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NSW Agriculture

Lucerne for pasture and fodder

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Lucerne flower

Cover:
Left: Hay cut in the Narrandera district (Photo: G Johnson); Right: Sheep on lucerne at Tamworth (Photo: NSW Agriculture)

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Warnings/Cautions:
Livestock health disorders
Pasture improvement may be associated with an increase in the incidence of certain livestock health disorders. Livestock and production losses from some disorders are possible. Management may need to be modified to minimise risk. Consult your veterinarian or adviser when planning pasture improvement.

Native vegetation
The *Native Vegetation Conservation Act 1997* may regulate some pasture improvement practices where existing pasture contains native species. Inquire through your office of the Department of Land and Water Conservation for further details.

ALWAYS READ THE LABEL

Users of agricultural or veterinary chemical products *must always* read the label and any permit, before using the product, and strictly comply with the directions on the label and the conditions of any permit. Users are not absolved from compliance with the directions on the label or the conditions of the permit by reason of any statement made or not made in this publication.

SUMMARY

Lucerne is a temperate perennial legume capable of producing high quality forage throughout the year, but its main production period falls in the spring, summer and early autumn.

Lucerne is the third most widely grown pasture legume in New South Wales (after subterranean and white clover), and is considered the only reliable pasture legume for a large area of the State.

It's wide range of uses, and high adaptability to the climate and soils of NSW makes it an integral part of the State's agriculture, especially in the wheat–sheep zone.

The area of lucerne declined during the 1970's, coinciding with an increase in cropping and the arrival of the destructive exotic lucerne aphids. The use of improved varieties has largely overcome the aphid problem and has brought the added benefit of resistance to a range of diseases previously restricting production, as well as benefits in seasonal production and overall productivity.

Lucerne is a reliable plant for use as extensive pasture, intensive forage, and fodder under irrigation.

Growing lucerne produces many benefits:

- **Economic gains** stem from both improved livestock production and increases in the yield and quality of subsequent cereal crops. Savings in application of nitrogenous fertilisers to subsequent crops and benefits in the area of weed control are also significant.
- **Environmental benefits** can be very significant. The ability of lucerne to lower high watertables, thereby reducing the potential effects of salinity, is outstanding. Lucerne also assists in improving soil structure and controlling erosion, especially as a part of a pasture mixture with grass species. Lucerne has also been used effectively as a fire-break, and because of its drought tolerance it enhances the stability of pasture swards.

Haymaking techniques have improved substantially in recent years. Better machinery, cubing, recompression of bales and the use of preservatives now make lucerne an even more useful and profitable species to grow.

The main problems restricting lucerne production are soil type and soil pH, susceptibility to heavy and continuous grazing, loss of livestock production through bloat, diseases such as common crown rot, and the need for inexpensive weed control.

Current breeding programs are investigating bloat prevention, grazing tolerance, improved nutrient content, disease resistance and better adaptation to specific situations (for example, cropping rotations). Herbicides are continually being tested in an effort to reduce the costs of establishment and production.

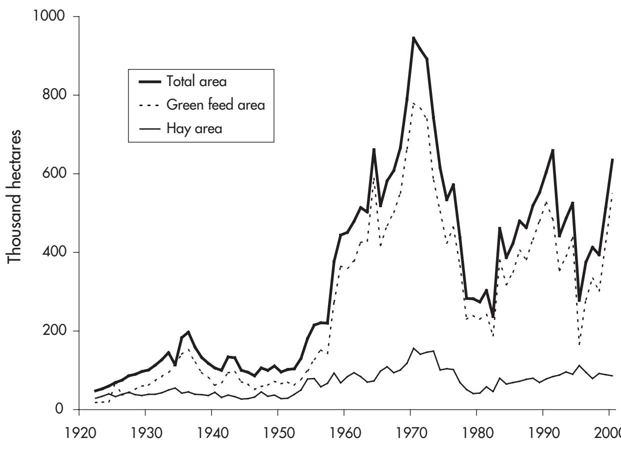
INTRODUCTION

Lucerne (*Medicago sativa* L.) is a high-producing, nutritious legume that is well adapted to a range of climates throughout the world.

Originating in the Middle East, it was introduced into NSW before 1806, and in time spread throughout Australia. It grows in conditions ranging from tropical to temperate and will tolerate frosty winters.

The area of pure lucerne in NSW in 1996 (from Australian Bureau of Statistics data; 1996 was the last year in which statistics were recorded for some issues relating to lucerne production) was approximately 280 000 ha (64 per cent of the total area sown in Australia). Of this area, an unusually high area (40 per cent) was cut for hay in that year (Figure 1); the majority was produced under irrigation, with the remainder under rain-fed conditions. It is also sown in pasture mixtures (almost all rain-fed), with 528 000 ha existing in 1996. A study by Hill and Donald (1996), suggested that NSW was also the State with the greatest potential for further increases in area of lucerne.

Figure 1. Area of lucerne in NSW (Source: Australian Bureau of Statistics 1922–97, estimates 1997–2000)



The area sown has varied markedly over the past twenty years. During the 1970s the area declined because of the trend to move away from pastures towards cropping. This situation was exacerbated by the arrival of the spotted alfalfa aphid in 1977. However, sowing of pure lucerne stands has increased steadily over recent years owing to confidence in new aphid-resistant varieties and increased interest in livestock production. The area of lucerne increased further following the drought years of the early 1990, as the benefits of lucerne as a drought-tolerant plant were highlighted. Approximately 30 per cent of the pure lucerne area and 30 per cent of the mixed lucerne area is resown annually. In 1996, this was equivalent to approximately 83 000 ha of pure lucerne and 153 000 ha in mixed pastures. Although the largest areas of lucerne are grown in the cropping belt, the heaviest concentrations occur along river valleys.

USES

Lucerne may be grown as a pasture for year-round and special-purpose grazing, or for hay, silage, green fodder, pellets, cubes, seed production, sprouts or protein fractionation.

The main use of lucerne in NSW is as a pasture for year-round grazing and in crop rotations. Grown either alone or with other species, it provides good feed in all seasons, provided there is adequate soil moisture.

Whether grazed or used as fodder, lucerne has a high nutritive value relative to other fodder at comparable growth stages: it is high in protein, metabolisable energy, vitamins and minerals, all of which can increase animal production. When sown as a pasture phase, it can improve soil nitrogen levels and control crop weeds such as wild oats and some summer-growing weeds.

Lucerne can also be used as a special-purpose pasture to finish prime lambs and beef cattle in late spring and summer, when other pasture species are low in protein and may have dried off.

The traditional role of lucerne in NSW is as a hay crop, with at least 406 000 t produced annually (1998–99). This represents 44 per cent of the lucerne hay produced in Australia. Production is usually on alluvial river flats and under irrigation, although opportunity hay is also made from dry-land grazing stands. Lucerne often gives higher yields than other pastures and can be made into first-class fodder (especially as hay and chaff). Hay yields from well managed irrigated stands are in the range of 10–22 t/ha, with best yields in the order of 25–27 t/ha under exceptional management and growing conditions.

Export of lucerne products (hay, cubes and meal) from NSW has declined in recent years, with export from the southern States increasing. A number of factors appear to favour this trend, including freight advantages, more favourable harvesting conditions, domestic demand and comparatively attractive domestic prices. The total export market for lucerne products was 150 000 tonnes in 1998–99, most destined for Japan. NSW exports in that year were less than 5 per cent of this tonnage.

Normally, lucerne is made into silage only if it is weedy or when the weather is unfavourable for haymaking. Lucerne can also be harvested and fed fresh to stock as highly nutritious green chop – particularly in feedlots and dairies – but feeding to cattle must be restricted to avoid bloat.

Specialist seed growers produce lucerne seed most efficiently, although some is opportunistically harvested, usually from grazing stands. A small proportion of the seed crop is marketed as alfalfa sprouts for human consumption.

As well as having a role as a legume ley in cropping rotations, lucerne also is used in conjunction with cotton production. Although its use is not widespread, a small area of a cotton field is sown to a strip, border or block of lucerne and managed as it would be for irrigated production. The lucerne strips effectively act as an attractant for some pests and beneficial insects contributing to integrated pest control programs. Associated dryland areas are also occasionally sown to lucerne for the same reason as well as to reduce the cost of weed control.

Potential also exists for protein fractionation, which provides products for specialised livestock feeding and pharmaceutical industries, and for other industrial uses in the area of energy and biodegradable 'plastics'.

SPECIAL FEATURES

Lucerne has a number of features that make it extraordinarily versatile and adaptable.

It is a reliable perennial, capable of producing green feed in most seasons subject to soil moisture and temperature, and often when other pastures are dormant. It can respond to rain in any season, so that the risk of extended feed shortages is greatly reduced and the opportunity for out-of-season production increased.

In suitable soils lucerne develops a long taproot, enabling it to draw on deep soil moisture. Thus, it can continue to grow long after surface moisture is depleted, shallow-rooted plants have wilted, and many annuals have died, giving it a strong competitive advantage over many weeds.

The taproot stores energy that is used to accelerate the production of new shoots. Established lucerne grows much faster after autumn rain than germinating annual species, providing quicker autumn feed and allowing more feed to build up before the onset of winter. This can offset the need for hand feeding.

After the plant is grazed or cut, fresh shoots grow either from the remaining green stems or from buds in the crown (the top part of the taproot). Heavy grazing damages new buds, but in most varieties these are rapidly replaced. The capacity of lucerne to produce buds and shoots from the crown at or below the soil surface promotes its survival, but continual heavy grazing will kill the plant.

Once nodulated, lucerne can fix nitrogen – that is, it can convert atmospheric nitrogen to a form available to the plant with the aid of rhizobium bacteria. This nitrogen allows the plant to maintain high protein levels and build up soil nitrogen. A good lucerne stand can add in excess of 140 kg N/ha to the soil in one year.

Lucerne may live for up to 20 years, although the life of an average stand is closer to five years. As swards age, inappropriate cutting or grazing management, weeds, disease and insects take their toll and the plant's survival declines.

When correctly managed and grown, either alone or with a perennial grass or annual legumes, lucerne restricts the growth and spread of many weeds.

The deep taproot can deplete soil water effectively and lower water tables. This can reduce the effects of salination. Similarly the deep roots can take up leaching soil nitrate, thus reducing the rate of acidification.

PRODUCTION ADVANTAGES AND NUTRITIVE VALUE

Lucerne is valuable as a year-round special-purpose pasture for finishing livestock. The protein and energy levels of well-managed green lucerne are high enough to maintain and fatten growing animals. The plant also contains sufficient concentrations of vitamins and most minerals for all classes of livestock. In spring, it compares very favourably with other pasture

Table 1. Metabolisable energy and crude protein levels of some common pasture species in southern NSW (collated by P Cregan)

Pasture species	Metabolisable energy (MJ/kg dry matter)		Crude protein (%)	
	mid-Sept	mid-Dec	mid-Sept	mid-Dec
Lucerne	10.8	7.8	24	14
Barley grass	9.6	5.7	13	6
Annual ryegrass	10.8	5.6	10	4
Subterranean clover	10.7	5.4	19	8
Phalaris	10.1	5.9	13	5
Vulpia *(Vulpia myuros)*	10.4	6.6	15	5
Demeter fescue	10.5	7.5	15	12
Wallaby grass	10.8	5.3	15	10
(Austrodanthonia spp.)				
Red grass	–	6.8	–	8
(Bothriochloa macra)				
White clover	11.3	7.5	25	14
Kikuyu	10.8	7.5	16	12
Weeks of growth	**6**	**12**	**6**	**12**

species. In summer and autumn, provided there is enough moisture for it to remain green, it is more digestible than species that mature and die off.

Comparative metabolisable energy and crude protein levels are set out in Table 1.

When lucerne is grown with an annual winter-growing legume, its high summer–autumn feed value combines with similar winter–spring feed values to give high-quality nutrition throughout the year.

Livestock production

Livestock production can be substantially increased by using lucerne. At Tamworth, for example, fertilised natural clover pastures can carry 6 dry sheep per hectare, but well managed lucerne can carry up to 15 dry sheep per hectare. At Trangie, with rotational grazing, lucerne has carried 10 dry sheep per hectare, compared with 2.5 dry sheep on naturalised pasture.

Research in the southern districts of NSW has shown that sheep and cattle production can increase by 10–20 per cent if lucerne is included in pastures based on subterranean clover or phalaris. (See Table 2.)

Using lucerne in crop rotations

Lucerne has a long record of use in our cropping systems. In northern NSW it is the most popular legume, whereas in the central areas lucerne and annuals such as subterranean clover and annual medics are of equal importance. In the south, annual legumes have traditionally been the most important legume, but lucerne is still important for opportunistic summer feed after rain, and larger areas are now being sown in the south.

The advantages of using lucerne in crop rotations are many:

- Reliable source of quality feed.
- Drought tolerant.
- The complementarity of lucerne-based livestock enterprise and winter cereals is high, providing a diversification of income.
- Contributes nitrogen to succeeding crops.
- Breaks the disease cycle in many crops.
- Improves soil structure (although much less than perennial grass-based pastures).
- Uses soil water to depth, reducing the effects of rising watertables in cropping systems and thus reducing the risk of salinisation.
- Can effectively control weeds of crops (for example, wild oats) when combined with good grazing management.
- Can be effectively undersown in most districts, given good sowing practice.

Table 2. Increases in animal production obtained in experiments from animals grazing lucerne-based pastures. Collated by E Wolfe and P Cregan (Wolfe 1983)

Experiment	Livestock	Product	Production increase from lucerne (%)*
Canberra 1967–68	Lambs and weaners	Wool (per fleece)	+ 10
	Lamb (growth per head)	+ 46	
Wagga 1969–72	Ewes and lambs	Wool	+ 10
	Lamb growth	+ 43	
Wagga 1969–73	Dry ewes	Wool	+ 12
Temora 1969–73	Ewes and lambs	Wool	+ 21
	Lamb growth	+ 15	
Canberra 1972	Steers	Steer (growth per head)	+ 103
Canberra 1973–75	Steers	Steer (growth per head)	+ 9
Wagga Wagga 1975	Steers	Steer growth	+ 11
Wagga Wagga 1976	Steers	Steer growth	+ 128
Wagga Wagga 1977	Steers	Steer growth	+ 11
Glen Innes 1984–87	Weaners	Lamb	+ 6
	Wool	+ 6	
Canberra 1981–85	Weaners	Lamb	+ 21

*In these experiments the production from animals grazing combinations of lucerne and subterranean clover or phalaris was compared with the production from animals grazing annual grass and/or phalaris with subterranean clover or, in the case of experiments at Glen Innes, with white clover.

- Reduces the leaching of nitrate nitrogen to the subsoil, thereby reducing the risk of soil acidification.
- Maintains levels of vesicular arbuscular micorrhiza (VAM) for subsequent crops.
- Improves soil fauna and ground cover relative to continuous cropping.

