Establishing Pastures

Hugh Allan, NSW Agriculture, Tamworth

Euie Havilah, NSW Agriculture, Berry

Harry Kemp, NSW Agriculture, Bega

NSW Agriculture

Acknowledgments

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Series coordinator Alex Ashwood, NSW Agriculture, Wollongbar

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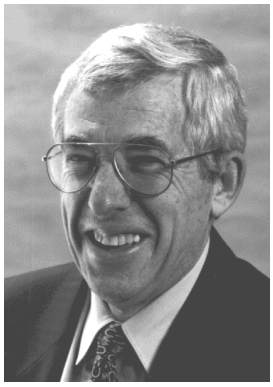
Foreword



John Craven, Program Manager, Farm Production, DRDC

Kevin Sheridan, Director-General, NSW Agriculture

Reg Smith, President, NSW Dairy Farmers' Association

Dairying is one of the most progressive rural industries in NSW. This is evidenced by substantial changes in herd sizes and increases in production by cows and from farms.

An outcome of these increases is that management has become more complex, requiring greater knowledge and technical skills.

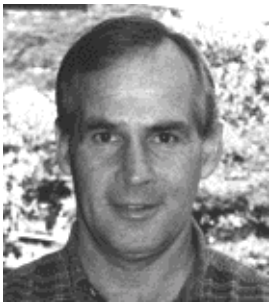
As farmers become more competitive through increases in both production and productivity, they will require even better technical information and management skills. Most important, they will need to know how to use the information in improving whole-farm performance and profits. This statement is supported by results of various Dairy Research and Development Corporation workshops and NSW Dairy Farmers' Association surveys, which have clearly indicated that farmers require technical packages that are current and relevant.

DairyLink is a series of integrated information packages that look at aspects of pasture, herd and feed management, and suggest practical ways of getting the best from your cows and pastures. The DairyLink series is a result of collaboration between NSW Agriculture officers, agribusiness and farmers.

The packages will be the basis of workshops and meetings for NSW dairy farmers.

DairyLink has much to offer the NSW dairy industry in helping improve farm productivity and profitability. We encourage farmers to attend and participate in the DairyLink workshops and meetings.

Preface



DairyLink is an innovative concept that introduces you to some important technical areas to help improve farm productivity and profits.

The modules in the series are of value to farmers, students, consultants and extension service providers.

DairyLink consists of the following information packages:

Establishing Pastures
Managing Pastures
Growing Heifers
Realistic Rations
Conserving Feed

The modules have been developed as technical manuals and farmer-friendly booklets, and are linked to the Tocal Dairy Home Study course.

I acknowledge and thank the various technical teams for doing an excellent job. I also appreciate the funding and support provided by the Dairy Research and Development Corporation.

Alex Ashwood
DairyLink Series Coordinator

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Introduction

This package has been written to help dairy farmers choose and establish pastures and forage crops for milk production.

Successful pasture establishment requires careful planning, a detailed understanding of the factors that affect establishment, and attention to detail for each operation, including correct timing. Planning requires predicting the feed requirements for the herd, and choosing the pasture or forage crop type and the area to be sown to supply the feed. Establishment and survival depend on what happens before, at and after sowing, including pasture management in the first year.

For further information, speak to your local advisory officer.

Hugh Allan

Plan your pasture

Matching feed requirements of the dairy herd with home-grown pastures every year requires careful, long-term planning. This will ensure a consistent supply of good-quality feed to meet seasonal demand from milking and dry stock while ensuring surplus feed for conserving as silage or hay.

A combination of summer- and winter-growing pastures or fodder crops is required to ensure that risk is spread to overcome droughts, floods and the seasonal extremes of temperature that are a regular feature of dairying in most districts. Deficits of pasture or crops can be supplemented by bought concentrates, hay or silage or from fodder reserves. The need for careful planning increases as stocking rates rise.

Matching herd feed requirements with paddock feed can be simplified by using FEED PLAN, a computer program available from NSW Agriculture as part of the Milkonomics package. Ask your local advisory officer for information. FEED PLAN calculates the feed supply needed to meet feed demand for the farm. There are two parts to the process.

First, a preliminary feed budget calculates the feed surplus or deficit for various times of the year based on the feed supply from permanent pastures and the feed requirements of the herd. Pasture production is predicted from growth rates for each district (see tables). This budget indicates the feed deficits that must be met by sowing crops and pastures. Depending on the balance of permanent pastures, the deficits will occur at various times of the year. FEED PLAN allows selection from a range of tropical and temperate forage crops and fertiliser options to fill some or all of the feed shortfalls left by permanent pastures.

The final plan includes the net extra feed production from the management alternatives chosen to prevent feed deficiencies and maximise the use of surplus feed. The net benefits of the management alternatives are the differences between the growth rates of the sown species and the replaced base pasture species. A range of alternatives can easily be examined so that the pasture system best suited to a particular farm can be designed. FEED PLAN allows quick and simple calculation of budgets, and produces graphs that conveniently illustrate the sufficiency or deficiency of the feed supply from the proposed pasture system. If a deficit remains after several sowing or fertilisation options have been tested, it may have to be met by supplementary feeding.

When you have chosen the combination of pastures or crops to meet herd requirements, you need to plan ahead:

- Identify areas for cultivation or direct-drilling.
- Decide timing of the operation.
- Assess the need for a fallow to increase soil moisture before sowing.
- Consider planting a break crop to reduce serious weed burdens, break the disease cycle and control the build-up of soil-borne pests.
- Control weed species that are likely to set seed and invade the new pasture in the first year after sowing.
- Concentrate stock to remove excess groundcover before ploughing, direct-drilling or using a herbicide before direct-drilling.
- Decide the need for pretreatment for hard-to-kill grass species such as African lovegrass or giant Parramatta grass.

For most pasture sowings a plan will be needed 3 months before sowing. For problem situations where difficult-to-kill weeds are present, a plan may be necessary up to 12 months before sowing.

Pasture growth rates (kg dry matter/ha)—Central Coast

	Kikuyu + nitrogen	Kikuyu + white clover	Paspalum + ryegrass + white clover	Perennial ryegrass + nitrogen	Perennial ryegrass + white clover	Highly winter-active lucerne	Semi-dormant lucerne	Lucerne + ryegrass + white clover
January	49	40	35	10	10	46	41	33
February	50	40	35	10	10	40	38	33
March	45	40	40	25	20	32	32	28
April	40	35	35	35	30	25	21	20
May	30	25	35	40	35	18	11	35
June	0	5	30	30	30	12	8	30
July	0	5	30	30	30	11	7	30
August	0	5	32	38	35	15	11	32
September	0	20	60	73	65	22	21	55
October	0	20	60	72	65	38	42	55
November	10	15	55	65	60	44	53	50
December	20	20	50	50	50	43	47	35

Pasture growth rates (kg dry matter/ha)—Tropical pastures

	Setaria	Kikuyu	Paspalum	Carpet grass	Ryegrass + clover	Ryegrass + nitrogen	Ryegrass	Lucerne
January	36	32	27	21	13	21	11	64
February	56	54	39	30	13	21	11	57
March	53	60	39	27	19	38	26	46
April	27	40	19	10	21	38	29	38
May	9	19	3	3	27	43	32	25
June	3	8	0	0	19	38	24	13
July	1	3	0	0	19	38	24	11
August	1	4	0	0	38	48	32	13
September	8	13	12	3	48	59	30	36
October	13	12	18	5	59	70	11	53
November	13	12	18	9	43	48	9	64
December	15	14	18	10	21	27	5	72

Pasture growth rates (kg dry matter/ha)—Southwest NSW

	Paspalum + clover high N	Paspalum + clover med. N	Paspalum + clover low N	Ryegrass + clover high N	Ryegrass + clover med. N	Ryegrass + clover low N	Subclover + annual ryegrass high N	Subclover + annual ryegrass low N
January	105	75	52	75	55	37	0	0
February	92	70	45	60	45	30	1	0
March	75	55	37	46	33	22	5	2
April	22	15	11	35	25	17	15	7
May	11	7	5	25	18	12	31	15
June	5	3	2	16	12	8	30	15
July	5	3	2	15	10	7	28	14
August	11	7	5	25	18	12	38	19
September	22	15	10	48	36	24	60	30
October	44	30	20	15	48	33	60	30
November	66	48	32	78	55	38	55	27
December	100	75	50	85	63	42	0	0

Pasture budgets

Pastures usually produce an inexpensive source of high-quality feed. The cost of developing a pasture is shown in the following tables. Figures are accurate as at 1996. For later dates, please be sure to use current figures for every item. These budgets are for a typical perennial ryegrass – white clover pasture.

Ground preparation (costs per hectare)

Cultivation		
Chisel plough × 1	1.5 h @ $8/h	$12.00
Disc harrow × 2	3.5 h @ $8/h	$28.00
		$40.00
Herbicide treatment		
Glyphosate	2.5 L @ $12/L	$30.00
Boom spray	0.4 h @ $8/h	$3.20
		$33.20
Knockdown herbicide application		
Glyphosate	1.0 L @ $12/L	$12.00
Boom spray	0.4 h @ $7/h	$2.80
		$14.80

Ryegrass–clover pasture (costs per hectare)

Establishment		
Cultivation		$40.00
Seed	12 kg perennial ryegrass + 6 kg clover	$94.00
Fertiliser	125 kg DAP @ $500/t	$62.50
Sowing	1.5 h @ $8/h	$12.00
		$208.50
Topdressing		
Fertiliser	180 kg N as urea @ $1.08/kg	$194.40
	15 kg P @ $2.70/kg	$40.50
	120 kg K @ $0.80/kg	$96.00
Broad-casting	0.25 h @ $8/h × 7 treatments	$14.00
		$344.90
Irrigation		
Average twice per grazing × 0.33 ML per irrigation @ $30/ML		$20.00
Total cost in first year		$573.40

In the first year the pasture will yield 20 t/ha DM (dry matter) at a cost of $573.40/ha or $28.67/t DM, or 2.867¢/kg. This figure emphasises the cost-effectiveness of pasture production.

Pasture consumed per hectare

This will vary from 3 to 15 t/ha DM depending on pasture management.

Pasture consumed (t/ha DM)	Cost ($/t)
3	191
6	96
9	64
12	48
15	38

How does pasture consumed affect the cost of producing 1 litre of milk?

