ladybird, ladybird larva and parasitic wasp.

Table 7.1 Aphids affecting lucerne in Australia.

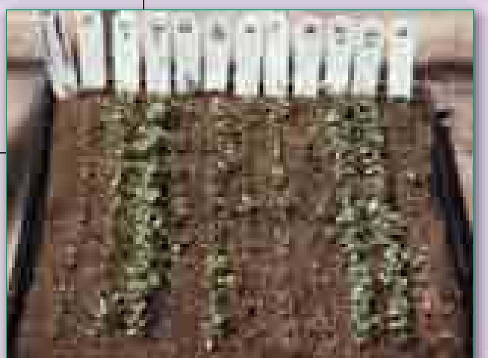
Aphid	Comments	Symptoms	Management
Spotted alfalfa aphid (SAA)  © NSW DPI 	Up to 2 mm long, pale yellow, with rows of dark spots on back, winged or wingless. Found on stems and under leaves and jump when disturbed. Seedlings can be killed by just a small population of aphids, while large numbers can kill mature plants. Active from spring to autumn. Attracted to stressed plants. 	First signs of plant damage include yellow veins and shiny, sticky leaves.  Ladybirds in lucerne indicate that aphids are present. Tiny white aphid skins are also visible on ground beneath when numbers are high. Plants turn black with sooty mould which develops on honey-dew secreted by aphids. Haymaking becomes difficult. Plants become stunted and distorted; leaves turn yellow and drop off. Plants finally die.	Integrated management is needed. Use insect resistant varieties. Most current lucerne varieties have resistance to SAA and BGA but not SCA. Vigorous stands are more resistant to attack, so ensure that the stand is well managed. Monitor stands closely and regularly, as numbers can build up quickly. Spray seedlings if aphids are present, as even the most resistant varieties can be damaged or killed by just a few aphids. Chemical control can be applied to mature stands if necessary. Be aware that SAA is resistant to a number of insecticides.
Bluegreen aphid (BGA) 	Blue-green in colour, 2–3 mm long, with or without wings. Usually found on growing tips and stems. Most common in autumn, winter, spring and cool summers.	Cause stunting and curling of leaves and shrinking of plants. Rarely kills established lucerne stands but can kill seedlings and cause substantial yield loss of mature plants of susceptible varieties.	 **Bluegreen aphid damage.**
Pea aphid (PA)	Similar to BGA but darker green, slightly larger (4–5 mm), with dark bands on the antennae. Occurs in spring, summer and autumn. Not as important as BGA in Australia; major pest in the USA.	Similar effects to BGA.	 **Lucerne cultivars are selected for aphid resistance.**
Spotted clover aphid (SCA) 	Similar to SAA. Active in the warmer months. A more recent pest in Australia but not a major problem to date. Significant in other countries.	Similar effects to SAA.	

Table 7.2 Mites affecting lucerne in Australia.

Mite	Comments	Symptoms	Management
Redlegged earthmite (RLEM)	Velvety black oval bodies about 1 mm long and orange-red legs. Common in autumn, winter and spring. Prefer sandy to loamy well-drained soils. Over-summering eggs are laid in spring and hatch in the following autumn after rain and 3 days at 18°C. Populations peak in mid-winter and spring.	RLEM feed on emerging shoots, cotyledons and leaves, leaving silvery patches on the leaf surface. Young seedlings shrink, shrivel and may die.	Commence control in the year before sowing lucerne. Spray in spring to reduce over-summering eggs. Use Timerite®, to determine the best time to spray. (www.timerite.com.au). Integrated pest control could include clean fallowing, weed control, seed treatment, preventive border sprays, bare earth sprays and foliar sprays. Monitor establishing lucerne closely for mites. Spray when 1–2 mites are found per seedling. BOM and RLEM react differently to insecticides, so it is important to identify the mite and numbers of each before choosing a chemical spray.
Blue oat mite (BOM)	Similar to RLEM but has a red dot on its back. Mixed populations of RLEM and BOM usually occur.  G. Warren © NSW DPI	 Mite damage on clover leaf.	

Table 7.3 Weevils affecting lucerne in Australia.

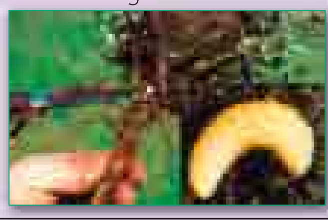
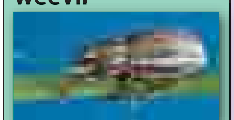
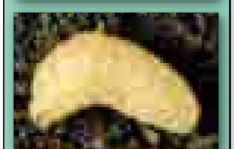
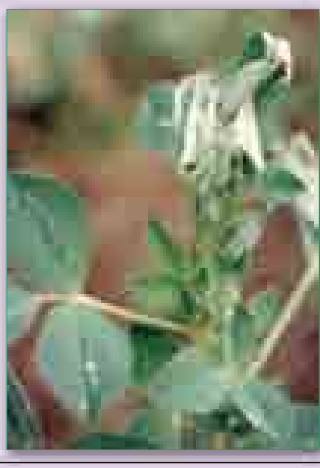
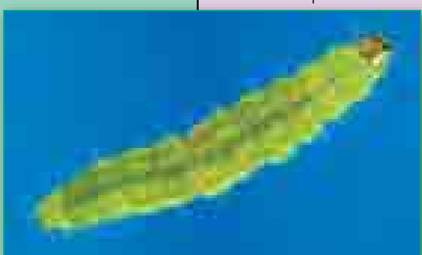
Weevil	Comments	Symptoms	Management
Sitona weevil	Adult weevils are 3–5 mm long, dark greyish-brown, with a short broad snout and 3 white stripes along their bodies. Larvae have white, legless bodies up to 5 mm long, with an orange-brown head.	Adults feed on leaves and stems in spring, autumn and warm winters. They cause scalloped leaf edges and some stem damage.  L. Turton © NSW DPI	Check stands regularly, especially in April–May. Spray promptly when adult pest numbers and damage are high to prevent egg-laying.
Whitefringed weevil   L. Turton © NSW DPI	Adults 10–13 mm long, dark grey, with 2 whitish bands on the sides of the head and body. Larvae have slightly curved, white, legless bodies, up to 13 mm long and 6 mm wide, with black mouth-parts.	Larvae burrow into taproots of established plants. Root damage can predispose plants to death from other stresses. Larvae can also damage sub-surface drip irrigation pipes. Adults rarely a problem, but their presence may indicate larval damage.	No chemical control available. Control larvae by cultivating in late spring before sowing, followed by two weed and legume-free grass forage or cereal crops. Do not re-sow lucerne into infested paddocks and sow new stands as far away as possible.

Table 7.4 **Caterpillars affecting lucerne in Australia.**

Caterpillar	Comments	Symptoms	Management
Native budworm (Heliothis)	Newly hatched caterpillars (1–1.5 mm long), have white bodies, dark spots and dark heads. Young caterpillars (up to 15 mm) are pale yellow, green or brown with dark heads and dark stripes on the back and sides of the body.  L. Turton © NSW DPI ***Helicoverpa punctigera* caterpillar**	Occur in spring, summer and autumn, often in seed crops at flowering. Feed on foliage, flowers and developing pods and can severely reduce hay and seed yields and quality.  L. Turton © NSW DPI ***Helicoverpa armigera* moth**	Early detection critical, so monitor carefully and spray early to prevent damage and build up of population. Select correct insecticides and rotate chemical groups to ensure chemical resistance does not occur. Check withholding periods carefully to avoid chemical residues in hay.
Cutworms	Feed on leaves and stems of seedling and mature lucerne in the late afternoon or at night. Can occur at any time of year and may thin-out seedlings or severely check regrowth.  L. Turton © NSW DPI	Rarely seen during daylight hours. Grey-brown, green-brown to black, with dark spots on back and sides. 20-50 mm long when fully grown. 	Clean fallow and remove weeds at least one month before sowing. Check patchy areas of the crop at night by torchlight. Spray in the evening if damage is severe.
Lucerne leaf roller	Slender pale yellow to green bodies with dark heads. Wriggle backwards and drop off leaves when disturbed. A serious pest in some areas.  L. Turton © NSW DPI	Feed on terminal leaves and stems, webbing them together and stunting plant growth. Found inside rolled, webbed leaves.	Graze, cut or spray when 30% of the terminal shoots are rolled. Chemicals may not always be effective because the caterpillars are protected by rolled leaves.

Lucerne diseases

Disease in lucerne can cause significant reductions in both hay yield and quality. Resistant varieties and careful management are required to avoid losses. A number of diseases affect lucerne establishment and growth including stem nematodes, fungal, bacterial, viral and mycoplasma diseases.

Fungal diseases

Root diseases are a major problem in irrigated lucerne or on poor draining soils. Fungal spores are spread in water and soil and enter the plants roots. Poorly drained clay soils are ideal for development of root diseases. Lucerne root disease fungi can affect other types of plants (especially broadleaf species) (*Table 7.5*).

Crown diseases are caused by fungi that enter cut and wounded stems and infect the stems and crowns. Disease is favoured by warm, humid conditions (typical of irrigated lucerne stands) and mechanical damage caused by heavy traffic and haymaking operations (*Table 7.6*).

Leaf diseases of lucerne caused by fungi can result in heavy leaf loss. They are favoured by warm moist conditions and delayed cutting, especially in coastal areas and under spray irrigation. Fungicide sprays are not usually economic for control of leaf diseases but they can often be managed by cutting. Leaf disease can induce the production of plant oestrogens which can have a detrimental affect on breeding stock. Do not graze lucerne with severe leaf disease (*Table 7.7*).

Other diseases

Two other important diseases of lucerne causing economic losses include stem nematode and bacterial wilt (*Table 7.8*).

Virus and mycoplasma diseases

Viruses are spread by infected seed and insects such as leafhoppers and aphids. Odd plants are usually affected to begin with and infected plants do not recover. Large stand losses are possible over time (*Table 7.9*).

Table 7.5 Fungal root diseases affecting lucerne in Australia.

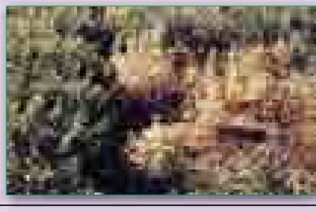
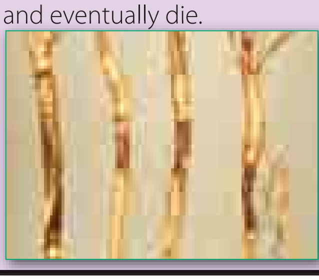
Disease	Comments	Symptoms	Management
Damping off (pythium)	Affects lucerne seedlings. Occurs in cool wet soils when plant growth is slow.	Roots of seedlings rot off within a few days of emergence, causing patchy establishment. Leaves often turn red or purple. Plants shrink, then shrivel and die.	Sow into well-drained soil and use fungicide seed dressings. Avoid sowing in cool, wet conditions.
Phytophthora root rot (PRR)	Affects both seedlings and mature plants. Occurs in wet, clay, poorly drained soils in spring, summer and autumn. Favoured by warm conditions.	Black girdling lesions on the tap roots. Secondary roots rot off. Plants wilt when water stressed. Shoots turn yellow to purplish/red and die.	Use resistant varieties, seed dressings, good layout and drainage. 
Rhizoctonia root canker	Spread by infected soil and plants. Attacks weakened plants and favoured by high temperatures. An important disease in the southern states.	Black, girdling and sunken lesions on roots. Lateral roots often rot off. Plants wilt, become stunted and eventually die.  A. Nikandrow © NSW DPI	Improve plant vigour with good fertiliser and irrigation management. Keep physical plant damage to a minimum

Table 7.6 Fungal diseases affecting lucerne crowns in Australia.

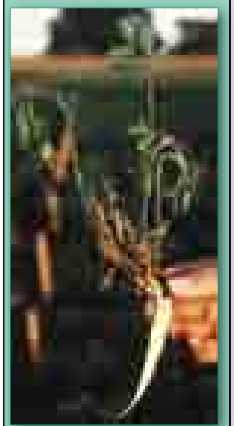
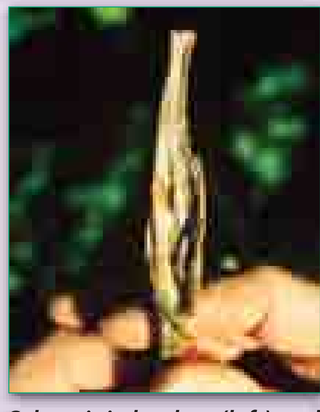
Disease	Comments	Symptoms	Management
Common crown rot complex (*Acrocalymma, Phomopis, Fusarium*)	A number of similar fungi often cause poor persistence and weak shoot growth in lucerne. Spread by infected plant debris and rain splash on cut or damaged lucerne plants. Spores survive for a long time on dead crowns.	Most noticeable during active growth and following stress or injury. Individual tillers turn red, brown. Plants wilt or die. A reddish-brown rot appears in the crown and in the tap root. 	Avoid plant stress and physical damage. Rotate lucerne with cereals. No difference in resistance between varieties, but low-crowned varieties are less damaged by cutting and may be less prone to this disease.
Anthracnose or Colletotrichum crown rot (CCR)  G. Drummond © NSW DPI	Favoured by warm, humid conditions and spray irrigation in spring, summer and autumn. Spread from infected lucerne plants and volunteer legumes by rain splash, machinery and water.	Scattered shoots suddenly wilt, turn yellow (anthracnose) and may curl over. Brown to black lesions with a pinkish ooze and black dots found on stems. Light brown girdling lesions appear on stems near ground, and the crown shows a typical blue-black rot.	Use resistant varieties. Rotate lucerne crops with cereals. Keep harvesting equipment clean to avoid spread.  © NSW DPI
Sclerotinia crown rot	Survives on old plant debris and as fruiting bodies (sclerotia) in the soil. Affects wide range of broadleaf species. Young and dense irrigated stands more susceptible.	White fluffy fungal threads at base of stems and crowns. Wilting stems. Crown and root rot. Small dark fruiting bodies (similar to mouse droppings) within the stem.  © NSW DPI	Rotate lucerne with cereals. Control broadleaf weeds that host sclerotinia crown rot.  © NSW DPI ***Sclerotinia hyphae (left) and fruiting bodies (above).***

Table 7.7 Fungal leaf diseases affecting lucerne in Australia.

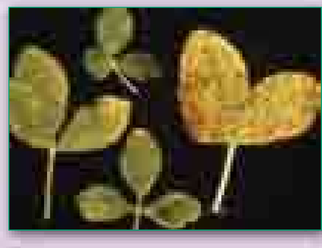
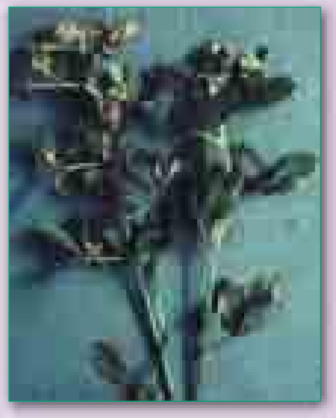
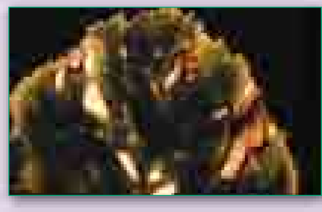
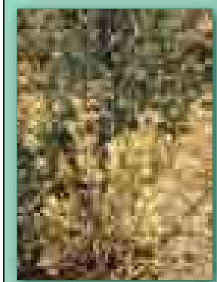
Disease	Comments	Symptoms	Management
Rust (Uromyces)	Survives only on living plants. Common in autumn, especially on mature growth.	Red-brown pustules on the leaves and stems. Clouds of spores rise up behind the mower at cutting.  G. Stovold © NSW DPI	Leaf diseases can be controlled by cutting and strategic grazing before the stand becomes too mature and the infection too severe. Keep the stand weed free to promote air movement through the crop. Aim to prevent leaf drop which will re-infect the stand.
Pepper spot (Leptosphaerulina)	Usually found in late summer and autumn. Affects a wide range of plant species.	Small black spots surrounded by a yellow halo on the leaves. Spots join to form tan lesions with a brown border. Leaves shrivel and drop off.  G. Stovold © NSW DPI	
Common leaf spot (Pseudopeziza)	Common in spring and autumn.	Small black pin-point spots on the leaves and stems. Leaves shrivel and drop off.  G. Stovold © NSW DPI	 R. Williams © NSW DPI **Stemphylium leaf spot**
Stemphylium leaf spot	Common where good autumn and winter rain occurs.	Light brown, scattered, oval to irregular spots (1–3 mm wide) with a dark margin.	
Downy mildew (Peronospora)	Occurs in spring and autumn. Chemical control is available, but is rarely necessary.	Light green patches on the upper leaves with a purplish grey fungus on the underside.	 **Downy mildew**
Black stem (Phoma)	Can be seed-borne but control is rarely needed.	Black lesions on the stems and petioles. Young stems and buds can be killed.	
Staganospora	Can also cause crown rot.	Brownish, V-shaped spots at the end of leaflets.  © NSW DPI	

Table 7.8 Other diseases affecting lucerne in Australia.

Disease	Comments	Symptoms	Management
Stem nematode (SN) (*Ditylenchus* spp.)  G. Drummond © NSW DPI	Tiny worm-like organism (1 mm long). Often occurs in stands on irrigated river flats. Most obvious in spring. Favoured by cool, showery weather. Spread by contaminated hay, seed, machinery, animals and flood irrigation water. Can remain dormant for up to 6 years in diseased tissue.	Dwarfed, distorted shoots. Pale, swollen, spongy crown buds which are easily detached. Plants die in patches.	Burn infected debris and plough out infected stands. Use resistant varieties and disease free seed.
Bacterial wilt	Can affect many plant species and is very contagious. Caused by bacteria, and spread by contaminated hay, seed, irrigation water and machinery. An important disease in the southern Australian states.	Small pale green leaves after cutting and stunted plants. When the root is cut open, the central woody core of the taproot appears yellow and the bark white.	Burn infected debris. Use resistant varieties and disease free seed.  © NSW DPI

Table 7.9 Virus and mycoplasma diseases affecting lucerne in Australia.

Disease	Comments	Symptoms	Management
Lucerne yellows 	Spread by leafhoppers. Symptoms develop in mid-late summer in drier districts. Number of infected plants increases with time.	Red to bright yellow foliage. Inner bark of tap root turns yellow, central core white. Plants produce spindly growth from crowns and often die. Badly infected plants do not set seed.	Monitor and control leaf hoppers if possible. No control available for infected plants. Plough the stand out when it is no longer productive and rotate with a cereal crop.
Witches broom 	Affects a wide range of plant species and is favoured by warm-hot conditions in drier districts. Transmitted by brown leafhoppers (jassids).	Plants dwarfed with small round leaves and many very fine shoots. Flowers turn pale green and leaf-like and the crown often dies.	No control available for infected crops. Graze or plough out when the stand is no longer productive.
Alfalfa mosaic virus (AMV)  G. Stovold © NSW DPI	Affects a wide range of plant species and is more prevalent in the cooler months. Can be seed borne or transmitted by aphids and machinery.	Yellow stripes or patches on leaves, stunted leaves and plants, and reduced yields. More noticeable soon after cutting.	No control available for infected plants. Sow disease free seed.

Nutrient disorders

Table 7.10 Symptoms of nutrient toxicity and deficiency in lucerne.

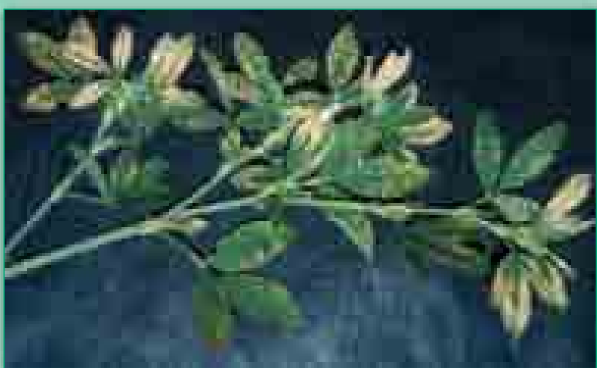
Nutrient	Symptoms
Nutrient toxicity	
Aluminium (Al)	Stunted roots and poor nodulation
Manganese (Mn)	Yellowing leaves with dry brown patches
Nutrient deficiency	
Phosphorus (P)	Small, dark green to purplish, curled leaves at the top of the plant. Lower leaves turn yellow and die.
Calcium (Ca)	Stems of the youngest fully developed leaves collapse. These leaves then curl up and die.
Sulphur (S)	Reduced tillering and new growth is pale green and stems have a reddish tinge. Similar to N deficiency, but younger leaves affected first.
Potassium (K)	Numerous small whitish spots around the margin of each leaflet, develop into brownish necrotic areas.
Nitrogen (N)	Older leaves are pale green, especially on the tips. Root nodules may be absent or inactive (white or green inside).
Molybdenum (Mo)	Very similar to N deficiency. Root nodules may be present, but inactive
Boron (B)	Dwarfed plants. Lower leaves reddish-purple while top foliage is yellow. Stems fail to lengthen, giving new shoots an 'umbrella-like' appearance.
Zinc (Zn)	Dwarfed regrowth (little leaf). Leaves have bronze spotting and young leaves curl upwards.

Aluminium toxicity symptoms in lucerne.

Photos: R. Weir © NSW DPI

Molybdenum deficiency symptoms in lucerne.

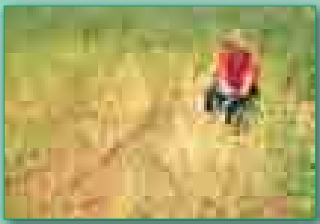
Boron deficiency symptoms in lucerne



Potassium (K) deficiency symptoms develop first in the oldest leaves of lucerne.

Other disorders

Table 7.11 Other disorders that can affect lucerne in Australia.