There are a number of issues that managers need to take into account where lucerne is the primary species used in rotations, especially in extensive cropping areas. Fortunately, sound management can reduce the potential impact of many of these issues. The issues are:

- Livestock disorders, for example, bloat. (See *Livestock health on lucerne*.)
- Lucerne dries out the soil profile, often disadvantaging the following crop. Remove lucerne early enough to make nitrogen and moisture available to the following crop.
- Limited herbicide options are available for low-cost weed management. Plan for weed control during the cropping phase and use sound grazing management to reduce many weed problems.
- Infrastructure (watering and fencing) should be such that lucerne can be rotationally grazed, or rested strategically to allow replenishment of root reserves. Low-cost electric fencing can be used to effect.
- Lucerne is less effective in building soil structure than grass-based pastures. Therefore, include other species where soil structure or erosion is a particular concern.
- Lucerne can be difficult to remove to provide weed-free fallow. Early planning and strategic timing of herbicides will allow greater flexibility.
- Leaf drop occurs under severe moisture shortage. Diversification of pasture types and use of forage crops and fodder conservation can be used to reduce the impact.

Nitrogen (N)

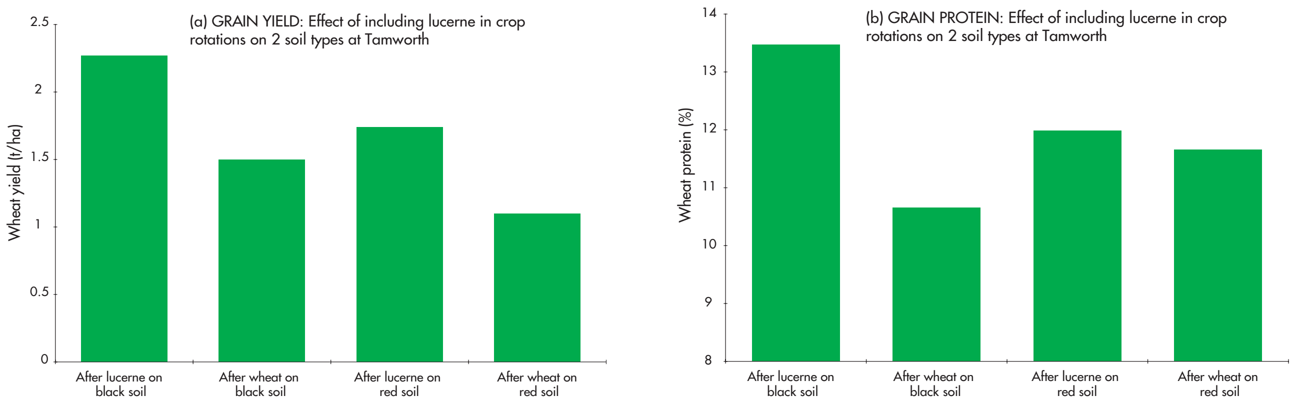
Lucerne nodules fix adequate nitrogen for the plant and also add nitrogen to the soil. The contribution of nitrogen to the soil is directly related to the amount of above-ground plant material produced. The duration of the lucerne phase can also have an effect, as can the management of lucerne.

Approximately 15–25 kg N is fixed for every tonne of dry matter produced. A similar amount is fixed below ground. While 25 kg N/ha/t may be fixed under ideal irrigated conditions, it is evident that under our wheatbelt conditions the contribution is of the order of 15–20 kg N/ha/t of dry matter. Lower rates of fixation have, however, been recorded in drier parts of the wheat belt (for example, 9 kg N/ha/t in the Trangie and Condobolin districts).

As soil nitrogen levels increase, lucerne will use soil nitrogen itself, in preference to fixing nitrogen. The benefit to soil nitrogen will depend on the productivity, plant density, weed content, management (for example, nutrition, grazing/cutting regime) and the duration of the lucerne pasture.

Research at Tamworth has shown that a lucerne phase of two and a half years in a cropping rotation can improve grain yields and protein levels because of added nitrogen from lucerne. These improvements are considered adequate to support two to three wheat crops on red-brown earth soil and three to five wheat crops on black earth soils, depending on the background soil nitrogen present. In addition, an improvement

Figure 2. Effect of a lucerne phase on the subsequent yield and grain protein percentage of wheat following lucerne compared with continuous wheat at Tamworth (Source: G Crocker, NSW Agriculture)



exceeding two percentage units in grain protein can be expected (Figure 2), depending on yield and seasonal influences. Benefits are directly related to the amount of forage produced by lucerne, so that management decisions that enhance production (for example, grazing management and nutrition) help the nitrogen input into the system.

The same trials examined the amount of bag nitrogen needed to grow wheat of similar yield and quality on these two nitrogen-deficient soil types. The equivalent amount of nitrogen needed to equal the effects of a three-year phase of well-managed lucerne ranged from 55 kg/ha to 125 kg/ha of nitrogen per season.

To get the maximum benefit from lucerne in a rotation, stands must be sufficiently dense, inoculated, relatively weed free, rotationally grazed and maintained in a healthy condition. Selection of a suitable variety and maintenance of soil nutrients can be important factors.

Similarly, in rotation with sorghum, large beneficial effects from lucerne have been measured in both grain yield and protein content for at least four years following well-managed lucerne (3.5-year phase). As with wheat, the effects have been more pronounced on black earth soils than on red-brown earth soils.

DISTRIBUTION AND CLIMATIC LIMITATIONS

Apart from rainfall, climatic limitations on the growth of lucerne in NSW are few it is other factors, such as soil type and pasture management, that restrict establishment and production.

The western limit of lucerne under rain-fed conditions corresponds to the western limit of the cropping zone. This approximates to the 350 mm long-term average annual rainfall isohyet in southern districts and the 400-mm isohyet in the far north of the State. As rainfall decreases, so does the potential for lucerne production.

The major growing areas are on the slopes and near plains, where lucerne is usually grown in association with crops. To the west, production declines owing to low rainfall. To the east, less suitable soil types and poor drainage, and on the coast, a higher incidence of disease, reduce the potential for high production.

The potential yield of lucerne is generally higher in northern inland areas than in southern districts because of higher summer rainfall and a slightly longer growing season.

The best temperature for lucerne growth is around 25°C. Reasonable production occurs in the range 10°C–30°C, but below 10°C, production can be significantly lower (for example, on cooler, elevated tablelands). Marked yield reductions are likely in western districts when temperatures reach around 40°C, despite the presence of adequate soil moisture (the so-called ‘summer slump’). Lucerne will germinate over a wide range of temperatures with an optimum of 19°C–25°C.

Lucerne is tolerant of frost, but there may be leaf damage to actively growing plants, especially if they have not been conditioned by a period of low temperatures before frost. ‘Frost lift’ and subsequent seedling death is not uncommon with late autumn-winter sowings on the tablelands. Lucerne can survive under snow when dormant.

The higher rainfall and humidity in coastal districts generally create greater weed and disease problems. These can be partly overcome by using disease-resistant varieties.

SOIL REQUIREMENTS

Lucerne will grow on a variety of soils, but does best on deep, well-drained soils of medium to light texture where the pH (Ca) of the topsoil lies between 6.0 and 7.0, with very low levels of exchangeable aluminium in the soil (less than 5 per cent). For best results, a good supply of calcium is also required. Other nutrients are also required. (See also *Nutrition* section.)

Rich alluvial soils are ideal, but lucerne also thrives on most of the red earths, red-brown earths, and well-drained black and grey soils found throughout the cropping zone. Native timbers like white box (*Eucalyptus albens*), yellow box (*E. melliodora*), bimble box (*E. populneum*), and kurrajong (*Brachychiton populneum*) indicate good drainage and deep soils that are not too acid. Skeleton weed is also a sign of deep, well-drained soil.

Established lucerne tolerates saline soils moderately well, but seedlings are less tolerant. Because of this tolerance it has a role in reclamation of slightly saline areas by lowering watertables.

Poorly drained soils

Although healthy, established lucerne can survive a brief period of flooding in moving water (two or three days), waterlogging often kills or weakens lucerne plants, particularly when temperatures are high. These high temperatures can increase plant death (a condition known as 'scald').

The presence of one or more of the following features indicates areas less suited to the long-term survival and production of lucerne:

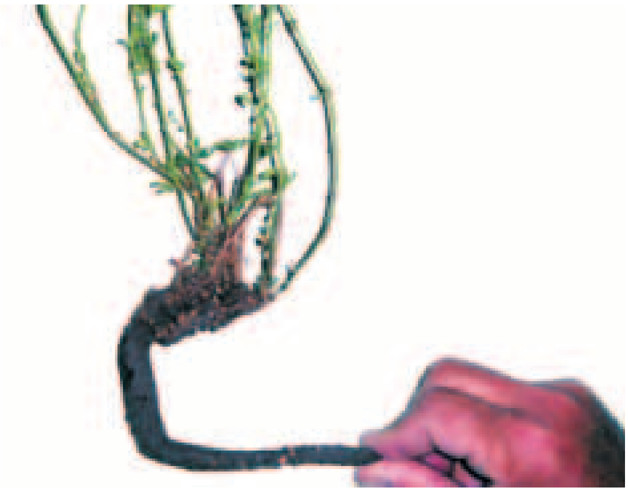
- boggy seepages
- impermeable clay subsoil
- light-coloured surface soil with yellow or grey clay subsoil and ironstone concretions
- valley floors prone to frequent flooding – the problem is compounded if the soil is heavy and subject to surface sealing
- smooth-barked eucalypts (gum trees) on poorly drained soils
- rushes and sedges.

When sowing in these conditions, select varieties with high resistance to root rot, and either consider improving soil drainage or accept a shorter stand life. Gypsum can improve water infiltration where high soil sodium levels are responsible for poor structure.

Acid soils

Lucerne is not as well adapted as subterranean clover and some other clovers to acid soils, especially those with a pH (Ca) less than 5.2.

The distorted roots on this plant emphasise the need for deep well drained soils. Plough pans can be particularly troublesome.



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Acid soils are usually deficient in calcium and molybdenum, and hence inhibit nodulation and root growth. Highly acid soils may also have toxic levels of aluminium and manganese, a problem magnified by fluctuations in moisture and temperature.

On soils with an acid topsoil and a satisfactory subsoil, lucerne can grow satisfactorily provided special techniques are used in the establishment phase. (See the section on *Establishing lucerne on acid soils*.)

The growing and removal of lucerne hay has an overall acidifying effect, and the need to correct pH should be monitored over time and ameliorated with lime when appropriate.

VARIETIES

There are now more than 30 varieties of lucerne available.

These varieties have a wide range of pest and disease resistances and growth patterns. Choosing a lucerne variety is a matter of matching the paddock to be sown with the intended use of the stand.

When selecting a variety, you should consider:

- the desired stand life
- aphid and disease resistance
- growth pattern and yield
- availability and price of seed.

Stand life

The lifespan of a stand is determined by the interactions between pests, diseases, environmental factors and management practices.

Where ley farming is practised, a stand life of three or four years is usually adequate and attainable, unless severe disease or pest problems are encountered.

When longevity is important, variety selection is critical, as is good management (for example, rotational grazing of lucerne). Likely pest and disease problems must be identified before sowing. If in doubt, consult your agronomist about possible problems, as the use of pest-resistant varieties can reduce losses and improve persistence. Pests and diseases of lucerne are described in the final section of this Agfact.

The dormancy characteristic of varieties is also important. Semi-dormant varieties with adequate resistance to disease and insects persist longer under harsh grazing than similarly pest-resistant highly winter-active varieties. Some winter-active varieties, however, combine the benefits of winter activity with the better persistence of semi-dormant varieties.

Aphid resistance

Resistance to the spotted alfalfa aphid (SAA) and blue green aphid (BGA) is essential. The old variety Hunter River is not recommended, as it is extremely susceptible to SAA and BGA.

Growing varieties that are susceptible to aphids allows aphid numbers to build up, increasing damage. This in turn adds to the cost of production and increases the rate of development of insecticide resistance. It also increases the risk of aphid strains developing that can damage varieties currently resistant to aphids.

Disease resistance

The need to select for disease resistance depends very much on the paddock characteristics.

It is essential to select a variety with resistance to *Phytophthora* root rot if you are sowing into soils that are poorly drained or occasionally waterlogged. Root rot resistant varieties should also be selected if you intend to irrigate. There is no variety resistant to waterlogging. It is desirable to have resistance to anthracnose, as occasional damage occurs from the crown rot form of this disease (*Colletotrichum* crown rot) on the coast and in central and northern NSW, especially in humid environments.

Unfortunately, there is no lucerne variety that is resistant to common crown rot, a damaging disease that is widespread.

Resistance to the less widespread diseases, bacterial wilt and stem nematode, is important on the coast and in some inland river valleys.

Your local agronomist can advise you whether these diseases are likely to be a problem.

Unfortunately there is very limited resistance to the range of leaf diseases that cause damage, especially in the autumn. There are, however, a number of varieties with resistance to *Stemphyllium* leaf spot. Many highly winter-active varieties tend to be particularly affected by leaf diseases in the field under humid conditions.

Growth pattern and yield

Lucerne varieties span a wide range of growth patterns, from highly winter-active to winter-dormant. However, all varieties grow best from late spring to early autumn.

Examples of varieties are:

- highly winter active: CUF101, Aquarius
- winter active: Aurora, Trifecta

Varieties do make a difference. In this 10-year-old trial at Cooma, the highly winter active variety to the left did not survive the management and growing conditions, unlike the dormant variety to the right.

W MCDONALD

- semi-dormant: Venus, Hunter River
- winter dormant: Prime, Pioneer Brand 54Q53.

Highly winter-active and winter-active varieties are generally more productive than semi-dormant and dormant varieties during the first three years. They have more vigorous seedlings, and recover faster after cutting or grazing. However, they lose quality relatively quickly when they are too mature, and they are less persistent under heavy grazing, particularly where disease is prevalent.

Winter-dormant varieties, having lower seedling vigour, are not well suited to late autumn–winter sowings in cooler districts. They are generally not suitable for dryland sowing because they do not grow well in times of feed shortage (autumn–early winter). They have, however, performed well in the colder areas of the Southern Tablelands, especially on the Monaro, and for specialist irrigated hay production. Winter dormant varieties, once established, tend to display excellent persistence.

In southern districts semi-dormant varieties out-yield highly winter-active varieties in the hay-cutting season, whereas highly winter-active varieties yield better than semi-dormant varieties from late autumn to early spring. Total yields from these groups are similar.

In northern districts (which are favoured by a longer growing season), well-adapted, highly

The low crown of a winter dormant variety on the left contrasts with the erect crown of a highly active variety on the right.

W MCDONALD

winter-active varieties have shown greater overall yield potential (in the order of 12 per cent) than semi-dormant varieties. However, management needs to be at a high level to take advantage of this gain.

The extra winter production from winter-active and highly winter-active varieties has proved valuable to livestock production in the cooler months.

Winter-active varieties have proven popular throughout much of the lucerne-growing area of the State, as they combine some of the advantages of both the highly winter-active group and the semi-dormant group of varieties.

Consult the NSW Agriculture web site or your agronomist for the latest information on variety availability and disease and pest resistance.