Pasture consumed (t/ha DM)	Cost to produce 1 L milk (¢)
3	14.8
6	8.9
9	7.0
12	6.0
15	5.4

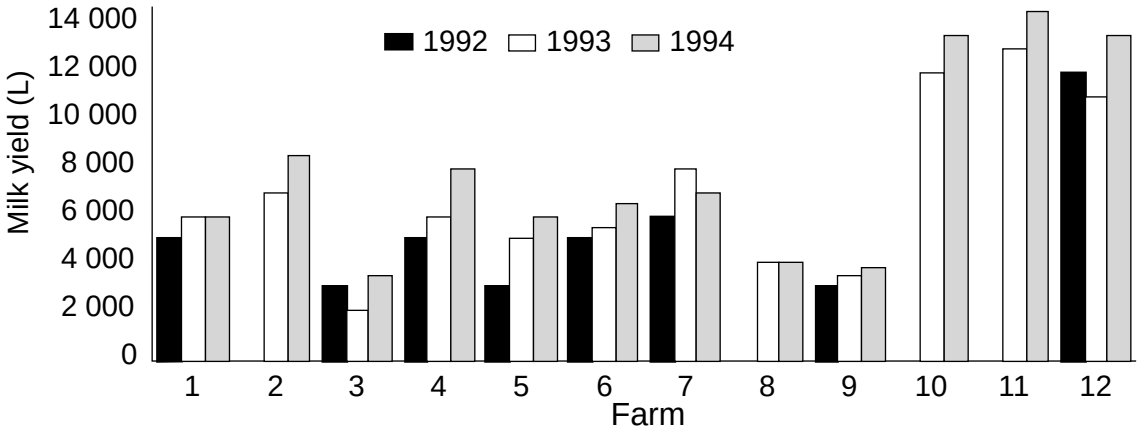
Growing high yielding pastures and achieving high pasture consumption are essential.

Yield and cost (at 100% use) of pasture species

Pasture type	Expected yield (t/ha DM)	Cost ($)
Oats	10	45
Annual clover	12	35
Annual ryegrass	12	40
Lucerne	18	35
Kikuyu	20	40
Maize	22	60
Forage sorghum	20	30

The average cost of pasture eaten on the 12 dairy farms in the following graph was $48 per tonne of dry matter eaten. The range was $10.67 to $92.79.

Litres of milk per hectare of pasture on 12 mid and lower Hunter dairy farms (1992–94)



Soil testing

The key to productive, persistent perennial pastures is a good fertiliser program.

Soil tests are a useful and necessary tool for assessing soil fertility and for determining the need for fertiliser or lime. Soil tests do not give all the answers, but do indicate whether a deficiency or toxicity exists. They are less useful in determining rates of fertiliser to apply. Over several years, however, they indicate whether the fertiliser applied over that time has increased, maintained or decreased the nutrient status of a paddock.

Ensure that you follow the soil sampling procedures recommended by the laboratory. Avoid soil sampling within 6 months of fertiliser application to obtain meaningful results.

Although it is expensive, tissue analysis is the most reliable means of testing for trace elements.

Soil pH

This is a measure of the acidity or alkalinity of the soil. Many soils are naturally acidic, but others acidify through nitrogen fertiliser use and legume nitrogen fixation. Soil pH is a useful guide to species selection and the need for lime. It also determines the need for the trace element molybdenum (Mo), which is essential for nitrogen fixation by legumes.

There are two different pH tests: water and calcium chloride ($CaCl_2$). The $CaCl_2$ test is preferred as it fluctuates less with seasonal changes, but readings are 0.5–0.8 pH units lower than water tests. The pH scale ranges from zero (acid) to 14 (alkaline), where 7 is neutral.

Soils with a pH ($CaCl_2$) of 4.5 or less are rated as strongly acidic. The toxic element aluminium is soluble in these soils and is available to plants. Soils with a pH of 4.5–5.0 are moderately acidic; pasture growth is satisfactory. The ‘ideal’ pH range for pasture growth and nutrient availability is between 5.0 and 6.5.

Phosphorus (P)

The availability of soil phosphorus will vary with the acidity of the soil. The more acidic the soil, the more phosphate that is ‘fixed’ by the soil and made unavailable to plants. On acidic soils, the interpretation of phosphate requirement is more difficult as all tests overestimate the amount available.

There are three main phosphorus tests used in Australia. They have different minimum levels (or ‘critical’ values) for maximum yield.

- The **Bray test** appears least affected by low pH and has a similar critical value across all soils (15ppm for pastures). The test is not suitable for soils with a pH ($CaCl_2$) above 7.0.
- The **Olsen test** can be used on alkaline and acidic soilss. Critical values are similar to those for the Bray test.
- The **Colwell test** is used extensively in NSW. Its critical value changes with soil type. On soils with high levels of aluminium or reactive iron, it overestimates; interpretation must take this into account. Divide the P test result from slate or shale soils by 2.5 and from basalts by 2. Red-brown earths, most clays and non-acidic granites don’t require correction.

(This section has been derived from *Management of Profitable and Sustainable Pastures* and is reproduced here with the kind permission of the authors, Michael Keys, Bruce Clements, Mark Conyers and Michael Duncan of NSW Agriculture, and Rosalie Strachan of Analysis Systems, Port Kembla.)

Critical value is 35.

Adding 125kg/ha of single superphosphate will add about 5–6mg/kg of phosphorus to the soil (as measured by the Bray test), provided P levels are moderately high before application.

Sulphur (S)

The recent KCl-40 test for sulphur gives a reliable way of measuring the more available organic forms of S. The critical minimum value is 8mg/kg (previously ppm).

Exchangeable cations (CEC)

A full analysis includes the 'exchangeable cations', which give a measure of overall soil fertility. The cations—calcium (Ca), magnesium (Mg), potassium (K), sodium (Na) and aluminium (Al)—are added together to give the cation exchange capacity (CEC). The higher the total, the more fertile the soil. Soils with a CEC below 2.5meq/100g ('light' soils) have very low nutrient levels.

The relative percentages of each cation and the actual levels are both important. The desirable ranges for relative percentages are:

calcium	65%–80%
magnesium	10%–15% (20% max.)
potassium	1%–5% (10% max.)
sodium	0%–2% (max.)
aluminium	0% (ideal) to 5% (max.)

The ratio of **Ca** to **Mg** should be 3:1 or more, but not more than 8:1. Low magnesium levels cause grass tetany in animals. High levels (> 20%) can induce potassium deficiency.

A response to **potassium** is possible when the absolute level is below 0.2meq/100g. Highly productive pastures should have 3%–5% potassium. Dairy production transfers huge quantities of potassium from outlying areas of the farm to lanes and other dairy areas, where dung and urine accumulate. Hay or silage cutting also removes large quantities.

Soils with a sodium level of more than 5% are unstable: the soil aggregates begin to fall apart when they are wet, causing waterlogging, poor aeration, poor drainage and surface crusting. When dry, they are often hard-setting and compacted.

Aluminium is toxic to plants; it reduces root growth and phosphate metabolism. It becomes available only when soil pH is below 5. Sensitive species such as lucerne and phalaris perform poorly when aluminium levels exceed 5%. The only way to overcome aluminium problems is to use lime. Where soils are acidic to depth, also use tolerant species.

Electrical conductivity

The figure given for electrical conductivity on the soil test report has been adjusted for soil texture to give the salinity rating. Soils with a rating of more than 4.0 are considered saline, and tolerant species need to be used to achieve a reasonable yield.

Leaf analysis

Leaf analysis is used for testing all elements, although it is used especially for checking the trace element status of the pasture plants. It is considered to be a more accurate test for soil nutrients than a soil test.

For **trace element** deficiencies it is best to sample clover leaves. Take the fresh new growth. For **other nutrient deficiencies**, take the leaf sample while the clover is actively growing and before it starts to flower. To determine **herd nutritional requirements**, take a mixed sample of what the animals are eating.

Soil acidity and liming

Soil acidification is a natural process that is accelerated by leaching of nitrate from the soil, addition of organic matter, and removal of calcium and magnesium in agricultural products such as milk.

As soils acidify there is generally an increase in undesirable nutrients such as aluminium and manganese, which can become toxic to pastures and crops and reduce productivity. Soil acidity is corrected by applying liming materials. The Agfacts *Soil acidity and liming* (AC.19) and *Liming materials* (AC.15) contain detailed information on the subject. These Agfacts should be in the back of this manual. If they are not, contact your nearest NSW Agriculture office for copies. The rest of this section presents information not found in those two Agfacts.

How much do I apply?

Approximate amounts of calcium carbonate (kg/ha) needed to raise the pH of the top 10 cm of soils of different texture *(From Pearson, R. W. and Adams, F. I. (eds), 1967.* Soil Acidity and Liming. *Agronomy Series No. 12, American Society of Agronomy, Madison, Wisconsin, USA.)*

	To increase pH from:	
Soil texture	4.5 to 5.5	5.5 to 6.5
Sand, loamy sand	850	1100
Sandy loam	1300	1950
Loam	1950	2400
Silty loam	2800	3200
Clay loam	3200	4100
Organic	6800	7900

Useful tips for applying liming products

- Lime is relatively insoluble. It must be worked into the soil to get best results. Broadcasting lime on top of the ground is wasteful. Lime moves only 2.5 cm a year. An average pasture root system of 15cm depth will receive the benefits only after 6 years.
- Do not mix lime with fertilisers.
- Calcium is one of five exchangeable cations (calcium, magnesium, potassium, sodium and aluminium). It is important that the 5 be kept in balance. Use soil tests to monitor this.
- Both calcium and magnesium compete with potassium for entry into plants. Therefore soils high in one or both of these cations will require large additions of potassium.

Further information

Agfact AC.15, *Liming materials*, NSW Agriculture

Agfact P2.2.7, *Inoculating and pelleting pasture legume seeds*, NSW Agriculture

Winter cereal management guide, NSW Agriculture

Soil acidity and plant growth, edited by A. D. Robson, Academic Press, Sydney.

Pasture species

Annual grass crops

Maize
Millet
Oats
Prairie grass
Ryegrass—annual
Sorghum—hybrid forage
Sorghum—sweet
Sudan grass

Perennial grasses

Cocksfoot
Kikuyu
Paspalum
Rhodes grass
Ryegrass—perennial
Perennial ryegrass – white clover pastures
Setaria
Tall fescue

Annual legumes

Balansa clover
Berseem clover
Cowpea
Lablab
Persian clover
Soybean
High density legumes

Perennial legumes

Kenya white clover
Lotus
Lucerne
Pinto peanut
Red clover
Strawberry clover
Subterranean clover
White clover

Other pasture species

Chicory

Annual grass crops

ANNUAL RYEGRASS—See Ryegrass

MAIZE (*Zea mays*)

High yielding fodder crop producing high quality roughage with a metabolisable energy (ME) > 10 MJ/kg. Can be stored long-term as silage for supplementation when paddock feed is low. Can also be used to increase stocking rates and thus to increase pasture use efficiency.