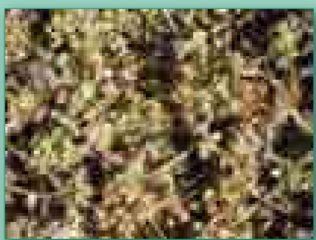
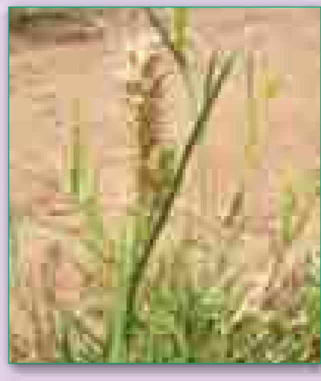
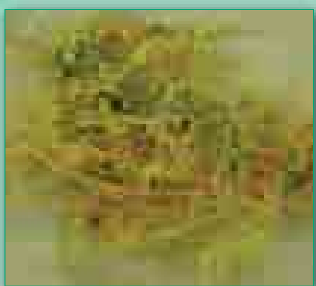
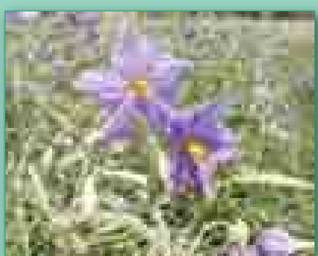
Disorder	Description
Waterlogging	Lucerne is very susceptible to waterlogging. Temporary waterlogging (e.g. from irrigation), stops plant growth for a period while prolonged waterlogging, especially in summer, kills plants. During winter, lucerne has been known to survive inundation for up to a week or more. Early symptoms include general reddening of the plants, followed by yellowing and plant death. To avoid waterlogging ensure that there are no low spots where water can pond in the field, and provide grades and layout to allow water to drain away quickly.
Scald 	Scald results when plants are flooded for too long during hot weather. Low oxygen around the roots and high temperatures when water covers the plants can cause rapid death of lucerne plants. This can occur quite quickly with flood irrigation in very hot conditions. Whole stands can be killed overnight in some instances. After about a week, rotted, foul-smelling plants can be easily pulled out of the soil. To avoid scald with flood irrigation, ensure layouts allow water to drain off the field quickly. Ensure that there is some regrowth after cutting to allow plants to 'breathe' when flooded and water at night when it is cooler.
Frost 	Although young lucerne seedlings can survive winter under snow, frost can damage foliage of mature plants, especially if the lucerne leaves are growing rapidly or after spray irrigation. Severe prolonged frost conditions can kill lucerne plants.
Herbicide damage 	Various herbicides can damage lucerne, resulting either from too high an application rate or spray drift of unsuitable herbicides from other crops. Symptoms vary and include slow growth, discolouration (bleaching or reddening), distortion of leaves, and/or death. Note that reddening and purpling of leaves is associated with many problems in lucerne, as it indicates that the plant is not able to access nutrients from the soil.

Weeds of lucerne

Weeds in lucerne reduce the quality and quantity of hay and the productive life of the crop. Winter annual weeds emerging in autumn can contaminate the first hay cut. Summer annuals germinating in spring are not a problem in the first hay cut but can contaminate subsequent cuts. Perennial weeds grow for several years and can be difficult to control in lucerne once they become established.

Several weeds pose particular problems for lucerne hay producers, either due to their effects on the hay or their difficulty of removal. Special attention should be paid to eliminating these before sowing and throughout the life of the stand. Consider which weeds are likely in your area. Examples of problem weeds in lucerne crops are listed in *Table 7.12*.

Table 7.12 Problem weeds of lucerne crops.

Weed	Description	Management
Wireweed (hogweed) 	A competitive annual weed which can be a problem in both establishing and older stands.	Can be controlled early with pre-sowing herbicide but once established in lucerne it can be difficult to remove.
Khaki weed and spiny burr grass  **Khaki weed.**	Both are problematic in lucerne hay due to the sharp, spiny burrs. Khaki weed can also be particularly competitive.	Few herbicide options available.  **Spiny burr grass.**
Golden dodder  R. Whitworth	A twining, parasitic weed with seed the same size as lucerne. A major problem in lucerne seed crops. Found along waterways. Spread by floods, machinery and animals, and in hay, grain, soil and seed.	Difficult to control once established. Quarantine infested paddocks from haymaking and grazing to avoid further spread.
Silverleaf nightshade 	A perennial summer growing weed with a deep root system, similar to lucerne. Spreads by seed or root segments. Once established it takes several years of herbicide treatment to remove.	Do not cultivate, as this will spread the infestation. Isolate and remove small infestations before they spread. Apply herbicide when it will be taken into the root system i.e. when plants are growing actively after rain. Repeated applications needed over many years.

Chapter 8
Irrigation for hay production

Successfully managing the irrigation requirements of a productive lucerne hay crop relies on:

- choosing and managing appropriate irrigation systems and technologies
- monitoring water quality
- assessing the water requirements of the crop at various growth stages
- determining soil water content and irrigation schedules.

Grower tips

'Lucerne needs plenty of water and drainage. Grow on the best ground you can with good slopes for flood irrigation'. *Geoff Dwyer, Kerang, Vic.*

'Make sure that you have an adequate water supply'. *Wayne Wright, Inglewood, Qld.*

'Do not try to grow too much area for the available water'. *Rob & Vicki Chaffey, Somerton, NSW.*

Focus Group recommendations

Know the soil variability, especially its moisture holding capacity, within a paddock.

Ensure water availability.

Ensure good water penetration.

Establish a good irrigation layout as it allows optimum water use efficiency.

Irrigation systems

Lucerne thrives under irrigation but can be easily damaged by waterlogging and scald which result from poor drainage. For optimal production the irrigation system must match the soil type and the layout must allow efficient delivery of adequate quantities of water, good infiltration and good surface drainage.

Lucerne can be irrigated by flood, spray or sub-surface drip systems. The choice of system depends on the soil type, topography, water source, capital costs, running costs, availability of labour and lifestyle. Efficient irrigation systems such as centre pivots and sub-surface drip systems, entail a high capital cost.

A range of technology is available for modern irrigation systems to save labour and improve the efficiency of irrigation. Examples are in *Table 8.1*.

Table 8.1 Examples of modern developments in irrigation technology.

Development	Comment
Soil mapping	Satellite and EM technology used, in association with yield mapping, to identify variability in paddocks so that the whole area can be managed appropriately.
Spray irrigation	Travelling irrigators allow large areas to be covered automatically. Improved nozzle design allows different flow rates for different situations.
Flood irrigation	Laser levelling smooths out surface irregularities and can provide new grades and bay sizes to improve water delivery and drainage. Water can be delivered into bays using large buried bay outlets rather than siphons, and sensors can be used to detect when the water reaches the end of the bay. These can be operated by hand or computer.
Subsurface drip irrigation (SDI)	SDI delivers water directly to the root zone. It allows easy, timely, efficient, labour-free irrigation controlled by computers.
Soil moisture monitoring	Monitoring equipment has become very sophisticated and can automatically monitor and record moisture at several depths at several locations over a period of time. Satellite imagery can also be used.
Automated irrigation	Computers have allowed automation of irrigation and substantial savings in time and labour.

Surface flood irrigation:
70% water use efficiency (WUE)

Flood irrigation is the main method used in irrigation areas on flat grades with clay soils. On non self-mulching clay soils rapid irrigation, slow water infiltration and surface crusting can severely limit lucerne growth. Layouts must be designed to ensure fast watering and drainage. An even grade is required, with no hills or hollows where water can lie for extended periods. Raised beds and terraced layouts allow quick drainage in large fields with very flat grades but machinery needs to be modified to suit the layout.

> **Focus Group recommendations**
>
> Design the layout to get water on and off quickly.
>
> Laser levelling provides suitable grades to move and drain water quickly.
>
> Water recirculation and automated irrigation systems save on labour and water.
>
> Smooth bays with slopes of 1:750–1:1000 and a bay size (correct width and length) are needed to move water quickly. Lucerne can be grown on slopes as flat as 1:1200 with a suitable design.

Layouts must be able to deliver and drain water within 8 hours but water must infiltrate well across the whole field. Border check, raised bed, or terraced layouts are ideal on clay soils. Maximum bay dimensions for border check systems are 35–50 m wide and 400 m long. With heavier soils and flatter slopes, faster irrigation and drainage can be achieved using narrower, shorter bays or higher flow rates.

Raised beds should be constructed to suit the subbing capacity of the soil (i.e. ability of the soil to allow lateral movement of water) and longer runs may be possible if the grade is suitable. Contour bays are not recommended for lucerne because irrigation and drainage are too slow.

Left: Checkbanks control lateral movement of water in flood irrigation layouts.
Right: Through-bank pipes with stops make flood irrigation easy.

Laser-levelling improves delivery and surface drainage on flat layouts. Very deep cuts and fills should be avoided. If necessary, the topsoil should removed before lasering and replaced on top afterwards to ensure high yields.

After landforming the filled areas eventually settle and form shallow depressions. To prevent this from occurring in a new lucerne stand grow an annual crop such as oats for a season before the lucerne is established. A minor re-levelling will be required after the cereal crop to form a smooth, uniform seedbed for establishment of the lucerne crop.

Spinner cuts (i.e. shallow ditches) can be constructed along the lower-end length of the bay to improve surface drainage.

Irrigation water must penetrate to a depth of 80–100 cm to ensure high lucerne yields. Normally, more than 90% of irrigated lucerne roots are found in this part of the soil profile. Irrigating more

frequently to compensate for poor infiltration on these soils will increase the risk of waterlogging damage and summer weed invasion. Soil water infiltration can be increased by retaining organic matter from preceding crops and pastures, and/or applying gypsum.

Groundwater pumps and sub-surface (tile) drains can be used in some areas to improve internal drainage of the soil profile. For each paddock, the high costs involved should be carefully considered against the long-term benefits.

Spray irrigation: 85% WUE
Although spray irrigation is reasonably efficient, machinery and pumping costs can be expensive. Spray systems are used along rivers and creeks, in small irregular shaped paddocks or on lighter, undulating ground or where slopes are steeper than 1:100. They offer greater flexibility for haymakers than flood systems as water can be applied when required and there is no delay after cutting. Sprays can also be used for the delivery of nutrients and herbicides.

Fixed spray lines or travellers can be used. For small areas, hand-shift or travelling-gun irrigators are preferred, while centre pivots, linear move and travelling low-pressure booms are suited to larger areas.

Focus Group recommendations
Use efficient irrigation systems–travelling spray irrigators are efficient and save labour.

Ensure even irrigation for an even crop. Travellers must overlap slightly (allow for wind).

Hand-shift pipes provide even watering although soil infiltration rate can be slow on some soils.

Determine costs–bore pumps used for irrigation can have high pumping costs.

The spray equipment must match the infiltration rate of the soil and must be managed to deliver the correct amount of water at the right time. This may involve extra labour for hand shift irrigation pipes, or engineering to ensure the correct nozzles and flow rates. In areas with high evaporation rates in summer (≥10 mm Et_0) spray equipment must be able to deliver at least 13 mm per day to meet the needs of a lucerne hay crop to avoid yield losses.

Sub-surface drip irrigation (SDI): 95% WUE
SDI is the most efficient means of irrigating lucerne and is becoming increasingly popular as water availability declines and the cost of water increases. However, installation costs for SDI are higher than spray or flood and careful maintenance is required to ensure the life and efficiency of the drip lines.

SDI is suited to loams and clay soils which allow the water to sub well (move laterally) below the surface. Since the surface remains dry, it is ideal for

Focus Group recommendations
Match the SDI system to the soil type.

Ensure the system is well designed and installed correctly.

Maintain SDI systems by regular flushing.

lucerne hay production. Growers can manage their cutting times more effectively and there is less weed growth. It also requires very little labour to operate, provided the system is well designed, installed and maintained.

Good planning and layout are essential for an efficient SDI system. It is important to check the subbing rate within the soil before installation and to ensure that the filters, pipes and emitters are correctly gauged, located and connected before burial. The filtration and flushing system is a critical part of an SDI system.

A separate water source, or rainfall, is usually needed for establishing lucerne on SDI (see *Irrigation for crop establishment* later in this Chapter).

Grower tip
'SDI filters must be flushed regularly.' *Don Barwick, Tamworth, NSW.*

Highly productive lucerne growing with sub-surface drip irrigation. The filters (foreground) must be well maintained.

Lucerne and irrigation

Irrigation is important for good lucerne hay production. Although lucerne has a reputation for good drought tolerance, its growth is very responsive to water. Limited water will result in reduced hay yield and quality.

The aim of irrigation is to supply enough water to replenish the soil profile before plant growth is reduced. Applying excess water is wasteful and expensive and can result in disease and waterlogging. It can also cause summer weed problems, soil compaction and nutrient leaching. Good management and irrigation scheduling is required to coordinate an efficient cutting and watering regime.

Lucerne can be a relatively high water user if there is plenty available. A highly productive irrigated stand can require 7–13 ML/ha of irrigation water over a full irrigation season. More water is required for irrigation in warmer areas.

In southern Australia lucerne is irrigated during summer from September to April. In Queensland the irrigation period may be extended into the cooler months if water is available. It generally requires 10–15 waterings of 75–100 mm (0.75–1.0 ML/ha) water per irrigation (i.e. 1–3 irrigations between each cut of hay with 4–6 weeks between cuts). Irrigations may be as frequent as 6–10 days in mid-summer.

Lucerne root growth responds to moisture and irrigated lucerne plants act differently to those grown in dryland conditions. Dryland lucerne develops a deep tap root system as it seeks moisture whereas irrigated lucerne develops a shallow root system with secondary roots near the water source. Regular, frequent irrigation is needed to keep the active root-zone supplied with water. This is

Lucerne water use efficiency (WUE)

As irrigation water becomes less available and the price of water increases, high water use efficiency (WUE) is of major importance to producers.

It is generally accepted that it takes 40–70 mm (or 0.4–0.7 ML/ha) of water to produce each tonne of hay in flood irrigated systems.

Efficient lucerne crops can produce at least 13–17 kg hay per mm (i.e. WUE of 1.3–1.7 t hay/ML) of available water (i.e. including irrigation and rainfall).

More efficient irrigation systems such as overhead spray or sub-surface drip, have recorded WUE for lucerne of 2–4 t hay/ML in Australia.

Grower tips

'Spend your money on irrigation'. *Brett Symons, Cowra, NSW.*

'Don't skimp on the water or you will lose production'. *Graham Bond, Inglewood, Qld.*

'Lack of water severely limits production'. *Karen Radcliffe, Kerang, Vic.*

'Crop water use is important'. *Ian Smith, Forbes, NSW.*

Focus Group recommendations

Ensure water availability.

Use water efficiently and evenly.

Provide good and consistent irrigation management.

Ensure good water penetration to the whole soil profile.

Get water on and off quickly.

particularly important in the establishment year to prevent moisture stress and to maintain production.

As lucerne roots grow deeper they may penetrate water tables (e.g. lighter soils in irrigation areas or river flats). This can be important for sustained production of both irrigated and dryland stands in some areas. However, access by lucerne to groundwater alone is generally not adequate to guarantee high hay yields. Therefore, although lucerne can use groundwater and lower the level of water tables, it may not necessarily produce high hay yields.

Irrigation with saline or sodic water

Groundwater or re-use water should be tested for salinity before being used on lucerne. Where irrigation is used to establish lucerne, use only low salinity water (<0.8 dS/m).

Mature lucerne growing on a red-brown earth can occasionally be irrigated with salinity levels up to 2.4 dS/m (or 1,500 ppm). However, repeated irrigations with this salinity over 2–3 years will reduce lucerne yields significantly. Occasional use of better quality water is required to leach salt from the topsoil.

Saline water (>0.3 dS/m) should not be used for spray irrigation as the salts can accumulate on the foliage, causing leaf burn. Saline water can be shandied with fresh water to reduce salinity but water of >5 dS/m should be avoided altogether.

Note that interactions can occur with sodic water (i.e. SAR>3) and soil which can lead to soil structural problems (dispersion, slaking and crusting). See *Chapter 6 Growing a lucerne crop: Planning and preparing for lucerne hay* for further information).

Irrigation for crop establishment

> **Focus Group recommendations**
> Irrigation can aid germination and establishment of lucerne.
>
> *Surface irrigation systems*: sow on moisture; pre-irrigate if needed and ensure water goes on and off paddock quickly (8–10 hours).
>
> *Watering up* (sowing then watering): depends on soil types–light soils and self mulching clay soils water up well; other clay soils seal up and inhibit germination.
>
> *Spray systems*: pre-irrigate or water immediately after sowing.

Pre-irrigating

Pre-irrigating ensures adequate sub-soil moisture storage and helps avoid soil crusting. This is the preferred method for surface irrigation on clay soils. In autumn, pre-irrigate while temperatures are still warm. Irrigating too late will cool the soil and may lead to waterlogging after winter rains.

Irrigating post-sowing (watering up)

Irrigation can be used to germinate seed sown into dry soil if timely rains are not forthcoming. Spray irrigation works well on free draining soils.

For surface irrigation, the soil must be well structured to avoid surface crusting. Water must flow over the soil slowly to prevent the seed from moving. Rolling the soil after sowing across the direction of water flow, assists even water distribution across the paddock.

Establishment under SDI

A separate irrigation source (or timely rainfall) is usually required to establish lucerne under SDI

Newly established lucerne stand with sub-surface drip irrigation (SDI).

because the watering front from the buried drippers does not usually reach the soil surface. New lucerne stands under SDI often show differential growth between the drip lines, especially if the drip line spacing is too wide. As the plants and root systems grow they are able to access more moisture and these differences usually disappear after the first year.

Irrigation for seedling lucerne

Spray irrigation can be applied as soon as the moisture is required. With flood irrigation on heavier soils, the first irrigation after sowing must be delayed as long as possible to avoid damaging the very young plants. Irrigation must occur before the lucerne seedlings become moisture stressed. In hot weather, scald and waterlogging can easily kill new seedlings. The aim should be to irrigate and drain quickly when the seedlings have produced at least two trifoliate leaves.

Note that irrigating in late autumn will lower soil temperatures, reduce seedling growth, and significantly increase the risk of waterlogging.

> **Grower tips**
> 'For good establishment, water up well–water, water, water!' *Greg Finlay, Texas, Qld.*
>
> 'Moisture and irrigation management are critical'. *Damian Jones, Kerang, Vic.*
>
> **Focus Group recommendations**
> Apply water immediately after sowing lucerne and ensure it drains off the paddock quickly (8 hours).
>
> Monitor soil moisture in new stands.
>
> Do not let seedlings suffer moisture stress. Irrigate again as soon as the soil starts to dry out.

Over-watering encourages weeds, weakens the establishing lucerne and wastes water. It is important to check the depth of available soil moisture in relation to seedling root depth. Irrigation should occur if there is any sign of plants wilting early in the morning.

Irrigation management for hay production

Grower tip
'Water is the key to lucerne production'. *Greg Finlay, Texas, Qld.*

Focus Group recommendations
Ensure persistence.

Don't flood irrigate when too hot or scalding will result.

Ensure water goes on and off paddock quickly (8–10 hours).

Water at night in hot weather.

There is generally a compromise between timing of watering and cutting to maximise the hay production. Irrigation should provide ample water for the crop when it is needed for growth but conditions need to be dry during haymaking. Irrigation management is critical to ensure yield, quality and persistence of lucerne hay stands.

Poor irrigation management leads to:

- waterlogging
- root and crown disease
- scald (root damage due to flooding during hot weather).

All of these can all thin or kill lucerne stands completely.

Good irrigation management practices can:

- increase hay yields and quality
- save on water costs
- ensure stand persistence
- help to avoid environmental problems associated with irrigation.

Irrigation and harvesting

The last irrigation before harvest must be timed to allow the soil surface to dry enough to prevent soil compaction by harvesting machinery but to provide adequate sub-soil moisture to allow quick regrowth after harvest.

Flood irrigation–under flood irrigation, rapid regrowth of lucerne is essential to minimise the risk of scald damage with the first irrigation after harvest in hot weather. The final irrigation before harvest can be 2–7 days before cutting, depending on soil type.

Spray irrigation–allows more flexibility with irrigation timing. Depending on the soil type, irrigation may be applied straight after hay is cut and removed.

Sub surface drip irrigation–the surface usually remains dry but will be quite wet at depth. It is important not to harvest straight after irrigation to avoid deep soil compaction by heavy machinery.

Focus Group recommendations
Co-ordinate cutting and watering so that lucerne will regrow quickly.

Ensure adequate soil moisture before each cut.

Spray irrigate straight after hay is removed to promote regrowth.

Do not flood irrigate until new leaves appear to prevent scald.

Irrigation scheduling

Scheduling irrigations to match plant water use can allow more efficient water use and help avoid waterlogging. In the past, observation of the plants was the main indicator used but other methods now allow more accurate decisions to be made (*Table 8.3*).

The intervals between irrigations will change depending on the time of year. In mid-summer irrigations will be more frequent (7–10 days) than in spring or autumn (25–30 days).

Calculating crop water use from weather and soil moisture data

Calculations of daily crop water use can be summed and when it reaches the and readily available soil moisture it is time to irrigate.

Crop water use

Crop water use (evapotranspiration or Et) is dependant on plant growth stage and weather (temperature, evaporation, wind speed, radiation etc.).

To calculate the crop water use by a specific crop (Et_c), a generalised Et_0 figure is multiplied by a crop coefficient which for lucerne, varies with growth stage (*Table 8.2*).

> **Calculating daily crop water use for lucerne using Et_0**
>
> Example: lucerne at early flowering
>
> Et_0 (without rainfall) = 9 mm/day; crop coefficient = 1.2
>
> So,
>
> Crop water use = 9 mm x 1.2
>
> = 10.8 mm

If Et data are not available an interval can be calculated from evaporation data. To convert pan evaporation (E_{pan}) to Et_0, first multiply by a pan factor and then use the crop coefficients in *Table 8.2*. Pan factors range from 0.6 to 0.9, depending on plant growth stage, but if not known use 0.8 as an estimate.

> **Calculating daily crop water use for lucerne using pan evaporation (E_{pan})**
>
> Example: lucerne at early flowering
>
> Evaporation = 10 mm; no rainfall
>
> Pan factor = 0.9; crop coefficient = 1.2
>
> So,
>
> Crop water use = 10 mm x 0.9 x 1.2
>
> = 10.8 mm

Table 8.2 Crop coefficients for lucerne to convert Et_0 to Et_c

Crop stage	Crop coefficient
Soon after cutting	0.4
Early flowering	1.2
Average (from cut to cut)	0.9

> **Grower tip**
>
> 'Water scheduling is critical–you need to know when and how much to water'. *Jenny Bryant, Cowra, NSW.*
>
> **Focus Group recommendations**
>
> Use water scheduling. Know lucerne wilting point; observe your plants. Water at the optimum time to prevent water stress.
>
> Monitor soil moisture; look at the colour of lucerne.

Soil moisture monitoring

Soil type and structure affect the amount of water that can be stored in soil after irrigation or rainfall. The water storage capacity affects the number of irrigations required in a season, with greater storage capacity allowing less frequent irrigations. In flood irrigated situations lucerne roots are produced close to the surface in response to the availability of soil moisture, so most of the soil water used by lucerne will be extracted from the top 1 m.

Calculating soil moisture

Readily available water (RAW) is the amount of water stored in the soil that the lucerne crop will use before moisture stress occurs. In a dry-down cycle, it is half-way between the soil's field capacity and the wilting point. Soil moisture must be kept within the RAW range to minimise plant stress. Below this plants must work harder to extract moisture and production losses occur. Above it, waterlogging may occur.

RAW depends on the soil type and rooting depth of the plant. *Table 8.4* shows the RAW for lucerne crops with 1 m effective root depth on various lucerne growing soils.

When irrigating, growers need to estimate the RAW and refill the soil to the same point. In some situations, the depth of water and lucerne root penetration will be less than 1 m. This will reduce the soil water storage capacity, so that more frequent irrigation will be required.