Current breeding programs in Australia aim to develop varieties that are more tolerant of grazing; resistant to leaf diseases; higher yielding; targeted at specific uses (such as ley rotations); less likely to cause bloat; and able to produce more wool from the same quantity of lucerne.

ESTABLISHMENT

Sowing time

Four main factors determine sowing time:

- moisture: enough moisture must be available for germination and seedling development in the spring
- temperature: there must be enough time for a strong seedling to develop before frosts and low temperatures or hot, dry weather sets in
- competition: competition from weeds and cover crop (if used) must be low
- companion species: consider the sowing requirements of a companion crop (if used) and companion pasture species.

Autumn and spring are the best times to sow lucerne. Avoid winter sowing in colder, wet localities, especially if the variety is winter-dormant. Sowing in early spring is suited only if you are sowing under irrigation or in districts where the spring rainfall is reliable.

The ideal time to sow in the wheat belt is mid-April to mid-May in the south of NSW, extending to mid-June in the north. Establishment has, of course, been successful outside these periods, with earlier sowing in the south and sowing often extending into July in the north. Winter sowing may have more reliable soil moisture for germination, but earlier sowing give seedlings more time to establish before the onset of cold weather and provides a better chance of survival in a dry spring. The slow growth following winter sowing leaves plants prone to damage by insects and disease, as well as being less competitive against weeds. An effective fungicide seed treatment is available to reduce effects of disease on emerging seedlings.

When a dense hay stand is required, sowing in early spring (late August–early September) often produces good results. However, there must be enough moisture to maintain seedling growth until late spring. Seedlings grow faster in spring than in autumn, as long as moisture is adequate and there is no competition from companion crops or summer weeds (for example, nutgrass, barnyard grass and wireweed). Spring sowing also reduces the risk of damage from earth mites and lucerne flea. If summer weeds are likely to be a serious problem, it may be best to sow in autumn.

On the wetter slopes and tablelands, spring sowing avoids slow winter growth and prolonged waterlogging, which is particularly damaging on acid soils. However, spring-sown seedlings may be at risk if high temperatures and or dry conditions are encountered.

Varieties and time of sowing

Varieties differ in seedling vigour, particularly when sown in winter. Generally, the seedlings of winter-dormant varieties grow more slowly, so varieties should be sown as early as possible in autumn or in spring. The winter-active varieties establish rapidly from a late autumn–winter sowing, except in very cold districts.

Preparing the seedbed

The ideal seedbed for lucerne is of reasonably fine tilth, free of weeds, and well compacted (firm 2 cm below the soil surface). This allows for good seed to soil contact. Most failures result from inadequate, hasty preparation. However, failure can also result from overworking a seedbed. If a pre-emergent herbicide is to be used, allow for the incorporation cultivation. **Do not overwork the seedbed.**

Ideally, plant one or two crops before sowing lucerne into newly cleared country or after pasture or lucerne. This helps to control weeds, diseases and insect pests and gives a cleaner seedbed. Sowing lucerne into loose soil and rolling before sowing will give better control of the depth of sowing.

If you are sowing lucerne with a companion crop (usually a winter cereal), a well-prepared seedbed tilth suited to cereals is generally a reasonable compromise. Ensure, however, that the lucerne is sown shallow (see below), and level the seedbed with a levelling bar in front of where the lucerne seed in sown.

Fallowing helps to store soil moisture and control weeds. It increases the chance of success in the drier parts of the wheat belt, and is necessary for good, consistent establishment of lucerne in the western sections of the central and northern wheat belt.

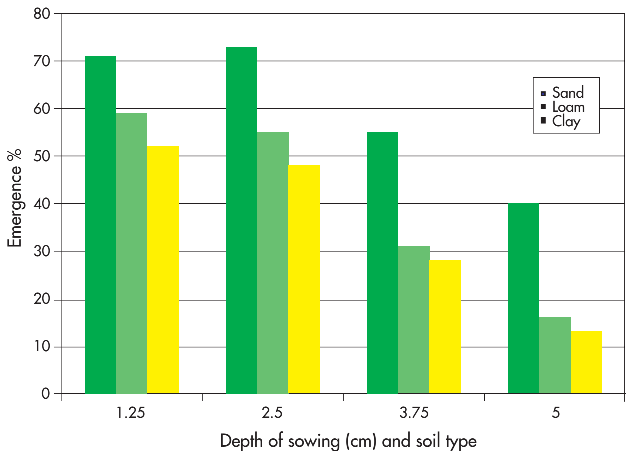
Sowing

Aim to place the seed in the best environment for germination and establishment. Techniques vary with soil and topography. If surface moisture is likely to last, a sowing depth of 1 cm is ideal. Under quick drying conditions sowing deeper (to 2–2.5 cm) may be a compromise, but a poorer establishment may result. Always aim to sow as near as possible to the ideal depth, adjusting for soil type, moisture content, sowing time and fertiliser placement (described later). Sowing too deep can result in unsatisfactory establishment. (See Figure 3.)

Combine or drill sowing

The most common method is to drop the seed onto the soil surface from a small pasture seed box attached to a combine or drill and then cover it using light trailing harrows. This method is satisfactory when the topsoil is likely to remain moist until seedlings emerge.

Figure 3. The effect of sowing depth (cm) on the percentage of lucerne emergence in different soil types (Sund *et al.* 1966)



For better results, smooth the soil surface with a levelling bar in front of the down-tubes from the small seed box, and trail a set of light harrows or a piece of mesh to just cover the seed. A band seeder attachment places seed more accurately.

Where the surface soil dries out quickly (as with early autumn or late spring sowings, or in the drier western part of the wheat belt), drilling 2–2.5 cm deep on a firm, moist bottom and covering with harrows helps the seedlings to establish.

On deep sands and self-mulching soils, where it is often difficult to keep the soil around the seed moist, use the furrow-sowing technique. In this technique the seed is directed through tubes from the small seed box to behind the rear cultivating tines. It is then placed on the firm, moist bottom of the furrow made by the tines and covered with up to a maximum of 2.5 cm of soil. Trailing harrows are not used. Subsequent movement of vehicles and machinery is not greatly impeded, as the furrows level out in time.

Using a roller after sowing can improve emergence if moisture at sowing depth is barely adequate. Do not roll soils that are prone to crusting. The use of press wheels aligned with sowing tines or band seeder tubes gives a significant improvement, and is advantageous because weed seeds between sown rows are not encouraged to establish.

Sowing lucerne with an air seeder has resulted in many failures because of deep sowing (Fig. 3). Modifications to air seeders to ensure shallow sowing, trailing a independent band seeder in tandem, or sowing as a separate operation with a band seeder are common ways to overcome the problem.

Sowing lucerne seed into a dry seedbed and irrigating or waiting for rain is usually successful only if the seedbed is free of weed seeds that might establish and compete.

After sowing, make regular thorough inspections for earth mites. (see the section on *Pests and diseases*.) Spray immediately with a registered insecticide if mite numbers are high or seedlings are damaged. If lucerne is sown after a long fallow or a stubble burn, it is usually necessary to treat only a strip around the perimeter of the paddock to stop mites migrating from surrounding areas.

Direct drilling
Sowing lucerne into an existing pasture is possible. This normally involves preventing competitive annual weeds from seeding in the spring and controlling pasture growth until the autumn. Competition from the existing pasture is usually controlled with herbicides just before sowing. Sowing is best done with a minimum-disturbance machine and the seedlings managed to ensure establishment.

Direct drilling lucerne into old lucerne to improve density has met with variable success. (See section on *Renovation*.)

Old lucerne stands have the disadvantage of a build-up of weeds, lucerne pests and diseases. Furthermore, the older lucerne plants will out-compete the seedlings if moisture becomes scarce.

Surface sowing
Lucerne has been established successfully by surface sowing on non-arable tableland country, where it is usually mixed with perennial grasses. Use the same management techniques as those used for direct drilling. Sow only where lucerne cannot be sown into prepared seedbeds or by direct drilling and where herbicide drift is not a problem. Where native vegetation is involved, consult the Department of Land and Water Conservation to ensure compliance with the *Native Vegetation Conservation Act 1997.*

COMPANION CROPS

Lucerne should be sown by itself for best results. Sowing with cover or companion crops increases the risk of a poor establishment and weakens lucerne plants so that survival through the first summer can be jeopardised.

Companion crops have nevertheless been used very successfully over a wide area of the State. Failures tend to be greater where spring rainfall is unreliable, where lucerne is not well adapted (for example, acid soils, shallow soils), where lucerne is sown late, where the cover-crop sowing rate or row spacing is inappropriate, or where a combination of these factors is present.

Crops such as cereals, linseed, sunflowers, lupins, Japanese millet, canola and turnips have been used, with cereals being by far the most popular. Companion crops do, however, compete with lucerne seedlings for moisture and nutrients; they can also deprive the lucerne plants of sunlight if sown too densely. Sowing the crop and lucerne in alternate rows is a successful method of establishing a companion crop in the wheat belt, but additional attention may be needed to control weeds and reduce erosion risk on some sloping country.

If a cereal crop is used, there are three main points to consider:

- Choose a short-strawed, erect variety if possible. Short, two-row barleys are best, followed by short-strawed wheats, taller-growing wheats, triticale, grain oats, and grazing barley or grazing oats.
- If rain delays the grain harvest and promotes the growth of lucerne seedlings (especially with the highly winter-active varieties), the green lucerne may cause harvesting difficulties with the shorter-growing cereals.
- The poorest companion crops are the cereals that tiller most (for example, forage oats), as their profuse growth overshadows the undersown pasture.

Use low seeding rates for companion crops
Sow cereal companion crops at about 50–75 per cent of the recommended rate for grain crops in the district. The lower the seeding rate, the greater the advantage to lucerne in seasons of average to below average rainfall.

Sow early
Lucerne is best sown early (before the middle of May), so the companion crop should be suited to sowing at the same time. Rather than delay sowing until a better companion crop can be sown, it is sometimes preferable to sow lucerne early with a reduced seeding rate of the companion crop, and to graze it lightly in winter.

Harvesting a cereal companion crop
When harvesting a heavy-strawed companion crop there is a risk that straw residue will smother the lucerne, so use a header straw-spreader to scatter the straw evenly. Also as mentioned above, tall green lucerne plant material can interfere with harvesting.

SEEDING RATE

Always use good quality certified or quality assured seed that is true to type. Hard seed is unlikely to contribute to stand density.

Imported seed is usually of certification standard. However, it is still advisable to check a recent

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Band seeders mounted on the rear of combines have successfully increased the reliability of establishment.

germination test, since correct seeding rates cannot otherwise be determined.

There are about 440 000 lucerne seeds per kilogram; at a seeding rate of 1 kg/ha this gives 44 seeds/m^2. Under good field conditions, 20–25 plants/m^2 will normally establish from this quantity. However, losses from disease and weeds can reduce this figure further.

The initial density of lucerne grown for good quality irrigated hay production needs to be at least 130 plants/m^2. Higher rates give higher yields and better weed control in the first year but little yield advantage in later seasons, although a quality advantage may persist for some time. Yields tend to drop significantly when lucerne densities fall below 50–60 plants/m^2.

Highly winter-active varieties have fewer stems than the larger-crowned dormant lucernes, and density is more critical, as they may not make the same compensatory growth as the winter-dormant varieties when density declines. A sparse sward will not give top yields, and stems will become too thick and woody (although the density is often suitable for seed crops).

The choice of seeding rate also depends largely on the care taken at sowing, the climate, and the condition of the soil at sowing time. Under ideal conditions low seeding rates can be very successful. When using companion crops, increase the seeding rate of lucerne by 25 per cent.

The following suggestions are for seed with a germination rate above 80 per cent.

Pure lucerne for hay and occasional grazing
For full irrigation 12–15 kg/ha is adequate. Higher rates (up to 20 kg/ha) are used by some farmers. The main benefit is in the first year, with increased yield and better weed control.

Seeding rates of 4–6 kg/ha are suitable in high rainfall and favourable dryland areas. However, in most dryland situations high seeding rates are wasteful, as the plants rapidly thin out during periods of moisture stress. A rate of 4 kg/ha of lucerne seed is usually adequate. On good creek or river flat soils, where moisture is quite reliable, this can be increased to 6–8 kg/ha.

Lucerne pasture for year-round grazing
A satisfactory pasture for year-round production in the more reliable areas of the wheat belt has in excess of 30 plants/m^2 at establishment, with 15–20 plants/m^2 remaining the following winter. In the marginal cropping areas, productive lucerne pastures tend to have densities in the range of 7–12 plants/m^2.

In southern and central NSW, lucerne for grazing is sown as a mixture with other species, especially subterranean clover. In this case it is usually sown at 2 kg/ha and subterranean clover at 5 kg/ha. With good sowing techniques, however, the amount of lucerne in this mixture can be reduced to 1 kg/ha. If a perennial grass is needed, add it at the rate of 1–2 kg/ha.

In northern and parts of central NSW, grazing lucerne is more often sown as a pure stand. A seeding rate of 1–2 kg/ha is satisfactory in drier areas. To the east of the State, as rainfall increases, raise the seeding rate to 2–3 kg/ha where the annual rainfall is around 600 mm, and to 3–4 kg/ha where the annual rainfall is 750 mm or more. Again, in the wheat belt, an initial density of 30 plants per square metre indicates excellent establishment, with the pasture thinning to around 15–20 plants in the following season and thus providing optimum production. If sowing lucerne with tropical grasses, keep the seeding rate of lucerne low (0.5–0.75 kg/ha) to reduce the effects of lucerne out-competing the perennial grass.

In the drier, western margin of the wheat belt, a density of 5–8 plants/m^2 is regarded as satisfactory for optimum production under the drier conditions.

Seed stands
Specialised stands for seed production under irrigation are sown at a maximum of 1 kg/ha. However, many seed production areas are dual purpose (grazing/cutting) and sown at a rate of 2–3 kg/ha.

INOCULATION AND LIME PELLETING

Lucerne, like all legumes, obtains its nitrogen from the air with the help of bacteria (*Rhizobia*) that form nodules on the roots. On old lucerne plants nodules are usually difficult to find, as they occur on fine roots. Nodules on inoculated seedlings at the three- or four-leaf stage should be easily visible clustered on the main root just below ground level. Effective nodules are pink inside. Plants that nodulate without the addition of inoculant tend to develop more widely scattered nodules.

The nodule-forming bacteria live on nutrients from the plant. In return, they provide nitrogen in a form the plant can use. There are many strains of these bacteria, each specific to a particular legume or group of legumes and needing certain conditions for survival.

The more acid the soil (that is, the lower the pH) the less likely it is that the required number of bacteria will be present to form nodules quickly and fix nitrogen. Molybdenum, often deficient in acid soils, plays a vital role in nitrogen fixation.

When buying the inoculum make sure it is the correct one for lucerne (group AL). Some pesticides used for seed treatment can kill the bacteria.

In some situations, inoculation has not given a large response. For example, where the soil pH (Ca) is more than 5.5, and where healthy lucerne and/or annual medics have been grown recently. Generally, though, inoculation should be a routine procedure, as it is inexpensive insurance. It is essential on soils with inherently low fertility or after extended cropping, which seriously depletes the nitrogen level, or on soils where the pH (Ca) is less than 5.5.