Strengths: High potential yields—up to 25 t/ha dry matter Useful cleaning crop in a pasture rotation to break disease and insect cycle. Maize silage in storage is usually much cheaper than purchased roughage of similar quality.

Weaknesses: Costly to grow; failure is expensive. A large capital infrastructure is required to plant, harvest, store and feed out the crop. With machinery in place, production is cost-effective. Low in protein; high protein supplementation required. Cannot be grazed.

Seasonality: Can be planted from late October to January, depending on the district and the maturity of the variety sown. Highly susceptible to frosts; choose sowing date and variety combinations to avoid frosts before the crop is ready to harvest.

Persistence: 100–150 days from planting to harvest.

Varieties: Early: 75–95 days Mid season: 110–120 days Late: 120–130 days.

Sowing: Sow into a weed-free, well prepared seedbed. Use precision sowing to ensure a density of 60–90 000 plants per hectare in rows 75–90cm apart.

Feed quality: Silage made from maize harvested when the milk line in the grain is half-way across the kernel will have an

ME content of 9.5–10.5MJ/kg. Protein content, however, is very low: 5%–7%. Use protein feed supplements when maize forms a high proportion of the diet.

Diseases: Leaf diseases and stalk rots. Use resistant varieties.

Pests: Cutworms, black beetle and wireworms can seriously limit yield.

Grazing management: Not suitable for grazing. Feed as green-chop or silage instead.

Companion species: Legumes have been grown with maize to increase total protein content, but the maize yield suffers. Sunflowers have also been grown with maize to increase energy concentration, but these combinations are difficult to manage. The aim should be to get the highest yielding maize crop possible.

Special factors: Weeds can compete with maize crops and substantially reduce yields if not controlled. Use a combination of pre- and post-emergence herbicides.

MILLET

There are two distinct types of millet sown as summer fodder crops—Japanese and pearl.

Strengths: Produces feed during summer and early autumn. Growth is rapid. Dry matter yields can be high. Suitable for hay or silage. Useful because cultivation for establishment cleans up summer-growing weeds.

Weaknesses: Pearl millet can be difficult to establish—needs a clean seedbed. Feed quality declines rapidly with advancing maturity—plants should be grazed when young. Rapid growth rate makes management for best feed quality difficult.

Japanese millet (*Echinochloa utilis*)

Strengths: Germinates under the cooler soil temperatures of spring (14°C) better than other millets and sorghums. Valuable as a short-term rotation crop for spring – early summer grazing, before the ground is prepared for the next crop or pasture. Rapid early growth can fill feed shortfalls in early summer after floods or drought. Good grazing is available 6–7 weeks after sowing. Gives two good grazings in northern NSW and repeated grazings in the cooler southern areas.

Weaknesses: Runs quickly to head under hot and dry conditions.

Varieties: Shirohie.

Sowing: Sow at 15–20 kg/ha into clean seedbed, late September onwards.

Feed quality: Fair if grazed when young—ME 8.5–9.5 MJ/kg. Protein content can decline from 25% to 6% with advancing maturity.

Diseases: None significant.

Pests: None significant.

Grazing management: Grazing before growth becomes too advanced aids recovery and lengthens the grazing life. Introduce stock when plants are 15–22 cm high.

Companion species: Millets are normally sown without any companion species, as legumes grow too slowly to be useful in combination.

Pearl millet (*Pennisetum glaucum*)

Requires higher soil temperatures (18°C) than Japanese millet for germination. Maximum growth during summer and early autumn.

Strengths: Higher digestibility throughout its growth cycle than forage sorghums.

Weaknesses: Often will not germinate and establish effectively. Extreme care is required in seedbed preparation, sowing depth and avoiding compaction at sowing.

Varieties: Nutrifeed, Feedmill, Supermill, Katherine, Ingrid, Tamworth.

Sowing: Sow at 5–15kg/ha into a clean seedbed, mid November – mid December.

Feed quality: High, but declines quickly with advancing maturity—ME is in the range 8.5–9.5MJ/kg. Protein content can decline from 25% to 6% with advancing maturity.

Grazing management: Introduce stock when plants are 45–90cm high. If left ungrazed, plants can reach 3m, and their rapid growth can cause management problems in maintaining high feed quality.

OATS (*Avena sativa*)

Although largely replaced by annual ryegrass, oats can be a useful winter forage crop.

Strengths: Large seed well suited to oversowing or direct-drilling into existing summer-growing pastures. Can be sown in mixtures with ryegrass to supply extra feed in late autumn – early winter. Produces vigorous seedlings. Two weeks quicker to first grazing than annual and Italian ryegrass. Produces high quality

feed in late winter – spring. With repeated grazings, oats thin out and are gone by early spring, leaving the ryegrass to continue without competition for another few months into late spring – early summer. N fertiliser can produce significant increases in feed when required. Excess growth can be conserved as medium to high quality hay or silage. Growth rhythm complementary to summer-growing species such as kikuyu.

Weaknesses: Overall, oats do not produce the yield of forage over the extended period that ryegrass does. The forage is also less digestible and lower in feed value. Feed supply will not extend into late spring – early summer. Susceptible to grazing mismanagement: grazing off the growing points at the wrong time can seriously impair regrowth and feed production. The high rates of nitrogen required for high production could pollute streams and ground water.

Varieties: Wide range of varieties including Saia, Enterprise, Yarran, Bimbil, Condamine, Culgoa, Cleanleaf, Blackbutt, Amby, Graza, Panorama, Camellia. Sown in mixtures, Saia is still the preferred cultivar. Enterprise has shown up well in early season production. Others with promise include Yarran, Bimbil, Condamine and Culgoa.

Sowing: Sow early autumn – early winter at 100–130kg/ha. Rates will be lower with smaller-seeded oats such as Saia. Reduce rate when sowing with annual ryegrass. Drill or broadcast into a clean seedbed. Direct-drill early sowings after suppression of summer pasture with herbicides. Later sowings will successfully establish after control of summer pasture by slashing or mulching.

Diseases: Most cultivars are affected by rust and yellow dwarf virus, which reduce yield and crop life.

Pests: None significant.

Grazing management: Graze when plants are 20–30cm high. After grazing, topdressing with nitrogen at 30–60kg N per hectare will promote good regrowth. Up to four grazings are possible before oats thin out. Grazing to a height above the plants' growing point will maintain the density of the crop and prolong its productive life.

PRAIRIE GRASS (*Bromus unioloides*)

Often naturalised in coastal dairy pastures. Produces high-quality feed in early spring. The naturalised strains mature rapidly and seed early, losing their quality. Commercial strains are later maturing and more useful for quality feed production in late spring and summer. Some of the improved strains are more perennial.

Strengths: Produces high-quality feed in early spring and high autumn growth rates.

Weaknesses: Weakly perennial. Can decline rapidly if grazing is not rotationally managed.

Seasonality: Perennial types produce autumn, winter and spring feed. Winter production can be higher than from other grasses. Sow early for best winter growth.

Varieties: Grasslands Matua

Sowing: Large seed; 120000 seeds/kg. Sow 15–30kg/ha alone or 5–8kg/ha with other grasses and clovers. De-awned and fungicide-coated seed (see 2.4) is available and flows more easily through machinery. Sow de-awned seed at half the normal rate. Sow in autumn.

Feed quality: High-quality feed. Highly palatable, making it prone to overgrazing. Feed quality declines near flowering and maturity.

Diseases: Seed must be treated with fungicide before sowing.

Pests: None significant.

Grazing management: Because of its high palatability, prairie grass must be grazed strictly rotationally. Can be used for hay crops, especially when combined with legumes such as red or berseem clover.

Companion species: Perennial ryegrass, white clover, red clover, berseem clover.

RYEGRASS —Annual ryegrass (*Lolium rigidum, L. multiflorum*)

Annual ryegrasses have become a major source of winter–spring forage over the last 20 years. They have replaced oats and other forage crops, mainly because of their longer growing season and better feed quality.

Strengths: Large seed well suited to oversowing or direct-drilling into existing summer-growing pastures. Produces vigorous seedlings. Provides forage May–December, around two months later than

oats. Produces high quality feed in late winter – spring. Mixture of annual ryegrasses and oats allows the strengths of one to cover the weaknesses of the other, and gives a more even distribution of forage throughout the season. Nitrogen fertiliser can produce significant increases in feed when feed is required. Excess growth can be conserved as medium to high quality hay or silage. Growth rhythm complementary to summer-growing species such as kikuyu.

Weaknesses: Being annuals, plants will seed down in late spring, but regeneration from seed in the following autumn can often be poor. For best results, sow annual ryegrasses each year. No production in autumn – early winter.

Varieties: Concord, Conquest, Corvette, Eclipse, Midmar, Aristocrat, Surrey, Noble, Tetila. Leading varieties in recent years have been Concord, Tetila, Aristocrat, Eclipse, Midmar, Southern Star and Surrey.

Sowing: For maximum production, sow in early autumn at 10–25 kg/ha. Use the higher rate for early production and the lower rates with clover and perennial ryegrass. Broadcast or drill into clean seedbeds. Direct-drill into clean seedbeds or after suppression of summer pasture growth with herbicides. For later sowings in late autumn – early winter, slashing is often sufficient to both cover the seed and remove competition.

Feed quality: High at the early grazings and then declines with maturity in spring. Late-flowering varieties (for example, Concord) provide better quality forage in spring than early-flowering varieties.

Diseases: Rusts, such as leaf and crown rust, can be a major problem in areas where hay is made from ryegrass in spring. Grazing management and nitrogen topdressing can reduce rust incidence. Most varieties have a rust rating of light to moderate. Eclipse is very light to light and Tetila is moderate to heavy. Host for annual ryegrass toxicity syndrome.

Pests: None significant.

Grazing management: Begin grazing when plants have reached the 3-leaf stage, at 6–8 weeks after sowing. Repeat at 3–4 weeks after each grazing. Annual ryegrasses respond well to nitrogen application after grazing. Apply 30–50 kg N/ha after each grazing; higher rates can be used during winter in colder areas.