Typical irrigation intervals for two different locations are shown in *Table 8.5*. Irrigation timing must also fit in with the lucerne harvest schedule and there may be 1–3 irrigations between cuts.

Table 8.3 Examples of tools for monitoring crop water use and soil moisture in lucerne.

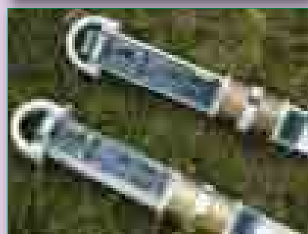
1. Observe the plants	
	Irrigate before symptoms of moisture stress appear in the crop. Moisture stress in lucerne is indicated by wilting, a dull green or 'bluish' leaf colour, lower leaves yellowing and falling, early flower production, slow development of new crown shoots and slow regrowth after cutting. Soil type and irrigation vary across the paddock. Good knowledge of the paddock is important to know which areas will be stressed first.
2. Check the soil moisture	
Push probe	Check water penetration one day after irrigation with a spring steel rod (10 mm diameter with a 12 mm pointed) hand driven into the soil.
Tensiometers	Tensiometers are simple instruments partly buried in the soil, designed to determine soil dryness. They estimate the 'suction' that a plant must apply to extract water from the soil. They can indicate impending crop moisture stress or determine the RAW for a specific soil type. They require careful installation, some interpretation of the measurements and regular maintenance. 
Electronic monitoring systems 	Various instruments provide an accurate estimate of soil moisture content and the best irrigation timing (e.g. neutron probes, Enviroscan, Gopher, Watermark, TDR, DRW, Gbug, etc). Many of these tools can be linked to weather stations and dataloggers, and most are developing improved systems and software. The price of many of these is now quite reasonable and contractor services are available. (Further information is available from irrigation officers in government and irrigation water agencies).   
3. Use weather data	
Crop water use or Evapotranspiration (Et_0)	Et_0 can be used to create a soil water budget to determine the rate of soil water depletion and the time to irrigate. It is affected by the weather and stage of plant growth. In established lucerne, the soil profile to 1 m depth is the soil water 'bank account'; with crop water use drawing down the 'account', and irrigation and rainfall adding to it. When the crop has used an amount of water equivalent to the RAW, without contributions from rainfall, then it is time to irrigate. Et_0 is calculated using temperature, wind and radiation data from automatic weather stations installed by the Bureau of Meteorology and government agencies. Daily figures are often presented in the local media (e.g. the 'Water Watch' service in NSW).
Evaporation	Pan evaporation can be used to estimate crop water use. This is measured as the change in water depth (mm) in a wide, open container. A standard 'Class A Pan' (1.2 m in diameter x 30 cm deep) is used on research farms, but growers can use a 200 L drum, cut cross-ways about one third up its length.

Table 8.4 RAW for lucerne at 60 kPa

Soil type	RAW and amount of water needed to refill soil to field capacity	
	Irrigation (ML/ha)	Water required (mm)
Sand	0.35	35
Hard setting red-brown earth	0.50	50
Friable, non-crusting red-brown earth	0.60	60
Red-brown earth	0.55–0.70	55–70
Well structured red-brown earth *	0.75	75
Non self-mulching clay	0.60–0.80	60–80
Self-mulching clay	0.80–0.90	85–90

* transitional red-brown earths with shallower top-soils (10–15 cm deep)

Table 8.5 Long-term average Et_0 values and time between each 75 mm irrigation at Tatura, Victoria and Griffith, New South Wales.

	Et_0 (mm/day)		Interval (days) for 75 mm irrigations*	
Month	**Tatura**	**Griffith**	**Tatura**	**Griffith**
Sep	2.2	3.3	37	25
Oct	3.5	5.1	24	16
Nov	4.8	6.6	17	13
Dec	6.1	8.6	14	10
Jan	6.4	8.4	13	10
Feb	5.4	7.1	16	12
Mar	4.3	5.7	19	15
Apr	2.5	3.5	34	24

* with no rainfall

75 mm is the RAW for well structured red-brown earth, irrigated to 1 m depth.

Average lucerne crop water use = Et_0 x 0.9

Chapter 9
Lucerne haymaking

The aim of haymaking is to dry or 'cure' the plant material, to preserve nutrients and make the forage safe for storage. Drying stops chemical and biological activity in the cut lucerne plants which can otherwise cause browning, heating, mould growth and deterioration of the hay.

The weather conditions and haymaking techniques have a large bearing on the final hay yield and quality. Hay must be made and stored as quickly and gently as possible to achieve the best quality and price.

Haymaking operations also affect how long the lucerne stand will last.

Making quality hay

Haymaking involves:

- mowing the crop at the correct stage
- conditioning to speed the drying rate of the crop
- raking to allow to the final curing to occur in the windrow
- baling the material as soon after cutting and with as much care as possible to preserve its feed value and minimise losses
- removing the bales from the paddock quickly
- storing and monitoring hay bales carefully.

Hay quality varies widely and the premium for producing high quality lucerne hay is usually worth the effort. Before growing lucerne for hay, consider the markets and plan to satisfy customer requirements to maximise your returns. While the weather cannot be controlled, good management and timing of operations can significantly improve the likelihood of producing a high quality product. There are many factors involved in producing high quality lucerne hay (*Table 9.1*).

Haymaking practices greatly influence the final hay quality. The key is to perform each operation on time, quickly and carefully. Planning and preparation should occur well before the haymaking season and suitable machinery must be available. Maintenance of machinery before and during the harvest season is essential to prevent costly time delays due to breakdowns. Paddocks should be free of objects that might cause machinery damage and/or contaminate the hay. Storage areas must be cleaned, stack slopes regraded, and twine or plastic and tyres for weighting stacks must be on hand. Access between the harvest area and storage site should be prepared and managed to enable safe transport. The withholding period for each herbicide or insecticide used on the crop must be passed before harvest. Feed testing and quality assurance systems help to document the quality of the hay so that it can be marketed more effectively. See *Chapter 3 Importance of lucerne hay quality* for further information.

Curing lucerne hay

The curing (drying) process of cut lucerne in the field affects both the storage and feed value of the hay. For effective storage lucerne must be dried from 80–90% moisture content to 15–20%. Moisture must be dried from within the stems and leaves, as well as any surface moisture from rain or dew.

The most important component of lucerne hay is the leaf which contains the majority of the nutrients in the plant—70% of the protein and more than 65% of the digestible energy. Leaves can become brittle and be lost during haymaking as they dry much quicker than stems, reducing both hay yield and quality. Lucerne hay growers should aim to dry the stem as quickly as the leaf, to retain as much leaf as possible.

The drying rate

Drying lucerne hay is a two-step process. The first stage, wilting, occurs in the field on the first day within a couple of hours of cutting. Wilting accounts for about 75% of the moisture loss. Moisture is lost mainly through the leaf pores which are wide open when the crop is cut.

The second stage starts when the hay reaches about 50% moisture content and moisture is drawn from within the stems. This stage is much slower—about one hundredth of the initial drying rate.

The old saying 'make hay while the sun shines' highlights the importance of fine weather conditions for curing hay. Warm days with low humidity, plenty of sunlight and wind are ideal (*Table 9.2*).

Wind speed and relative humidity (RH) largely control the drying rate. A 20% increase in wind speed or a 20% decrease in RH can speed drying by more than 50% (Undersander, 2003). The effect of relative humidity is shown in *Table 9.3*. Note that in very humid conditions (>90% RH) the hay may not dry adequately for storage.

Weather and soil moisture conditions affect the drying rate of lucerne hay (*Table 9.4*). In Australia curing may take one to three days in dry, sunny summer weather, but may require five to seven rain-free days under cloudy, cool conditions on moist soil.

Table 9.1 Summary of factors affecting the quality of lucerne hay.

Factor	Effects
Lucerne variety	Leafy varieties with high leaf retention and fine stems produce high quality hay. Highly winter active varieties often have thicker stems and are more prone to weed invasion as the stand ages and thins. They are generally more prone to leaf disease and have a smaller harvest window because they mature more rapidly than winter dormant types.
Establishment and management	Aim for a dense, uniform lucerne crop, free of insects, weeds and leaf disease. Good stand management and timely irrigation are critical to ensure good stand establishment and to ensure the crop is in the best condition at the time of cutting.
Season	The highest quality feed occurs with new growth in spring and quality declines steadily over summer. Spring cut lucerne is more digestible than summer cut lucerne. Producing both high yield and high quality hay during extreme summer temperatures is often difficult.
Plant maturity	Lucerne quality declines with maturity as leaves are lost and stems thicken. Young leafy lucerne promotes higher livestock intake levels and digestibility than older lucerne. Each day after the optimum cutting time protein drops by 0.5%, ADF increases by 0.7% and NDF increases by 0.9%.
Fertiliser	Excessively high levels of applied nutrients which lead to rapid growth can reduce lucerne quality. Excess potassium (K) in lucerne can reduce the availability of magnesium (Mg) in animals, causing possible health disorders.
Purity	Grasses or broadleaf weeds in hay will reduce its quality and some weeds can be toxic to animals. Hay should have no contaminants such as sticks and stones.
Anti-quality factors	Compounds such as phyto-oestrogens, dust and mould can lower intake or cause animal health issues. Levels of anti-quality factors depend on the season and the environment. Their effect on livestock depends on the animal sensitivity (e.g. leaf disease in lucerne can increase plant oestrogens which can affect animal fertility; horses are sensitive to dust and mould).
Harvesting	Quality can be lost through leaf shatter, respiration and leaching. Make hay on time and avoid excess handling.
Time of harvest	Afternoon cut hay is sweeter (soluble sugars accumulate during the day) but respiration can continue in cut plants overnight, resulting in loss of the extra sugars and dry matter before baling.
Weather	Temperature, wind and humidity affect the drying rate of hay which affects its quality. Quality is preserved by fast drying.
Rainfall	Rain during curing damages the leaf which can greatly reduce both digestibility and protein. The drier the hay when the rain occurs, the greater the damage.
Hay moisture and storage	Weathering, respiration and microbial activity can cause losses in protein, digestibility and palatability. Store hay at the correct moisture content, cover it and exclude livestock
Silage	Silage must be well made, compacted and sealed to maintain quality. Botulism in stock can result if it is contaminated with dead animals.

Table 9.2 **Summary of factors affecting the curing of lucerne hay.**

Factor	Comment
Wind speed	One of the most important factors in drying forage in the field. Drying increases with wind speed.
Relative humidity (RH)	Humidity of the air governs the final moisture content of the hay. High RH prevents cut forage from drying effectively (See *Table 9.3*)
Solar radiation	Sunshine is important but not as effective as wind and low humidity. Spread swaths wide to capture sunlight.
Air temperature	Has a marginal effect on drying in mild conditions–but is a major factor under very high temperatures.
Soil moisture	Wet or damp soils can re-wet hay from underneath by capillary action, prolonging drying time. Thick crops and a higher cutting height keep hay off the ground to aid drying on wet soils.
Conditioning	Mechanical or chemical conditioning can speed drying.
Maturity and leafiness of the crop	Leaves dry much quicker than stems. Young vegetative lucerne (55–60% leaf) dries much faster than at full flower (35–40% leaf).
Swath density and thickness	Open, thin swaths dry faster than dense, thick ones.
Swath width	Wide, flat swaths dry faster than tight, narrow ones.
Type of bale	Large, dense bales take longer to dry, so need to be baled at low moisture contents. High RH at cutting may limit the bale size.

This interval can be extended substantially with humid weather or rain. Where hay is made in winter (e.g. Queensland) it may take several weeks to fully cure.

Drying rate can be increased through management such as conditioning the hay, using wide open swaths and raking.

Losses during haymaking

Lucerne hay can suffer substantial losses of both yield and quality during harvesting, drying and storage due to poor technique or conditions. Knowing how and when these losses occur can help keep them to a minimum.

Field losses

Plant and microbial respiration

Immediately after cutting, lucerne respiration continues and microbes remain active. Both use plant sugars, reducing nutritive value and dry matter of the lucerne. The respiration rate is higher in warm conditions. It slows when the cut forage reaches 30–40% moisture content, but continues at very low rates until the lucerne dries to 20% moisture.

Under good drying conditions respiration losses in hay can be 2–8% per day, but may be up to 16%

Table 9.3 **Effect of air temperature and relative humidity on the final moisture content of baled hay.**

Source: Hill *et al.* (1976).

Air temperature °C	Relative humidity of air (%)			
	30	50	70	90
	Final moisture content of hay bale (%)			
21	10	13	21	39
27	8	12	20	38
29	7	10	18	37
35	5	8	16	36

Table 9.4 **Time to dry lucerne hay from 80% to 20% moisture content in controlled environment conditions.**

Source: Rotz and Chen (1985).

Conditions	Typical season	Time (hrs)
Shaded, cold air (10°C), wet soil	winter	44
Shaded, warm air (20°C), dry soil	spring	31
Sunny, hot air (30°C), dry soil	summer	12

under poor drying conditions, and up to 30% in extremely wet and humid conditions (Rees, 1982).

Rain damage

Rain on cut lucerne hay delays baling and can cause hay losses. The amount of damage depends on the timing, amount and duration of the rain, and the dryness of the curing lucerne. The drier the forage is when it rains, the greater the likely damage. Rain during curing can restart respiration in partially cured plants. Rain damage can result in leaching, leaf loss or bleaching.

> **Reducing the risk of rain damage**
>
> *Hay preservatives* may help reduce losses in hay baled up to 25% moisture content (see 'Hay preservatives' section).
>
> *Weather forecasts* for up to seven days used ahead of cutting (e.g. Internet sites www.bom.gov.au and http://wxmaps.org/pix/aus.vv.html) help with decision making on cutting time.
>
> But remember, it is important to mow when the crop is ready, rather than to delay cutting and miss out on a cut later in the season.

Leaching–rain can leach nutrients out of drying hay. Up to 50% dry matter can be lost, as well as digestibility (up to 40%) and sugars in the forage. Extended periods of light rain can result in much more leaching than isolated heavy falls (thunderstorms) (Collins, 1983). The crude protein content may actually be higher than before rain because other nutrients have been lost.

Leaf loss–up to 20% or more of the leaf can be lost with heavy rain. The extra raking and handling required for drying after rain can cause even more leaf loss.

Bleaching–sunshine on moist, freshly cut lucerne will generally not damage the hay. However, when the plant is nearly dry, surface temperatures can rise to levels that cook the plant's surface tissue, destroying the green colour and some nutrients. Despite bleaching, hay may still retain much of the original nutritive value.

Mechanical losses

Mechanical losses due to conditioning, tedding, raking and baling can amount to 30% of yield and 50% of leaf loss of lucerne hay (*Table 9.5*). Haymaking operations must be performed at the optimal moisture content. The drier the hay, the higher the leaf shatter and damage.

Lucerne hay stand losses

Lucerne shoots, stems and crowns can be severely damaged by machinery, even on dry paddocks. The longer the raking, baling and carting operations are delayed after cutting, the more likely the damage to new shoots and stems.

Up to 70% of the area of a lucerne hay field can be trafficked by wheels during each harvest. Wheel traffic in paddocks can be up to 6–10 times that of other crops so hay production and stand life may be greatly reduced (Gupta and George, 2000).

Plant damage can be reduced by:

- tram-lining
- using wider mowers
- merging windrows
- using direct routes to the edge of the paddock
- minimising traffic.

Table 9.5 Mechanical losses during haymaking.
Source: Pitt (1990).

Operation	Yield loss %	Leaf loss %
Mowing, conditioning	2–4	3–5
Raking		
60% moisture content	2	3
50% moisture content	3	5
33% moisture content	7	12
20% moisture content	12	21
Baling (pickup+chamber)		
25% moisture content	3	4
20% moisture content	4	6
12% moisture content	6	8
18% moisture content (round, variable chamber)	6	10
18% moisture content (round, fixed chamber)	13	21
Total losses	7–31	12–50

To prevent additional crown damage and compaction avoid driving on or grazing wet paddocks.

'Traffic resistant' lucerne varieties which persist better than other varieties under repeated heavy traffic have recently been bred in the USA. Low-crowned lucerne varieties could also be expected to survive and yield better under traffic than higher crowned ones.

Storage losses

Mould and heating can cause losses of stored lucerne hay. The degree of loss depends on the moisture of the hay at baling and shedding, and its exposure to the elements. Storage losses can be considerable if hay is too moist at baling or exposed to the weather. Total losses occur if the hay ignites. See *Storing hay: Heating and combustion of hay* later in this Chapter for further information.

Newly made hay has a moisture content of 15–25% and can lose 5–10% of its weight through evaporation in the first few months in a dry climate. Once stabilised at a moisture content of 8–15%, well-stored hay should only lose about 1% nutrients per year.

Mould

Moulds grow in hay stored at 20–30% moisture. They reduce the palatability and animal intake of hay. They consume nutrients which reduces the feed value. Mould spores and toxins can be detrimental to the health of both animals and humans.

Heating and browning

A 'browning reaction' results from microbial activity when hay is stored at moisture contents of 25–40%. When the hay heats to 38°C or more, proteins, amino acids and plant sugars combine to form a brown, lignin-like polymer and the hay 'caramelises'. This reduces the protein and dry matter digestibility of the feed. Browning reactions release heat and severe browning can result in combustion of hay. Mild heating can discolour and reduce the feed value of lucerne hay. See *Storing hay: Heating and combustion of hay* later in this Chapter for further information.

Mowing lucerne

Lucerne cutting time

Timing the mowing of lucerne is critical to producing high quality hay. Cutting time is a compromise between the correct lucerne growth stage, the irrigation schedule and the weather. It is affected by a number of factors.

Lucerne should be cut when the crop is ready and not according to the weather or the calendar. The plant itself is often the best indicator.

Grower tip
'Cut when the plant is ready, and don't rush the following procedures'. *Ray Sanderson, Forbes, NSW.*

Season

Lucerne hay can be made when weather conditions allow drying with minimal risk of rain (September to April in southern Australia, most of the year in Queensland).

High moisture cuts in spring can be stored as silage if drying conditions are not suitable.

The interval between cuts varies through the year–longer in autumn and spring, shorter in summer. In Australia intervals are commonly 28–35 days but range from 20–50 days. An early spring cut establishes the cutting schedule and maximises the number of cuts for the season.

Lucerne crop

The maturity and vigour of the lucerne at harvest affects hay yield, quality and stand persistence (*Table 9.6*). These factors are inversely related, so cutting time is always a compromise.

Table 9.6 Effect of maturity of irrigated lucerne at cutting on hay yield and quality, Kyabram, Vic.

Source: adapted from Moran (1996).

Growth stage	Number of cuts per year	Dry matter t/ha	Energy ME (MJ /kg DM)	Protein CP (% DM)	Weed content (%)
Early vegetative	7	13.5	10.2	24	20
Late vegetative	6	15.0	9.8	22	9
Early flower	5	16.4	9.4	19	4
Mid flower	4	16.3	9.2	17	2
ME–metabolisable energy; CP–crude protein					

Cutting earlier improves hay quality but results in lower yield per cut, although more cuts can be made during the season. Frequent early cutting (less than 30 day intervals) depletes the plant's root reserves because there is not enough time between cuts for them to be replenished and plants may not remain productive for as long. Frequent cutting also encourages more weeds to invade the stand as there is less competition for moisture, nutrients and light.

Newly sown lucerne should not be cut until early flowering to allow root reserves to be stored and maximise persistence.

Under dryland conditions, spring cuts generally yield more than later cuts, but with irrigation yields can be maintained throughout the season as long as water is available.

Lucerne forage quality is higher during spring and autumn than in mid-summer. Digestibility is lower in summer compared to spring and autumn, so for best quality during summer, shorter cutting intervals may be required. This may result in lower yields per cut but an extra cut or two may be achieved in a season, boosting the total yield (*Figure 9.1*).

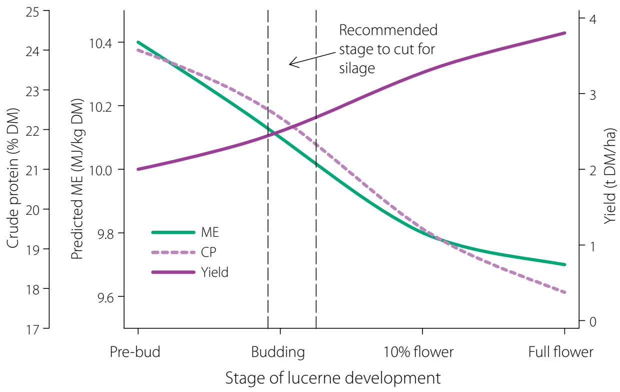


Figure 9.1 The relationship between plant maturity, yield and quality in lucerne.

Source: Kaiser *et al.* (2003).

Weather

Growers often delay cutting due to impending wet weather. This is not good practice as unnecessary delays may cost the grower a cut later in the season. Weather forecasts for seven days ahead are now available to help make better decisions. (e.g. http://xmaps.org/pix/aus.vv.html)

> **Grower tip**
> 'Weather can pose problems but don't let it control your decisions; quality pays'. *Sandra Peacock, Timmering, Vic.*

Irrigation

Irrigated lucerne producers usually irrigate once or twice between cuts. Irrigate a few days before harvest to allow the plant to regrow quickly. The soil should be allowed to dry just enough for machinery to travel on the field without bogging. Cutting when the soil is too wet can damage plants and the soil surface, while missing an irrigation can delay regrowth.

Avoid flood irrigating straight after harvest to prevent scald, especially during hot weather. Leaves should start to regrow before irrigating so the plant can 'breathe' when flooded.

G. Wing

Time of day

The optimal time of day for cutting lucerne depends on weather conditions and season. In good haymaking conditions with cool nights and dews, cutting in the morning allows a longer wilting period. In drier weather or hot climates, an afternoon cut followed by raking at sunrise the next day after the hay has wilted, may be better. Afternoon cutting can increase the sugar content of the forage slightly but this quality advantage may be lost as respiration continues in the cut forage overnight.

Moisture stress

When lucerne reaches 40% moisture content leaves begin to shatter. The drier the plants are at harvest, the more likely leaves will be lost.

Assessing lucerne for cutting time

There are various techniques available for assessing when lucerne is ready to cut. Calendar date and visual assessment serve as a guide. Plant growth stage (*Table 9.7*) and plant analysis are more accurate predictors of cutting time. See *Chapter 4 Importance of lucerne hay quality* for further information.

Plant growth stage

Crown shoots and flowers are both good field indicators that the plant is ready to cut. Crown shoot growth is usually a better guide, as flowering is controlled by daylength and some lucerne varieties produce crown shoots well before flowers appear in spring or autumn.

Cutting lucerne for hay

Cut as cleanly as possible by keeping the mower blades sharp. Blunt blades damage the crowns and encourage disease to enter the plant, and leave clumps uncut which will contaminate the next cut. Tractor power requirement and fuel consumption also increase.

The swath

Lucerne is cut and laid down in a swath behind the mower on top of the stubble or formed into a windrow, depending on the weather conditions. Cut only as much crop as can be baled in one day to avoid excess field losses.