If there is any doubt as to the need to inoculate, then inoculate and pellet. Directions for this procedure are readily obtainable on inoculant packets or in Agfact P2.2.7 *Inoculating and* *pelleting pasture legume seed*, available from NSW Agriculture web site (www.agric.nsw.gov.au)

After inoculation, sow seed as soon as possible (always within 12 hours). Keep inoculated seed in a cool, shady place until you are ready to sow. If seed has also been lime-pelleted, it can be stored in this way for up to a week. However, even under these conditions many of the bacteria will die, so whenever possible avoid storing treated seed.

Follow this procedure for pre-inoculated seed products as well. Although the shelf life of these products may be enhanced, the survival of bacteria will be greater the better it is stored and the sooner it is sown after purchase.

When you are sowing pasture alone, it is often more satisfactory to mix lime-pelleted seed with the fertiliser and sow shallow.

Lime-pellet inoculated seed before mixing it with fertiliser – otherwise the fertiliser will kill the bacteria. Do not store pelleted seed in close contact with fertilisers or agricultural chemicals. Note that many growers now add molybdenum as part of this process. (See under *Nutrition*.)

Where inoculation failure is evident in a paddock, consult the Agfact mentioned above.

ESTABLISHING LUCERNE ON ACID SOILS

Lucerne is difficult to establish if the top 10 cm of soil has a pH (Ca) below 5.2 and the exchangeable aluminium level is greater than 5 per cent. Acid soils are more common in higher rainfall zones (those with an average annual rainfall of 550 mm or more in southern NSW or 650 mm in northern districts), and are more widespread in the south than in the north of NSW. In drier districts, skeletal ridge country is sometimes acid.

When checking for soil acidity, take into account the pH of the subsoil as well. Correcting acidity in the surface soil will help lucerne to establish, but an acid subsoil can adversely affect root development. Your district agronomist can provide information on the pH levels of your soils.

Overcoming acidity and aluminium toxicity

On mildly acid soils (pH (Ca) of 5.1–5.4) inoculation and lime pelleting or banding with lime and appropriate rates of molybdenum and phosphorus will assist establishment. Banding with agricultural lime has been very successful, especially at pH levels around 5.1; mix 100–250 kg/ha of lime with superphosphate (or equivalent fertiliser) and sow the seed into the band.

If you are applying lime through a combine, mix it with superphosphate first so it will flow freely, or spread bags of each alternately into the fertiliser box and mix. A mixture of lime and superphosphate in equal parts is available, but lime is more expensive in this form. On the wetter slopes of southern NSW, some farmers have had more success in establishing lucerne on acid soils by tripling the ratio of lime to superphosphate.

On moderately acid soils and on very acid soils (pH (Ca) 4.5) especially where aluminium toxicity is a problem, more than 2.5 t/ha of lime may be needed (a soil test will indicate quantity required). Since lime reacts slowly with soil, and moves very slowly down the soil profile, work it well into the soil before sowing (6–8 weeks at least). This procedure is most successful when it is combined with inoculating and lime-pelleting seed and then drilling it in with a lime-superphosphate mixture.

SPECIES TO GROW WITH LUCERNE

In the wheat belt, where winter active and semi-dormant lucerne varieties are grown for grazing, lucerne can be sown with an annual legume (either subterranean clover or medic). This can result in better animal weight gains (Table 2) and reduce supplementary feeding.

The winter production of subterranean clover or medic complements the spring, summer and autumn production of lucerne, especially where semi-dormant lucerne varieties are grown as opposed to winter-active varieties (Figure 4).

Combining an annual legume (such as balansa clover or subterranean clover) with lucerne has an added advantage. In long pasture phases where lucerne density tends to decline, the annual legume can improve in density, ensuring the presence of a reliable legume component, as well as improving the winter productivity of the pasture.

Choose the correct variety of annual legume suited to the soil type, rainfall and intended use. Sow a mixture of two or three annual legumes of differing maturity, ranging from the variety normally sown as pure annual pasture to a variety that matures one or two weeks earlier, to give a mixture adapted to a wider range of seasonal and paddock conditions. Also, after rainfall in summer or early autumn, lucerne grows rapidly and quickly dries out the soil surface. As a result, substantial numbers of newly germinated clover or medic seedlings will 'burn off' if no more rain falls. Select subterranean clover varieties with a high percentage of hard seed, which is more resistant to premature germination in summer–autumn.

Improved medic varieties have a narrow range of maturity. The variety best adapted to the locality should be sown with lucerne. Varieties resistant or tolerant to aphids can prevent build-up before spring, reducing pressure on lucerne growing in the area.

Aim for a moderate lucerne density (no more than 20 well-established plants/m^2) to ensure the persistence of subterranean clover with lucerne.

Adding a perennial grass to the mixture

Growing a perennial grass with lucerne can reduce the risk of bloat and add stability if a long-term pasture is needed. Erect winter active varieties of phalaris (for example, Holdfast, Sirosa) are suited to districts with a minimum average annual rainfall of 525 mm in the south of the State and 675 mm in the north. Varieties such as Atlas PG, which have a degree of summer dormancy, may be more suited to the drier margins of such areas. In districts with higher rainfall (for example, above average annual rainfall of 700 mm), a wider range of grasses can be used. Grasses check soil erosion more effectively than lucerne, and they also have a greater potential to improve soil structure and improve water infiltration. They can, however, act as hosts for some diseases of cereal crops.

Under extended dry conditions lucerne can suppress some perennial grasses like phalaris and fescue. However, lucerne may thin early unless grazing management is appropriate.

Table 3. Quantities of major nutrients removed in 1 tonne of lucerne hay

Nutrient	kg removed
Phosphorus	2.5
Potassium	21.0
Calcium	12.0
Sulfur	3.0

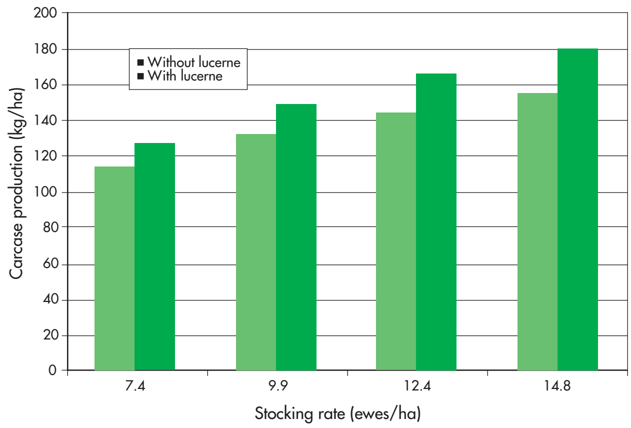

Figure 4. Production of prime lamb carcases (kg/ha) from a spring lambing over four years

Direct drilling winter cereals (for example, oats) or forage ryegrass into aging lucerne stands can boost winter production and reduce the bloat risk. In drier districts this technique can be unreliable, because lucerne dries out the soil profile over the summer, so that there is often not enough moisture in the soil at optimum sowing time.

NUTRITION AND FERTILISER

Fertile soil is needed for maximum production and persistence. Good soil fertility also promotes quicker regrowth after cutting or grazing. A lack of nutrients in the soil can arise from:

- a low natural level of nutrients
- depletion of nutrients by continual removal in the form of crop, conserved fodder or animal products
- an imbalance caused by incorrect use of fertiliser.

When high-yielding lucerne is cut for hay, more nutrients are removed from the soil than with grazed pastures and cereal crops. This applies particularly to phosphorus, nitrogen, potassium and calcium. (See Table 3.) The removal of large quantities of hay also has an acidifying effect. This effect is the equivalent of 70 kg/ha of lime for every tonne of hay removed. Some soils will require the application of lime to offset this effect, especially if the paddock is used as a hay or silage paddock. Monitoring pH by soil testing will indicate if there is a problem.

If lucerne has been effectively nodulated it will not respond to added nitrogenous fertiliser, but deficiencies of other nutrients can be corrected with fertilisers. Do not wait for severe symptoms of deficiency to appear before applying fertilisers – by then, production may have been checked. Use soil tests, tissue analysis and paddock records to diagnose likely deficiencies.

The lack of a single element can restrict production, even though all other nutrients are plentiful, and growth will not improve until the level of the limiting nutrient is raised. Deficiency symptoms can be misleading, and care is needed in identifying and treating them; in some instances, where there is an interaction between particular nutrients, a shortage of one may show up as a toxic level of another and vice versa.

Placement of fertiliser

Different methods can be used, but there are some basic principles that apply for best results.

For quick, early growth the fertiliser must be placed where it can be reached by the young roots soon after germination; banding fertiliser 2–3 cm below the seed is best. Subsequently, in areas with an average annual rainfall of more than 600 mm (or under irrigation), topdressing established lucerne with fertiliser gives good results (although shallow-rooted weeds can benefit more than lucerne).

Responses to topdressing are less reliable in drier areas, because the surface 5 cm of soil often becomes too dry for the plant to use the nutrients. In these areas fertiliser should be placed 7–15 cm deep. The common procedure is to build up soil phosphorus during the cropping phase and then, when the last crop is undersown with lucerne, to place the appropriate amount of fertiliser at the required depth. If fertiliser is needed later it is usually top-dressed. The alternative is to return to a crop or a series of crops and repeat the cycle.

Fertiliser requirements

Lucerne in NSW is prone to deficiencies in phosphorus, sulfur, molybdenum, potassium, calcium (lime), boron, zinc and nitrogen.

Phosphorus (P)

Most soils are low in phosphorus, and usually a phosphatic fertiliser must be used. Application rates vary with soil type and fertiliser history. Phosphorus-deficient lucerne (growing with adequate soil moisture) has fine, spindly stems and narrow leaves. As the plant becomes deficient, the leaves become bluish green and, in severe cases, purple.

Soil testing can help to determine soil phosphorus status and fertiliser requirements.

Establishment. Application of fertiliser at sowing is most important. Generally, soils low in available phosphorus need up to 30 kg P/ha (375 kg/ha of single superphosphate or equivalent) in higher rainfall areas, declining to 10 kg P/ha in drier districts. Under irrigation up to 40 kg P/ha is needed for hay production. These amounts can be reduced if the soil is of medium to high phosphorus status.

Maintenance. Soils in areas under irrigation or with an average annual rainfall of more than 600 mm in southern NSW, or 700 mm in northern NSW, and rated by a soil test as low to medium in available phosphorus, will normally respond to 10–20 kg P/ha, plus up to 5 kg P/ha (depending on lucerne yield) for each hay cut or equivalent grazing by milking cows, applied as an annual topdressing. In hay stands, remove weeds before topdressing. In lower rainfall areas topdressing is usually needed only if insufficient phosphorus was applied at sowing, or if the stand is more than four years old. (See *Placement of fertiliser.*)

Sulfur (S)

Symptoms of sulfur deficiency are yellowing and stunting of young actively growing shoots. Since cultivation releases sulfur for plant growth, the symptoms tend to deteriorate as the stand grows older. The recently developed 'KCl' sulfur soil test is a useful tool. Strip tests with gypsum and plant tissue analysis are also useful methods of diagnosing sulfur deficiency.

Lucerne growing in soils diagnosed as sulfur deficient by a surface soil test may not show symptoms, because the tap root may be gaining

Phosphorus deficiency is common, especially in more acid soils

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access to sulfur deeper in the soil. Lucerne may not respond to sulfur application in this situation.

Sulfur-deficient soils occur mainly on the tablelands. In the north there are large areas that require sulfur fertiliser only. In other districts, where both phosphorus and sulfur are deficient, both must be applied for top yield and persistence. Increased production from sulfur often occurs in soils derived from basic rocks (for example, basalt and limestone), on virgin soils, and on heavier-textured soils, especially at higher altitudes with more reliable rainfall.

On soils that lack both phosphorus and sulfur, single superphosphate fertiliser has the correct ratio of these elements to sustain vigorous growth if used at the recommended rates. High analysis fertilisers like double and triple superphosphates do not contain enough sulfur for these conditions. The response of lucerne to sulfur is usually rapid, especially when the sulfur is applied as gypsum and sulfur-fortified superphosphate. Elemental sulfur (a component of many compound fertilisers) can be equally effective although it works more slowly, depending on particle size. The plant can use it only after the fine particles have been converted biologically into a more available form.

Soils low in sulfur on the slopes and tablelands may need up to 25 kg S/ha a year to maintain maximum growth. However, in low rainfall areas of the slopes and on eastern areas of the plains, and where soils have a good fertiliser history, the requirement can be as low as 3–10 kg S/ha a year.

Calcium (Ca) and lime

Calcium deficiency is uncommon in lucerne pastures, but it can occur, because the plant takes up large amounts from the soil. Calcium in the form of agricultural lime reduces soil acidity and the associated toxic effects of aluminium and manganese. Of the commonly grown legumes, lucerne is one of the most sensitive to soil acidity, and it is often essential for seedling survival to use lime. In most instances, a pH (Ca) between 5.2 and 7.5 is ideal for good yields. Use a soil test to determine whether lime is needed.

Liming can increase the availability of molybdenum and phosphorus in the soil, but sometimes too much lime reduces the availability of phosphorus, potassium and boron, so it must be used carefully.

For further information on using lime see the NSW Agriculture web page (www.agric.nsw.gov.au).

Potassium (K)

Potassium deficiency is not widespread, but the incidence is increasing, especially in paddocks subjected to long-term hay production. It shows up as white or yellow spots around the margins of older leaves and as a yellowing of the leaf margins and tips. Leaf analysis is a useful diagnostic guide.

Potassium is present in lucerne in higher concentrations than other elements obtained from the soil (except nitrogen). A deficiency of potassium can not only reduce yield but can also be associated with increased incidence of leaf disease and premature leaf drop.

Repeated cutting removes large quantities of potassium from the soil, and if the supply is marginal a deficiency soon arises. Mixed lucerne and grass swards, in particular, need enough potassium for the lucerne to establish well and persist.

Analysis of a soil sample (at 0–15 cm depth) is also helpful for monitoring potassium levels and assessing future requirements. Where a deficiency is suspected, strip-test actively growing lucerne with muriate of potash (50 per cent potassium) at

Characteristic white spotting of the leaf margins caused by potassium deficiency

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rates ranging from 250 to 800 kg/ha. In most cases 250–375 kg/ha will overcome a deficiency, but there have been instances of such rates being clearly inadequate. Annual applications of between 125 and 375 kg/ha may become necessary where hay is made regularly. Fertiliser mixtures containing both phosphorus and potassium are available.

Boron (B)

The upper leaves of boron-deficient lucerne turn yellow, with a reddish-purple tinge. In addition, the growing point and flowering heads are malformed and often die. Little seed is set. Plant analysis is the most reliable method of diagnosis.

If deficiency symptoms persist after rain or irrigation, apply 2–3 kg/ha of boron as solid fertiliser or liquid, or as a custom-mixed fertiliser. Do not use more than this rate, as there is a very small margin between enough boron and an excess (sub clover is more sensitive than lucerne). Consult your agronomist or fertiliser representative for the most cost-effective treatment for your situation.