Companion species: Besides oats, white and red clover can be sown with annual ryegrass to increase forage yield and quality later in the season.

SORGHUM—Hybrid forage sorghum (*Sorghum bicolor* × *S. sudanense*)

Summer-growing fodder crop. Can be cut or grazed up to 3 times. More suited to hay or silage because of potential to mature quickly.

Strengths: Rapid growth produces a large bulk of feed quickly in summer – early autumn. Good dry weather performance. Dry matter yields can be high. Can be used to build up depleted feed stocks quickly. Can be conserved as hay or silage for reserve feed. Useful because cultivation for establishment cleans up summer-growing weeds.

Weaknesses: Quality declines rapidly with advancing maturity if not harvested early for forage. Should be grazed when young, but can cause prussic acid (cyanide) poisoning if grazed when very young or stressed. Requires clean seedbed for effective establishment. Rapid growth rate makes management for best feed quality difficult.

Seasonality: Summer-growing fodder crop. Frost-susceptible. Soil temperature dictates sowing time in early summer.

Varieties: Speed Feed, Super Sudax, Cowpow, Jumbo. Late-maturing varieties that require shortening days to stimulate flowering are available; for example, Jumbo. These varieties are easier to manage and do not decline as rapidly in quality as other varieties.

Sowing: Sow into a clean seedbed November–January at 5–10kg/ha under dryland conditions and up to 15kg/ha under high rainfall or irrigation. Minimum soil temperature 18°C.

Feed quality: Best when plants are harvested at 1–1.5m tall. Digestibility at this stage is 65%; ME 9.5MJ/kg. Quality declines rapidly with maturity and can be as low as 50% digestibility and 6.5–7MJ/kg ME. More highly digestible, brown-midrib varieties are now available. Protein content can decline from 25% to 6% with advancing maturity.

Diseases: None significant.

Pests: Armyworms can cause severe

damage to seedlings and to leaves of growing plants. Black beetle.

Grazing management: Probably best to use for hay or silage production. If used for grazing, it is important to start grazing as soon as plants are more than 50cm high and safe from prussic acid poisoning as they will be growing very quickly and declining in quality. Best to strip-graze and back-fence to allow plants to recover quickly.

Companion species: Best in pure stands.

Special factors: Stock require sodium and sulphur supplements with sorghum.

SORGHUM—Sweet sorghum (*Sorghum bicolor*)

Summer-growing forage crop that produces high yields of moderate quality feed. Not grown as extensively in recent years as in the past, when it provided a valuable bridge between summer and winter pastures for late autumn – early winter feed.

Sowing hybrid cultivars in mid spring can often provide two silage cuts during the season, whereas open-pollinated cultivars will generally give only one silage cut and some grazing on the regrowth in autumn.

Strengths: Versatile and cheap source of energy—can be grazed, green-chopped, ensiled or left in the paddock until required. Rapid growth produces a large bulk of feed quickly in summer – early autumn. Dry matter yields can be high. Can be used to build up depleted feed stocks quickly. Can be conserved as hay or silage for reserve feed. Useful because cultivation for establishment cleans up summer-growing weeds.

Weaknesses: The decline in use of sweet sorghum comes largely from the need for quick rotation of crops between summer and winter. Sweet sorghum can lock up productive land for too long in autumn and delay the sowing of winter pastures and forage crops, thus reducing yield. Quality declines rapidly with advancing maturity if the sorghum is not harvested early for forage. Should be grazed when young, but can cause prussic acid poisoning if grazed when very young or stressed. Often poor regrowth after grazing. Requires clean seedbed for effective establishment. Rapid growth rate makes management for best feed quality difficult. Highest yield as standalone crop for silage and grazing.

Varieties: Sugargraze, Sugarsweet, Saccaline (open pollinated), FS26. Sugargraze and FS26 are preferred.

Sowing: Sow November–January into a clean seedbed at 10–20kg/ha. Either broadcast or drill into rows 35–55cm apart. Don’t sow too late in frost-prone districts.

Feed quality: ME 7.7–8.6MJ/kg, crude protein 5.6%–8.6%, digestibility 51%–57%.

Diseases: In coastal districts, sweet sorghum can suffer damage from leaf blight, rust, root and stalk rot, and seedling blights. Control measures depend largely on good management and crop rotation.

Pests: Cutworms, armyworms, wire-worms and black beetle can reduce yields.

Grazing management: If the sorghum is to be used for grazing, avoid stressed plants and young plants below 50cm high, which can contain potentially high amounts of prussic acid. In some instances, sweet sorghum plants may ratoon and grow again in the next year, but plant density declines to about half that of the original population, and it is not usually economic to leave such crops for a second year.

Special factors: Stock require sodium and sulphur supplements with sorghum.

SUDAN GRASS (*Sorghum sudanense*)

Summer-growing fodder crop. Can be cut or grazed up to 3 times or used for hay or silage. Open pollinated and hybrid types available. Sweet sudan grass hybrids have been developed.

Strengths: Rapid growth produces a large bulk of feed quickly in summer – early autumn. Dry matter yields can be high. Thinner stems and higher leaf content allow for higher quality forage than hybrid forage sorghums, but yields are lower. Rapid growth more manageable than hybrid forage sorghums. Lower prussic acid poisoning potential than hybrid forage sorghums. Can be used to build up depleted feed stocks quickly. Can be conserved as hay or silage for reserve feed. Useful because cultivation for establishment cleans up summer-growing weeds.

Weaknesses: Quality declines rapidly with advancing maturity if not harvested early for forage. Should be grazed when young, but can cause prussic acid (cyanide) poisoning if grazed when very young or stressed. Requires clean seedbed for effective establishment.

Seasonality: Summer producer. Can be sown when soil temperature reaches 18˚C.

Varieties: Open pollinated: Greenleaf, Piper; Hybrid: Trudan, Superdan, Sweet Sudan.

Sowing: Sow into clean seedbed early November – January. Sow at 3–8kg/ha in 35cm rows rainfed, 8–10kg/ha in 35cm rows irrigated, 10–15kg/ha broadcast.

Feed quality: Declines rapidly with increasing age.

Diseases: None significant.

Pests: Armyworm and cutworm can cause serious damage to seedlings and mature plants.

Grazing management: Graze when plants are taller than 45cm to reduce risk of prussic acid poisoning. Don’t delay too long, though, as quality drops quickly. Cut well before maturity to obtain effective regrowth. Suitable for round bale silage because of its thin stems.

Companion species: Best grown alone.

Special factors: Stock require sodium and sulphur supplements with sudan grass. The potential for prussic acid poisoning is retained with haymaking but there have been no reported difficulties with silage.

Perennial grasses

COCKSFOOT (*Dactylis glomerata*)

Strongly tufted, erect perennial. Purplish-green flowering heads in one-sided clusters.

Strengths: Better summer growth and more drought tolerance than perennial ryegrass. Greater tolerance to acidic soils and aluminium than fescue or phalaris. Tolerates poorly fertile soils better than other perennial grasses. Well suited to cattle grazing in more heavily stocked dry-run situations.

Weaknesses: Requires good drainage. Forms tussocks if not grazed heavily enough. Poorest quality of all the perennial grasses.

Seasonality: Two distinct types: European (summer-active and winter-dormant) and Mediterranean (winter-active and summer-dormant). Summer-active types have filled a useful role in the Southern Highlands. Persistence is good on well-drained soils with the right grazing management.

Varieties: Porto, Grasslands Kara, Currie.

Sowing: Sow at 2–4kg/ha into a clean seedbed, no more than 2cm deep. Plant in autumn or spring or mild winter.

Feed quality: 60%–70% digestibility, 9.5–10.5MJ/kg ME, 10%–18% crude protein. Poorer quality than perennial ryegrass.

Diseases: Leaf rust can be a periodic problem.

Pests: Grass grubs and cockchafers—phalaris and fescue are more tolerant.

Grazing management: Persists best when moderately and rotationally grazed. But grazing pressure must be sufficient to prevent the development of tussocks and shading of associated legumes.

Companion species: Often sown in mixtures with other more nutritious grasses such as perennial ryegrass (early maturity types), fescue and phalaris. Sown with white clover or subclover.

FESCUE—See Tall Fescue

KIKUYU (*Pennisetum clandestinum*)

Vigorous, summer-growing perennial grass. Responds well to nitrogen fertiliser. Can produce large quantities of medium-quality feed from late spring to autumn.

Strengths: High production from late spring to autumn. Tolerant of dry conditions. Capable of supporting very high stocking rates. Resilient to grazing. High protein content for summer-growing

grass. Responsive to N fertiliser. Vigorous growth excludes weeds.

Weaknesses: Decline in nutritive value with advancing age. Apparent serious decline in quality in autumn. Susceptible to frosts. Strong seasonality of production—no winter – early spring growth. Vigorous growth excludes establishment of autumn–winter–spring species such as white clover and ryegrass in autumn. Susceptible to kikuyu yellows. Requires high fertility.

Seasonality: Most rapid growth in late summer – early autumn. Nitrogen fertiliser can stimulate earlier spring production. Autumn saving can carry forward medium quality feed to late autumn – early winter. Highly persistent—difficult to eradicate seeding strains.

Varieties: Common (runners only); Whittet, Noonan.

Sowing: Runners, turf or rotary-hoed pieces (1 runner per square metre). Sow seed at 1–4kg/ha in early autumn, or in spring – early summer with irrigation. Drill or broadcast into a clean seedbed. Slow to establish.

Feed quality: Protein content and digestibility decline with age and are higher when N fertiliser is applied. Protein content at 3 and 6 weeks is 17% and 14% without N and 23% and 14% with 130kg N/ha. Digestibility at 3 and 6 weeks is 73% and 65% with 130kg N/ha. Quality is best when stolons are removed by slashing and mulching and when the sward is kept leafy.

Diseases: Kikuyu yellows severely reduces swards north of Taree. Noonan is resistant.

Pests: Armyworms can eat large amounts of kikuyu.

Grazing management: Remove stolons by slashing early in the season. Graze at 3–4 weeks' regrowth. Remove excess material after grazing with followers, by slashing or mulching, or with a combination of both. Kikuyu is a vigorous competitor with high quality pasture species such as perennial ryegrass and white clover and should be controlled to obtain the best from these species.

Companion species: Late autumn – spring production can be improved by

direct-drilling annual ryegrasses or oats. With careful management white clover can be grown in association with kikuyu.