Wide, uniform swaths allow rapid initial drying of lucerne hay. Tight or narrow windrows may be required in very hot weather to avoid sun bleaching, but in cooler weather they can cause uneven drying so that the lucerne in the middle may not dry adequately.

The swath should have a maximum width of half the cut width, if it is to be double-raked, or two-thirds of the cut width if it is to be raked only once. Driving on the cut lucerne slows drying, so swath width should be narrower than the span of the tractor tyres for tow-behind mowers, or the rear tyres on self-propelled mowers. Leave some ground uncovered to allow the hay to be turned onto dry ground to assist drying.

Cutting height

Cut lucerne as low as possible without damaging the crowns or new shoots (*Figure 9.2*). There should be enough stubble left to keep the cut plant material off the ground for aeration and to stop moisture from the ground moving up into the hay (7–10 cm is ideal).

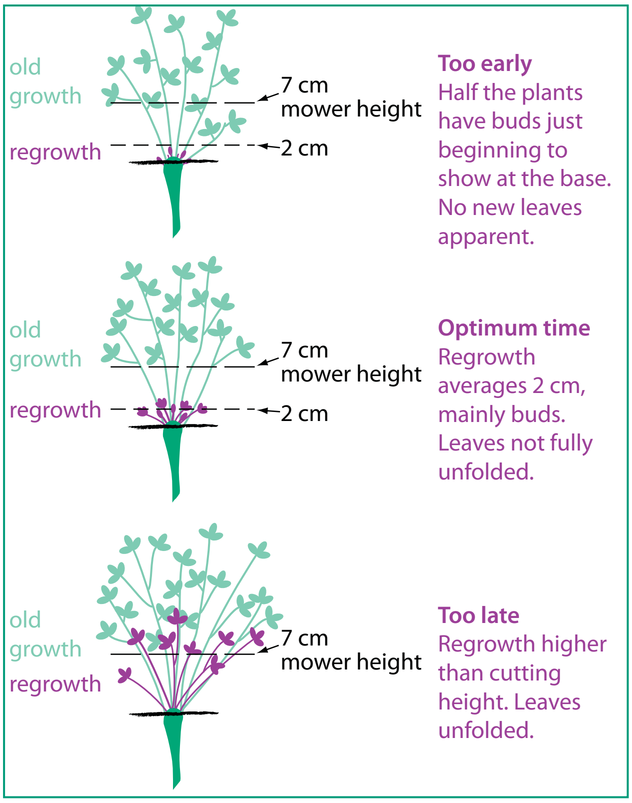
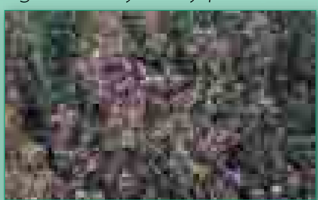
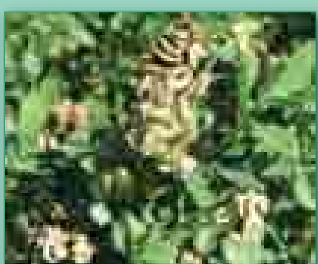


Figure 9.2 Cut lucerne when new crown shoots are at least 2 cm long but below mower height (7 cm in this example) to ensure persistence.

Source: adapted from Flint and Clark (1981).

Table 9.7 Growth stages of lucerne.

Growth stage	Description	Comments
Vegetative and pre-flower Crop leafy and well-grown; no sign of flowers or seed pods. 	Stems and leaves grow actively using energy stored in roots until leaf area is adequate to support plant growth. Leaf growth slows as plant matures and nutrients are then channelled into the roots and crown for storage. When root reserves are replenished, crown buds appear.	The first spring cut should be based on appearance of crown shoots which is usually before flowering at that time of year. Cutting at this stage produces high quality hay but yields less than if left longer. Frequent cutting of young growth depletes root reserves and weakens plants, encourages weeds to invade and reduces stand life.
Early bud Flower buds begin to appear. Crown shoots 1 cm long on half the plants. 	The plant switches from vegetative to reproductive state, triggered by temperature and daylength. Flower buds appear more rapidly in summer. Energy is channelled into flower and seed production rather than leaves and stems. Forage quality begins to decline as lower leaves are lost and stems thicken.	Lucerne cut at this stage yields more than if cut earlier and produces excellent quality hay. Root reserves not yet fully replenished. Frequent cutting at this stage depletes root reserves. Allow lucerne to mature past this stage occasionally to extend stand life.
10% flower About 10% of the stems have open flowers. Crown shoots 1–2 cm long on just over half the plants. 	There should be sufficient root reserves to allow new shoots to grow away strongly. Note: winter active varieties produce new shoots at the 10% flowering stage, while winter dormant varieties are 1–2 weeks later (30% flowering), depending on time of year.	Traditional indicator for cutting. A good compromise between quality, yield and stand persistence, although quality is declining by this stage. Cut before new crown shoots reach mower height to avoid damage. N.B. Flowering can also be triggered by moisture stress.
Full bloom At least half the stems have open flowers. Crown shoots more than 5 cm long on nearly every plant. 	Root reserves decline as they are utilised by the flowers and new shoots. Plants have fewer leaves and thicker stems.	Cutting at or after this stage reduces both hay yield and quality. Delays in cutting can cause large reductions in quality and total yield for the season, as the number of cuts is reduced.
Seed-pod stage Pods formed on all plants. 	Long days and low humidity favour flowering, pollination and seed development. It takes about 90 days from cutting to seed harvest in summer. Rain can greatly reduce seed yield and quality.	Generally, hay stands are too dense for high seed yields but some growers successfully produce both hay and seed from the one stand. Careful irrigation and insect management are important to achieve good seed yields.

Cutting higher improves the quality of the hay (less stem) but reduces yield. Lower cutting increases yield but removes more stem shoots and may delay regrowth.

Mowing equipment

Many types of mower are available (*Table 9.8*). They can be self-propelled or towed behind a tractor and include single 3-point linkage, trailed, front-mounted, front and rear mounted, and self-driven machines housing three to five mowers. Some newer, larger models utilise a 1000 kW (1340 HP) PTO and require a large tractor (up to 270 kW (360 HP)) for operation.

Modern mowers have a number of advantages over older ones including:

- linking two or three mower units together cuts a wider swath (9, 12 or 15 m wide)
- road travel is faster (up to 30 km/hr)
- work rates are higher—up to 3.5 ha/hr
- ability to cut more hay, more uniformly
- improved manoeuvrability, suspension and durability
- easier to maintain and transport
- many additional comfort and safety features.

Conditioning lucerne hay

Lucerne leaves dry three to five times faster than stems and become quite brittle before the hay is ready to bale. The aim of conditioning is to dry the stems as quickly as the leaves, so that the hay can be baled while the leaves are still pliable. Conditioning is useful if drying conditions are not ideal or if the windrow is heavy and can speed up the hay drying rate by up to 30%.

Conditioning is usually done as part of the mowing operation and can be either chemical or mechanical. Modern mowing machines are often integrated with a roller or tined conditioner.

When lucerne is conditioned in a separate operation it should be done within 30 minutes of cutting while the plant is still fresh. Conditioning when hay is wetter results in less leaf loss and produces a softer, better quality hay.

Conditioned hay must be baled and shedded quickly. It absorbs water more readily than untreated hay and is therefore more susceptible to damage if rain occurs before the hay is baled. The more aggressively the hay is conditioned the faster the hay will re-wet and the greater potential for damage.

Mechanical conditioning

Hay is crimped, crushed or abraded to break or bruise the waxy surface layer of the stems, allowing it to dry faster. *Table 9.9* shows types of conditioners available.

Conditioner adjustment

The amount of conditioning needed varies with the volume and condition of the crop and the machine should be adjusted for each crop, not just once a year. Conditioner adjustment affects drying time and losses more than the type of conditioner.

Roller conditioner

Adjust by changing the space between the rollers and the pressure applied to them. Rollers should be set so that the stems are crimped or crushed with minimum marking on the leaves. Roller spacing should be even across the machine. Higher yielding crops need wider roller spacing to allow the material to flow through and more tension or pressure to crimp the stems. The rollers should never touch while operating.

Tractor engine speed is also important–slow speed in high yielding crops can cause blockages while high speed can cause over-conditioning.

Flail conditioners

The hood clearance should be adjusted so that conditioning is adequate but leaves are in tact. Increasing the hood clearance reduces the amount of conditioning.

Use a slow rotor speed to avoid leaf loss.

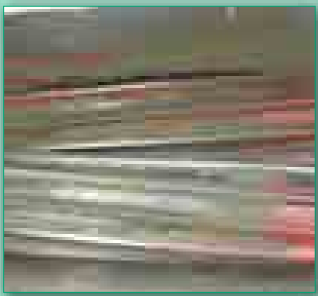
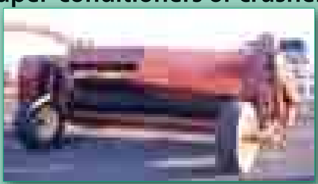
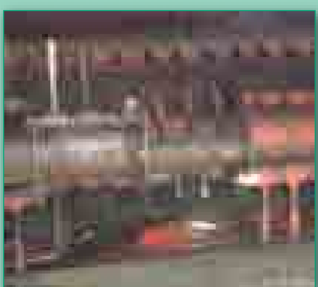
Chemical conditioning

Chemical additives or drying agents which break down the waterproof coating on the stems can speed hay drying. Chemical solutions can be sprayed onto the lucerne as it is mown. Potassium carbonate (K_2CO_3) and sodium carbonate (Na_2CO_3) are relatively safe to handle and use (the same chemicals are used to dry sultana grapes). However, palatability can sometimes be a problem for horses and some customers require 'chemical free' hay. Note that K_2CO_3 works on lucerne in a different way to

Table 9.8 Types of mower used to cut lucerne.

Mower	Description and comments
Cutter bar	Old style of tow-behind mower no longer widely used. Uses a reciprocating knife and fingers mounted on a bar to lift and cut the crop. Slow and requires a separate conditioner. Only works well on even ground.
Sickle bar and haybines 	Similar action to cutter-bar but larger and bar is usually mounted on the front of the tractor. Cut lucerne cleanly on even ground but blades can be damaged by stones. Blades difficult to replace.  Speed of tractor and PTO must be matched to suit the terrain and crop condition (e.g. slower ground speed and faster PTO speed in damp conditions). Cutting bar can be quite wide and can be angled to suit the conditions. Haybines include a conditioner and windrower on the unit.
Rotary disc and discbines 	Cutting discs rotate at high speed. Suction from the spinning discs stands the crop up for a clean cut. Can bruise stems and slow lucerne regrowth if cut too low. Disc mowers handle dense or tangled crops well. Do not 'clog' as much as sickle bar mowers, so can be driven faster and can cut more hay. Can be simultaneously mounted on the front and back of the tractor to increase cutting capacity. Produce consistent moisture within the windrow, so are good for larger bales. Can cut earlier in the day when dew is still on the crop. Discbines include a conditioner and windrower on the unit. More expensive and require more power than sickle bar mowers. Normally lose about 2% more harvested dry matter than sickle bar mowers. Can be dangerous in rough paddocks due to flying stones or blades.
Drum 	Knives (2–4) are mounted on a horizontally rotating cylinder head driven by a V-belt from the top. Sometimes a disc (or stone guard) is attached underneath to protect the blades. May have 2 or more drums mounted on the mower. Most older disc mowers operate at slow PTO speed (540 rpm) which may be difficult to obtain with a high powered tractor. Ensure that the mower is not operating too fast to prevent wear. Hay dries slower than if cut with a rotary disc mower. A separate conditioner is often needed.
Flail 	A series of blades rotate vertically at high speed around a shaft, cutting and conditioning the crop at the same time. Generally too aggressive for lucerne hay causing losses in leaf, dry matter and quality. Can be used for silage.

Table 9.9 Types of mechanical conditioners used to increase the drying speed of lucerne.

Conditioner	Description and comments
Roller conditioners	
	Lucerne passes between a pair of rollers behind the mower, crimping or crushing the stems. Rollers can be smooth, fluted, grooved or inter-meshing. Rollers can be made from steel, rubber, polyurethane or combinations of these. Generally promote faster drying than flail types. Can be a separate unit or mounted on a tractor with a mower. When mounted with a mower, ensure that the hydraulic capacity of the tractor is adequate to drive both implements.
Crimper or Chevron roller	Intermeshing rollers crimp stems at intervals but leave them intact. Stems are kept in line and on top of stubble, allowing good aeration. Crimping is considered by some to be gentler on lucerne leaves than crushing. 
Super-conditioners or crusher 	Flat rollers flatten and split the stems. Rollers can be smooth, grooved or grid-patterned. Super-conditioned hay dries very rapidly but wets up quickly if rained upon. Availability of replacement rubber rollers in Australia may be a problem.
Macerators 	Extreme super-conditioner. Flat or grooved metal rollers rotate at different speeds to crush and tear the hay. Faster drying rate than other roller conditioners. Units are expensive, extra power is required and hay must be stored very quickly. Technology is relatively new and not yet widely used in Australia.
Re-conditioners	Compact, tow-behind super-conditioners. Lightly crimp the hay with rollers and fluff it up with adjustable deflectors to aerate and direct the placement of the hay. 
Flail or tine conditioners	
	Fingers on a revolving hub pass the cut forage against a conditioning hood, rubbing off the waxy layer on the stems. Stems are laid in different directions and settle on the ground, drying slower. The resulting hay is not uniform. Designed for use on grass pastures and often considered too aggressive for lucerne, causing up to 3% more leaf loss than rollers. Newer V-flails are 'softer' on lucerne than older designs.

propionic acid. See *Hay storage: hay preservative* later in this Chapter for further information.

Potassium carbonate is normally used as a 2% solution (4 kg K_2CO_3/200 L water per tonne of hay). Even coverage of the forage is important. Large volumes of water are needed for treatment and metal corrosion of machinery can be a problem if equipment is not washed directly after use. The resulting product is sometimes referred to as K-Hay.

Combining chemical and mechanical conditioning in humid climates can significantly speed drying (Akkharath *et al.,* 1996). Drying time for lucerne hay can be reduced by up to a day in summer and three days in winter. The actual drying rates will vary depending on the weather conditions, crop density, effectiveness of spray application and type of conditioning.

Focus Group recommendations

The secret of the making is in the raking.

Rake hay at the right moisture.

Raking speed is important—too slow and the hay will rope. Rake faster for fluffier hay.

Set rakes at an acute angle to the swath.

Rake in the same direction as mowing.

For power-driven bar rakes, set the rake velocity as slow as ground speed permits to avoid roping.

If damp, wait for the hay to dry further to avoid roping.

If too dry, wait for the dew to descend before raking.

Rake in a pattern to allow the outside rows to be raked away from the back and forth pattern of parallel rows.

Avoid running over rows.

If raking two rows together, leave a gap between them–do not toss them on top of each other.

Raking

Raking is used to:

- gather hay into windrows
- turn or move hay windrows to aid drying
- merge windrows to suit a large baler.

Swaths or windrows can also be tedded (fluffed up) to aid drying.

In humid environments hay may need frequent raking, while in very dry conditions raking may not be necessary at all.

The moisture content of the hay at raking is critical. Handle the hay according to its moisture content and keep raking to a minimum.

Hay windrows

Once the cut lucerne has wilted in the swath it can be raked into a windrow for further drying and/or baling. Windrows are triangular shaped rows of inter-locking stems lying in different directions, with plenty of airspace in between. They allow maximum airflow for drying, minimum contact with the soil to prevent hay from wetting from underneath and some protection from sunlight to help prevent bleaching. Heavy windrows tend to collapse under their own weight, restricting airflow and impeding drying.

Windrows can be made loose and fluffy to aid drying, or tight and narrow for baling. They should be straight and uniform, and the same width as the baler intake. When making small bales, two rows can be raked into one windrow, while for large

John and Lance Pollock, Gatton, Queensland prefer ropey windrows for chaff making.

bales four or more (total width up to 15 m) can be raked into one large windrow. Narrow windrows allow the ground in between to dry out. Turning the windrow onto dry soil aerates the moist material at the bottom of the swath and lifts more hay above ground level.

Windrows help dry bulky crops under cloudy, slow drying conditions and in very dry conditions they can help preserve the colour of hay. But a light crop raked at low moisture is likely to suffer high losses.

Some mowers can produce windrows of varying dimensions to suit the crop, weather conditions or baler.

Geoff Dwyer, Rochester and Libby Roesner, NSW DPI inspecting lucerne hay windrows.

Timing hay raking

Lucerne swaths should be raked into windrows as soon as the forage is well wilted. There should be no sign of water on the surface, but still enough moisture for the leaves and stems to be strong and pliable. Raking should be complete before the crop reaches 40% moisture content (60% DM content). If too wet, the forage will wrap around the rake or flop together to form tight, poorly aerated windrows; if too dry the leaves will shatter.

The drier the hay is at raking, the greater the losses. About 30% lucerne dry matter can be lost if raking is delayed until close to baling moisture content (about 18%). Most of this loss is leaf, so quality is also reduced. If raking is delayed until just before baling, it should be done after the hay has re-absorbed moisture from dew. The hay should be soft, but not wet.

Successful haymakers are flexible and often work at night, carefully monitoring the changes in the dew point and the hay to produce a quality product.

Lucerne in windrows can be turned over or made into larger windrows after the forage has wilted. In humid climates hay may need raking or inverting onto dry ground for several days until it has reached the right moisture content, while in drier environments the less handling the better.

Rain on windrows

Windrows can shed light rain, but can be flattened by heavy rain. After the exposed surface has dried, invert the windrow onto dry ground. If the ground is very wet, invert an hour before baling to prevent wetting from underneath. Avoid raking more than once after rain to reduce excessive losses.

Raking equipment

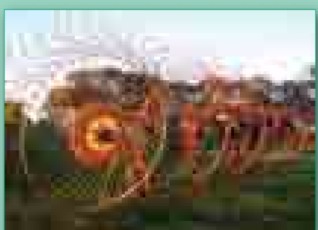
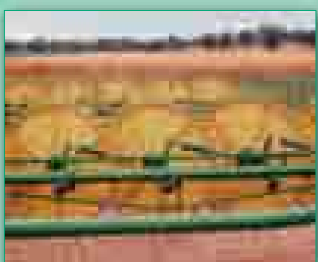
Hay rakes for lucerne are designed to gently gather hay slowly, with an even flow, over a short distance to prevent leaf loss. Selecting the correct equipment and operating it correctly optimises hay quality and operation efficiency. Rakes can be towed behind or mounted on the rear of a tractor and PTO, or ground-driven. They can be hitched together to increase raking capacity. There are several types available (*Table 9.10*).

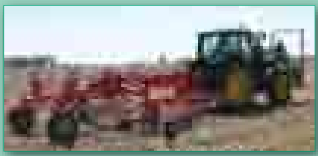
Rakes have low maintenance requirements and will last well, provided they are serviced regularly and the tines are replaced as needed.

Rake adjustment and speed

Rakes should be adjusted to clear the ground by about 25 mm. Their speed should be matched to the crop, the ground conditions and the manufacturer's specifications. Generally, parallel bar rakes operate at about 8 km/hr, finger wheels at 13 km/hr and rotaries from 8–15 km/hr, depending on whether they are raking or tedding.

Table 9.10 Types of rakes used when making lucerne hay.

Rake	Description and comments
Parallel tine or basket rakes (e.g. Rollabar) 	Tines attached to a series of parallel bars which in turn are attached to a reel at each end, forming the basket. The basket rotates, lifting the hay and pushing it forwards and sideways, rolling it into a windrow. Less aggressive than other rakes but more expensive and only rake narrow widths. Windrows can be made loose and fluffy or tight. Ground-driven machines - ground speed controls the reel speed. PTO driven machines - variable speed possible which can help to avoid leaf drop. In thick crops use a high reel-to-ground speed ratio; in light crops use a lower ratio. Can be expensive to maintain. Not effective for spreading or tedding hay.
Finger wheel rakes  	Series of overlapping, tined, spring-mounted wheels, attached vertically to a bar and ground-driven by the tines. Hay is picked up by the tines and rolled from wheel to wheel to form the windrow on the outside. Best raking capacity, good on rough terrain and cheapest raking option. Wheels can have long flexible, fingers radiating from a central point or can be solid with shorter tines (metal or rubber) attached to the outside of the wheel. Units can be trailed or mounted on the front or rear of a tractor and can be hitched together (e.g. V-rakes). Height adjustment of the wheel above the ground is critical to ensure that the hay is raked properly without digging into the ground. Adjust each wheel separately. Can result in more leaf loss because the hay is moved so far and can pick up trash, reducing hay quality. Can cause hay to 'rope' which can reduce airflow in windrows, but chaff makers prefer roping, as it feeds into the chaff mill more easily.

Rake	Description and comments
Rotary rakes  	Long tines attached to spokes of large, PTO-driven wheel which rotates horizontally above the ground. Tines sweep hay sideways into the windrow, keeping it fluffy and open. Handle heavy, wet conditions better than other rakes and are especially good for merging rows for big balers. The most expensive hay rakes but perform well, creating a well-formed, less ropey windrow to assist aeration and drying. Can spread and ted (fluff up) hay. Can have single, double or multiple rotors for larger raking capacity. Can have swath deflector which can be adjusted to capture the most hay and to vary windrow size. Window width can be controlled by adjusting the distance between the rotors on some machines. Correct combination of ground speed and PTO speed is needed to ensure that the hay is swept into the windrow without leaf loss. Tines must be attached securely for the machine to work well and to avoid losing them during raking.
Windrow mergers and inverters	A merger picks up one or two windrows and lays them on top of the adjacent windrow. An inverter picks up a windrow and turns it over. Both reduce the risk of getting rocks in the windrow.
Tedders  	Designed to spread and fluff-up the swath to aerate hay. Should only be used at high plant moisture levels (greater than 50%) to prevent leaf shatter and must be used within 24 hours of mowing. Tedders are especially useful after rain to flick water off the crop, to spread the crop for extra exposure to the sun, or when using a drum mower. Can be used to turn windrows, rake swaths into a windrow or rake rows together. Can reduce hay drying time by 25%. Useful when making silage to obtain a rapid wilt, but often considered too aggressive for lucerne, especially if partly dry. Limited use on lucerne but useful in humid environments such as Queensland, soon after a cut or after rain. Will not allow the ground to dry, as narrow windrows do. Adds an extra expense, as it is a separate operation.

Baling

The aim of baling is to create dense packages of hay that can be transported and stored for later use. Bales can be small enough for a person to lift, while large bales may weigh up to 1 tonne.

Before baling, hay should be evenly dried to prevent damp wads occurring in bales. Damp patches can result in mould, heated hay and even spontaneous combustion.

Hay losses during baling

Baling losses are usually less than raking losses, but can be high if not done correctly. For example, hay baled in the mid-afternoon at 15% moisture can lose 23% DM, whereas the same crop baled at night might lose only 10% DM.