Nitrogen (N)

If lucerne is correctly inoculated at sowing, or if there are enough compatible *Rhizobium* bacteria in the soil and levels of other nutrients, such as phosphorus and molybdenum are adequate, then nitrogen fertiliser is not necessary for lucerne.

If cold or wet weather is likely to restrict nitrogen fixation, or if the soil is deficient in nitrogen, nitrogenous fertiliser can be used to satisfy the seedling's initial requirement.

Generally, only small quantities are needed (5–10 kg N/ha). The use of nitrogen fertiliser can encourage weeds, which can be detrimental to the competing lucerne seedlings. Too much nitrogen can adversely affect nodulation. Plants will generally use fertiliser nitrogen before they fix nitrogen.

Molybdenum (Mo)

Molybdenum is a trace element needed in very small quantities. However, it is essential for efficient nodulation, plant survival and production.

A deficiency of molybdenum makes the older leaves pale – particularly the leaf tips – and also causes wilting of petals, restricted flowering, and stunting. Molybdenum deficiency starts to appear when the plants are young, and contributes to premature thinning of stands. It is usually patchy, and becomes marked after fertiliser application without molybdenum.

Deficiencies occur most commonly in acid soils where the molybdenum is in a form that the plant cannot use. The more acid the soil, the more likely there is to be a molybdenum deficiency.

Use molybdenised fertiliser on all soils with a pH (Ca) of less than 5.0. The rate of molybdenum needed on most soils is about 50 g/ha every four or five years, although some soils in high rainfall areas have responded to more than this (for example, 100 g/ha). Seek advice before using such high rates of molybdenum, as excessive rates may induce copper deficiency.

Superphosphates containing 0.02 or 0.04 per cent molybdenum are available. The required rate of molybdenum is supplied by applying 0.02 per cent molybdenum superphosphate at 250 kg/ha. Maintenance dressings of 25–50 g Mo/ha may need to be applied every four years, but care should be exercised not to apply too much molybdenum, as this can cause a copper deficiency in grazing animals. Molybdenum is also available in custom mixes with other fertilisers.

As an alternative to fertiliser, incorporate molybdenum trioxiode in the lime when you are lime-coating seed. Molybdenum trioxide contains about 66 per cent molybdenum, so apply about 75 g/ha.

If the deficiency shows up after sowing, the required quantity of molybdenum can be applied by topdressing with molybdenised superphosphate or equivalent, as specified above. Alternatively, a foliar spray of ammonium or sodium molybdate can be used.

Zinc

Recent research in northern NSW has highlighted the importance of zinc. The application of zinc sulfate to lucerne on a deficient soil increased the yield and was associated with a lower incidence of root rot, leaf disease and premature leaf drop.

Zinc deficiency tends to occur more often on high pH soils than on acid soils. Soil tests can be useful in identifying a problem. Leaf symptoms may not be present. Strip testing using zinc sulfate at 20–25 kg/ha can be used to indicate a responsive lucerne paddock.

GRAZING MANAGEMENT

During establishment

If lucerne is sown early (for example, in April) with a companion crop, it may be necessary to graze in winter if the crop is dense. This allows light to reach the lucerne seedlings and reduces the danger of smothering by early lodging of the crop. After the companion crop has been harvested, a brief grazing (10 days, or less if the stocking rate is high) will help to disperse the stubble. It also promotes initiation of new stems and makes use of grain lost from the header.

The lucerne should then be allowed to flower to replenish its root energy reserves. However, if a dry spell sets in, allow a second short grazing before too many leaves drop. Once the lucerne has flowered, begin rotational grazing as outlined below.

Lucerne sown without a companion crop should first be grazed when in full flower. Earlier grazing or mowing may be necessary if weed competition has been severe or if a dry spell sets in. After grazing, allow lucerne to start flowering and then start rotational grazing. (When grazing stubbles, be aware of the possibility of grain poisoning.)

Established lucerne

The principles

Grazing management is one of the essential inputs needed in the production and persistence of lucerne. It is an extremely important tool, but it must be used in conjunction with variety selection, good establishment and good soil nutrition for the benefits to be realised.

Lucerne benefits from a grazing system that has a period of spelling or recovery, alternated with a period of grazing. Spelling allows the essential root reserves of energy to be replenished; without this, rapid regrowth after grazing is not possible and survival through stress periods is threatened.

Research has shown that the essential energy reserves in the roots are at their lowest approximately two weeks after cutting or grazing (Figure 5). In a traditionally managed stand (based on cutting at 10 per cent flower), the energy levels are largely replaced by the time the next cut takes place (for example, one month later). Highly winter-active varieties, because of their quick regrowth, may not allow these root reserves to replenish as rapidly as more dormant varieties and may therefore be more prone to damage from premature grazing or cutting.

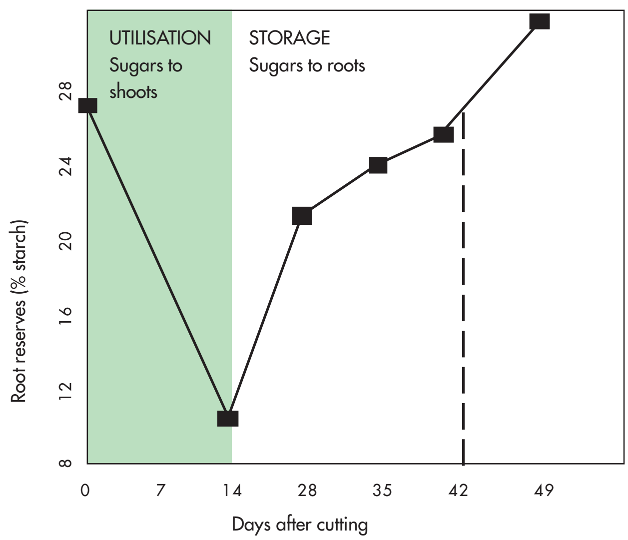
It is the spelling time, therefore, that is the most important point to consider in working out a grazing system. During the main growing season and under good growing conditions the optimum recovery time is around one month. The grazing time needs to be as short as practicable so that regrowth from the buds at the base of each plant is not grazed prematurely. Under optimum growing conditions and during the main growing season this will range from one to three weeks.

Experience has shown that these principles are the key to long-term productivity. The best grazing system for your lucerne is the one that can incorporate these principles into your enterprises as far as practicable, while allowing a considerable degree of flexibility for issues such as climate variability, low winter growth, lambing requirements, stock type, labour requirements, and cropping needs with regard to intensive subdivision etc. Rigid grazing systems are unlikely to be successful, because of these many practical requirements.

Continuous grazing can kill lucerne – the heavier the stocking rate, the more rapid the decline in the number of plants, as constant removal of new shoots depletes essential root reserves. Some varieties exhibit some tolerance to grazing (for example, semi-dormant varieties compared with highly winter-active varieties), but still respond to rotational grazing to provide good production and persistence

The **height** to which lucerne is grazed must take into account the class of grazing stock, as well as any possible damage to plant crowns. When most

Figure 5. Root energy reserves in lucerne in relation to cutting time (Boschma and Williams, NSW Agriculture, Tamworth)



of the leaf has been eaten and mostly stems remain, animal production is likely to decline, but leaving large amounts of stubble can reduce lucerne regrowth, as can leaving no stubble.

Livestock with high nutritional requirements, such as weaners, finishing stock and lactating animals, should be moved off lucerne while there are still adequate quantities of quality leaf material present. Livestock with lower needs, such as wethers, dry ewes or cows, can then follow to remove the remaining leaf and excess stubble. Similarly, cattle can be grazed before wethers. Observation suggests that lucerne persists better when cattle, rather than sheep, graze lucerne.

Graze small areas of lucerne in association with other feed sources to improve persistence and production. As far as is practicable, in the growing season, graze lucerne paddocks for up to three weeks, and then move stock to another source of feed and allow the lucerne to recover for five or six weeks (or to the 10 per cent flowering stage) before returning stock to the paddock.

During the cooler months spelling periods need to be longer, and alternative pastures based on subterranean clover are particularly useful. Oats, though of lower nutritional quality, can also effectively fill the winter feed gap.

Stage of growth for grazing/cutting

A number of methods are used that use these principles to indicate when to put stock on to lucerne:

- The **early flower or the 10 per cent flower** stage (when 10 per cent of stems have commenced to flower) has traditionally been the visual indicator as a good time to graze or cut, as it is a good compromise between high yield, quality, and replenishment of root energy reserves. The time to flower can be affected by temperature, moisture stress and variety, so that the appearance of flowers does not necessarily indicate that root reserves are replenished, especially under adverse growing conditions or with highly winter-active varieties. Grazing later than 10 per cent flower has the disadvantage of lower quality feed and greater chance of leaf drop. This is particularly important if large paddocks are involved.
- **Regrowth from buds** is a useful method of determining when to cut or graze. Bud regrowth is enhanced by leniently grazing lucerne at a late stage of growth. The important guideline is to reduce damage to the regrowing buds. As a compromise, graze before lucerne bud regrowth reaches 5 cm. Grazing higher, for example with cattle, allows faster regrowth from buds in leaf axils. Cattle generally cause less damage than sheep.
- **Grazing to a time schedule** is practical for many producers, as it allows planning for labour etc. This is satisfactory as long as it takes into account the principles of resting and grazing over a short period to protect regrowth, and grazing times are altered to account for seasonal differences (for example, 35 days in summer, longer in cooler months).

Feed quality considerations

Digestibility, energy and protein are not maximised at the traditional cutting or grazing stage. There is always a compromise between yield, quality and persistence of the stand. This compromise has been satisfactory for most enterprises, but some are now demanding a higher level of nutrition.

The dairy industry is a case in point, where units operating at very high production levels need higher feed quality. There are also certain hay markets that require cutting at bud or pre-bud stage to achieve better quality. The down side to cutting or grazing earlier is that the per annum yield of lucerne will be reduced and, importantly, the stand life is likely to be reduced, increasing the cost per tonne of lucerne produced.

Depending on relative costs of establishment and production, as against the cost of additional supplementary feed and increased milk yield, grazing earlier (bud or pre-bud stage) may be a proposition.

Subdivision

The degree of subdivision necessary will vary according to the production needed, the required life of the lucerne stand, the reliability of lucerne production, the environment, the class of stock, and the likely availability of other feed and other practical considerations. Moreover, subdivision is expensive and rotational grazing requires extra

Rotational or strip grazing is highly desirable to optimise production and persistence. Use a back fence when strip grazing.

management, and they may not be practicable in many situations. For example, subdivision may not be suitable when it is in association with a large-scale cropping program, although the availability of low-cost electric fencing has reduced this problem.

The need for subdivision is greatest where maximum use of feed is required, where stocking rates are high, and where rainfall is low or erratic. Where stocking rates are low to moderate, where a short pasture life (say, three years) is acceptable, or where other species such as subterranean clover are grown with lucerne, less intensive subdivision is appropriate.

Successful rotation systems

On the **tablelands** under reliable rainfall conditions, rotations based on two to four paddocks provide good production and persistence, with rest periods ranging from five weeks in summer to eight weeks in winter and a grazing period of up to three weeks. More than three weeks' grazing is possible where growing conditions are favourable and where there is an abundance of other species, such as clover, in the pasture. The persistence of lucerne is reduced when grazing periods are extended and young regrowth continually removed.

On the **slopes**, under drier conditions, four to six paddocks are suited for good production and persistence, with a rest period of at least five weeks and a grazing period of one or two weeks. With low stocking rates, and especially when other species are sown with the lucerne (for example, subterranean clover), good production over three or four years has been achieved by using three paddocks with rest periods of at least five weeks and grazing periods of up to three weeks.

On the **plains**, a system of six to eight paddocks with a spelling time of at least five weeks and a grazing period of one week has given maximum production and lucerne persistence. Having fewer than six paddocks and extending the grazing period beyond 10 days is likely to reduce plant persistence dramatically, except under favourable growing conditions or low stocking rates, or where there is an abundance of other palatable species.

Under **irrigated conditions**, where stocking rates are high, strip grazing or multiple paddock systems are suitable, with spelling times of at least five weeks (depending on the feed quality required) and grazing periods of one week or less.

Rotational grazing of a lambing flock can lead to mismothering and reduced lamb survival. If lambing must occur on lucerne, spread the flock over as large an area as possible to minimise damage to the lucerne.

When the rotation is relaxed in this way during the cooler months it can be difficult to return to the rotation, as the pattern of feed supply will have been disrupted.

Where it is possible to spell lucerne during the winter, increased spring and summer production can be expected. Excess production during the warmer months can be conserved as hay or silage.

Stocking rates

Optimum stocking rates will vary with climate, enterprise and management. Stocking rates that have been carried successfully under rotational systems in trials have ranged from 12.5 wethers per hectare at Trangie, on the plains, through to 15 dry sheep per hectare on the slopes at Wagga Wagga and Tamworth, to 20 breeding Merino ewes per hectare at Canberra on the tablelands. At higher stocking rates, however, the need for fodder conservation is increased, and the conservation of excess lucerne in spring to feed back in winter needs to be considered, as was necessary in some trials. Your local district agronomist or livestock officer can provide guidelines on suitable stocking rates for your area.

Where subdivision is impractical

Where subdivision to the extent outlined is not possible, then subdivide as far as practicable and rotate stock. Place emphasis on allowing for a spelling period as far as practicable. Even two paddocks are preferable to one.

Where rotational grazing is not used, the following management practices may reduce losses in production and persistence:

- Ensure that lucerne-based pastures are well established before grazing, and select a variety adapted to the environment (that is, in terms of resistance to pests and diseases).
- Ensure soil nutrition is adequate.
- When sowing lucerne, include other species, such as subterranean clover or medic, which do not compete to any degree. These will reduce the grazing pressure on the lucerne and provide the basis of a productive pasture when the lucerne dies out.
- Use a semi-dormant rather than a highly winter-active variety. Semi-dormant varieties are generally more persistent than highly winter-active varieties, especially when they are set-stocked.
- Use conservative stocking rates.
- Do not set-stock for long periods, even at low stocking rates.
- Allow lucerne to flower whenever the opportunity arises (for example, when excess feed is available elsewhere on the property). If such spells can be timed to precede a stress period, such as summer, so much the better.

LIVESTOCK HEALTH ON LUCERNE

There are few health dangers to livestock grazing lucerne. The most serious of them is bloat. Lesser problems are pulpy kidney, red gut of sheep, nitrate/nitrite poisoning and pizzle rot in sheep, photosensitization in horses and reduced twinning rates in ewes. Meat tainting can be avoided by moving stock on to an alternative type of feed for three days before slaughter. Brief notes on bloat, red gut and reduced twining percentages follow. Consult your veterinarian for more detail.

Bloat

The risk of bloat must be balanced against the potential productivity increases from using lucerne. (See Table 2.) The tendency of lucerne to cause bloat needs to be assessed against the problems of using alternative pastures, some of which can also cause bloat (for example, clover). Many farmers who successfully stock lucerne year-round find bloat is a minor problem once all pastures contain at least some lucerne.