PASPALUM (*Paspalum dilatatum*)

Summer-growing perennial grass. Usually sown with legumes, particularly white clover. Characterised by vigorous summer growth, which is often difficult to control effectively by grazing. Usually has to be slashed or mown during summer to control excess growth and keep available a fresh supply of young, highly digestible feed. Summer-growing pastures based on paspalum have been replaced by kikuyu along the coast, although paspalum with white clover is still used in irrigation areas.

Strengths: Grows quickly and produces well during summer, but requires good grazing management or slashing to restrict seed production and ergot formation. Quality of forage declines rapidly as plants run to head in late summer and autumn. Useful grass in wetlands as it can tolerate waterlogging. Often added to other grasses as it is relatively cheap. Basis for summer-growing pastures in irrigation areas as it combines effectively with white clover. Withstands effects of heavy grazing. Seed heads can be infected with ergot, which can poison livestock.

Weaknesses: Persistence appears to depend on soil fertility. If fertility declines, carpet grass comes in to replace it. As fertility increases, kikuyu often becomes dominant. Only moderately tolerant of frosts. Rapid decline in feed quality with advancing maturity, particularly as it approaches maturity in late summer and autumn. Prone to infection with ergot when allowed to go to head; livestock poisoning is possible.

Varieties: Common.

Sowing: Sow at 4–10kg/ha in spring – early autumn. Drill or broadcast with companion legumes into a clean seedbed and lightly cover seed.

Feed quality: Feed quality is generally good for young leafy material, but falls drastically when plants run to head. Slashing of the stemmy growth will benefit white clover and improve the feed value of the pasture.

Diseases: Ergot poisoning most commonly affects cattle when early summer rains, which promote rapid growth and maturity of the paspalum, are followed by a relatively dry period.

Pests: Occasional problems for paspalum can arise from attack by black beetles, cutworms, armyworms and scarabs.

Grazing management: To maintain feed quality, keep plants short to prevent them from running to head. Where grazing pressure is insufficient, slash.

Companion species: White clover is the most common companion species sown with paspalum. Its persistence in the sward can be encouraged by heavy grazing in late summer and fertiliser application in autumn.

PERENNIAL RYEGRASS—See Ryegrass

RHODES GRASS (*Chloris gayana*)

Summer-growing perennial. Forms strong bunch-type stools and stolons anchoring at the nodes to give rapid soil coverage.

Strengths: Establishes well on poorer soils and is an ideal species for soil binding and erosion control. Though primarily a summer grower, it shows moderate frost-tolerance and can provide grazing well into late autumn in most areas. Responds well to improved fertility from associated legumes, but can run down where fertility is not maintained. Tolerant to salt, more so than paspalum.

Weaknesses: In dairy situations, its use is confined to northern NSW. Persistence under heavy grazing is inferior to that of kikuyu and other summer grasses.

Varieties: Callide, Katambora, Pioneer. The first two are more productive but are less tolerant to frost than Pioneer.

Sowing: Sow at 1–4kg/ha into a clean seedbed in spring or late summer – early autumn.

Feed quality: As with other tropical grasses, feed value decreases as the plants mature and become rank, stemmy and unpalatable.

Diseases: None significant.

Pests: None significant.

Grazing management: Avoid rank, stemmy growth. Slash or burn over-mature pastures.

Companion species: Difficult to maintain in Rhodes grass pastures because of the stoloniferous habit of the plant. Lucerne, phasey bean, siratro and centro have had some success in coastal south-eastern Queensland.

RYEGRASS—Perennial ryegrass (*Lolium perenne*)

Densely tufted, multi-tillered perennial. Leaves shiny on undersurface; flowering stalks are erect spikes.

Strengths: Highest yield of quality grass in high rainfall areas (>900mm) or under irrigation. Perfectly suited to rotational grazing in dairy systems. Responds well to nitrogen applied as fertiliser or fixed by legumes. Easier to establish than other

perennial grasses. Resistant to frost. Tolerates saline and sodic soils and some waterlogging. Persists best under high fertility conditions.

Weaknesses: Lacks drought-tolerance, especially late-maturing cultivars. Persistence is limited by competition with subtropical grasses, especially north of Taree.

Seasonality: Best growth in autumn and spring. Early maturing cultivars give good winter growth. Late maturing cultivars give good summer growth under irrigation. Infection with high levels of endophyte* fungus aids persistence. Old high-endophyte stands in the Shoalhaven and Bega Valley have persisted for 100 years.

Varieties: Early maturing: Kangaroo Valley, Roper; late maturing: Yatsyn, Dobson, Ellett, Embassy, Verdette, Banks. New varieties are frequently released.

Sowing: Sow at 10–14kg/ha in autumn (dryland) or spring (irrigated and Tablelands). Direct-drill after suppression of existing growth by herbicide. Drill or broadcast following mulching or into a clean seedbed. Susceptible to competition from annual ryegrass. Restrict sowing rate of annual ryegrass to no more than 7kg/ha when sown with perennial ryegrass.

Feed quality: Highest quality grass available. Digestibility 65%–80%; ME 11–12MJ/kg; crude protein 15%–20%. Soluble carbohydrate levels generally lower than in Italian ryegrass varieties. High-endophyte cultivars can reduce milk production by up to 10% compared with low-endophyte cultivars, but persistence of stand is reduced without the endophyte. Very few cases of ryegrass staggers have been observed in NSW perennial ryegrass pastures.

* Endophyte: An intercellular fungus (*Acremonium lolii*) living entirely within the perennial ryegrass plant.

Diseases: Crown and stem rust are serious problems, particularly under irrigation and north of Taree. Rhizoctonia can weaken the root system and allow pulling by stock. Yellow dwarf virus and ryegrass mosaic polyvirus can reduce stand health.

Pests: Susceptible to pasture scarabs, grass grubs, armyworms. Argentine stem weevils have been found in ryegrass pastures in the Bega Valley. High-endophyte cultivars tend to be more

resistant to insect attack than low-endophyte cultivars.

Grazing management: Grazing when the third leaf is as long as the second leaf (third-leaf stage) provides for maximum use of perennial ryegrass pasture and allows the plant to build up higher amounts of carbohydrate.

Companion species: White and red clover.

PERENNIAL RYEGRASS – WHITE CLOVER PASTURES

Perennial ryegrass sown in association with white clover forms the base pasture for most dairy farms in NSW. This base pasture has the potential to produce high quality feed from autumn to early summer. Production is restricted in summer – early autumn and alternative sources of feed have to be sought to supplement the base pasture. The main objective in managing perennial ryegrass – white clover pastures is to ensure that the survival and productivity of both species are preserved. Well understood management strategies are available for this objective; adopting them can significantly increase base pasture productivity.

Strengths: Both species produce highly digestible feed. Increasing clover content can increase the feed quality and milk production potential. Nitrogen fixation by the clover reduces fertiliser costs. High productivity of pasture allows high stocking rates to be sustained in the growing period. High quality conserved feed can be produced from excess spring production.

Weaknesses: Lack of summer–autumn productivity. Difficulty in sustaining grass–clover balance. Potential for invasion by annual and perennial summer-growing grasses. Short-term survival of the pasture (2–5 years). Difficulty in maintaining ryegrass and clover throughout summer for the next season of growth. Irrigation is essential to ensure survival in subtropical dairying districts.

SETARIA (*Setaria* spp.)

Summer-growing, tufted, perennial grass. Adapted to a wide range of soil types from low to high fertility. Usually sown in association with legumes, particularly white clover. Characterised by vigorous summer growth, which is often difficult to control effectively by grazing. With excellent persistence and greater productivity, setaria should replace carpet grass in the dry-runs of dairy farms along the coast.

Strengths: Grows rapidly during summer and into autumn. High dry matter yields. Extremely persistent once established. Does not crowd out companion legumes such as white clover. Clump-forming habit allows successful regeneration of white clover. Responsive to nitrogen fertiliser. Resistant to dry soil conditions.

Weaknesses: Rapid decline in feed

quality with advancing maturity. Susceptible to frosts. Potential for oxalic acid poisoning. Requires slashing or mowing to control excess ungrazed material.

Varieties: Newer cultivars such as Solander and Narok have generally shown greater frost tolerance and lower oxalate levels than the older cultivars Nandi and Kazungula.

Sowing: Sow at 1–5kg/ha in February–March or in spring – early summer, particularly with irrigation. Sow into clean seedbed. Seed is small, so don't sow too deep when drilling. Broadcasting, covering and rolling can also be used.

Feed quality: Like many tropical grasses, feed quality of setaria falls rapidly with advancing maturity. If kept short by rotational grazing and strategic mowing, young leafy growth can have about 12% crude protein, 9.2MJ/kg ME and 61% digestibility. On rare occasions, cattle can suffer oxalate poisoning from setaria, especially after heavy applications of potassium or nitrogen fertilisers.

Diseases: None significant.

Pests: In coastal areas, armyworms can damage setaria in summer. Grass seed crops have been destroyed by the yellow peach moth grub and the buffel grass seed caterpillar.

Grazing management: Usually has to be slashed or mown during summer to control excess growth and to keep a fresh supply of young, highly digestible feed available. Maintain short leafy growth at about 25–30cm in height. If growth gets away, paddocks may be closed for hay or silage. Use heavy grazing or slashing in early autumn to open up the sward to allow white clover to grow during winter and spring.

Companion species: Companion species have usually been cover crops with an annual ryegrass, red clover and white clover. The lotus cultivar Goldie has also been used. Cowpeas have been a successful cover crop for summer sowings.

TALL FESCUE (*Festuca arundinacea*)

A perennial, spring- and summer-growing pasture grass. Reasonably persistent. Adapted to waterlogged sites and area where moderate salting occurs.

Strengths: Spring and summer production can complement ryegrass-dominant pastures, which lose quality late in the season when they begin the reproductive growth stage.

Weaknesses: Persistence is often poor owing to inappropriate management. Suffers from competition from vigorous perennials like ryegrass. Slow to establish, but once established can become a productive, persistent pasture. More suited to dry stock than to milkers.

Seasonality: Spring, summer and autumn. Takes 2 years to establish properly. After that it becomes very persistent.

Varieties: Demeter, Au Triumph, Cajun, Dovey.

Sowing: Sow 5–15mm deep at 8–10kg/ha dryland and 10–12kg/ha irrigated. Broadcast and harrow or drill into a clean, firm seedbed.