In lucerne, baling losses of 1–5% for small rectangular balers and 3–30% for large round balers operating in typical conditions have been measured. With large round bales losses can occur both in the baler pickup (1–12%) or the bale chamber (up to 18%) (Grisso R *et al.*, 2002).

Baler losses can be reduced by:

- ensuring that the moisture content of the hay is correct
- adjusting the baler pickup and bale chamber
- using wider windrows
- travelling faster when baling

Correct hay moisture content for baling

Hay baled and stored with more than 23% moisture content will deteriorate with mould and may heat in storage. Hay baled at less than 15% moisture content will have brittle leaves that shatter. Baling hay at very low moisture content (<12%) may result in excessive leaf loss, powdering and poor bale density, reducing its ability to be handled and stored.

Grower tips

'Bale when the hay is ready'. *Greg O'Sullivan, Goornong, Vic.*

'Make sure the moisture content is correct'. *Ron Teese, Texas, Qld.*

'Timeliness is everything; if you are not nocturnal, you are not hay'. *Greg Finlay, Inglewood, Qld.*

'Don't take anything for granted. Check your hay daily–each paddock and baling will be different'. *Jenny Bryant, Cowra, NSW.*

Small or loose bales can be baled at slightly higher moisture content than large dense bales, as they will dry further after baling. The lower limit of hay moisture content for baling depends on the relative humidity of the air. *Table 9.11* indicates suggested moisture contents for baling a range of bale sizes.

Table 9.11 Suggested moisture contents for baling lucerne for safe storage.

Source: Frank Mickan, Department of Primary Industries Victoria.

Bale type and size	Hay moisture content (%)
Small square	18–20
Medium square, large round	14–18
Large square	12–14
Export hay	<12

Some markets require hay with lower moisture content (e.g. 12% for export). Export haymakers have strategies to achieve this without losing quality (e.g. store in loose stacks for further drying–moisture content may drop to 7% in summer; or use super-conditioners at mowing to dry the hay faster).

Hay moisture–dew vs sap

Dew moisture is the moisture on the outside of the hay and evaporates easily in good drying conditions. Sap moisture is moisture inside the stem and in lucerne it is critical that this dries adequately before baling. Leaves can rehydrate with dew if too dry, but it is difficult to dry sap moisture out of hay once it is baled.

Table 9.12 Methods of assessing the moisture content of hay.

Method	Details
Twist test 	Hold a small bundle of stems in both hands and twist or 'crank' it three or four times. If the stems fail to break, the crop is probably too moist to bale. Note: allow for stems that have been weakened by mechanical conditioning.
Scratch test 	Scratch the stems with the thumbnail. If the 'bark' lifts the hay is too moist to bale. Note: to help distinguish between sap moisture and dew moisture, check the crop in the evening, before dew begins to settle.
Hay moisture meter 	Useful for assessing moisture in the windrow and the bale in the field. But there can be large sampling errors. Meters require regular calibration. Moisture meters cannot distinguish between dew and sap moisture.
Oven drying method	An accurate technique but takes longer to get the results than other methods. Use electronic digital kitchen scales that can measure to 0.1 g. Take samples (100–200 g) from the windrow and keep in sealed plastic containers until weighing. Weigh each of the samples to obtain a wet weight (WW). Dry the samples using either a microwave or conventional oven. *Microwave oven*–chop samples into 2.5–5 cm lengths. Place a cup of water in the microwave with the sample to prevent over-heating. Heat the sample for 4 minutes on high setting. Weigh the sample, then stir and re-heat for 1 minute. Repeat the heating and weighing until a constant weight (DW) is achieved. If charring occurs, use the previous dry weight. *Conventional oven*–spread hay thinly and dry samples for 2 hours at 135°C. Weigh to obtain the dry weight (DW). Moisture content is calculated as follows: WW=wet weight, DW=dry weight. Moisture content % $= \frac{WW - DW}{WW} \times 100$
The baler	The hay is too moist if: • lucerne wraps around the moving parts of the baler • engine labours unduly • bales are too heavy • hay lacks spring • there is a smear of moisture on the side of the baler or tyres. The hay is too dry if: • hay shatters or is too dusty • there are too many leaf fragments • bales are too loose and light (even at the tighter bale settings).

Hay should be evenly dried to about 15% moisture content during the day and then baled in the evening dew at 16–20% moisture content, depending on the bale size. Hay can be baled at slightly higher moisture with dew, because dew moisture dries more easily than sap moisture.

Overdry hay

Lucerne leaves can become too dry and brittle by the time stems reach ideal moisture content for baling. If the leaves begin to shatter, stop baling and wait until the leaf re-wets and softens and the stems strengthen with the overnight dew.

In very dry conditions, water can be used to moisten windrows before baling in place of dew, or to extend the baling period in low humidity conditions. A fine, even spray mist can be applied at 60–75 L/ha using cone nozzles. More than one application may be needed with 10–30 minutes between applications, depending on the weather (Orloff, 1997).

Steaming the hay as it is picked up for baling can also reduce leaf shatter but there is limited equipment available in Australia for this purpose.

Darryl Jenson and Charlie Williams, Rochester, Victoria check windrows for moisture.

Assessing hay moisture content

In addition to the methods outlined in *Table 9.12*, experienced operators can tell the moisture of hay by the feel and strength of stems (*Table 9.13*).

When sampling hay windrows for moisture content:

- Take three to five samples from different locations
- Select hay from the centre of windrows
- Make sure that the whole depth of the windrow is sampled.

Table 9.13 Guide to hay moisture content.

Source: Frank Mickan, Department of Primary Industries Victoria.

Hay moisture content	Characteristics of forage
50–60%	Little or no surface moisture. Leaves limp. Juice (sap) shows on stems or leaves if rubbed or pressed hard.
40–50%	No surface moisture. Parts of leaves brittle. Moisture may be seen in stems if twisted in a small bundle. Hay is still tough.
30–40%	Leaves begin to rustle. No sign of moisture unless rubbed very hard. Moisture shows in stems scratched with a fingernail, or less easily when twisted.
25–30%	Hay rustles. Bundle twisted in the hand snaps with difficulty. Little sign of moisture. Thick stems may show moisture if scraped or split open with a fingernail.
20–25%	Hay rustles readily. Stems snap when twisted. Leaves may shatter. There are few moist stems. 'Skin' on stems cannot be raised easily with a fingernail.
15–20%	Hay fractures easily. Bundles snap easily when twisted. Leaves shatter readily. It is difficult to see any moisture.

Table 9.14 Typical dimensions and weight of a range of lucerne hay bales.

Bale description (imperial measurement)	Height x Width (cm)	Length (cm)	Weight (kg)	Number 25 kg bales/tonne
Small square (14”x18”)	35 x 45	75–90	25–28	35–40
Small square (16”x18”)	40 x 45	75–90	25–28	35–40
				Equivalent number of 25 kg bales
Mini bale (compressed)	30 x 30	50	30–40	1–1.5
Large square (2’x3’x8’)	60 x 90	250	250–300	10–12
Large square (3’x4’x8’)	90 x 120	250	300–900	12–36
Large square (4’x4’x8’)	120 x 120	260	up to 1300	up to 52
	Width x Diameter (cm)			
Round (4’x4’)	120 x 120		320	12
Round (4’x5’)	120 x 150		500	20
Round (4’x6’)	120 x 180		720–900	28–36

Hay bale size and shape

Hay can be made into rectangular or round (cylindrical) bales of various sizes and weights to match customer requirements (*Table 9.14*). Large square bales are a good option if hay is to be transported long distances. Round bales are preferred by dairies or if the hay is to be used on-farm, as they are much easier to feed out, but they are not as easy or safe to transport. Horse owners use small bales, while large squares or small compressed bales are preferred for export.

Large square bales are commonly referred to by their imperial rather than metric dimensions or weight (e.g. 3’x4’x8’or three-by-four-by-eights). Baling machinery must be properly adjusted to ensure that each batch of hay bales is uniform in size, weight and density.

Bale density

The density or tightness of hay in the bale varies depending on the moisture content and coarseness of the hay, and the machinery used to bale it. Density affects the weight and shape of the final product, its ability to lose moisture, its stability in transport and storage and its susceptibility to heating. Density can be adjusted during the baling operation. Common lucerne hay bale densities are shown in *Table 9.15*.

Good quality lucerne hay usually weighs more than mature grass hay in the same sized bale. Higher moisture hay compresses more easily than drier hay, so when baling with a settling dew, bale density may increase. Lucerne hay infested with aphids can stick together due to the exudates from the insects on the hay, making bales denser and heavier than normal.

Focus Group recommendations

Bale in the same direction as raking.

Never try to clear blockages without first disengaging and turning off the baler.

Be aware that large bales are heavy and that round bales can roll, so safety precautions are critical.

Large square bales are ideal for transport but very dense large bales are more difficult to open and can have higher losses due to ‘powdered’ leaves.

When wrapping bales for haylage or baled silage, tight bales are required to help exclude air.

Looser bales may help reduce heating but can create handling and storage problems. Hay for chaffing is usually baled more loosely, so that it will flow into the chaff cutter.

Table 9.15 Common lucerne bale density ratings.

Source: MacDonald and Clark (1987).

Bale size	Density (kg/m^3)
Small square	160–300
Square bales	160–240
Round bales	110–250
Cubes	400
Pellets	550

Table 9.16 Types of hay balers used when making lucerne hay.

Baler	Description and comments
Small square 	Pick up windrow, compress hay with a plunger into a number of wads or 'biscuits', tie the package with twine which is knotted automatically, and eject the bale onto the ground or a trailer. Both L-shaped balers (feeding from the side) and in-line balers (feeding from the sides to the centre) are available. They can be towed beside or behind the operator. A bale chute added to the baler can turn bales ninety degrees to allow pickup. Minimum tractor size of 40–45 kW (50–60 HP) required. Baler capacity depends on the throat size, stroke rate and length of the plunger. Modern balers with fast plunger speeds produce uniform well-shaped bales with thin wads and minimum losses. Bale density in small bales affects the final weight, size and shape of the bale. Small bales will curve if not compressed correctly. A slow stroke can produce large wads and poorly compressed bales. High ground speed and poorly formed windrows increase losses. Plunger knives must be kept sharp and knotters adjusted correctly (tension, threading and timing).
Large square  	Work on a similar principle to small square balers but have a pre-compression chamber to produce denser bales. Large balers work at a PTO speed of 1000 rpm. Haymaking is much more efficient but the capital cost for the baler and handling equipment is high. Large bales cannot be handled manually, so specific handling equipment is required. More strings and heavier duty twine are required. Newer models are designed to increase the bale density so that bales retain their shape and rigidity for transport and storage. In-cabin monitoring systems monitor the weight, density and number of bales as they are being made. Larger twine storage capacity allows long work periods. Remote control hitching devices make coupling quick and easy. Some balers have automatic stacking and loading devices. Some can bind up to six small bales in one large one.
Round   W. Holding	Round balers have either a fixed or a variable bale chamber: ***Fixed chamber machines*** wind the hay around the central core, to produce a bale with a soft centre. They produce only one sized bale but density and bale weight can be adjusted. Different sized machines are available. ***Variable chamber machines*** tension the hay with a system of belts as it feeds into and rotates within the bale chamber, resulting in a uniformly dense bale. The bale width is fixed but its diameter can be varied to produce different sized bales. They produce a better density for larger bales than fixed chamber balers. Large round balers can travel at 7–10 km/hr and can package up to 18 t/hr (medium balers package 8–12 t/hr). Minimum tractor size: 45–60 kW (60–80 HP) PTO.

Baling equipment

Baling equipment design has improved considerably in recent years. Modern balers have many improvements over old style equipment including:

- easier operation and maintenance
- less labour required
- faster travelling speed
- larger hay handling capacity
- better bale quality control
- hay monitoring and recording systems included
- slicing and wrapping capabilities added
- improved operator safety and comfort.

Operating large round balers

In large round balers hay losses can occur in both the baler pickup and the bale chamber. Pickup losses are often 1–3% but can be as high as 12%. Bale chamber losses are normally 2–3 times higher than a large square baler and have been measured as high as 18%.

To reduce both pickup and chamber loss ensure that hay moisture content is as high as possible for safe storage. A number of other strategies can help reduce loss.

Baler pickup

Synchronise field speed and rotational speed of the pickup to allow hay to be lifted gently from the windrow, rather than being pushed or pulled, so that the windrow will flow smoothly into the baler. If the forward speed is too slow, the pickup will snatch the hay and pull the windrow apart. If too fast, the hay will be 'bulldozed' in front of the pick-up.

Heavy windrows reduce pickup loss because the baler operates at a slower field speed, so contact with pickup components is minimised. Windrows should not be so wide that hay is lost at the sides of the baler pickup.

With narrow windrows, undesirable barrel-shaped bales can result if the operator drives straight down the windrow or follows a smooth weaving pattern moving back and forth across the windrow. For uniform bales, make sharper turns. Aim to crowd hay into one side of the pickup for 10–12 seconds; then cross quickly to the other side of the windrow and crowd it into the opposite side for 10–12 seconds. For light crops, stay on each side a bit longer and for heavy crops, a bit less.

Check pickup components regularly for missing or bent tines and to ensure that the windrow is handled gently as it flows into the bale chamber.

Bale chamber

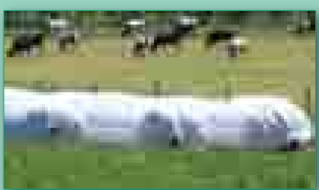
To reduce bale chamber losses, the feed rate should be as high as possible to minimise the number of turns within the bale chamber. This can be achieved with large windrows and fast ground speeds. If windrows are small or field speeds slow, use a lower PTO speed to produce fewer revolutions to form a bale. The PTO speed must be fast enough relative to the field speed to maintain satisfactory pickup performance.

It is usually better to accept some pickup loss by driving faster to reduce the time required to form a bale, since bale chamber losses often exceed pickup losses. In one study of round balers, bale chamber losses were 2% when the bale was formed in 2 minutes and 11% when the same hay was baled in 13 minutes.

When wrapping twine, do not rotate the bale more than necessary.

The fines, mostly leaves, which fall from the bale chamber during twine wrapping indicate the level of bale chamber loss. Since these fines contain large amounts of nutrients, it is important to minimise their loss (Grisso *et al*., 2002).

Table 9.17 **Additional equipment used in fodder conservation.**

Equipment	Description and comments
Forage harvesters 	Harvest and chop forage in the field for silage making or if feeding freshly cut or wilted forage directly to livestock. Can be tractor-mounted or self-propelled, and powered by a PTO. Can be linked to a forage wagon to collect the chopped forage. ***Flail harvesters***: chop length 150–250 mm. ***Double-chop harvesters***: use a flail plus a flywheel or cylinder cutter to cut the forage to 60–150 mm lengths. ***Precision chop harvesters***: use a flywheel or cylinder to cut forage as small as 3 mm. Minimum tractor size: 300 kW (400 HP). Operate at 1000 rpm.
Bale taggers	Recording when and where bales come from in the field is important for quality control. This can be done manually in the shed or by using automatic bale-taggers and pre-coded tags in the field for automated operations.
Knives, metal detectors, magnets and safety cut-outs	Knives in balers and forage harvesters pre-chop forage for specific animal requirements, or for silage to ensure that high packing densities can be achieved to exclude air. Metal detectors and magnets ensure that metal contaminants such as wire or broken tines are detected and removed. Cut-outs are activated when obstacles are encountered.
Bale wrappers 	Hay bales secured with twine or netwrap can be plastic-wrapped, either at or just after baling, to extend the storage life of the hay. Self-adhesive or stretch wrap can be used on individual bales in place of twine or twine-wrapped bales can be plastic-wrapped in lines as they are placed in the storage area (tube-line wrap or bale-sleeve). Various machines are available to wrap individual bales using either netwrap or plastic. These use rollers to rotate the bale as it is being wrapped, orbital arms to apply the net or plastic and mechanisms to gently lower the bale to the ground. Originally designed for round bales, newer models can handle both large round bales (up to 150 cm diameter) and square bales (120 x 180 cm, weighing up to 1300 kg). Wrappers have their own PTO systems to cater for their heavy power requirement. Moisture must be low before wrapping.
Stretch or line wrappers 	These can wrap a continuous line of round or square bales with stretch plastic film using 30–40% less plastic than individually wrapped bales. Bales are wrapped where they are to be stored.
Tube or sock wrappers  F. Muller	Tubes are suitable for chopped forage or round bales. The forage is forced into a heavyweight plastic bag which is sealed at the end to exclude air. This system is designed for short term storage (up to 3 years) since the plastic can be damaged by birds or rodents.

Additional hay equipment

New technology has been developed to improve existing haymaking equipment while specific machines are available for specific purposes such as silage making (*Table 9.17*).

Twines and wraps

Twine is an important consumable used in hay production and plastic wrap and sheeting for silage production (*Table 9.18*).

Hay and silage users should dispose of twine and plastic carefully. While it is possible to recycle these, it is currently not economical and there are no plants available to do so. Twine and wrap should be collected and disposed of at a local garbage tip. Do not burn twine and plastic—it releases undesirable pollutants into the atmosphere.

Grower tips

'Have the right gear to produce good quality hay'. *Wayne Wright, Inglewood, Qld.*

'Use efficient, up to date, reliable machinery'. *Anthony Nicholls, Gundagai, NSW.*

'Don't use old machinery–if you can't afford new machinery use a contractor'. *Brett Symons, Cowra, NSW.*

'Try not to get too big too soon'. *Gary McDougall, Inglewood, Qld.*

'Ensure machinery is well maintained–breakdowns can be costly'. *Greg O'Sullivan, Goornong, Vic.*

'Know your machine–how it works, how it breaks down, how to prevent problems'.

Donald Barwick, Tamworth, NSW.

Grower tips

'Never grow more lucerne than you have equipment to comfortably handle.

Have the right equipment to do the job quickly and enough handlers to remove it fast.

Ensure your machinery capacity matches the size of your operation.

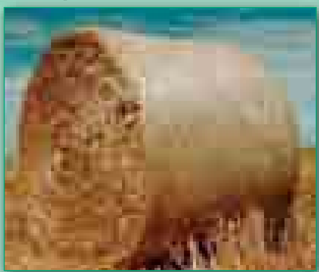
Maintain machinery–knives, tines and baler.

Keep blades sharp for a clean cut and have spare parts on hand.

It pays to have your own machinery if you are making more than 250 tonnes of hay'.

Ron Teese, Texas, Qld.

Table 9.18 Twines and wraps used in fodder conservation.

Twine or wrap	Description and comments
Polypropylene twines 	Have largely replaced sisal binder twine for securing larger bales  Stronger, cheaper and better storage life than sisal. Various strength and colours available. Heavier twines needed for larger bales. Bright colours improve visibility for quality control. Some markets, such as chaff makers or wool growers, still prefer small hay bales to be wrapped in natural sisal or wool twines to avoid wool contamination from synthetic twine. Small bales require around 225 m of twine per tonne of hay, while large round bales use about 50–70 m per tonne of hay.
Netwrap 	An open-weave, high density, polypropylene netting that secures and completely covers round bales without the need for twine. Claims to wrap bales faster and firmer than twine and to reduce storage losses by shedding water better.
Plastic film wrap  W. Holding	Developed to improve the storage life of hay and to allow the wrapping of individual bales for silage. UV stabilised plastic film wrap can reduce weathering of hay bales from 35% without wrap, to 7% with wrap. For baled silage it is important to wrap the bales with 6–8 layers of plastic to ensure an adequate thickness of plastic to prevent air movement into the bale. Holes in silage wrap should be sealed immediately to prevent deterioration by microbial activity.
Plastic sheeting 	Heavy duty plastic sheets can be used to cover above ground silage buns, silage bunkers or modules of large square bale silage. Air must be excluded and the edges sealed. Available in 50 m rolls with widths of 6–18 m. White or green wrap is claimed to maintain the silage at least 10–15% cooler than black plastic. Store as much silage in an individual bun or module as can be used in a short period of time (maximum of 2–3 weeks supply for large square bales) to prevent spoilage during feeding out. Plastic sheeting can be moulded into tubes and used for storing bulk forage. This is compressed directly into long 'sausage' or sock for on-site storage. Available in 50–150 m lengths. 

Handling lucerne hay

Lucerne hay bales should be removed from the field and covered as soon as possible to reduce the risk of rain damage or sun-bleaching of the hay, and to allow the crop to regrow quickly and evenly.

If the hay moisture content is slightly high, it should be moved to the edge of the field and allowed to dry further before carting to more permanent storage.

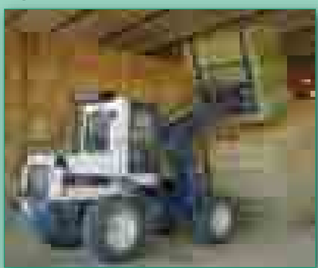
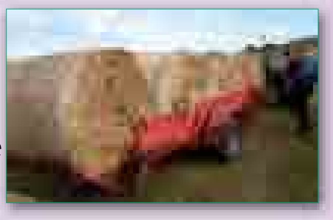
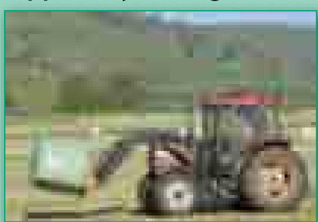
Manual handling of small bales is labour intensive and time consuming, and limits the size and weight of bales. Mechanical handling of both small and large bales has made hay-carting a faster, more efficient and cost effective operation. New machinery designs greatly reduce the labour requirement.

Hay handling machinery

Hay carting machinery has progressed considerably in recent years. There is a range of equipment available (*Table 9.19*) and handling capacity is generally reflected in the price.

For articles and reviews on the latest haymaking and handling equipment, see publications such as Farming Ahead and Power Farming (Australia), The Hay and Forage Grower (USA), and Ag Contractor and Large Scale Farmer (NZ).

Table 9.19 Hay handling methods for a range of bale types.

Type of bale	Description of hay handling methods and equipment
Small bales 	*Bale wagons and accumulators* have replaced old style elevators and conveyers for carting small bales. These can collect, stack, transport and unload many bales at a time, easily and quickly in a one-man operation, significantly reducing the manual labour requirement.  *Bale throwers* attached to balers can toss small bales into a trailing wagon, allowing bales to be made and collected in one pass. *Flat-topped trucks* or trailers allow rapid field collection.
Large bales  	*Forks, prongs or grabs on tractors, front end loaders and telescopic handlers* are all used to handle large bales.  *Purpose-built machines* for handling, transporting and stacking multiple large square bales, lifting either from the side or over the cabin, are now available in Australia. *Bale wagons.* Multiple large round bales can be collected in long bale wagons that roll the bales onto the ground at the storage site.  
Wrapped hay or silage bales 	Implements are designed to move bales without piercing the plastic wrap. These can have removable roller sleeves that fit over conventional spikes, hydraulic pinchers that cradle round bales between tubular roller tines, paddles that grip from either side, or clamps that grip bales side-to-side or end-to-end.