Cattle grazing lucerne pastures during the bloat season (winter and spring) are liable to suffer from frothy bloat. Cattle do occasionally suffer from bloat in summer or autumn, but at these times the problem is rarely serious.

Sheep are slightly susceptible to bloat, but this should not be a deterrent to grazing them on lucerne.

The severity of bloat varies from a slight distension of the rumen, which causes no distress, to very severe bloat and sometimes death. Death from bloat is generally an isolated occurrence, but losses are sometimes devastating. Chronic bloat may also reduce weight gains by 20–30 per cent at the peak of the bloat season.

There are a number of ways of reducing the risk of bloat:

- If cattle show symptoms, remove them from the pasture. Either graze sheep on the pasture until after the bloat season has ended, or save the lucerne for spring hay.

- In a mixed sheep and cattle enterprise, the sheep might graze the lucerne pastures in winter and spring while the cattle graze annual pastures, fodder crops, or other non-bloat pastures. In summer and autumn the sheep might be put on dry annual pasture or stubble, for example, while the cattle graze the lucerne.
- Ensure that cattle are well fed when they enter lucerne paddocks.
- Mature stands are less risky. Avoid grazing cattle on young and succulent stands.
- Dense, pure swards cause more problems than thin, weedy swards.
- Feed hay during periods of high risk.
- In small, intensively managed areas such as dairy farms, livestock can be given anti-bloat agents by drenching, by flank application, in roller drums, in drinking water, by spraying the pasture, or with anti-bloat capsules.
- Some animals are more susceptible to bloat than others. It is a good idea to graze animals that you know to be susceptible on pasture, where there is a lower risk of bloat.
- Pulpy kidney (enterotoxaemia) is often associated with, or confused with, bloat. Have all animals fully vaccinated against pulpy kidney before they are allowed to graze lucerne.

Drilling a cereal or ryegrass into older lucerne stands that are due for removal may reduce the problem in those paddocks, and set-stocking instead of rotational grazing during high bloat risk periods may reduce the incidence.

Red gut

This condition is associated with lush, growing lucerne and continuous grazing of lucerne by sheep. Livestock symptoms are similar to those of pulpy kidney. Sheep in good condition are often affected. Addition of a supply of roughage may reduce the incidence. Rotating stock between lucerne and other pastures – five days on lucerne and two days off – seems to be satisfactory. (See Agfact A3.9.23 *Red gut in sheep*.)

Reduced twinning rates

A reduction in twinning rates in ewes grazing lucerne has been associated with high levels of coumestans (oestrogenic compounds) in the leaves of the plant. The effects in sheep are a reduction in the rates of ovulation and multiple births. The effects on cattle are unknown, but effects on reproduction have been suspected.

High coumestan levels can occur in all varieties, but only when the leaves are stressed, such as by disease or insect attack. Leaf disease has been particularly implicated. Heavy leaf disease infection occurs more frequently in humid areas.

The effects on livestock are short-lived, and the problem can be avoided by removing breeding animals from stressed lucerne pastures four weeks before and during joining.

HAYMAKING

Properly harvested lucerne hay is a high-quality feed with a metabolisable energy (ME) level of up to 11 megajoules per kilogram (MJ/Kg) of dry matter and a crude protein (CP) content of around 20 per cent (Table 1). Its quality varies with such factors as the stage of growth at cutting (Table 5), the ratio of leaf to stem, the haymaking technique, the proportion of weeds, the extent of weather damage, and the presence of mould.

Yields

Commercial yields are generally within the range 10–22 t/ha, from five to seven cuts between early October and late April, although yields of 25 to 27 t/ha have been achieved under excellent management and growing conditions.

In northern districts there is potential for an additional cut by taking advantage of the extended haymaking season and by using highly winter-active varieties. In cooler environments, such as the upper slopes and tablelands, the number of cuts is reduced (by one or two) and the yield lowered accordingly.

In very hot conditions, which can occur in the far west of the State, yields may be depressed. This condition is called ‘summer slump’.

Do not budget on all hay cuts being of equal value. In the north, typically one cut per season may be unsaleable at good hay prices and one or two cuts may be downgraded because of weather damage. The first cut of the season may also be downgraded by excessive weed content.

Grazing hay stands during the winter can also depress spring and summer yields of hay.

Marketing

Hay is produced in a variety of forms: small rectangular bales, round bales and large square bales. Small rectangular bales have been the most popular package for hay, and remain so for the horse trade in particular, but large round and square bales have increased rapidly in popularity.

Hay marketing in Australia has been based traditionally on price per bale or per tonne. In the interest of both the end user and the producer, hay is best traded on a weight basis, with adjustments made for feed quality. The system promoted by the Australian Fodder Industry Association (AFIA) is one such example (Table 4). It is based on objective measurement of the feed value of hay or silage using ME and crude protein (CP). The AFIA system replaces the use of descriptive terms such as 'choice', 'prime', 'medium' or 'grassy' hay, which were based on visual assessment. Although visual assessment can identify colour, amount of leaf and impurities, it is not always a reliable indicator of feed quality.

Hay is generally sold by the tonne or by the bale.

As the efficiency of grazing enterprises increase, producers are becoming more demanding in their requirements. Marketing will also become more objective, with the price more accurately reflecting nutritional value, rather than the weight alone. Additionally, the presence of undesirable weeds is likely to become more of a marketing issue as quality standards rise.

Cutting

For the most profitable long-term returns, lucerne hay should be cut at the correct stage of growth and baled at the correct moisture content. The correct stage of growth will vary with product quality requirements, yield and persistence targets.

Deciding on the best time to cut is a compromise between the requirements for high yield, good quality and stand persistence. The hay is at its best quality when lucerne is cut at the bud stage, but routine cutting at this stage may shorten stand life and is not justified unless a price premium is obtained for very high quality hay. As lucerne matures, the quality declines significantly (Table 5).

Cutting at the 10 per cent flowering stage (when 10 per cent of the stems show flower) is traditional and a reasonable compromise for yield, quality and persistence. It is not, however, the best cutting time for very high quality hay.

The basis for cutting or grazing according to the need for replenishment of root energy reserves has been outlined in the section on grazing management and is illustrated in Figure 5.

Note that the time of appearance of flowers is influenced by a combination of soil moisture, temperature, and day length and variety. In hot weather, especially when soil moisture is inadequate, the 10 per cent flowering stage can occur much sooner, thus reducing the harvest interval. Flowering per se does not necessarily indicate that root energy reserves have been restored. Highly winter-active varieties may also flower earlier than semi-winter dormant varieties.

Using **crown bud length** (for example, when 50 per cent of crown buds are 1–2 cm long) to decide when to cut is also variable, because both the time of appearance and the rate of elongation of buds vary with factors such as variety, growing conditions and past management. However, cutting should always occur before new shoots are high enough to be damaged by the cutter bar.

Cutting on a time interval basis is convenient and practical for many producers, as it allows for planning of irrigation and labour use. This is satisfactory as long as the principles outlined above for resting are followed.

Research at Tamworth showed that harvesting irrigated lucerne at intervals of 35 days, regardless of the winter-activity rating of the lucerne variety, produced high yields of good quality hay and maintained the density of the stand. This coincided with the 10 per cent flowering stage of

Table 4. AFIA national fodder grades for legumes pasture hay and silage

Digestible dry matter (DDM) (%)	Metabolisable energy (ME) (MJ/kg)	Crude protein (CP) (%)			
		> 19	14–19	8–13.9	< 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

the stand. Cutting on a 28-day cycle caused plant density to decline rapidly by the fourth year of the stand and was associated with increasing invasion by weeds.

Cutting later than the ideal stage gives higher yields and possibly better persistence. However, the hay will be of lower quality, especially with highly winter-active varieties harvested early or late in the season. A lower leaf to stem ratio and the possibility of leaf damage and loss from disease and moisture stress can reduce quality.

Cutting earlier than the ideal stage is necessary for some markets. Specialised export markets, for example, require hay to be free of flower and of a good green colour, and this means cutting at the bud stage. The requirements of processors undertaking protein fractionation are similar. However, constant early cutting or grazing is likely to shorten stand life and increase weed problems.

Cut as close to ground level as possible without damaging the crowns. This is particularly important with highly winter-active varieties with high crowns, which are easily damaged. A cutting height of around 5 cm above ground level is suitable in most situations. Leaving excess stubble and leaf is unlikely to be of benefit unless the intervals between cuttings are shorter than recommended. Keep cutting edges sharp, especially on slasher-type mowers. Blunt edges can damage the crowns, particularly of erect, winter-growing varieties, and so make the plants vulnerable to fungal infection.

Cutting newly sown lucerne is best delayed until early flowering, at the earliest.

Hay cut in the afternoon is marginally higher in nutritive value than hay cut in the morning. However, cooler conditions following cutting allows respiration to continue, with subsequent losses in nutritive value.

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An irrigated hay stand being cut at the early flower stage

Drying

After cutting, the aim should be to remove moisture as quickly as possible to avoid continued respiration, nutrient loss from weathering, and degradation from microbial activity. As much leaf needs to be retained as possible during this process. A number of factors will affect the rate of drying, and management must be flexible to account for them. (For this reason, making hay is often referred to as an 'art'.) These factors are the stage of cut, air temperature, wind speed, relative humidity, soil moisture, and the structure and density of the windrow.

Lucerne hay is usually dried to a moisture content of around 17–18 per cent, with material of up to 21 per cent moisture baled only in hot, dry conditions. Hay with a moisture content of

Table 5. The effect of stage of maturity of lucerne on its nutritive value (after Moran 1996)

Stage of maturity	Crude protein (%)	Metabolisable energy (MJ/kg DM)	Digestibility (%)
Early vegetative	23	10.4	72.9
Late vegetative	20	9.9	70.0
Early bloom	18	9.3	66.5
Mid-bloom	17	8.9	64.1
Full bloom	15	8.4	61.2

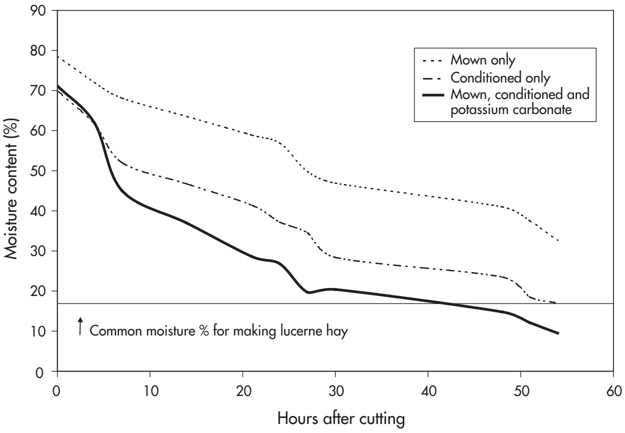

Figure 6. The effect of conditioning and using potassium carbonate on the drying rate of hay (Source: Crocker and Lodge 1981)

around 15 per cent and below is required for some markets. Take care when drying to low moisture contents, as lucerne stems become very brittle and too much leaf will shatter and be lost. Uneven curing in windrows should be taken into account when deciding on the best moisture content for baling.

Roller-type mower conditioners, which cut and condition the lucerne by crimping or crushing the stems, give more even and rapid drying; they can shorten drying time by as much as half, thereby reducing leaf drop and the risk of rain damage (Figure 6). However, if rain does fall on conditioned hay, the hay deteriorates faster than it would if it had been left untreated.

Hay will dry quickest when it is left spread across a paddock. It must be raked into a windrow however, while leaves are still moist and flexible, to minimise leaf shatter.

Lucerne leaves dry out more rapidly than the stems, and tend to shatter. Raking helps maintain an even drying rate and reduces uneven bleaching of material in the windrow. Daily raking of freshly cut hay while dew is still evaporating helps keep a good drying windrow structure and reduces leaf loss. As hay dries, raking may be extended to every two or three days. Leaf loss can be minimised by raking before dew evaporates and reducing tractor speed. Under very dry conditions it may be necessary to turn windrows several times a day to ensure an even drying rate, but handling operations should be minimised once drying hay reaches 50 per cent moisture content. Raking at night assists in reducing losses.

Tedders are occasionally used to 'fluff up' windrows and enhance the movement of air through the windrow. They should be used only on high-moisture hay (above 50 per cent moisture content) to avoid excessive leaf loss.

Take particular care with hay making machinery, as accidents can readily occur. In particular, stop machinery before attempting to clear any blockage.

Hay additives/treatments

K-hay or chemical conditioning (to hasten drying)

To make K-hay, potassium carbonate is used as a desiccant to accelerate drying. The solution is applied when cutting. The mower is modified by fitting a crop bar to lay the crop over and expose the stems, and a boom is used to spray the material on to the stems just before cutting.

Figure 6 shows the main advantage of using K-hay. Despite this advantage the technique is not commonly used.

The advantages of using potassium carbonate are:

- The chance of weather damage is reduced.
- There is less damage to regrowth.
- More leaf is retained, and colour improves slightly.
- The hay-cutting season is extended.

The disadvantages are:

- The machinery has to be modified.
- A large amount of water has to be carried.
- Potassium carbonate is mildly corrosive, so machinery has to be washed after use (Avoid splashing into the eyes and skin contact.)
- The process does not work on the grass component of pastures.
- Treated hay absorbs more water if rain falls.
- Buyer resistance is occasionally raised as an issue.

Producers intending to use additives need to check with their marketing outlets as to the acceptability of the treated product and also need to list treatments on vendor declaration forms.

Preservatives (to inhibit mould)

Preservatives (based on ammonium propionate or propionic acid) are used successfully overseas, and are available in Australia. They are used on hay that is slightly above the ideal moisture content for normal baling to prevent moulds from forming and spoiling the hay. However, they do not permit material with a moisture content of more than 30 per cent to be baled. Low volumes of the liquid are sprayed on to the lucerne as it enters the baling chamber. Use of this material in NSW indicates that it has the following advantages:

- Mould is effectively reduced.
- Both the equipment and the product are relatively cheap.
- It can improve hay colour.
- It allows greater flexibility in haymaking.
- It potentially extends the times when baling can take place.
- The time from cutting to baling can be shortened, avoiding weather damage. (Treated hay can usually be baled one day earlier than untreated hay.)
- Preservatives currently available and based on ammonium propionate or propionic acid are not toxic and are safe to use.

The process does, however, have some disadvantages:

- It does not allow wet hay (above 30 per cent moisture) to be baled; use moisture meters to ensure that material to be baled is not too wet.
- It cannot substitute for good haymaking practices.

Equipment for applying hay preservative is inexpensive and easily installed. Note the container, pump and spray line directed over the entry to the baling chamber.

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- It does not replace potassium carbonate treatment, and the two materials may be used on the one haycut.

Although both chemical conditioning and use of preservatives can be effective, they are not widely used at the present time. Producers intending to use additives need to check with their marketing outlets as to the acceptability of the treated product and also to list treatments on vendor declaration forms.