Feed quality: During late spring – summer, quality is superior to that of ryegrass. Under adequate grazing management, it is good enough for fattening stock or milking purposes.

Diseases: Under adverse conditions some cultivars are affected by rust; this can also indicate that the crop lacks adequate nutrients.

Pests: Treat soil or seed with miticides to reduce the effect of earth mites during establishment.

Grazing management: Do not graze hard during the first 2 years. After this, it will tolerate heavy grazing.

Companion species: Red clover, strawberry clover, chicory.

Annual legumes

Annual legumes grown alone as a forage crop can produce high yields of high-quality feed, particularly in spring and early summer. Best production is obtained from early sowing in late February – early March. These early sowings will produce some late autumn – early winter feed. Sowing rates have to be kept high so that these crops can establish quickly. Late maturing varieties allow productioninto early summer. These legumes can be useful crops grown after a maize silage crop is harvested.

Advantages: High yields of highly digestible, high protein feed. Can be grazed or conserved as high quality hay or silage. Fit well into autumn–winter–spring production in cropping systems such as maize cropping.

Disadvantages: Bloat, which can and should be controlled. Lack of autumn–winter–spring production if not sown early. Have to be resown annually into a weed-free, cultivated seedbed.

BALANSA CLOVER (*Trifolium balansae*)

Grows predominantly in winter and has an early spring flush. High seeding ability helps in colonising other areas when seed is transferred by livestock. Adapted to areas with at least 500mm of winter - dominant rainfall.

Strengths: Good regeneration in irrigation districts but less so on the coast. Resistance to clover scorch. High seed yield. Can handle mildly acidic soils, waterlogging and mild salinity. Useful for haymaking. Excellent persistence owing to high seed production. Hard seed content is apprimately 70%, which allows some seed in reserve for dry times. Useful fodder crop if rainfall is less than 700mm.

Weaknesses: Hollow stems allow inaccurate estimation of hay yield. Growth is slow during autumn. Red-legged earth mites damage plant and cause losses, especially at establishment.

Seasonality: Begins growth at the autumn break but is slow. Has relatively good winter and spring yield. Not summer-active.

Varieties: Paradana.

Sowing: Autumn (dryland) or early autumn (irrigated or with good moisture conditions). Sow into a clean seedbed.

Feed quality: Good, but not as good as Persian clover. Protein content of up to 18%.

Diseases: Highly tolerant of all major diseases.

Pests: The major insect pest is the red-legged earth mite, especially in the establishment year. Other pests include blue-green aphids and heliothis caterpillars.

Grazing management: Do not graze after sowing till the plant starts to tiller, and then only lightly in the first year. After establishment, continuous grazing rather than rotational grazing will promote persistence. Remove stock at flowering time.

Companion species: Subterranean clover, Persian clover, phalaris, cocksfoot, tall fescue, ryegrass.

BERSEEM CLOVER (*Trifolium alexandrinum*)

Used as forage crop because of high yields.

Strengths: Grows in wet conditions. Allows multiple grazings or cuttings. Makes good hay. Slightly less bloating than other legumes. Good winter and spring yields.

Weaknesses: Requires high fertility and adequate moisture for effective

production. Frost-sensitive. Needs 700mm rainfall. Sensitive to low molybdenum. Requires high sowing rate.

Seasonality: Can be sown as early as February. Given a reasonable spread of rain or irrigation through the growing period, can be grazed or cut up to 6 times through to late spring. Will set seed, but the usual method is to resow each year.

Varieties: Multicut (= Carmel), Bigbee.

Sowing: Sow at 6–10kg/ha late February – early March into a clean seedbed. It is usually sown by itself but can be sown with other legumes, oats or winter-growing grasses, such as tetraploid ryegrasses.

Feed quality: Excellent.

Diseases: In wet spring conditions, leaf and stem blight can occur when growth is rank.

Pests: Host to blue-green aphids, but these usually do not cause a great loss. Red-legged earth mites can devastate a crop, especially with late-sown crops. Heliothis caterpillars occasionally damage leaves at the end of spring.

Grazing management: Begin grazing or cutting when plants reach about 25cm in height after planting and after each grazing. Can be left to grow higher for silage or hay.

Companion species: Usually sown as a monoculture but can be sown with other annual species such as annual ryegrass or oats.

Special factors: Responds well to nitrogen, phosphorus, potassium and molybdenum.

COWPEA (*Vigna unguiculata*)

Summer-growing forage legume crop. Valuable source of protein in subtropical and tropical dairying districts. Can be grazed or conserved as hay or silage to supplement low-quality pastures.

Strengths: Early-sown crops are superior in growth to lablab with early sowings. Digestibility is usually higher than that of lablab. With careful management up to two regrowths are available for grazing. Relatively high yields. Produces high protein feed in summer when summer grasses are deficient in protein.

Weaknesses: Susceptible to stem- and root-rot diseases and to insect attack, particularly from bean fly. Will not grow as late into autumn as lablab. Dry weather performance can be poor. Difficult to graze or harvest for silage in wet summers. The stem portion of the crop becomes more indigestible as the crop ages and will be rejected by stock. Damaged severely by frosts.

Seasonality: Summer producer. Growth is reduced by low night temperatures in autumn.

Varieties: Poona, Caloona, Red Caloona.

Sowing: Best results when sown into well prepared seedbed with ample conserved moisture. Sow seed 4–6cm deep at 10–14kg/ha in dryland districts and at up to 20 kg/ha in high rainfall areas. Can be direct-drilled after controlling competition with herbicides.

Feed quality: Better than that of lablab and soybean.

Diseases: Root and stem rots.

Pests: Bean fly can cause serious losses.

Grazing management: Can be grazed 2–3 times during summer. Should be grazed lightly so that the growing points near the stem are not destroyed. Graze or ensile before first frost.

Companion species: Can be sown with maize or sorghum to increase protein content of the combined crop, but yields are much lower.

LABLAB (*Dolichos lablab*)

Twining, summer forage legume crop. Valuable source of protein in subtropical and tropical dairying districts. Can be grazed or conserved as hay or silage to supplement grazed pastures low in protein.

Strengths: Produces high protein feed in summer when summer grasses are deficient in protein. Suitable for grazing. Will regrow for subsequent grazings with careful management. Relatively disease-resistant. Will continue to grow and retain feed quality into late autumn. Valuable green manure crop. Can be made into silage. Produces up to 4t/ha dry matter .

Weaknesses: Difficult to graze or harvest in wet summers. Stems toughen rapidly, become more indigestible as the crop ages and will be rejected by stock. Damaged severely by frosts.

Seasonality: Susceptible to frost but grows later into the autumn than other summer-growing forage legumes. Without frost will survive and grow into the next summer.

Varieties: Rongai, Highworth.

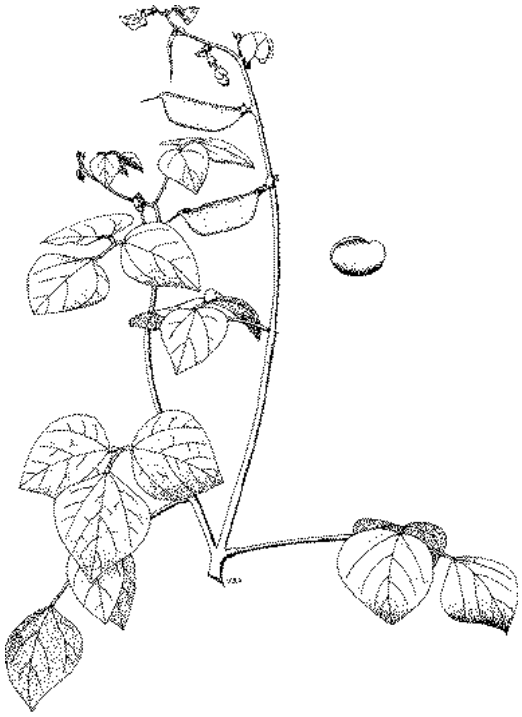
Sowing: Sow into a clean seedbed at 15–20kg/ha dryland and 30 kg/ha in high rainfall districts. Drill in 18–35cm rows 4–6cm deep. Can be direct-drilled after chemical control of existing pasture.

Feed quality: Leaves produce high quality, high protein feed and are selectively grazed. Stems lignify and are low in digestibility. Stems are rejected in hay but are eaten in silage.

Diseases: None significant.

Pests: None significant.

Grazing management: Lenient grazing so that growing points are not damaged. Aim for 2–3 grazings. Do not graze during wet periods. Graze or ensile before first frost.



Companion species: Can be sown with maize or sorghum to increase protein content of combined crop, but yields are much lower.

PERSIAN CLOVER (*Trifolium resupinatum*)

Late-maturing annual clover used as a forage crop. Produces high-quality feed autumn–spring. Used over a wide range of environments. Often used in southern NSW irrigation areas and districts.

Strengths: Non-oestrogenic clover; very palatable and produces high-quality feed. Late maturity extends the growing season later than subclover varieties. Can be grown on for a hay crop after grazing period. Capacity to produce high yields: up to 16t/ha of dry matter .

Weaknesses: Susceptible to rust.

Seasonality: When sown early in irrigation districts (February), can be grazed twice before winter. Later sowings produce little autumn–winter growth because of low temperatures. Matures 2–4 weeks later than subclover.

Varieties: Maral, Kyambro.

Sowing: Sow at 4–5kg/ha dryland and 6–8kg/ha irrigation. Very small seed (800000/kg); sow not more than 1cm deep. Sow on the surface of a prepared seedbed and cover with light harrows or a sheet of weldmesh. Can be direct-drilled but seedlings are not very competitive: control all competition.

Feed quality: Highly digestible. More digestible than lucerne, red clover and pasture hay. Digestibility 63%–78%. High protein content: 16%–21%. Low fibre content increases voluntary intake.

Diseases: Subclover rust (*Uromyces trifolii-repentis*) and clover rot (*Sclerotinia trifoliorum*) can cause serious damage in spring. Effect can be reduced by grazing or mowing to reduce humidity in the sward and reduce inoculum potential. Kyambro more resistant than Maral to rust.

Pests: Red-legged earth mite and lucerne flea can attack seedlings and should be controlled by chemical spray within 1 week of germination when the pests are present. Sitona weevil and heliothis can cause damage but seldom need control; but careful observation is required. Also susceptible to blue-green aphid and pea aphid but resistant to spotted alfalfa aphid.

Grazing management: Can be grazed or taken for hay production after grazing.