Storing hay

Lucerne hay made and stored at the correct moisture content can last for several years. Storage losses can be considerable if hay is poorly made, has a high moisture or is exposed to weather. To preserve the quality, colour and dry matter of hay move it to covered storage as soon as possible. See *Losses during haymaking: storage losses* earlier in this Chapter).

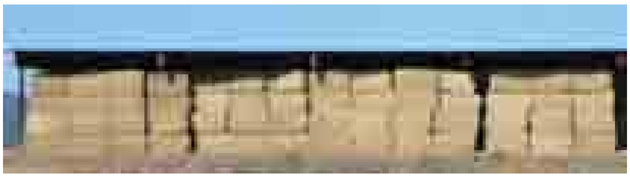
Iain Bryant, Cowra Shows that hay quality and colour are preserved by covered storage.

Square bales

Small square bales are especially vulnerable to weather damage and do not store well in the open. When first made, they can be tilted on their ends against each other or turned to dry if rained upon before carting. Large square bales can be temporarily placed on top of each other in stacks of two or three single bales to aid drying. If hay is moist, building stacks in the field with air spaces between the bales is safer than moving the hay straight into the shed.

Bales should be stacked with strings on top so the ends of the cut stems are on the sides, for maximum stability.

Stacking small square bales into a fully enclosed shed.



Large square bales are often stored in uncovered stacks in the field in warm dry climates, but large losses can still occur in these conditions. US studies (Guerrero *et al.*, 2005) indicate that in very hot, dry climates lucerne hay left uncovered in the field can quickly lose dry matter and quality when exposed to continuous high temperatures (> 35°C), even with no rain, but maintains its nutritive value if shedded or tarped.

Round bales

Large round bales were designed so they could be stored uncovered in the field and fed directly to livestock. The outer surface of the bale weathers to form a thatched layer that helps shed rain. Lucerne does not form as good a thatch as cereals, so nutrients are leached out more easily by rain.

The thatched layer disintegrates with age if stored outside, reducing the storage life of the hay. The size and density of the bale determine the degree of loss–the larger the bale, the smaller the relative loss. A 5 cm weathered layer can account for 16% of a 120 x 120 cm round bale; a 10 cm layer in a 150 x 120 cm bale can represent 25% of the bale. Hay losses in unprotected bales stored outside can be 35–40%.

Hay in round bales can lose more digestibility, protein and energy than square bales in the same moisture range, possibly due to restricted heat and moisture exchange (Collins *et al.*, undated).

Round bales can also be wet from underneath leading to microbial decomposition, so drainage in the stack area is critical. Bales stored in the open may only have a life of six months in wet environments, but much longer in drier areas.

If storing round bales in the open, they need to be placed on their sides with the flat ends pushed tightly together, running down the slope, with at least 30 cm between rows of bales to allow air flow and drainage. Lines of bales should run north-south to allow even exposure to the sun and should be well away from tree lines which can shade or drip on

bales. Bales can also be stored in two layers (one row on two) and covered with a tarpaulin.

Plastic wrapped round–bale silage should be stored vertically (flat side down) to ensure there is a thick layer of plastic on the top and bottom of the bales. Holes should be patched immediately to avoid spoilage.

Storage options

Sheds

The best option for maintaining high quality hay is a purpose-built, fully-enclosed shed with waterproof flooring. This maintains dry matter, feed value and colour of the hay for extended periods. Allow 6–7 m^3 capacity for each tonne of hay, and store different grades of hay separately.

Open sided sheds are cheaper. Low quality hay can be used as a 'wall' to protect better quality hay stored on the inside.

An igloo made from polypropylene over a metal frame is a cheaper, less permanent alternative to a steel shed.

Grower tip

'Spend your money on covered sheds'.

Brett Symons, Cowra, NSW.

Tarped stacks

Stacked hay bales in the field can be covered with tarpaulins for temporary storage. A range of purpose-built covers is available with special securing systems which do a better job than a sheet of plastic. Tarpaulins are labour intensive and can be physically difficult to install. Tarping contractors are available to cover and uncover stacks.

Stacks should be made with a ridge or peak on the top to aid drainage. Tarpaulins should be well secured to the stack to avoid wind damage and to allow water to drain off. Ensure the site is well-drained and in the open, to allow water drainage and air circulation and provide a layer of waterproof flooring material underneath the stack.

Artificial drying

In most haymaking areas in Australia warm weather is usually adequate to dry hay. Where conditions are wet or humid, hay driers can be used. The equipment and process is expensive, uniformity of drying can be a problem and current units have a limited capacity, but it will allow extra hay to be made.

Heated air (about 38°C) is blown over and through the hay, allowing hay baled at 35–40% moisture content to be dried to 12% relatively quickly, preserving the leaf and protein.

Air is sometimes evacuated from covered hay and silage using a vacuum pump to enhance preservation.

Hay preservatives

In humid environments or if rain is expected before the hay is adequately cured, organic acids and bacterial inoculants can be used as preservatives to inhibit mould growth in hay baled at slightly high moisture content (18–25%). They should not be used on a routine basis to replace good haymaking practices.

Bacterial inoculants are applied to forage as it is cut or baled. Propionic acid solution (under various trade names) can be applied evenly to hay as it is baled via a spray jet on the baler. Take care to fully assess the registrations, safety regulations and the effectiveness of these products under your conditions.

Heating and combustion of hay

Heating of hay normally occurs for 2–3 weeks after lucerne is cut due to plant respiration and microbial activity. Initially, a small amount of heat helps evaporate moisture without causing any damage to the hay. In normal conditions heating stops as the hay dries and moisture content stabilises. However, if hay is stored too wet (>25%), microbial activity can trigger a chain of reactions that heat the hay causing browning or spontaneous combustion.

R. Argento

Large square bales are more likely to heat and self-combust due to their high density and large volume, but all types of bales can ignite. Even with mild heating, hay can discolour and lose feed value via a browning reaction See *Lucerne haymaking: losses during haymaking* earlier in this Chapter for further information.

During the first stage of heating, temperatures of 45°C can be reached, at which point different micro-organisms become active, generating more heat. Once the food and oxygen for the microbes is exhausted, activity ceases and the stacks usually cool down.

However, if the heat reaches the critical temperature range 66–70°C, chemical reactions take over which generate more heat and the temperature can rapidly reach ignition point (200°C for hay, 280°C if oxygen is limited).

Heating can also occur in silage if there is too much oxygen when the silage is made and stored, promoting biological activity. Note that long periods of heating at temperatures as low as 88°C can also produce spontaneous combustion if there are volatile gases from oxidation present.

Although heat is generated in the centre of a haystack, spontaneous combustion usually occurs from hot spots near the outside. Hay around the hot spots cooks, sealing in gases and heat, until the pressure from the gases opens the stack. The hay stack then bursts into flame as the smouldering hay is exposed to oxygen.

W. Holding

Preventing hayshed fires

- Be aware of the risks and be patient when baling hay. Don't bale hay before it is properly dry.
- Ensure that the windrow is even and that all of the hay has dried adequately. Check various parts of the paddock, not just the outside rows. Even small wet patches can result in fires.
- Bale at the right moisture content–small bales 18–20%, large round bales 14–18%, large square bales less than 14%.
- Do not stack hay in sheds unless it is properly cured (especially large square bales).
- Store hay in different lots in the shed and check the moisture of each separately. Headlands baled first are considered high risk and should be stored separately or on the outside of the hay stack.
- Use shed layouts that provide adequate air flow through the stack and good ventilation at the top to dissipate heat.
- Repair any leaks in the shed roof to avoid a layer of moisture forming across the top of a stack that would keep heat in.
- Monitor stacked hay for heating–insert a crowbar into the stack and feel it regularly (*Table 9.21*).
  N.B. After several hours, if the bar is too hot to hold or if the hay turns dark brown or smells like tobacco, it is ready to ignite. Pull the stack apart carefully. Be aware that bales that have reached the critical temperature may ignite as they are exposed to air. Always keep water and fire fighting equipment on hand.
- Never walk on top of heating hay stacks. Smouldering bales could collapse with your weight and if you fall in, the accompanying air could ignite the stack.

Table 9.20 Nutrient losses caused by heating of moist hay.

Source: F. Mickan, Department of Primary Industries Victoria and V. Marble, University of California, Davis, USA.

Maximum stack temperature (°C)	Nutrient loss		Hay Characteristics
	Protein (%)	Energy (%)	
<45	0	5–10	Normal.
45–55	10–30	5–15	Moulds and odours occur, decreasing palatability.
>49			Digestibility of protein, fibre and sugars is reduced.
55–70	30–80	15–30	Hay is brown and very palatable due to caramelisation of sugars but nutritional value is reduced.
66–75	100	40–70	Hay turns black, possible spontaneous combustion.

Table 9.21 Checking hay stacks for heating.

Source: Frank Mickan, Department of Primary Industries Victoria

Feel of iron bar inserted into hay bale	Temperature (°C)
Comfortable to hold	27–38
Tolerable to hold	38–55
Tolerable to hold for a short time	55–60
Tolerable to touch only	60–66
Too hot to touch Danger point: if bar is too hot to touch or hay has dark brown parts and smells like tobacco, it is ready to ignite. Temperature increases rapidly from this point and hay can ignite at 200–280°C	>71


G. Stevens © NSW DPI

Processing lucerne hay

Processing lucerne into other marketable products can add value to the hay and increase the returns to growers. Bales of various sizes, chaff, cubes, pellets and meal are produced in Australia. See *Chapter 10 Lucerne hay products* for further information.

Double compressed, sliced lucerne bales for specialty markets.

Lucerne silage

Lucerne silage compliments a lucerne haymaking operation. Silage is a good option for conserving lucerne:

- early in the season when weather conditions are not suitable for haymaking
- during humid or wet seasons
- in fields where weeds are a problem.

Turning the first lucerne harvest into silage rather than waiting until weather conditions are suitable for haymaking, produces better quality feed for that harvest and may allow an extra cut for the season. Silage can be stored in pits, bunkers, silos or wrapped bales. Silage usually costs more to make than hay.

Important steps involved in making good quality lucerne silage

- Cut the lucerne at the correct growth stage–early maturity.
- Chop to the lucerne to short lengths for better packing.
- Wilt the lucerne to the 35–40% dry matter content.
- Compact the lucerne well to remove all the air.
- Seal bunkers, pits or bales completely to exclude oxygen–patch holes in plastic immediately.
- Consider using an additive to improve the ensiling results (lucerne is more difficult to ensile than other species).

Silage is conserved using a different process to hay. Hay relies on drying the forage to reduce microbial activity, whereas silage is preserved by the action of bacteria on high moisture forage. Lactic acid bacteria use the plant's water soluble carbohydrates (simple sugars) in the sealed silage to produce lactic acid which preserves the forage (anaerobic fermentation). The final level of acidity (pH) will depend on the water soluble carbohydrate (WSC) concentration and dry matter content of the forage. For any given forage, lower dry matter content produces more acid.

Lucerne is more difficult to ensile than other species because it has a high buffering capacity (ability to resist pH change due to the presence of organic acids) and low WSC content. Wilting overcomes this problem by reducing the moisture and organic acids in the lucerne and concentrating the sugars, but the wilt must be rapid to be effective. With modern machinery (e.g. conditioners and/or tedders) it is possible to achieve a rapid and successful wilt and produce high quality lucerne silage. Without adequate wilting the fermentation is dominated by undesirable bacteria which results in poor fermentation and reduced palatability.

Bacterial additives may be used to improve and assist the fermentation. When applied to high quality lucerne, they can improve silage dry matter recovery and support higher levels of animal production compared to uninoculated silage.

See *Successful silage* (Kaiser *et al.*, 2003) for further information on silage.

Transporting hay

Trucks laden with hay are a common sight on regional Australian roads, especially during drought. Safe transport of these loads is paramount.

To improve load stability of hay on trucks:

- ensure bales are dense and uniform
- stack the bales on the truck appropriately
- restrain the bales correctly.

Bale density

Dense bales hold their shape and are more stable in transport. This is controlled during baling.

Stacking hay bales on trucks

Bales should be stacked onto trucks so that they are locked together where possible.

Square bales pack well and are relatively stable. Small bales should be interlocked to secure the load.

Round bales can be unstable when stacked on trucks, especially if soft. They should be stacked on the flat edge to avoid rolling, in two or three layers, depending on the size of the bales and the truck. The centres of loads of round hay bales loaded on their curved edge may shift during transport if they are not well secured.

It is important not to exceed the maximum allowable load dimensions to ensure that bales on the top layer do not fall off and that the load remains stable during transport.

Restraining the load

Each group of bales must be tightly and correctly secured crosswise along the length of the load with webbing, not rope. In some states road transport authorities require loads to have end gates, mid-load straps, end protectors and/or a tarpaulin cover. See relevant website for each State's guidelines (*Appendix B: References and information sources*).

C. Peace

Research commissioned by the Australian Fodder Industry Association (AFIA) and the Rural Industries Research and Development Corporation (RIRDC) has examined loading patterns and restraint methods for hay trucks using truck tilt tests and computer simulations and has identified which load configurations provide the best stability.

The research found that rollover stability of loads varies depending on bale type, stacking arrangement, vehicle configuration and load restraint method. Large square bales have more than twice the rigidity of round bales at 4.6 m high, while tri-axle trailers are more stable than tandem axles.

G. Wing

This work has produced a safer alternative restraint system for carriers, which can be used in all states, provided copies of the reports of the project are carried in the truck (Blanksby *et al.*, 2008).

The reports are available from RIRDC (www.rirdc.gov.au) and AFIA (afia.org.au).

Some key points include:

- double straps or 'double-dogged' single straps (i.e. tensioned on both sides of the load) provide substantial improvement to vehicle stability without requiring excessive work in restraining the load
- double-dogged single straps can be applied to all bale types
- double straps can only be applied to rectangular bales
- it is important to use diagonal load-binder straps on the front and rear blocks, pulling the load towards the centre.

Critically, these reports show that the use of steel angles, rear gates and mid-load straps are not necessary to comply with the load restraint guidelines set down by the National Transport Commission.

Hay transport regulations

All loads of hay must comply with safety and transport regulations including load size and restraint system.

Regulations for maximum height and width of loads in Australia vary from state to state and during drought, so it is important to know the regulations for each state.

Slight breaches of the dimension regulations are classified as overloading in some states, attracting large fines. Check the regulations for each state. See *Appendix B: References and information sources* for useful websites.

Drivers must be aware of the regulations, secure their loads correctly and comply with any other requirements, such as special times or routes. At the time of writing AFIA is attempting to bring consistency to hay transport regulations between states.

OH&S for hay and silage makers

Many workplace deaths and injuries occur in the hay industry each year as a result of poor machinery maintenance, lack of machinery guards, missing or inadequate roll over protection structures (ROPS), or improper use of equipment. Mowers, balers and large hay bales can all be killers. Inexperience, consumption of alcohol, lack of sleep and inattention have all contributed to accidents in the workplace. Sunburn, dust, back and hearing problems can also be hazards for haymakers.

It is important to use trained, experienced operators and to identify, assess the risk, and remove the hazards.

Safety tips for hay makers

Remember, accidents can happen in an instant

Be vigilant at all times

Ensure an approved ROPS is fitted to each tractor.

Ensure safety guards are fitted to all machinery.

Have well maintained fire fighting and safety equipment on hand.

Keep children and dogs away from the paddock, haymaking equipment and hay stacks.

Do not wear lose clothing.

Tie up long hair.

Always turn off the machine before making adjustments.

Always keep clear of large bales being ejected from the baler, and during loading and transport.

Secure all loads correctly.

Watch out for overhead power lines.

Be patient and take your time.

Do not continue working when over-tired.

If using chemical additives, read and follow the label instructions and use the specified personal protective equipment.

Consult the OH&S regulations in your state and ensure that your workplace and practices are safe.

Chapter 10
Lucerne hay products

Most lucerne produced on Australian farms is either grazed or sold as baled hay. Hay prices are subject to wide fluctuations depending on the seasonal availability, and unless the grower has plenty of storage he must accept the market price. Lucerne growers can capitalise on high prices by having as much covered storage space as possible which allows them to sell hay at any time.

Innovative growers add value to their lucerne by processing and packaging it into other products. The range of lucerne products includes bales of various shapes and sizes, chaff, cubes, pellets, meal and seed. The important thing is to do the market research, explore the possibilities and then produce a consistent, high quality product.

Presentation, labelling, packaging and branding can be a key part of marketing a quality assured product. Similarly, plastic or shrink wrapping can turn bulk hay into a premium hay product for both the export and domestic markets. Vacuum packaging can reduce the size of the bale further and has been used to create mini silage packs.

Lucerne chaff

Chaff has long been a very marketable premium hay product, being the preferred high quality feed of horse owners. It is also sold as feed for ostriches, chickens or as garden mulch.

Bagged and branded lucerne chaff.

Chaff is made in a purpose-built chaff mill from the best quality lucerne hay. The hay must be cut when it is leafy, and baled at the correct moisture to prevent mould growth or the leaves powdering. The hay must be fragrant, green and free of dust, mould and contaminants. 'Ropey' windrows allow the hay to be fed from bales into the chaff mill more easily, where it is chopped by a series of knives to the required length. Additives, such as molasses, can be added. Chaff is bagged into 20–25 kg labelled or tagged bags suitable for stacking on pallets which may also be plastic shrink-wrapped for transport.



High quality leafy lucerne chaff can be bagged and branded to add value to lucerne hay.

Compressed or split bales

Compressed or split bales suit export markets, and horse or pet owners who wish to buy and transport small amounts at a time. Small dense bales fit the maximum amount of hay into shipping containers, but also fit easily into the boot of a car.

Large bales can be split, compressed or prised apart and then pressed into small dense bales, while small bales can be compressed into even smaller ones. Small compressed bales can be sliced before wrapping with tapes, so that the package breaks into smaller 'biscuits' when opened. Bales can also be plastic wrapped individually or in groups on pallets for transport.

Cubes

Lucerne cubes are small, high density hay packages (typically 3 x 3 x 8–15 cm) which are sold as stock feed and garden mulch. They take up less space for storage and transport, and are easier to handle and feed out than hay.

Cubes are made by prising bales apart, then compacting and extruding the hay through large dies. The hay must be quite dry (12% moisture) and different quality hay or species (e.g. grass and lucerne) may be mixed to suit the customer. Cubes can be stored in bulk or bagged in smaller quantities (e.g. 20 kg). There are a small number of mobile cubers in Australia that make cubes in the field, avoiding the need for baling.

Left: splitting large square bales of lucerne.

Right: lucerne hay cuber.

Left: wrapped and branded mini-bales of lucerne in container for export.

Above: lucerne hay cubes.

Right: pallet of bags of lucerne hay cubes.

Garden mulch

Mulch is a good way to market poor quality lucerne hay, provided it does not contain burrs and other weed seed. Chopped lucerne hay and cubes are sold in attractively labelled 15–20 kg plastic bags through garden centres and supermarkets. The lucerne absorbs moisture readily and breaks down to supply plant nutrients.

Bagged and branded lucerne garden mulch.

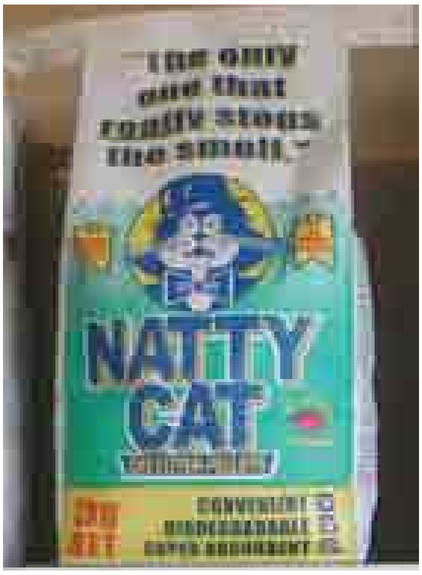
Pellets

Pellets are processed in a similar way to cubes using smaller dies to suit the customer. They are used in intensive animal industries such as lamb feedlots, pigs, poultry, deer, ostriches, domestic animals (horses, rabbits, guinea pigs, etc.) and zoos.

Pellets are often packaged in much smaller quantities (1–2 kg) for sale through supermarkets. Good quality weed-free lucerne is required for stock feed. Lower quality hay can be sold as kitty-litter. Lucerne is ideal for this purpose because it is naturally absorbent of moisture and odours, is biodegradable and adds nutrients to gardens when disposed of.

Silage

Lucerne silage is a good option for weedy or first cut lucerne, or when conditions are too moist for making hay. Silage can be stored cheaply in pits or bunkers for on-farm use. Baled and plastic-wrapped silage (or baleage) is a more easily transported and can be sold off-farm but is more expensive to make and can only be stored for short periods (12–18 months).



Top left, above: lucerne pellet cat litter.

Left: lucerne pellets.

Right: lucerne pellet stockfeed.

Careful attention is needed when making and storing lucerne silage to ensure its quality. It must be well compacted and sealed and lucerne silage may benefit from bacterial inoculants to enhance the fermentation process. See *Chapter 9 Lucerne haymaking: Lucerne silage* for further information.

Alternative products

A number of specialist small scale, niche markets exist for a range of alternative lucerne products.

Green-chop

Lucerne can be cut by a forage harvester and fed fresh to animals, or can be cut, wilted to about 60% moisture and then collected, chopped and fed out. Wilting helps remove some of the moisture and makes the feed more attractive to animals by concentrating the sugars.

This system has less costs and losses than haymaking. However, transport costs of green-chop lucerne are high, given the high water content, and it must be used immediately. There is also little flexibility in sales and the grower is locked into a regular supply, which can become a problem if the season is unusually hot or the water supply limited. Close proximity to the end-user (e.g. dairies or horse stables) is essential.

Lucerne meal

Lucerne hay can be ground with a tub grinder to produce a high-protein meal for animal or human consumption, though markets are limited. Fines from hay processing and cubing plants, mostly shattered leaf material, can also be collected by vacuum and sold as lower quality stock feed. Finely ground hay is digested more quickly by animals, so consumption and animal production are high.

Human health foods

Lucerne meal can be sold as protein and vitamin supplements in powder, tablet or capsule form, while juice extracts command high returns in the health food market. Lucerne tea is also claimed to have favourable health benefits while alfalfa sprouts is a popular salad vegetable product.

Fractionation technology

Techniques have been developed to separate the fibre and juice fractions of lucerne to produce other products. The fibre portion can be used to produce synthetic building materials (fibre board) or can be burnt to produce energy. The liquid fraction can be used as juice in the health food market, or turned into biodegradable plastics or ethanol fuel. However, commercial opportunities have been limited to date. The cost of production is high and large quantities of lucerne are needed on a regular basis to make this process viable.