Hay inoculant

Inoculants for use on hay are available and may improve the efficiency of haymaking. Experience, however, is limited at this early stage. Research is needed to ascertain the efficacy of these materials under NSW conditions as well as their relative merit when compared with materials such as preservatives.

Measuring moisture

Baling

The most common bale size is the small rectangular bale weighing approximately 25–28 kg (35–40/t). Round bales are typically 320, 500 or 720 kg/bale depending on the diameter. Because little drying out is possible in a tightly packed bale, hay should be baled at the correct moisture content and then put under cover as soon as possible.

A reliable moisture meter helps to determine the moisture content at which to bale (15–18 per cent, extending to 21 per cent in hot, dry conditions). The accuracy of meters varies considerably, and many are not sealed against moisture and dust. Meters need calibrating to ensure that readings on hay are reasonably accurate.

The use of a microwave oven to check the moisture content of a sample of hay is a useful method, especially if you are unfamiliar with field methods. It is not as accurate as oven drying as used by laboratories for calibration. If you use this method, ensure that your sample is representative of the hay cut in the paddock, that the sample is dried to a constant weight, and that a cup of water is present in the oven to prevent combustion. Contact your agronomist for instructions on using a microwave correctly for drying pasture samples.

Judging moisture content without a meter comes with experience. The following tests give an indication of when it is safe to bale:

- Twist a few stems from the windrow; if moisture is evident the crop is too damp.
- Scratch the skin of the stalk with a fingernail (the 'bark test'). The skin will lift if the lucerne is too moist, but not if it is dry enough. If you are still in doubt, make a few trial bales and examine them. Their weight and tightness, or the presence of moisture either along the sides or in the biscuits themselves, will indicate their unsuitability for baling.

Remember, it is too early to bale if the crop wraps itself on to moving parts of the baler or the baler engine labours heavily, if moisture is detectable on the side of the baler, or the bales are too heavy. Baling too late is indicated by excessive leaf shatter or dusty hay, or if the bales are too loose, even after tightening the baling chamber.

In good, dry haymaking conditions, it is usually necessary to cease work with the pick-up baler during the day to prevent leaf loss. At night and in the early morning the hay is tougher and less likely to lose its leaf. However, do not bale in heavy dew.

Finally, bales left to dry in the paddock are safest from the weather in stooks or small stacks.

If you have to bale when the moisture content is higher than ideal, adjust the pressure so that bales will not be packed too tightly, and use a hay preservative. This will allow some further drying out. Do not stack hay that is high in moisture. Even small pockets of moisture can make hay overheat and lead to a fire weeks after stacking.

Using a round baler

Baling losses (particularly leaf) can occur when using a round baler. This mainly occurs in the baling chamber owing to vigorous handling of the forage with belts and rollers. These losses can be reduced by forming large windrows and maintaining a higher ground speed. The forage will then feed more quickly into the baler. This will reduce loss and increase digestibility and protein content, but bale weight will be reduced owing to lower bale density.

Cubes and recompressed bales

An export market for lucerne cubes and recompressed bales exists, and there is also a domestic market for these products. The quality requirements for these products differ from the requirements for traditional rectangular bales. An advantage of cubing is that mobile cubers can pick up windrows in the heat of the day.

Hay cubes are dense, bite-sized units of chopped hay about 30 mm square and 50–80 mm long. They are produced by a mobile cuber that picks up hay from the windrow, or by feeding baled hay through a stationary machine. The market requires that cubes be made from leafy lucerne with a protein content of at least 15 per cent, a maximum moisture content of 12 per cent, and of a good green colour with no flowers. Higher quality cubes (24 per cent protein) can be achieved by using mobile cubers.

Recompressed or 'double-dumped' bales (two rectangular bales pressed into one, or one reduced to half the normal size) have the same quality requirements as cubes. However, the moisture content of bales for double dumping needs to be below 12 per cent.

Moisture content and storage

The ideal moisture content for safe storage of traditional lucerne hay bales in open-sided farm sheds is 17–18 per cent. The risk of storage problems increases if the moisture content exceeds 22 per cent. Hay stored in closed sheds or containers must be drier. Round bales are more likely to heat in the centre than conventional bales, and should be stored drier as well.

Take care with hay made from unevenly cured windrows, as pockets of high-moisture hay may mould, heat up, and even combust.

Hay heating in storage

When hay is stored, the temperature of the stack is likely to increase, depending on a number of factors. At the extreme, spontaneous combustion is possible. The important points to keep in mind are:

- If hay is baled and stored at below 22 per cent moisture slight heating can be expected, but hay will normally return to air temperature after a short period.
- Where moisture content is above 25 per cent or hay has been wet through rain or flooding, further heating is possible and care should be exercised.
- If stack temperatures rise to 70°C, a rapid rise in temperature is possible if oxygen is available. Spontaneous combustion can then occur.

- Heating can occur because of the presence of moist pockets of hay in a stack. Avoid storing unevenly moist hay. Rake and bale to avoid the formation of moist pockets of hay.
- Stacks of large bales, because of their size and density, can be more prone to heating problems.
- Heating can cause extremely high losses in both the protein and energy content of hay and can reduce the feeding value dramatically.
- If you have any doubts about hay heating in a stack, test the stack with a crow bar (or a hollow pipe that allows for a thermometer to be lowered in) to determine whether there is a high temperature problem. (Most problems occur two to seven weeks after storage.)
- As a guideline, if the temperature within the stack is approaching 70°C you can touch the bar only briefly, and if it is over 70°C you cannot hold the bar.
- If the temperature is above 70°C the stack should be dismantled. Ensure that all necessary precautions to handle a fire are in place before you move the hay.
- Never climb on top of a stack that is showing signs of heating, such as condensation, mould growth or acrid fumes.

(From: Mickan F (1999) *What happens when hay heats?* Agriculture Notes AG0206, Victorian Department of Natural Resources and the Environment, www.nre.vic.gov.au)

Transporting and handling hay

Stacked hay can be dangerous, and care needs to be exercised to prevent injury from falling bales. Similarly, handling bales can pose a threat to health and safety. Note that loading requirements exist in respect to transporting hay. These requirements and information on safely loading your truck can be obtained from your Roads and Traffic Authority office or the RTA website (www.rta.nsw.gov.au).

MAKING SILAGE

Lucerne can make high-quality silage provided it is wilted quickly before ensiling. Silage is produced when an anaerobic (no oxygen) bacterial fermentation uses plant sugars to produce lactic acid, which preserves the forage.


A CROSS

Using a moisture meter to check the moisture content of hay about to be stored

Direct-cut lucerne is high in moisture and too low in sugar to allow an effective silage fermentation to occur. Being a legume, lucerne is also high in protein and calcium, which buffers any changes in acidity.

Wilting to remove excess moisture has the effect of concentrating the plant sugars, allowing a better silage fermentation. A mixed pasture that includes grasses with lucerne is easier to ensile, because grasses such as ryegrass have more sugar for fermentation.

Despite these limitations, lucerne can be successfully ensiled if it is wilted to a dry-matter content of at least 30 per cent (70 per cent moisture) – preferably 35–45 per cent dry matter (55–65 per cent moisture) – before being picked up by the forage harvester, or 40–50 per cent dry matter (50–60 per cent moisture) if it is to be picked up with a baler.

Baling drier than 50 per cent dry matter (50 per cent moisture) can increase losses in the field. In addition, the drier material is more difficult to compress. Ineffective compression allows more air to remain in the bale and will, in turn, result in increased ensiling losses.

It may take from 24 to 48 hours of wilting to get the lucerne to the correct stage, depending on the weather.

When ensiled correctly, lucerne produces very palatable and nutritious silage – a valuable feed for both cattle and sheep. Less forage is lost in making silage in the field than in making hay. Silage is usually more digestible and higher in crude protein than hay made from the same material.

Lucerne may be stored as bulk, chopped silage stored in a pit or bunker, or it may be stored in round or large square bales that are wrapped in plastic to exclude air. In all cases silage must be compacted to remove air and then sealed to keep air out.

If the compaction and sealing are effective, then silage fermentation will occur naturally. There is a range of silage inoculants available that can be used to ensure that the best silage bacteria are present and plentiful and to promote the production of good silage, but results from using silage inoculants have been variable. In some cases there has been little benefit. They do not overcome problems of poor quality forage being harvested or poor wilting and compaction. However, good quality inoculants have been shown to further improve the quality of well-made silage.

Silage inoculants do not remove the need for wilting. In wet environments additives such as formic acid can be used to preserve silage when adequate wilting is not possible. This practice is not common in Australia.

Wrapped large square or round bales of lucerne silage have become popular in some areas, especially when weather conditions make hay drying unreliable. Although plastic-wrapped bale silage is relatively expensive, it can be justified by the convenience in making and feeding out. As with round bale hay, these silage bales are traded, unlike conventional silage. The life of the silage is short (one year), as puncturing or deterioration of the plastic can occur, allowing air into the silage and spoiling it.

Wrapped silage is usually made at a higher dry matter content of 40–50 per cent (50–60 per cent moisture). This is done for convenience and cost reasons (lighter bales to handle). The quality of these bales has been acceptable where they are baled tight and sealed well.

RENOVATION

Renovation is the practice of cultivating lightly to rejuvenate old, thinning lucerne stands.

Improvement varies in degree, but it is usually short-lived and is often accompanied by crown damage and plant thinning due to infection by crown rots and bacterial wilt.

Seed is sometimes over-sown during renovation in an attempt to improve the density of the stand. This is usually unsatisfactory because of competition from established plants. Over-sowing into fertile self-mulching soils under good seasonal conditions or irrigation is occasionally successful.

The frequent failure of these attempts and the occasional failure of sowing lucerne back into old lucerne country is often attributed to alleleopathy (the suppressing effect one plant has on another through the action of plant chemicals). It has been demonstrated overseas that exudates from the leaf and, to a lesser extent from the roots, can reduce the emergence of plants from new seeds sown shortly after ploughing out. Competition for moisture, however, is a common factor in our lucerne-growing districts that readily prevents establishment. The presence of insect pests and disease can similarly cause failure.

With thin lucerne stands, you should first identify the reason for plant loss before considering renovation or re-sowing. If, for example, root and crown rots are active, renovation is unlikely to succeed. It would be better to crop the area and then sow a variety with good resistance to the disease. Similarly, the activity of white-fringed weevils can thin stands, and renovating or re-sowing such stands is a waste of money.

Occasionally, renovation is useful to reduce run-off and allow rain to soak in, or to incorporate other species (oats, ryegrass and subterranean clover) or fertiliser into the sward. Renovate only when the soil is moist, and use a tined implement fitted with narrow points to minimise damage to established lucerne plants.

Take care not to keep low-density lucerne-based pastures for too long, as the potential benefits to livestock and following crops may not be realised. For example, weeds that respond to high nitrogen levels, such as barley grass, encroach on the pasture, depleting soil nitrogen and causing a build-up of diseases that may affect cereal crops.

TERMINATING THE LUCERNE PHASE

Two of the major disadvantages of growing lucerne, especially in a cropping situation, are the difficulty of removing lucerne from the cropping rotation and the extraordinary ability of lucerne to dry out the soil profile. If the situation is not well managed, this may lead to reduced yield in the following crop.

As a general rule for crop production, the lucerne phase needs to be removed while it is still relatively productive and seasonally in time for moisture and nitrogen to be available for the following crop. There are, however, other factors that need to be considered, such as crop sequencing requirements, weed levels, livestock requirements, machinery commitments and, importantly, relative returns from enterprises.

In consideration of soil water and nitrogen availability, in dry climates lucerne is best ploughed out well before sowing time to allow soil moisture, particularly at depth, to be replenished for the following crop. This may mean ploughing in spring to ensure that summer rain is collected and weeds are prevented from seeding down. Similarly, ploughing early allows nitrogen a greater chance to become available for the succeeding crop. The optimum time of the year to terminate a lucerne stand for the succeeding crop will vary with the locality in the State. Check with your local agronomist or adviser.

The success of control of lucerne in crop fallows with herbicides has been variable, and widespread dissatisfaction has been common. Research in both southern and northern districts has resulted in the registration of two herbicides that provide reasonably good control of lucerne.

Herbicide effects may be enhanced if soil moisture is good in the two weeks before treatment and if the lucerne is not grazed, cut or mown for two weeks after application.

Decisions about replacing lucerne stands are best based on profitability rather than on such factors as 'lucerne plants per square metre' or the amount of grass invasion.

IRRIGATION

Lucerne growth is very responsive to water, and under irrigation dry matter yields of up to 25 t/ha are achievable. However, highly productive lucerne hay stands can have high water use. Irrigation can also promote problems if management is neglected. Lucerne is susceptible to waterlogging, root and crown diseases and scald (root damage due to waterlogging in hot weather). Good irrigation management practices can increase yields and quality, save on water costs, ensure stand persistence and help to avoid environmental problems associated with irrigation.

The main prerequisites for irrigating lucerne are:

- profitable markets
- well-drained soil
- good irrigation and drainage layout
- varieties resistant to root and crown diseases.

Deep, sandy-loam soils are ideal for irrigated lucerne, but clay soils can be utilised provided that the internal and surface drainage is adequate. Irrigated lucerne generally uses water from the top 1 m of soil, but if the roots can reach the watertable (for example, in lighter soils in irrigation areas or river flats) this can supplement irrigation.

Limitations to irrigated lucerne

Irrigated lucerne is prone to a number of problems that can limit dry matter yields and stand persistence.

Poor establishment

Acid, saline or sodic soils, hard pans, poor land preparation, mismanagement of sowing or irrigation, or failure to control pests, diseases and weeds, can produce thin, unproductive lucerne stands.

Disease

Root rots are common under flood irrigation. Crown rots are encouraged by hay cutting and traffic, and leaf, crown and root diseases are all promoted by dense stands and warm humid conditions.

Waterlogging

Lucerne is very susceptible to waterlogging. Temporary waterlogging during irrigation can stop plant growth; prolonged waterlogging due to poor drainage kills plants. Early symptoms include general reddening of the plants, followed by yellowing and plant death.

Scald

Low soil oxygen levels due to ponding of water and high temperatures can cause rapid root and crown damage and death of lucerne plants. Rotted, foul-smelling plants can be easily pulled out of the soil within a few days of flooding in hot weather.

Inadequate water supply
Lucerne avoids moisture stress by reducing its leaf area (leaf drop and slower growth), channelling energy into growing deeper roots and inducing a state of temporary dormancy in the plant. Weaker plants are lost through competition for moisture and light. All these factors may reduce dry matter yield and stand density.

Shallow water penetration into the soil
Where surface soil structure is a problem, inadequate water infiltration will reduce root growth, available stored soil water and hay yield.

Weeds
Dodder and other weeds can be spread through irrigation water.

Irrigation methods

Lucerne can be irrigated by spray, flood, or subsurface drip systems.

Spray irrigation is reasonably efficient (up to 85 per cent), but machinery and pumping costs can be expensive. It is popular along rivers and creeks, in small irregular shaped paddocks or on lighter undulating land. For small areas, hand-shift or travelling-gun irrigators can be used, whereas centre pivots, linear-move and travelling low-pressure booms are suited to larger areas.