Companion species: Can be sown with oats or annual ryegrass to reduce bloat risk and spread production. Oats will provide more early feed and ryegrass will provide more winter and spring feed.

SOYBEAN (*Glycine max*)

Forage crop best used for silage. Valuable source of protein in subtropical and tropical dairying districts. Can be grazed or conserved as hay or silage to supplement low-protein pastures.

Strengths: Produces relatively high yields of high-protein forage. Can be ensiled as either round bale or precision chopped silage. Yields of 6–10t/ha dry matter .

Weaknesses: Difficult to harvest in wet summers. Lignification of stems leads to high rejection by stock when conserved as round bale silage. Damaged severely by frosts.

Seasonality: Summer-growing forage crop. Whole crop is harvested and area is then available for sowing with a follow-up pasture or crop.

Varieties: Wide range of varieties to suit different environments. Plant any of the grain varieties recommended for the district. Use the latest maturing varieties.

Sowing: Sow mid November to December.

Feed quality: Valuable source of protein in subtropical environments where there could be a protein deficiency in other feeds. Yields are highest at the full-sized green bean stage but digestibility of the whole plants at this stage may be only 60%. Lower yields but better whole-plant quality will be obtained with earlier harvests.

Diseases: None significant.

Pests: None significant.

Grazing management: Not suitable for repeated grazing as it doesn't recover well after grazing. Stock select leaves very heavily. When a mature crop is grazed there is serious wastage. The most effective method for using soybean is to harvest the whole crop for hay or silage. Wastage is greater with hay and round-bale silage than with precision-chopped silage.

Companion species: Grown as a monoculture.

HIGH DENSITY LEGUMES

Mixtures of annual and perennial legumes are sown at high sowing rates with the aim of giving a wide seasonal spread of production. Mixtures include Clare subclover, red clover, white clover and Persian clover sown at high rates. Up to 40kg/ha of legume seed is sown. Early (March) sowings are most effective. These sowings are usually managed as an annual crop. Nevertheless, high-density, irrigated clover pastures in subtropical districts can produce effectively throughout summer and into autumn.

Strengths: Sown instead of annual ryegrass pastures, which are heavily fertilised with nitrogen. They give a much higher quality feed for a lower overall cost of production. Productivity is maintained throughout a much longer season. Production extends through to autumn with irrigation.

Weaknesses: Bloat is a serious problem. Slower to establish than ryegrass when planted in April–May. Weed control is more difficult than in an annual ryegrass pasture. Some of the legumes are sensitive to acidic soils and could require lime for effective growth.

Perennial legumes

KENYA WHITE CLOVER (*Trifolium semipilosum*)

Stoloniferous perennial similar in appearance to white clover but leaflets and stems are softly hairy.

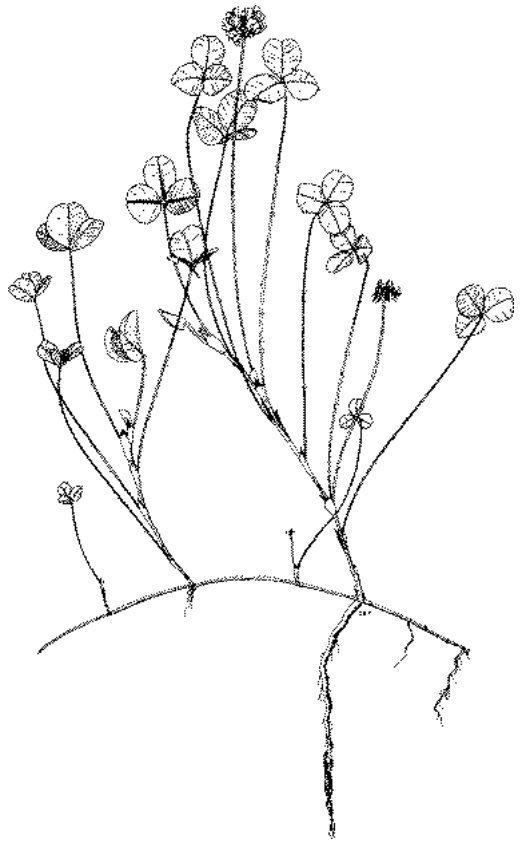
Strengths: Better summer growth and drought survival than white clover north of Taree. Grows well on acidic soils and is more compatible with summer-growing grasses than white clover.

Weaknesses: Difficult to establish. Not as frost-tolerant as white clover.

Seasonality: Spring, summer and autumn growth. Good persistence with correct grazing management.

Varieties: Safari.

Sowing: Sow in autumn at 2–4kg/ha into a clean seedbed. Small seeded—don't plant too deep. Susceptible to waterlogging.



Feed quality: Similar to that of white clover. No oestrogens.

Diseases: Big bud MLO (mycoplasma-like-organism) can cause stunting in cooler environments. Susceptible to a range of viruses.

Pests: Slugs can be a problem at establishment. Amnemus and white-fringed weevil larvae can cause damage.

Grazing management: Lightly graze to remove grass competition in the first year to allow seed set and a seed bank for subsequent germination to develop. Subsequently tolerates heavier grazing than white clover. Grazing should be sufficent to suppress summer grass growth.

Companion species: Kikuyu.

LOTUS (*Lotus pedunculatus*)

Rhizomatous perennial with 5 leaflets per leaf, 2 at the base and 3 more prominent at the end. Yellow flowers give rise to long cylindrical pods borne in clusters resembling an inverted bird's foot.

Strengths: Grows better than other legumes in low fertility, acidic soils. Tolerates high amounts of aluminium. Well suited to acid sulphate soils. Tolerates some salinity and sodicity. Contains condensed tannins, which provide bypass protein and prevent bloat. More drought-tolerant than white clover.

Weaknesses: Requires lenient grazing management for persistence. Will not persist under frequent grazing rotations.

Seasonality: Good growth in spring, summer and autumn. Will tolerate frosts but winter growth is limited. Persistence is limited by summer drought and frequent heavy grazing.

Varieties: Grasslands Maku, Sharnae.

Sowing: Sow at 1–2kg/ha in late winter – early spring or late summer – early autumn. Sow into clean seedbed and not too deep. Can be oversown into short pasture. Best if a cover crop is also sown when planting in a clean seedbed.

Illustration drawn by María A. Migoya and graciously provided by Ana M. Arambarri, Argentina.

Feed quality: Digestibility 60%–75% (lower than white clover). ME 11–12MJ/kg. Protein 15%–20%. Presence of condensed tannins lowers digestibility but increases the availability of the protein to the animal. Tannin concentrations of less than 1% of dry matter in the diet prevent bloat. On balance, milk production is similar to that from white clover as long as tannin concentrations do not exceed 6%.

Diseases: None significant.

Pests: Old, heavily grazed stands are susceptible to white-fringed weevil larvae.

Grazing management: Graze infrequently in first year after establishment to remove grass competition. Rotational grazing favours lotus persistence. Twenty-year-old stands in the Illawarra and Highlands prove that lotus can persist with the right grazing management. A summer spell will encourage seed production, especially

south of Taree. An autumn spell will encourage rhizome development. Better suited to dry-run areas than to the milking area.

Companion species: Fescue, carpet grass, setaria (as long as grass is grazed well). Perennial ryegrass can improve winter production from lotus stands, but use only low sowing rates (< 15 kg/ha).

Special factors: Responds to phosphorus and potassium fertiliser.

LUCERNE (*Medicago sativa*)

Deep-rooted, semi-erect to erect plant with stems arising from a crown. Highly winter-active and winter-active varieties can produce grazings from autumn to spring. Stands with these varieties tend not to last as long as stands with semi-dormant and dormant varieties.

Strengths: Highest yielding legume for well drained, slightly acidic to alkaline soils in coastal and inland irrigation areas. Valuable crop for rotational grazing and hay or silage production. Growth is rapid in spring–autumn. Winter activity is useful for grazing in autumn–spring but produces only 20% of summer yield. High protein content makes it a valuable protein supplement for the milking herd. Nitrogen fixation capacity of lucerne allows for minimal nitrogen fertiliser use. The growth rhythms of ryegrass–clover pastures and lucerne pastures are complementary. In combination, these pastures can produce a year-round source of high-quality feed. Surplus production can be sold for cash as hay.

Weaknesses: Does not tolerate waterlogging, salinity or acidic soils high in aluminium. Requires careful management for best yields. Weeds, pests and diseases can cause substantial loss in production and should be managed effectively. Bloat can be a serious problem when the crop is grazed. Risk is highest in winter: spray bloat oil on the pasture. Feed quality declines with advancing maturity. Severe decline in quality at flowering can lead to fall in milk production.

Seasonality: Predominantly a warm-season species; divided into winter-dormant, semi-winter-dormant, winter-active and highly winter-active categories. Winter-dormant types tend to be more persistent: they last 3–8 years depending on drainage and management.

Varieties: Highly winter-active: Aquarius, Pioneer Brand L69, Sceptre, Pioneer Brand 5929; Winter-active: WL516, Aurora, Quadrella, Trifecta, Hunterfield; Semi-dormant: Pioneer Brand L52, Pioneer Brand 581, Nova, WL Southern Special; Dormant: Pioneer Brand 545, Prime, WL320.

Sowing: Sow 1–5kg/ha dryland or 8–15kg/ha irrigated in autumn or spring when the temperature is high enough and there is enough moisture to ensure establishment. Sow into a clean seedbed. Drill or broadcast. Cover effectively and roll.

Feed quality: 65%–75% digestibility, 15%–25% crude protein, 8–11MJ/kg ME. Spray with bloat oil before grazing lucerne-dominant stands. Low in soluble carbohydrate: animals need to be fed carbohydrate supplements. Feeding maize silage while grazing lucerne can often provide a well-balanced ration.

Diseases: The most serious are phytophthora root rot, colletotrichum crown rot and common crown rot. (See Agfact P2.5.25 for more details.)

Pests: Blue-green aphid and spotted alfalfa aphid are the major pests. Full resistance to blue-green aphid is not available. Pea aphid is an occasional problem. Other pests include red-legged earth mite in cooler areas, white-fringed weevil larvae, lucerne-leaf roller, lucene flea, cutworms, sitona weevil, heliothus and wingless grasshopper.