Other niche products

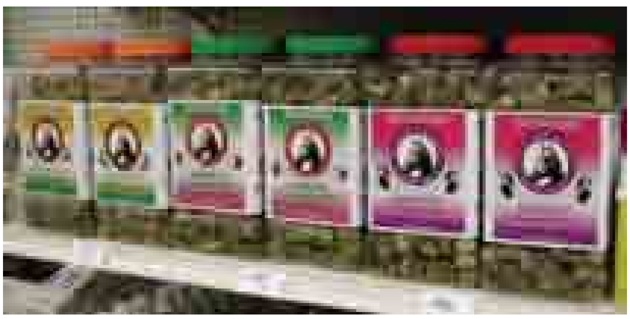
Niche markets exist for a range of innovative lucerne products, for example fresh bunches sold at local markets for pet food, small vacuum packs for the horse market, molasses coated cubes and pellets for horse confectionery, and mini-bales for tourist, craft and home decorating markets. These are generally small scale enterprises involving a high labour requirement but good returns can be achieved.

Lucerne seed

Seed for sowing or sprouting can be a viable enterprise but it is important to note that lucerne seed and hay crops are managed very differently. Specialist seed producers generally grow low density lucerne stands, however it is possible to combine seed and hay production on the one farm. This provides extra flexibility and income for growers, but good management is needed, especially irrigation and insect management, to achieve high seed yields.

Right: alfalfa sprouts.

Below: lucerne horse treats.



Chapter 11
Marketing lucerne hay

Producing a quality product is only the first step in running a profitable lucerne hay business. A well planned marketing strategy is required to get the best returns possible, as the market price varies greatly, generally being dictated by supply and demand.

Marketing lucerne successfully depends on:

- producing a quality product
- accurately describing the product (using feed testing)
- understanding the feed value of the product (interpreting feed test results)
- knowing customer requirements (livestock class, timing, storage)
- understanding the market (seasonal variations, market drivers)
- providing a dependable service
- developing and maintaining a good relationship with customers (communication, honesty, reliability
- pricing the product fairly and realistically.

The use of marketing assistance and advice from individuals, groups or organisations, or internet marketing can be very useful when developing a marketing strategy.

Marketing tips from successful lucerne hay producers

Focus groups conducted with successful Australian lucerne hay producers and contractors unveiled a wealth of information on the strategies used to market lucerne hay. A summary of the discussions follows.

Product quality

- Top quality hay will sell itself.
- Add value to a good product by packaging and branding.
- Grade hay and price according to feed tests results.
- Consider selling using the AFIA grades.

Grower tip

'You can always sell quality. Have a use or market for weathered hay'. *Glen Rubie, Forbes, NSW.*

Quality assurance

- Demonstrate quality assurance for ease of marketing.
- Know your product–you must always accurately describe your hay.
- Traceability is important–track where the hay comes from and goes to.

Business management

- Use a marketing strategy and budget to plan sale quantities, pricing and timing to help maintain cash-flow and estimate returns. But be flexible.
- Store some of the hay made each year and sell when it reaches your trigger price.
- Set a realistic trigger price.
- In a mixed enterprise, sell good quality hay and keep poorer hay for on-farm use. Make sure there is enough storage for the quality, saleable hay.
- Consider employing the services of a good marketer or use the internet to market hay.

Grower tips

'Good marketing of lucerne hay is all about quality, timing and service.

Have a point of difference.

Develop a premium for quality and service.

Market all of your hay. Never 'get rid' of product–grade it and market it. Find the right customer.

Lead the market–be a price setter, not a price taker.'

David Wallis, Quirindi, NSW.

Grower tips

'Join a marketing co-operative to get advice on growing and making hay, and to help market it'. *Garry McDougall, Inglewood, Qld.*

'Have some markets before you start to produce hay. Ask for help from someone experienced'. *Dennis Gillingham, Kerang, Vic.*

'Source, check and find markets. Join a professional lucerne group to help source markets'. *Jamie Semmler, Kerang, Vic.*

Market intelligence

- Good market intelligence is important. Be aware of what the market is doing (falling, rising, steady or inactive) and understand when the usual seasonal demand increases. A weekly hay index is published on the Dairy Australia website (www.dairyaustralia.com.au) and in rural newspapers.
- Sell small bales by the bale, and large bales by the tonne.
- Check the current market and price before deciding whether to sell or store.
- Understand the market requirements (quality and size) and produce the most suitable product for the budgeted price.

Supplying the market

- Supply hay all year round–this needs adequate storage on farm.
- Sell out of season–the winter market receives the best prices.
- Seek alternative sales for poor quality hay.
- Cut and bale to suit the market demand (bale size, weight, maturity).
- Feedlots prefer bales pre-sliced (cutters in balers).
- Some horse owners do not like hay treated with additives e.g. K-hay or propionic acid.
- There is a market for horse owners who like short, light and green bales.

Customer service and integrity

- Know your customer as well as your market.
- Describe the quality of the hay accurately and honestly–it is better to slightly underestimate, than to overestimate and disappoint the customer.
- Provide a delivery service or contacts for a reliable contractor.
- Honesty and integrity are important for return customers. Regular customers are a key to the business.
- Match your hay to a range of customer requirements and supply the most applicable hay for the purpose.

Communication

- Good customer relations are critical.
- Contact customers and find out what they want. Talk to them regularly. Listen to what they have to say and respond to their feedback.
- Invite new customers to come and inspect the product.
- Talk to customers regarding ration requirements for their livestock.
- Communication with transport operators is also important. Keep them in the loop.

Grower tips

'Look after your customers to ensure they come back'. *Tricia Kiddle, Coolah, NSW.*

'Getting paid is critical to success. Delivery of hay to customer allows personal contact and a cheque in the hand'. *David Neuendorf, Gatton, Qld.*

Guarantees and policies

- Provide a guarantee on quality and a replacement policy.
- Follow up on hay sales, especially for faulty hay.

Advertising

- Advertising is important to gain new customers.
- A good product is the best advertisement.
- Word of mouth and regular customers ensure sales.
- Bag branding can be useful to ensure regular customers.
- Promote business through hay groups.
- Consider using the internet to market hay.

Challenges

- Customers often buy on appearance rather than feed tests.
- Direct contact with the client can avoid bad debts.
- Setting a price is a challenge when some producers undercut the price and dump cheap, poor quality hay on the market.

Chapter 12
Economics of lucerne hay production

Lucerne hay production can be highly profitable but is often considered risky due to the weather and the fluctuating domestic price. Careful management can improve lucerne yield and quality, and reduce the risk.

The profitability of lucerne hay production is affected by:

- costs–establishment, production, haymaking, processing
- potential yield
- stand life
- risk of weather damage
- market requirements
- variable market price due to season or competition from other feed-stuffs.

The producer's experience and management skills, other farm enterprises and the size of the farm are also involved.

Gross margin budgets provide producers with a tool for analysing their business, as well as a guide to current management practices.

Lucerne hay costs

The cost of producing lucerne hay can vary greatly with location, the growing system and the inputs required. Lucerne hay involves high capital costs (e.g. irrigation and haymaking equipment, storage sheds) and may have high labour requirements. Variable costs such as water, fertiliser and fuel can vary, depending on the productive capacity of the stand. Investment in new technology can reduce production risks and the variable costs, and improve the overall efficiency and returns.

The basic equipment required for a lucerne hay enterprise includes tractors, cultivation and planting implements, a fertiliser spreader, a boomspray and irrigation equipment, if applicable. Soil and hay moisture monitoring equipment, GPS technology, bale handling and transport equipment are all useful additions. All equipment should be assessed to ensure that the benefits of ownership can be justified by the returns. Ownership of haymaking equipment should only be considered if the profit from the quantity of hay being made can cover the interest and depreciation costs.

Establishment

The establishment of lucerne sets the potential for the life of the stand. It is important not to skimp on inputs at the beginning–poor establishment results in compromised yield and profit. Establishment costs are similar, regardless of the yield or land value, and should be costed over the life of the stand. The key costs include:

- sowing
- seed, inoculum and fertiliser
- herbicides and their application for weed control
- irrigation water (if applicable).

Production

Keeping the lucerne stand healthy and productive by ensuring adequate inputs and management is critical to achieving high returns. The key costs involved with managing a productive stand of lucerne include:

- water (if irrigation is used)–a major driver of production
- fertiliser–high inputs required for highly productive stands
- herbicides–for weed control to ensure purity of the finished product
- insecticides–to manage insect pests to optimise productivity
- product application costs–spreading, spraying, irrigating.

Irrigation

Producers of irrigated hay need to ensure they have enough water to meet their production targets. It is often better to water a smaller area well, than to lose yield and quality by spreading the resource too thinly.

Higher water prices, reduced availability and competition from other users means that the enterprise must be efficient to be profitable. Water requirements, availability and price vary from region

to region. Each type of irrigation system also has different costs and levels of efficiency.

Sub-surface drip and travelling spray irrigation systems are highly efficient and have low labour costs but their initial capital cost is high. Side-roll and hand-shift systems are cheaper to install but entail high labour costs.

Pumping costs are high for all spray systems. Surface flood systems are cheaper to operate, but land preparation to create efficient layouts may be costly. There are often no pumping costs but more water is needed to produce each tonne of lucerne, access to fields is restricted after each irrigation and lucerne stand life is generally shorter, especially on clay soils.

Haymaking

Haymaking costs depend on the location of the operation and the availability of equipment and/or hay contractors. In humid areas, frequent turning is required to dry the hay. Haymaking losses should be minimised to maximise profits.

Small square bales are more expensive to bale than larger bales but usually receive a higher return per tonne. Large square bales are more efficient to bale and transport. Net wrapping large round hay bales is slightly more expensive than twine but can reduce wastage.

Modern haymaking and handling equipment has greatly improved the efficiency of the operation and saves labour costs, but the initial outlay can be high.

Basic equipment for haymaking includes a mower (or mower/conditioner), hay rake, baler, hay handling/loading equipment and trucks. Additional equipment is needed for larger enterprises to cope with peak production periods or to handle hay in humid environments (e.g. tedders).

Hay processing equipment such as hay driers, chaff cutters, cubers, compressing plants, wrappers, etc. are expensive to buy but can add considerable value to the product.

Storage sheds are a critical investment to maintain quality and maximise profits. Large storage capacity can allow hay to be stored until the right price is available. A fully-enclosed shed ensures quality is maintained and the cost can be justified by the extra profit and market access.

Transport

Hay is usually transported by road within Australia at high cost, especially if long distances are involved. Good bale density, appropriate stacking technique and skills in securing loads is essential. High moisture content, soft bales or inappropriate bale size will increase the cost of transport. Small bales take longer to load, although stacking on pallets can speed the process and assist with occupational health and safety (OH&S) requirements for unloading.

Carriers must comply with the road transport authority regulations for the appropriate state. Fines may be incurred if transport regulations are breached.

Compressed hay in shipping containers is a cost effective way to transport export hay. However, because of the large distances from Australia to its markets compared to other countries and those markets, shipping costs are high.

Labour

Cost of labour should be estimated at the relevant hourly rate including 20% for workers compensation and other compulsory costs. Although family labour is often not considered a variable cost it should be included, as it could otherwise be used for other productive activities. It can be calculated using a labour cost equivalent to the most profitable alternative operation.

Overheads

Fixed costs such as storage sheds, machinery, insurance and registration do not vary with usage, however the costs can be spread over the throughput–the more hay produced, the cheaper the overhead cost per tonne of hay. Interest and depreciation are two major costs that should be included. Cost calculators are available to calculate overhead costs. See *Calculating machinery costs and contract rates* at www.dpi.nsw.gov.au.

Contractors

For top quality lucerne hay, it must be cut, raked and baled when the crop is ready. This usually means a heavy investment in machinery and labour to make sure the job is done on time. With increasing costs of machinery ownership it may be more cost

effective to use contractors, especially for smaller scale operations.

When using contractors, planning and communication are important and a written contract safeguards against legal action.

For large bales it is preferable to pay the contractor and sell hay on a dry matter basis, rather than on a 'per bale' or 'wet tonne' basis. Baling hay at lower moisture content than necessary may be cheaper per tonne of dry matter, but is likely to result in higher field losses.

Contract rates

Haymaking contract rates should be negotiated beforehand. Rates can vary with the size and type of equipment, the size and ease of the job, fuel prices, distance to storage and local competition between contractors. For more information see *Calculating machinery costs and contract rates* at www.dpi.nsw.gov.au

Agricultural contractor organisations often provide guideline rates for their members but do not regulate their use. Ask local hay producers and contractors or those in the Australian Fodder Industry Association Inc. network to compare contract rates (see www.afia.org.au).

Timeliness

Timeliness is critical for haymaking. Substantial losses in yield, quality and price can be incurred for each operation performed too early or too late, whether it be cutting, raking, baling or storing.

Lucerne hay returns

Lucerne hay producers have the option to sell their hay on the export or domestic market. Lucerne can be sold uncut in the field, as hay, as a processed hay product, as green chop or as silage.

The price received for lucerne hay varies greatly, depending on the intended market, the quality of the product and the supply and demand situation at the time of sale.

Export hay– price is generally stable and usually higher than the domestic price, but never reaches the peak domestic price during periods of drought. Quality is paramount and the product must compete with other countries, such as the USA, which can produce and transport export lucerne hay more cheaply than Australian producers.

Domestic hay–price for lucerne hay is strongly linked to supply and demand, fluctuating widely between and within seasons, depending on seasonal conditions. Growers need adequate storage capacity for the forecast production to take advantage of market highs.

Typical domestic lucerne hay prices are listed each week in rural newspapers or on the internet (e.g. http://theland.farmonline.com.au/markets). These prices are only an indication of the current market in certain locations and are useful to identify price trends. The real price may vary markedly depending on location or product (e.g. small bales vs large bales).

Processing, packaging and branding hay can increase its value considerably. Lucerne chaff, pellets, cubes, or compressed mini-bales can be sold at a greater margin than baled hay, but there is a high capital cost involved in setting up a processing plant.

Lucerne can also be sold uncut in the field to local contractors or processors. The grower receives a lower price per tonne but the haymaking costs and risk associated with the weather are shifted to the buyer.

Gross Margin budget example

Flood irrigated lucerne (establishment) for the Murrumbidgee and Murray Valleys, NSW

Gross margin budgets include all variable costs associated with the enterprise and the gross income. To determine the variable costs prepare a calendar of operations and list the associated costs of operations and inputs. In this example the operations may include:

- seedbed preparation and pre-sowing weed control –cultivation, herbicide application, harrowing
- sowing–seed, inoculant, seed fungicide dressing, fertiliser and sowing
- post-sowing insect and weed control–insecticide and/or herbicide application, insecticide, herbicide
- irrigation–delivery and water
- haymaking–cut, rake, bale, twine or netwrap
- hay storage–cartage, stacking, temporary covers

Income can be estimated by looking at likely hay production, the number of cuts and the estimated price. The Gross Margin is then calculated as in *Table 12.1.* Sensitivity tables (*Table 12.2*) are useful to determine the likely income range as affected by changes in hay yield or price. Other examples can be found at www.dpi.nsw.gov.au

Table 12.1 Example Gross Margin budget for establishment of flood irrigated lucerne in the Murrumbidgee Valley, southern NSW with water applied at 8 ML/ha.

Source: NSW Department of Primary Industries

Gross Margin budget	
Income	**$ per ha**
5.00 t/ha @ $350/t (on farm)	1750
3.00 t/ha @ $200/t (on farm)	600
A. Total income ($/ha)	**2350**
Variable costs	
Cultivation	25
Sowing	107
Fertiliser	78
Herbicide and application	63
Fungicide	5
Insecticide	5
Irrigation	224
Cut, Rake and Bale	416
Cartage and Stack	160
B. Total variable costs ($/ha)	1083
C. Gross Margin (A-B) ($/ha)	1267
D. Gross Margin ($/ML)	158

Gross margin budgets

A gross margin (GM) is the gross income from an enterprise, less the variable costs incurred in achieving it. Variable costs are directly related to the enterprise and vary in proportion to its size (e.g. cost of seed, chemicals and fertilisers). A gross margin is not gross profit, as it does not include fixed or overhead costs (e.g. depreciation, interest, rates, permanent labour, haymaking equipment, irrigation plant or haysheds) which must be met, regardless of the size of the enterprise.

Gross margins are generally quoted per unit of the most limiting resource (i.e. per hectare land or a per megalitre water). They are influenced by factors common to all farms (prices, costs or rainfall), and also by the individual characteristics of each farm. Management practices are influenced by soil type, topography, climate, weeds and pests and inputs will be different in each situation.

Gross margins can be used to compare paddocks or years, and can be benchmarked against district standards. Major differences may be due to particular farm characteristics, but may also indicate an area where significant improvement can be made.

NSW Department of Primary Industries lucerne GM budgets are based on achievable production using current prices and best management practices. They should be used as a guide only. Growers should use their own management practices, and current costs and prices.

See example *Tables 12.1* and *12.2*. Regularly updated budgets can be found at www.dpi.nsw.gov.au

Table 12.2 Income sensitivity tables

Effect of yield and price on gross margin per hectare					
YIELD	**On-farm price ($/t)**				
t/ha	**194**	**244**	**294**	**344**	**394**
6	$245	$545	$845	$1,145	$1,445
7	$371	$721	$1,071	$1,421	$1,771
8	$496	$896	**$1,296**	$1,696	$2,096
9	$622	$1,072	$1,522	$1,972	$2,422
10	$747	$1,247	$1,747	$2,247	$2,747

Effect of yield and price on gross margin per megalitre of water applied					
YIELD	**On-farm price ($/t)**				
t/ha	**194**	**244**	**294**	**344**	**394**
6	$31	$68	$106	$143	$181
7	$46	$90	$134	$178	$221
8	$62	$112	**$162**	$212	$262
9	$78	$134	$190	$246	$303
10	$93	$156	$218	$281	$343

Risk management

There are several risks involved in lucerne hay production that can affect returns. Rain during haymaking is the most obvious and reduces both the quantity and quality of hay produced. When budgeting, assume that not all hay will be top quality. Use best management practices for haymaking to reduce this risk and consider making silage with some cuts.

Production risks (e.g. insects, disease, and poor soil fertility) can be minimised by good management. Using irrigation reduces the seasonal rainfall production risk.

Market risk, largely due to seasonal supply and demand, can be managed through storage and developing markets with regular customers.

Tagging, quality testing and vendor declarations all help to ensure high returns, while poor quality hay can be value-added and sold at a good price to a well-targeted customer.

Maximising profit

Once the costs of production have been met, extra yield and quality will translate into extra profit. Care is needed to maintain the stand in a highly productive state for as long as it is required and to minimise losses during haymaking and storage.

Lucerne crops thin with time, so producers need to be able to assess the stand's profitability and decide when it is no longer viable for hay production. Many growers keep their hay crops too long because it still 'looks good'. Older stands pose the additional risk of the invasion and build-up of weeds.

The life and profitability of older lucerne hay stands can be extended by grazing or over-sowing with a cereal or grass for hay production or grazing.

Comparing the value of different lines of hay

When comparing different lines of hay, it is important to assess them on a 'feed value' basis, rather than simply cost per tonne of hay. The customer may consider drier hay to be cheaper on a per tonne dry matter basis, but it may not be on an energy or protein basis.

Drier hay may be cheaper on a 'per tonne dry matter' basis, but not on an energy or protein basis.

High feed-quality hay is often better value for money than lower quality hay, but this depends on the needs of the user. To compare the nutritive value of different hay lines, first convert to a dry matter basis. See *Chapter 4 Importance of hay quality* for further information.

Table 12.3 compares the relative feed value and cost of four different lucerne hay lines and one oaten hay line. Each hay line has been graded according to the AFIA quality grading system.

Table 12.3 Feed cost comparison of four different lucerne hay lines and one oaten hay line.

Source: Feed Cost Calculator (www.dpi.nsw.gov.au), NSW Department of Primary Industries using AFIA Hay Grades (*Table 4.5* and *Table 4.6*)

Nutritive value and cost	Hay type (AFIA quality grade)				
	Lucerne Hay (A1)	Lucerne Hay (B2)	Lucerne Hay (C2)	Lucerne Hay (C2)	Oaten Hay (B3)
Energy (MJ/kg ME)	10	9	8	8	9.3
Protein (% CP)	20	17	15	15	5.8
Cost ($/tonne hay)	250	250	200	180	200
	Calculated values				
Feed Cost ($/tonne DM)	278	278	222	200	222
Energy content (MJ/t DM ME)	10 000	9 000	8 000	8 000	9 300
Energy Cost (c/MJ ME)	2.78	3.09	2.78	2.50	2.39
Protein content (kg/tonne DM)	200	170	150	150	58
Protein Cost ($/kg)	1.39	1.63	1.48	1.33	3.83

Appendix A
Glossary

acid soil–soil with a pHCaCl2 less than 5.2. Restricts growth of lucerne shoots, roots and nodules.

accumulator–machine used to pick up, transport and stack small hay bales from the field.

additive–chemical which aids drying of hay e.g. organic acids, potassium carbonate, bacterial inoculants.

acid detergent fibre (ADF)–the indigestible fibre in a feed. The lower the ADF, the better the feed quality. Lucerne has low ADF (30–35%).

aerial (or satellite) image–digitised computer image taken from a plane or satellite which indicates soil or plant differences in a field.