Surface flood irrigation (up to 70 per cent efficient) occurs on flat grades and heavier soils. Layouts must be designed to ensure fast watering and drainage. Raised beds allow quick drainage in large fields with very flat grades, but machinery needs to be modified to suit the layout.

Sub-surface drip irrigation (SDI) is suited to loams and clay soils and is the most efficient (up to 95 per cent) method of irrigating lucerne, but installation costs are high and the life of the drip lines may be limited.

Factors that should be considered when selecting and designing your choice of system are:

- Soil type. The soil water-holding capacity, infiltration rate and any soil structural problems are important factors.
- Peak water requirements. Provision of adequate soil moisture for germination and supply of water six to 10 days after germination if the soil surface dries out are important. You must be able to meet maximum daily or maximum monthly requirements, schedule irrigations to avoid plant stress, and water efficiently.
- Distribution uniformity (DU). Water needs to be applied evenly to the entire irrigation area.
- Source of supply. Water quality must be suitable for lucerne and the soil type, and the volume required must be sustainable.
- Pump selection. The pump selected should be the most efficient available for the duty required. This will minimise pumping costs.
- System selection. When you select a system, take into account the topography, running costs, labour requirements, capital cost and your lifestyle needs.

Further details on these issues can be obtained through the Waterwise program – inquire at your nearest NSW Agriculture office.

Water requirements

The object of irrigation is to supply enough water to replenish the soil profile before plant growth and yield are reduced.

Too little water will reduce yield and quality. Too much water is wasteful and expensive. It can also cause problems with disease, waterlogging, summer weeds, soil compaction, nutrient leaching, rising watertables and salinity. When water is limited lucerne can survive with less frequent irrigation, but plant production will be reduced.

Centre-pivot spray irrigation systems are efficient and suited to large areas.

M LATTIMORE

Lucerne generally requires 40–70 mm of water to produce l tonne of hay. This equates to 7–13 ML/ha of irrigation water for a highly productive irrigated hay stand during a full irrigation season.

Lucerne is irrigated from mid-August to late April depending on the location and climate. It generally requires 10 to 15 waterings (two or three irrigations between each hay cut, with four to six weeks between cuts). This can mean watering every seven to 10 days in mid-summer. Good management is needed to coordinate cutting and watering.

When to irrigate

Irrigation scheduling allows more efficient water use and helps to avoid waterlogging. The timing of irrigation will depend on the stage of growth, the water-holding capacity of the soil, the irrigation layout and the weather. Regular monitoring and observation of soil moisture levels is required. This can be done in a number of ways.

1. Soil-based observation

Most of the soil water used by lucerne is extracted from the top 1 m, so it important to monitor the moisture in that zone. The soil's water-storage capacity (and structure) affects the number of irrigations required. Greater soil water storage requires less frequent irrigations.

The depth of water penetration can be checked with a **push probe** (a 10 mm diameter spring steel rod, with a 12 mm pointed tip) hand-driven into the soil one day after irrigation.

A **soil auger** or **shovel** can also be used to sample the soil at different depths, so that moisture can be assessed by **hand texturing** (squeezing a soil sample between with your fingers and the palm of your hand). Irrigation is required when:

- (for loams and clay loam soils) the soil cannot be rolled to form a thick ribbon 25–75 mm x 3 mm
- (for sandy soils) the soil will not hold together when pressed into a ball.

A more accurate method is to determine the **readily available water** (RAW); namely the soil moisture that plants will use before moisture stress occurs. The RAW is roughly 50 per cent of the moisture-storage capacity of the soil and is calculated for each layer of soil and summed. The soil moisture level needs to be kept within the RAW to minimise plant stress. Below this amount, plants must use excess energy to extract moisture, and production losses will occur. The RAW depends on the soil type and the rooting depth of the plant. The RAW for lucerne with a rooting depth of 1 m in various soil types is shown in Table 6. If the rooting depth is less than 1 m, soil water-storage capacity will be reduced and more frequent irrigation will be required. Growers need to estimate the RAW and to refill the soil with the same amount of water. For example, for a loam soil, irrigate before the RAW reaches 85 mm (at 60 kPa if using a tensiometer) to maintain maximum production.

Various other instruments can also be used to accurately assess soil moisture, including tensiometers, neutron probes and electronic monitoring systems. Many of these are now quite affordable, and contractor services are also available. The important thing is to choose a system to suit your level of management and to provide the information you need for your irrigation scheduling system.

2. Weather-based observations

Crop water use or **evapotranspiration** (Et) can be used to create a progressive soil water budget to determine the level of soil water depletion and to predict the time to irrigate. 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 the amount of water equivalent to the RAW, without contributions from rainfall, then it is time to irrigate.

Generalised Et_0 (evaporatranspiration from a reference crop) values can be calculated from temperature, wind and radiation measurements taken from automatic weather stations installed by the weather bureau and government agencies. Daily figures are often presented in the

Table 6. Soil water storage capacity of various soil types to 1 m depth, and corresponding readily available water (RAW) value for lucerne at –60 kPa

Soil type	Plant-available soil water to 1 m (mm)	RAW to 1 m (mm)
Clay	145	55
Medium clay	160	55
Loam	150	85
Sandy loam	115	65
Sand	60	35

local news media, such as NSW Agriculture's Water Watch service, which operates in southern NSW.

To calculate specific crop Et_0 at different stages of plant development, multiply the generalised Et_0 figures by correction factors (**crop coefficients**). These range from 0.4 just after cutting to 1.2 for a dense stand at early flowering, with an average of 0.9.

For example, to calculate the daily water use of a lucerne crop when evapotranspiration (Et_0) is 9 mm/day, with no rainfall, with lucerne at the early flowering stage, multiply by 1.2:

Daily crop water use = 9 mm x 1.2 = 10.8 mm.

Pan **evaporation** can also be used to estimate crop water use. This is simply the change in water depth (mm) in a wide, open container. To convert open container evaporation to a generalised Et_0, multiply by a modifier called the 'pan factor' and then by the appropriate crop coefficient. Pan factors may vary from 0.6 to 0.9. If the factor is unknown, 0.8 will give a good estimate.

For example, for lucerne at early flowering with evaporation of 10 mm and no rainfall:

Scald damage caused by irrigation mismanagement on poorly drained soils

L TURTON

Daily crop water use = 0.8 x 10 mm x 1.2 = 9.6 mm.

Time between irrigations can vary significantly, depending on the time of year, the location, soil type and weather.

3. Plant-based indicators

Typical symptoms of moisture stress in lucerne include a dull green or bluish colour, wilting of the foliage, leaf drop, early flowering and slow regrowth after cutting. To maximise yields, irrigation should occur **before** stress symptoms appear in the crop. This can be difficult, as soil types can vary considerably across paddocks, so observation of stress on the areas with the lowest water-holding capacity could be used to signal when irrigation is needed.

4. Computer programs

Programs are available to help growers irrigate as efficiently as possible. One such program, Haymaker utilises weather and soil data to improve irrigation efficiency in lucerne. Its use by spray irrigators in northern NSW has significantly increased the yield and efficiency of hay production.

The final irrigation before harvest should be timed to allow adequate drying of the soil surface to prevent soil compaction by harvesting machinery. (This is less important with SDI.) However, adequate subsoil moisture should remain to allow quick regrowth after harvest. This can be two to seven days before cutting, depending on the soil type and the weather. Under flood irrigation, rapid regrowth is essential to minimise the risk of scald damage during hot weather. Ensure that plants have regrown some leaf before the first watering after cutting.

Key points on management of different lucerne irrigation systems

1. Spray irrigation

Well-managed spray irrigation should yield lucerne hay at a rate of 15–25 t/ha. The main barrier in achieving these yields is usually the inability of the system to satisfy the peak water demands of the crop. A spray irrigation system must be well designed to ensure its economic feasibility.

Pressure is required in spray systems, and the higher the pressure required the more expensive the system is to operate. In recent times low-pressure spray irrigation systems have become popular. These systems have reduced operation costs but usually have a high instantaneous application rate and are not recommended for soils with low infiltration rates.

2. Surface flood irrigation

Good management of flood-irrigated lucerne is essential on heavier soils to avoid damage to the stand and to maximise yields and quality. Growers should aim to provide the best drainage possible and to avoid any moisture stress by watering efficiently.

Key features of flood irrigation systems are:

- Root rot resistant varieties are essential.
- Good layout and drainage are essential to avoid waterlogging.
- Irrigation and drainage should be completed within 8 hours.
- Ensure that water penetrates to 80–100 cm into the profile.
- To avoid scald after cutting, do not water until regrowth appears.
- Water at night in hot weather.

3. Sub-surface drip irrigation (SDI)

SDI is an extremely efficient system and has gained popularity in recent years with the realisation that our water resources are limited and therefore valuable.

SDI has the ability to optimise soil moisture for plant growth by irrigation frequently with small quantities, as labour is not a problem. This system also has the ability to deliver water evenly to the entire irrigation area (high distribution unifomity). Some labour may be required to fix blockages or leaks caused by vermin attack (for example, by mice or crickets).

Improving water infiltration

Water infiltration of a soil can be improved by incorporating organic matter from preceding crops and pastures or, on sodic soils, by applications of gypsum. Typical application rates for dispersive clay soils are 2.5–5 t/ha, but lower rates can be applied in irrigation water. The soil's sodicity should be reassessed every few years.

Groundwater pumps and subsurface (tile) drains may be used to improve internal drainage of the soil profile. For each paddock, the high costs of such works should be carefully considered against the long-term benefits.

PEEL IRRIGATION AND WATER SUPPLIES

Laying sub-surface irrigation tape. This system is efficient and can deliver water evenly over the target area.

Fertigation

This is a technique for supplying dissolved fertiliser to lucerne through the irrigation system. It has been used successfully in pressurised spray irrigation systems such as SDI, centre pivot and lateral move systems.

Continuous application using fertigation has the following advantages:

- savings on the labour needed to spread solid fertiliser
- reduction in the compaction caused by conventional machinery
- placement of fertiliser by SDI into the root zone, where it can be used more efficiently
- more rapid uptake than solid fertiliser.

Further information on irrigation can be sourced from Irrigation Officers of NSW Agriculture.

SALINITY

Lucerne seedlings are very susceptible to salt damage, but mature plants are moderately tolerant relative to other agricultural plant species. Lucerne as a species is more tolerant than either white clover or subterranean clover but less tolerant than balansa or Persian clover. Lucerne has a particular role in reducing salinity because of its ability to lower watertables.

Saline water
Use of saline water can reduce lucerne yields, increase soil permeability and raise salt levels in the soil surface. Ground water and re-use water suspected of being saline need to be salt tested before being used on lucerne.

Flood irrigation and saline water
Where irrigation is used to establish lucerne, use only low salinity water (< 0.8 dS/m.) Mature lucerne can occasionally be irrigated with water containing salt at levels up to 2.4 dS/m (or l500 ppm). However, repeated irrigations with this level of salt over two or three years will reduce yields significantly. Occasional use of better quality water is required to leach salt from the topsoil.

Spray irrigation and saline water
If water is moderately saline, it is best to avoid irrigation on hot days to prevent salt concentrating on the leaves and causing leaf burn. Frequent light irrigations should be avoided, as they do not assist leaching.

Saline soil
Soil salinity (EC_e) levels of < 2.0 dS/m should have little or no significant effect on lucerne yields on well drained soils. At 2 dS/m up to a 10 per cent yield reduction can be expected. A 25 per cent loss can be expected at 5.4 dS/m, and levels > 6 dS/m can cause even larger yield reductions. Expected losses on poorer draining soils are greater, with a 10 per cent loss expected at 1.3 dS/m, and a 25 per cent loss at 3.5 dS/m. If EC_e > 2.0, a chloride test can be used to confirm the presence of harmful salts.

Establishment issues on saline soils
Soil salinity levels should be tested down the profile before sowing. Fertiliser and gypsum should not be applied before you take samples for soil testing, because they will interfere with the measured salt levels.

Although mature lucerne is moderately tolerant of salt, it will achieve maximum yields only on the best soils. Saline soils should be leached of salt by growing an irrigated annual salt-tolerant crop such as millet or barley, followed by an application of gypsum. The gypsum provides calcium to displace sodium from the soil and maintains a high electrolyte level, which helps to prevent soil crusting and maintains a porous structure. This improves infiltration and allows deep wetting and better leaching of harmful salts.

GROWING LUCERNE FOR SEED

The market for lucerne seed is very competitive, and seed production has become specialised. Opportunity cropping of grazing or haycutting stands for seed production has become less attractive, but it can be a useful sideline when seasonal conditions permit.

Control of insect pests, pollination and irrigation water scheduling is critical for efficient production of seed.

Insect pests, such as thrips, heliothis and lucerne seed wasp, damage developing seeds and need daily monitoring. Thrips attack the flower buds at or just before flowering and need to be controlled early. Heliothis generally attack lucerne flowers, burrowing into the developing seed pod and eating the seed. Spray with a registered insecticide when heliothis numbers exceed about five to eight insect larvae per 10 sweeps with a sweep net.

Lucerne seed wasp attacks green seed pods for about 10 days after flowering. Seed wasp can be controlled with good management practices such as removing volunteer lucerne plants, reducing seed residues over winter and cutting the lucerne stand for the seed crop as early as possible to avoid the increase in wasp numbers that occurs after January. Regular use of insecticides to control pests like heliothis should keep seed wasp numbers low.

Seed crops need adequate insect pollination, and a minimum of three hives of active bees per hectare is normally adequate. Pollinating insects such as honey bees should be introduced into the crop just before first flower. Insect pests can be controlled during flowering only by late-evening application of those registered insecticides that have low efficacy against bees. Never apply insecticides in the morning during flowering.

Adequate control of irrigation water should allow the crop to grow without inducing severe water stress. Well-watered seed production stands should have a short flowering period lasting about two weeks.

Lucerne is generally ready to harvest about 90 days after cutting or about 60 days after first flower, when 80 per cent of the pods have turned brown. Desiccation with a registered herbicide improves seed recovery. More than 60 per cent of seed can be lost by inappropriate harvester set-up. Be prepared to adjust harvester settings throughout the day as the temperatures and moisture levels of the crop change. Consult the manufacturers for correct set-up for different operating conditions.

Seed yields vary from about 100 kg/ha for average dryland stands up to about 800 kg/ha for well-managed irrigated stands with good insect pest control, adequate pollinating insects, excellent water management and favourable weather conditions throughout the growing and harvest period.

Seed of varieties registered under Plant Breeders Rights (PBR) can be sold only by the owner of the variety.

In NSW small quantities of seed are used for the production of alfalfa sprouts. The industry favours regular deliveries of smaller quantities of highly winter-active varieties with low hard-seed content and germination in excess of 90 per cent.

CONTINUED:

Agfact P2.2.25 Lucerne for pastures and fodder

For the second section of this Agfact on

- Weed Control,
- Pests and Diseases
- References

Please follow this link to the second section.