AFIA–Australian Fodder Industry Association Inc.

alfalfa–1. synonym for lucerne (*Medicago sativa*) used in the USA. 2. lucerne sprouts in Australia.

allelopathy–(autotoxicity) the inhibition of new seedling growth due to the presence of old plant material, probably related to chemical exudates.

anaerobic–without air (oxygen in particular).

aphid–small insect that feeds on sap from plants, often spreading viruses. Lucerne aphids are often confused with jassids and lucerne flea.

ash–the mineral (inorganic) component of a feed.

bale–large package of hay secured with string or netting. Hay bales can be: small square (25 kg); large round (300–900 kg); large square (300–1000 kg); or mini-bales (small, dense bales).

baler monitor–in-cab computer which monitors and controls the baling process.

baling (pressing)–operation of picking up the cured (dried) hay from the windrow, and compressing and tying it into a bale with a baler.

bale wagon–machine used to pickup and transport multiple bales in the field.

bay outlet–structure in flood irrigation bays controlling the flow of surface water into the bay.

baleage, bale silage–high moisture content forage conserved by wrapping bales in plastic.

benchmarking–process of evaluating performance against set criteria or benchmarks to improve performance.

best management practice (BMP)–practices used by growers achieving high production, profit and sustainability levels.

bleaching–discolouration of exposed hay. Occurs when hay that is nearly dry is heated to a high temperature by the sun.

border check–flood irrigation system with banks running down the slope of the field.

botulism–bacterial disease of livestock resulting from dead animals contaminating hay or silage. Bacterial toxins can cause rapid death of livestock.

browning reaction–chemical reaction associated with high temperatures in moist hay or silage (25–40% moisture). Proteins, amino acids and plant sugars combine to form a brown lignin-like polymer which reduces feed quality. Browning releases heat which can trigger further heating and possibly, spontaneous ignition.

buffering capacity–ability of forage to resist change in pH during ensiling. Lucerne has a high buffering capacity.

buns and bunkers–above ground covered silage stacks with sloping (buns) or vertical (bunkers) sides.

carbohydrate–sugar compound in plants that supplies energy. Determines digestibility of a feed.

centre pivot–large automated, spray irrigator which travels around a central water supply.

chaff–finely-chopped, hay or straw.

check banks–raised banks running along the length of the field, which contain water for flood irrigation.

companion cropping–sowing another compatible species in the same field with lucerne (see also *nurse crop* and *undersowing*).

compressed hay–see *double dumping*

conditioning–mechanical or chemical disruption of the waxy surface of cut lucerne stems to speed drying.

conditioner–machine used to condition hay, towed behind or mounted on a tractor with a mower. There are several types:

crimper, Chevron roller–inter-meshing metal and/or rubber rollers crimp stems at intervals but leave them intact.

crusher, super conditioner–flat rollers flatten and split stems.

flail or tine conditioner–stems beaten by bars or blades; aggressive action.

macerator–rollers rotate in different directions to tear the hay, resulting in extreme conditioning and accelerated drying rates of hay.

re-conditioner–roller conditioner with hay deflectors to aerate and direct placement of hay.

cotyledon–the first two leaves of a seedling that emerge from the soil when a plant germinates.

crop choppers–knives in a forage harvester or baler, reduce the length of the stalks, especially for silage.

crown–the base of the stems of the lucerne plant from which new shoots grow.

crown buds, crown shoots–new shoots close to the ground arising from the crown, indicating that a new growth cycle has commenced. These develop into main stems.

crude fibre–historical measure of fibre in a feed, now replaced by NDF and ADF. Crude fibre underestimates the useable fibre.

crude protein (CP)–the total amount of nitrogen in a feed, expressed as a protein equivalent
CP = total N x 6.25

cube–small, highly compressed unit of hay extruded through a dye, used for animal feed or mulch.

developmental orthopaedic disease–joint and limb abnormalities in young horses associated with high energy intakes and mineral deficiencies or imbalances.

digestibility–the portion of feed consumed that is digested and used by an animal for growth. Directly related to ME level.

discbine–combination disc mower and conditioner.

dormancy–lucerne varieties are classified according to their winter dormancy or amount of growth in winter. They can be dormant, semi-dormant, winter active or highly winter active. Dormancy in lucerne can also occur in summer due to heat and moisture stress, independent of winter dormancy.

double dumping–processing large hay bales into smaller ones by compression.

dry matter (DM)–the proportion of plant material remaining when a forage is completely dried.

dry sheep equivalent (DSE)–the energy required to maintain one 50 kg Merino wether. The standard against which carrying capacities for other classes of stock are measured.

electrical conductivity (EC)–measure of salinity (salt concentration) in water (ECw) or soil (ECe).

elevator–machine attached to a truck or wagon to pick up small hay bales from the field.

ensiling–the process of making silage.

ESP (exchangeable sodium percentage)–measure of soil sodicity (amount of exchangeable sodium cations) in soil.

establishment–germination and survival of seedlings for the first year.

evapotranspiration (ET0)–the amount of moisture used by a crop. ET0 depends on temperature, wind, evaporation and sunlight.

fermentation–anaerobic process whereby sugars are turned into acids, preserving the forage as silage.

fibre–cell wall components of plant cells providing structure, rigidity and protection for plants. Contains cellulose, hemicellulose and lignin.

flail harvester–machine that uses a row of vertically rotating blades to cut and chop forage.

flood irrigation–water applied to the soil surface for plant production.

fodder–a general term to describe livestock feeds (fresh, dried or processed). In the USA fodder refers to low quality conserved feed.

forage–plant material other than grain that can be grazed or harvested to feed livestock. In the USA forage refers to high quality conserved feed.

forage harvester–machine that cuts and chops forage directly in the field, usually for silage.

founder–see *laminitis*

germination–emergence of the root and shoot from a seed to form a seedling.

global positioning system (GPS)–navigational system using satellites to provide the longitude and latitude of a location.

gross margin–income from an enterprise, less variable costs (seed, fertiliser, etc.).

hay–plant material preserved by drying, used as feed for livestock.

haybine–combination sickle bar mower and hay conditioner.

haylage–wilted forage baled at 40–75% DM and wrapped in plastic to exclude air. Preserved by anaerobic fermentation. (Also known as *baleage* or *baled silage*).

herbicide resistance–weeds can become 'immune' to a herbicide due to repeated use of similar chemicals. Use alternative herbicides or different weed control methods to avoid the problem. Insects can also develop resistance to insecticides.

herbicide, post-emergent–a chemical sprayed onto a crop after the crop has emerged to kill weeds.

herbicide, pre-emergent–a chemical sprayed onto a field before the crop is sown to kill weeds during early establishment. Pre-emergent herbicides have some residual effect.

inoculant *1*. commercial peat-based product containing rhizobia bacteria, applied to legume seed before sowing to ensure nodulation and nitrogen fixation. *2*. commercial bacteria culture used to enhance hay or silage making.

inverter–machine which lifts and turns over windrows.

irrigation bay–subdivided areas of fields confined by banks or ditches to channel irrigation water.

jassid (brown leaf hopper)–small insect responsible for spreading virus infections of lucerne. Often confused with aphids.

K-hay–hay treated with potassium carbonate (KCO3) to assist drying.

lactic acid bacteria (LAB)–important in silage making. Produce acid which preserves forage.

laminitis–a condition causing lameness in horses caused by an overload of starch and sugar in the hindgut due to high intakes of grain or lush pasture. Not so likely to occur with lucerne.

lateral move irrigator–large automated overhead spray irrigator which moves along the length of the field pumping water from a channel alongside.

legume–plant that fixes nitrogen for use by the plant by means of bacteria in root nodules (e.g. lucerne and clover).

listeriosis–bacterial infection that can cause abortions, brain damage and death in ruminants, especially sheep. Caused by aerobic conditions in poorly compacted and sealed silage.

lucerne flea–tiny insect that eats the surface of the lucerne leaf leaving small holes or 'window panes'. Often confused with aphids.

macerator–machine which results in extreme conditioning of hay. Rollers rotating in different directions tear the hay, allowing it to dry quickly.

micro-organism–bacteria, yeast and fungi (mould) which perform important functions in the soil, silage and the digestive systems of animals.

monitoring–close observation on a regular basis e.g. insect activity, or plant or soil moisture.

mower–machine used to cut lucerne. Can be self-propelled or towed by a tractor (tow-behind or offset). Modern units usually include a conditioner and windrower mounted on the machine. There are several different types:

cutter or *sickle bar*–reciprocating knives attached to a horizontal bar

rotary disc–free swinging knives mounted on horizontal circular discs which rotate at high speed.

drum disc–knives mounted on a horizontally rotating cylinder head, driven by a V-belt from above.

flail–blades rotate vertically at high speed around a shaft.

neutral detergent fibre (NDF)–total amount of fibre in the feed. Lucerne's low NDF (40–45%) promotes high animal feed intakes. As lucerne matures, fibre increases, so the feed quality and intake decline.

netwrap–open weave polypropylene netting used to wrap and secure round hay bales.

NIR (near infra-red reflectance spectroscopy)–technique used for rapid analysis of feed nutritive value.

nitrogen fixation–process by which nitrogen is captured from the atmosphere by rhizobium bacteria living in the root nodules of leguminous plants.

nodule–small 'lumps' on the roots of legumes containing rhizobium bacteria colonies. Active nodules are pink inside. The formation of nodules is known as *nodulation.*

nurse crop–a companion crop sown with lucerne to compete with weeds and aid lucerne establishment. Both species are generally sown at high rates to ensure good competition against weeds. Good rainfall or irrigation required.

overseeding–sowing another crop (e.g. oats) into an established lucerne stand in its final years to extend the life of the stand.

pan evaporation–the amount of water evaporating from a standard-sized open pan of water; used to calculate plant water use.

pellet–small highly compressed units of finely chopped hay extruded through a dye. Used for animal feed.

pH–measure of acidity and alkalinity (e.g. soil, water or silage). pH 7 is neutral, above 7 is alkaline while below 7 is acidic. pH affects availability of soil nutrients, plant growth, nodulation and the effectiveness of the ensiling process.

pH_{CaCl_2}–soil pH measured in calcium chloride solution in a laboratory, generally 0.8 units lower than a commercial soil pH kit or pHwater.

photosynthesis–process by which plants use sunlight energy to convert carbon dioxide, water and nutrients into organic compounds used for plant growth.

phosphorous–important soil nutrient needed for plant growth.

rake–tined machine used to gather up or turn hay, or move it to a different location in the field.

parallel tine, basket **or** *rollerbar rakes*–tines attached to parallel bars and reels, forming the basket. The basket lifts hay forwards and sideways into a windrow.

finger wheel rakes–a series of tined wheels attached vertically to a bar which pick up hay and roll it from wheel to wheel into a windrow.

rotary rakes–tines attached to the spokes of a large wheel which rotates horizontally above the ground.

tedders–long tines attached to horizontally rotating arms used to fluff-up high moisture hay (greater than 50%) within 24 hours of mowing to assist drying. Used for initial wilt of silage. Can also be used to turn windrows, rake swaths into a windrow or rake rows together.

RAW (readily available water) or **plant available water (PAW)**–the amount of soil water easily accessed by plants, between field capacity (wet) and wilting point (dry).

respiration–process by which plants break down starches and sugars. This happens at night and continues after plants are cut until they dry.

RFV (relative feed value) and **RFQ (relative feed quality)**–modern terms used in the USA to classify the nutritional value of feeds.

rhizobia–specialised bacteria that infect the roots of legumes and fix nitrogen from the air.

sausage or tube wrap–a continuous tube of plastic used to store silage, either as loose or baled forage.

scald–death of lucerne plants due to flooding during hot weather—a result of low soil oxygen and high temperatures.

salinity–concentration of soluble salts in water. Saline soils and water can inhibit lucerne growth.

SAR (sodium absorption ratio)–measure of sodicity in water. The amount of sodium cations in relation to calcium and magnesium cations.

scheduling–matching the water supply to the crop water use, as determined by the soil and weather conditions.

side roll irrigation–pipes mounted through the centre of large wheels which are moved by rolling sideways.

sub-surface drip irrigation (SDI)–water is supplied directly to the root zone of the crop via buried tubes and drippers.

silage–forage preserved by the acids produced by anaerobic fermentation of the plant sugars by lactic acid bacteria. Typically 30-50% DM. Stored in silos, pits, buns, bunkers, wrapped bales or plastic covered stacks (see *baleage* and *haylage*).

siphon–tube used to deliver water from channel to field for surface flood irrigation.

sodicity–the amount of exchangeable sodium in water or soil. Expressed as ESP in soil and SAR in water. Sodic soils (ESP>6) and sodic water (SAR>3) can affect lucerne growth. See *ESP* and *SAR*.

spontaneous combustion–heat from biological activity in moist forage (see *browning reaction*) can result in spontaneous ignition of hay.

spray irrigation–water applied to the soil surface by overhead sprays e.g. spray gun, centre pivot.

stand–term used for a crop of lucerne.

stand persistence–the period of time a crop of lucerne can survive.

surface irrigation–irrigation applied to the soil surface by spray or flood.

swath–the row of cut hay left on the ground behind the mower. Swaths are usually raked into windrows to dry or bale.

tedder–see *rakes.*

thatch–external weathered layer of a round hay bale that helps shed rain water.

tine–spoke on a hay rake, or the cutting blade on a ploughing implement.

tramlining–driving on the same wheel tracks in a field to reduce plant damage and soil compaction.

travelling irrigators–large automated spray irrigators (e.g. guns, pivots, lateral moves).

trifoliate leaf–a three-lobed leaf typical of lucerne and other legumes.

tubeline wrap–plastic wrapped around a line of high moisture round hay bales placed end to end.

twine–strong synthetic string used to secure hay bales.

undersowing–term used in Australia for sowing dryland lucerne at a low rate (say 1 kg/ha) with another crop (usually a cereal) in the same operation. Income from grain offsets the costs of establishing lucerne. Cereal sowing rate must be low to ensure lucerne establishment.

water use efficiency (WUE)–the amount of dry matter produced for each unit of rainfall or applied irrigation water.

wilt–initial rapid loss of plant moisture in the field after cutting. Wilting concentrates plant sugars and is important for silage making.

windrow–a low, loose, continuous mound of cut hay left to air dry in the field before baling.

windrower–machine used to form hay into a windrow, often mounted on a mower.

water soluble carbohydrates (WSC)–plant sugars important in the silage making process.

Appendix B
References and information sources

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Newsletters and magazines

Newsletter. Australian Fodder Industry Association Inc.

Ag Contractor and Large Scale Farmer. AML, Christchurch New Zealand

Hay and Forage Grower Magazine. Minneapolis, USA (www.hayandforage.com)

Lucerne Newsletter. WA Lucerne Growers, Katanning, Western Australia.

Resources–contacts

Commercial feed testing services

Feed Quality Service, NSW DPI, Wagga Wagga, NSW www.dpi.nsw.gov.au

FeedTest, DPI Victoria, Hamilton, Victoria. www.feedtest.com.au

Independent Lab Services, Claremont, Western Australia. Phone 08 9242 5876

SGS Agritech, Toowoomba, Queensland. www.au.sgs.com

Weston Technologies, Enfield, New South Wales. www.georgewestontechnologies.com.au

Training

Irrigated lucerne for profit short course. New South Wales Department of Primary Industries. www.profarm.com.au

Resources–websites

Departments of agriculture	
Agriculture, Fisheries and Forestry	www.affa.gov.au
Queensland Department of Primary Industries and Fisheries	www.dpi.qld.gov.au
NSW Department of Primary Industries	www.dpi.nsw.gov.au
Department of Primary Industries Victoria	www.dpi.vic.gov.au
South Australian Research and Development Institute	www.sardi.sa.gov.au
Agriculture and Food, Western Australia	www.agric.wa.gov.au
Northern Territory Department of Agriculture	www.nt.gov.au/dpifm
Department of Primary Industries and Water Tasmanian	www.dpiw.tas.gov.au
Other organisations	
Australian Fodder Industry Association Inc.	www.afia.org.au
Australian Pesticides and Veterinary Medicines Authority	www.apvma.gov.au
Bureau of Meteorology	www.bom.gov.au
CSIRO	www.csiro.au
GFS Precipitation Forecast	http://wxmaps.org/pix/aus.vv.html
Grains Research and Development Corporation	www.grdc.com.au
Hay and forage grower magazine	www.hayandforage.com
Kondinin Group	www.kondinin.com.au
Meat and Livestock Australia	www.mla.com.au
National Association of Testing Authorities, Australia (NATA)	www.nata.asn.au
Rural Industries Research and Development Corporation	www.rirdc.gov.au
Pestgenie	www.pestgenie.com.au
Queensland Transport	www.transport.qld.gov.au
Roads and Traffic Authority, New South Wales	www.rta.nsw.gov.au
VicRoads	www.vicroads.vic.gov.au
Transport SA	www.transport.sa.gov.au
Mainroads WA	www.mainroads.wa.gov.au
NT Planning and Infrastructure	www.dpi.nt.gov.au
Department of Transport, Tasmania	www.transport.tas.gov.au
Transport ACT	www.transport.act.gov.au
USA alfalfa research	
University of Wisconsin–forages	www.uwex.edu.forages
University of California–lucerne (alfalfa)	www.alfalfa.ucdavis.edu
US National Hay Association	www.nha.com
Lucerne seed companies	
Alfagreen	www.alfagreen.com.au
Auswest Seeds	www.auswestseeds.com.au
Heritage Seeds	www.heritageseeds.com.au
Michel Belair Seeds	www.michelbelair.com.au
Pacific Seeds	www.pacificseeds.com
Pioneer Hi Bred Australia	www.pioneer.com/australia
PlantTech	www.planttech.com.au
Seed Distributors	www.seeddistributors.com.au
Wrightson Seeds	www.wrightson.net.au

Appendix C
Lucerne varieties

Source: NSW Department of Primary Industries 2007

		Resistance ratings					
Variety	**Dormancy rating**	**Spotted alfalfa aphid**	**Blue green aphid**	**Phytophthora root rot**	**Anthracnose+**	**Stem nematode**	**Bacterial wilt**
Winter dormant							
54Q53Φ	4	R	MR	HR	HR	HR	HR
WL 342HQ-MF	4	R	R	HR	HR	R	HR
Semi winter dormant							
KaitunaΦ	5	R	HR	MR	R	HR	R
Hunter River*	5	S	S	S	S	S	S
SARDI FIVEΦ	5	HR	HR	HR	HR	R	~
L55Φ	5	HR	R	HR	HR	MR	R
L56Φ	5	HR	HR	HR	HR	HR	HR
VenusΦ	5	HR	R	MR	LR	~	~
Winter active							
Aurora*	6	HR	HR	R	MR	R	LR
Hunterfield*	6	HR	LR	S	S	S	S
WL 414	6	HR	HR	HR	MR	R	R
Stamina™ GT6	6	HR	R	R	HR	HR	~
IconΦ (SuperAurora)	6	HR	HR	HR	S	~	~
FlairdaleΦ	7	R	HR	R	LR	R	~
GenesisΦ	7	HR	R	R	R	~	~
Q75Φ	7	HR	R	HR	HR	R	MR
QuadrellaΦ	7	R	R	MR	R	LR	S
SARDI SEVENΦ	7	HR	HR	HR	HR	R	~
Trifecta*	7	R	HR	MR	R	LR	R
UQL-1Φ	7	HR	HR	HR	HR	~	~
Highly winter active							
AquariusΦ	8	R	HR	HR	LR	R	MR
HallmarkΦ	8	HR	R	HR	HR	HR	~
Multi Foli™-8	8	HR	HR	HR	R	R	R
Australis (SuperSiriver)Φ	8	R	HR	R	MR	~	~
WL 525HQ	8	HR	HR	HR	MR	R	MR
Cropper 9.5®	9	HR	HR	HR	MR	R	MR
CUF101*	9	R	HR	MR	S	S	S
L90Φ	9	R	HR	HR	HR	R	LR
PegasisΦ	9	HR	LR	R	MR	~	~
SaladoΦ	9	R	HR	LR	LR	MR	~
Saturn™	9	HR	HR	HR	MR	MR	~
Sirosal	9	HR	HR	R	S	S	~
Sequel*	9	R	R	MR	R	S	S
Sequel HRΦ	9	R	R	R	HR	R	~
SuperSequel (SuperCufΦ, BlueAce)	9	HR	HR	R	LR	~	~
SilveradoΦ	9	HR	HR	HR	HR	MR	~
Siriver*	9	HR	MR	S	S	S	S
Siriver MkIIΦ	9	HR	R	LR	S	~	~
WL 925HQ	9	HR	HR	HR	MR	R	MR
Multileaf® ML99Φ	10	HR	HR	HR	HR	MR	~
SARDI TENΦ	10	HR	HR	R	R	R	~

HR–highly resistant, R–resistant, MR–moderately resistant, S–susceptible, ~–no data available (ratings based on glasshouse tests of seedlings)

+ Ratings do not reflect all races of anthracnose (*Colletotrichum trifolii*). The distribution and importance of a recently identified race is not known.

Φ Protected by Plant Breeder's Rights (PBR) * Public variety—not covered by licensing agreements or PBR. See www.dpi.nsw.gov.au.

AFIA Vendor Declaration

Australian Fodder Industry Association Inc

Fodder Vendor Declaration Form

VDF No.:________
Contract No. ________

1. Vendor's Details	2. Buyer's Details
Vendor's name:	Buyer's name:
Address:	Address:
Tel: Fax:	Tel: Fax:

3. Production Details If vendor not the producer, provide corresponding producer's VDF No:

Paddock identification:	Delivery date:
Commodity:	Cutting date:
Is this free of genetically modified organisms **Yes** ☐ **No** ☐	Other:

4. Fodder Quality	Analysis: Lab Reference no.
Product description:	Dry matter: %
Species :	Crude protein: % of DM
(if mixed include estimate of percentage)	Metabolisable energy: MJ/kg of DM
Quantity: Bale size:	Other -
Weeds:	-

5. Testing and Chemical Status

This form only applies to a single "lot" of hay (see Sampling Protocol on pressure sheet)

Has the fodder sample been taken according to AFIA sampling procedure? (one test per 200 tonne lot or paddock) **Yes** ☐ **No** ☐

Has the fodder been tested for ARGT? **Yes** ☐ **No** ☐

or Phosisic acid? **Yes** ☐ **No** ☐

If yes name the Laboratory Case or Sample No: and Result

Has the fodder been tested for pesticide residues? **Yes** ☐ **No** ☐

If yes, attach details of testing results on the delivered product

Has the crop been grown on a property with either an organochlorine (OC) status classification, or under quarantine because of OC residues within the past 12 months? *If yes give details* **Yes** ☐ **No** ☐ **Don't know** ☐

Does the property from where the fodder is grown carry accreditation under an independently audited QA program? **Yes** ☐ **No** ☐

If yes give name of program

Has the fodder crop been subject to spray drift during its production? **Yes** ☐ **No** ☐ **Don't know** ☐

If yes attach a list of chemicals applied to neighbouring crops, the date sprayed and application rates.

If selling fodder to a client, operating within a livestock QA program, who require a full list of chemical names, rates and dates both applied to the fodder crop, as well as those applied to neighbouring crops within 100 metres, please attach the details to this form.

6 Declaration

I/We ______________________________ (name of fodder supplier)

declare that I/we have the systems in place to ensure that the fodder complies with all State and Federal laws and the requirements relating to chemical and pesticide residues and specified Government designated maximum residue limits. These systems include:

(i) any chemical treatment applied to any component of this consignment during storage on our premises or otherwise in our possession was as per product label approved by the National Registration Authority for Agricultural and Veterinary Chemicals and that the withholding period specified on that label has been observed; and

(ii) in relation to the sourcing of raw materials:

a) the property on which the fodder was grown, or the storage facility in which the fodder has been stored, carries accreditation under a recognised, and independently audited QA program, which includes chemical residue management provision; OR

b) has been purchased under a contract in which the supplier warrants that the fodder complies with all State and Federal laws and requirements relating to chemical and pesticide residues and specified Government designated maximum residue levels; OR

c) in relation to direct farm purchases that the supplier of the fodder has attested to the effect that any pesticides/fungicides used on the fodder have been applied in accordance with the registered labels of these chemicals, at rates not exceeding the maximum rate set out on the label of these chemicals and the appropriate withholding periods have been observed.

I/we further declare that this consignment at the time of the sale:

1. is free from animal material as defined and required under State legislation and
2. it is otherwise fit for the purpose of feeding to the category of livestock indicated in the product description above.

Intended Use/Purpose ______________________________

VENDOR'S SIGNATURE______________________________ **DATE**__________

- The AFIA Inc does not accept responsibility or any liability for the information contained in this declaration. December 2002

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