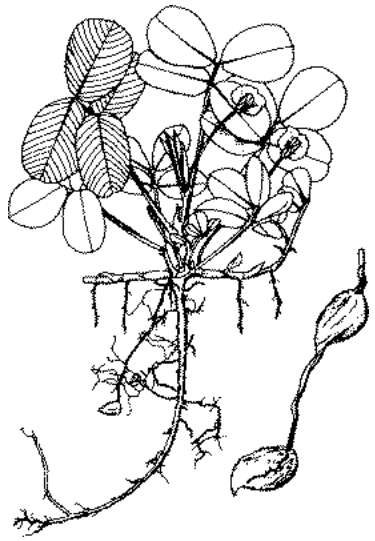
Grazing management: Rotational grazing with back-fencing and cutting at 36–40-day intervals gives the best balance between harvesting quality feed and allowing the lucerne plant to store carbohydrate in the crown for continued persistence.

Companion species: Phalaris, fescue, cocksfoot. Most commonly sown as monoculture on dairies.

PINTO PEANUT *(Arachis pintoi)*

Mat-forming perennial peanut with promise for producing high-quality feed in the tropics and subtropics.

Strengths: Produces high-quality feed from October to May in moist humid



environment. Tolerant of heavy grazing. Tolerant of frosts when established but slow growing in winter. Persistent under a wide range of conditions but prefers moist conditions on well drained soils. Tolerant of shading from tall-growing grasses.

Weaknesses: Requires specific rhizobium for effective nitrogen fixation (*Bradyrhizobium* spp.). Often the plant remains yellow even after inoculation, which suggests poor nitrogen fixation. There is only one seeded variety; others have to be planted from runners or cuttings.

Seasonality: Maximum production in summer under higher temperatures. Will grow for an extended period. Highly persistent. Develops mat of underground rhizomes.

Varieties: Amarillo.

Sowing: Sow between September and March to avoid frost damage to young seedlings. Plant 15–20kg/ha of seeds-in-pods 2–6cm deep, where there is adequate moisture, preferably in a clean seedbed. Never plant on the surface. Must be inoculated with the correct rhizobia. Plant *A. glabrata* from runners.

Feed quality: Higher feed quality than the grasses with which it grows. This can help to increase the protein intake of stock

grazing subtropical grass–legume pastures.

Diseases: None significant.

Pests: None significant.

Grazing management: Tolerant of heavy grazing. Correct timing of grazing is required to allow rhizome development and effective spread and persistence in the pasture.

Companion species: Can be grown with either creeping short grasses or tall grasses because of its shade tolerance.

RED CLOVER (*Trifolium pratense*)

Often used as a pure stand for hay and silage. Suited to well drained, fertile soils, particularly in areas with an annual rainfall of 700mm or where irrigation is available.

Strengths: Abundance of quality feed during spring–summer. Useful component of mixed pasture swards, although not always long lived. Supplies quality forage when most other legumes grow poorly.

Weaknesses: Often short lived in a mixed pasture sward if inappropriate grazing management allows damage to plant crowns. Some cultivars are oestrogenic and can cause fertility problems in stock. Poor winter growth.

Seasonality: Most production in spring–summer.

Varieties: Grasslands Hamua, Grasslands Pawera, Grasslands Colenso, Redquin, Renegade, Astred, Pac 19.

Sowing: Sow in autumn or spring at 2–5kg/ha in mixtures with grasses and white clover for perennial pastures; 5–8kg/ha for hay crops or in mixtures with annual ryegrass. Inoculate seed before sowing.

Feed quality: Crude protein and digestibility are adequate for fattening or milk production.

Diseases: None significant, although can be affected by root and crown rots on poorly drained sites.

Pests: Red-legged earth mite and blue oat mite can have a devastating effect during establishment. Heliothis can also cause damage.

Grazing management: Responds best and persists longer if frequent close grazing or cutting is avoided. The recommended minimum residual grazing or cutting height is 75mm. Can sometimes dominate the pasture during late spring – early summer. Graziers should take adequate bloat precautions.

Companion species: White clover, perennial ryegrass, tall fescue and many other pasture plants such as chicory.

STRAWBERRY CLOVER (*Trifolium fragiferum*)

Spring–summer-growing legume that spreads by runners. Well suited to saline or poorly drained sites.

Strengths: Provides a useful contribution

to pasture quality during spring–summer when other legumes are less active. Will regenerate well from seed following drought. Very persistent. Will withstand frequent close grazing and grows well in situations that are too wet or too dry for other perennial clovers.

Weaknesses: Not as productive as white clover and should not be sown where white clover will grow successfully.

Seasonality: Main production from spring to autumn.

Varieties: Palestine, O'Connor.

Sowing: Sow at 1–4kg/ha in autumn (dryland) or spring (irrigated). Sow into a firm, clean seedbed. Drill less than 1cm or broadcast and cover and roll. Inoculate seed before sowing.

Feed quality: Good. Adequate protein and energy for fattening.

Diseases: None significant.

Pests: Establishment can be affected by red-legged earth mites.

Grazing management: Reasonably tolerant of a wide range in grazing management, although continuous close grazing, particularly by sheep, can lead to a thinning of the sward.

Companion species: Most often mixed with tall fescue, cocksfoot and sometimes tall wheat grass. In wet saline areas it is most often the only legume sown. Often included at low rates in more general pasture mixes in order to colonise occasionally wet parts of the pasture.

SUBTERRANEAN CLOVER (*Trifolium subterraneum*)

As there is far more to be written about subclover than would fit in this manual, details are not given here. Instead, read the Agfact *Subterranean clover in NSW—identification and use* (P2.5.16), which should be in the back of this manual.

WHITE CLOVER (*Trifolium repens*)

Prostrate stoloniferous perennial legume (can also be a self-regenerating annual). The flower head is large, round and white or light pink.

Strengths: Highest quality legume available for high rainfall (>900mm) and irrigation areas. Responds well to phosphorus and potassium fertiliser. Tolerates acidic soil as long as aluminium concentrations are below 10%. Well suited to frequent rotation grazing on dairies.

Weaknesses: Lacks drought tolerance. Poor stolon survival over summer. High requirement for potassium can disadvantage it when growing in

competition with kikuyu. Does not tolerate waterlogging or salinity.

Seasonality: Grows well in autumn and has a marked spring flush. Tolerates frost. Some winter growth in early-flowering cultivars. Summer growth can occur in Ladino types if moisture is available. Persistence through stolon survival is poor in most districts without irrigation. Will re-establish with correct grass management. Many coastal districts have a large seed-bank of naturalised white clover, which can make a significant contribution in some years.

Varieties: Haifa, Grasslands Huia (NZ white clover), Irrigation, Pitau, Osceola, Grasslands Kopu, Prop, Grasslands Prestige, Aran, Sustain, Grasslands Tahora, Tamar.

Sowing: Sow at 1–4kg/ha on good moisture in early autumn to early winter (dryland) or spring (irrigated and Tablelands). Sow on the surface, cover and roll. Don't sow too deep.

Feed quality: Highest quality legume available. Digestibility 70%–85%; ME 11–12.5MJ/kg; crude protein 18%–25%. Low in soluble carbohydrate; needs to be grown with high-soluble-carbohydrate grass, or animals need to be fed carbohydrate supplements. Bloat can be a problem: spray white-clover-dominant pastures with bloat oil before grazing.

Diseases: Rugose leaf curl, lucerne mosaic virus, white clover mosaic virus and rusts can cause yield losses. Rhizoctonia and other root and stolon rots can affect white clover.

Pests: Nematodes can affect white clover stands in coastal NSW. Cutworms, white-fringed weevil larvae, aphids and some mites can also cause damage.

Grazing management: When grown with perennial ryegrass, graze when the third ryegrass leaf is as long as the second leaf (third-leaf stage) or when the lower white clover leaves are just beginning to age. When it is grown with subtropical species such as kikuyu, it is important to follow the 'golden rule of management': graze heavily and slash or mulch so that a kikuyu mat does not develop. This approach allows space for white clover seedlings to emerge from an autumn germination.

Companion species: Perennial ryegrass, fescue, phalaris, kikuyu.

Other pasture species

CHICORY (*Cichorium intybus*)

Chicory is a relatively new species for sowing into pastures. There is a wide variation in types and distinguishing features. At present, the only commercial cultivar is Puna. It is a deep-rooted, perennial plant that is active in spring and summer and produces little during winter. Other varieties could vary significantly from this description.

Strengths: Deep-rooted. Puna is drought-tolerant and capable of providing a quality feed base during the hotter months.

Weaknesses: A very demanding grazing management strategy needs to be used to realise the full benefit from the crop.

Seasonality: Main production spring–autumn.

Varieties: Puna.

Sowing: Sow at 0.5–1 kg/ha in mixtures with ryegrass and clover. Best when sown into a clean seedbed.

Feed quality: Protein and energy are adequate for milking or fattening. Able to extract a variety of minerals and trace elements from the soil; this can be beneficial to stock health.

Diseases: None significant in Australia, although sclerotinia, a crown disease, has been noted overseas, particularly where the crop is grazed and trodden on in wet conditions.

Pests: None significant, but take precautions against earth mites at establishment.

Grazing management: Good production and persistence have been obtained from rotation grazing. A rotation involving 3 weeks' grazing followed by 3 weeks' rest is ideal. Under dairying conditions, particularly during summer, the rotation needs to be shorter to keep up with available feed, possibly 14 days. Needs to be grazed down to 15cm for best results. Ideally, chicory should not make up the entire diet for a dairy animal. Stock should have access to chicory for 3–4 hours a day following milking and then be put on ordinary pasture.

Companion species: Chicory will respond to the nitrogen made available by companion legumes such as red and white clover, strawberry clover and possibly lucerne. It can also be included in pasture mixtures, at low rates, with a variety of complementary grasses.

Weed control before sowing

The NSW Agriculture publication *Weed Control in Lucerne and Pastures* gives detailed information on weed control. It is included in this manual. Please refer to it for help in effective weed control.

Weeds as both existing plants and seeds can pose a problem to establishing pastures. Existing weeds can be killed by cultivation or by spraying with the appropriate herbicide or by inclusion of a cropping phase. Read *Weed Control in Lucerne and Pastures* for pre-sowing weed control in coastal areas. In inland districts, annual weeds such as barley grass or *Vulpia* can be reduced by spray-topping with herbicide.

Pasture topping

In inland areas where annual winter grasses are a problem, pasture topping with glyphosate or spray-topping with paraquat is important in year-before weed control in preparation for sowing perennial pastures. Topping involves the application of low rates of herbicide after head emergence to prevent the formation of viable seed. It may also be effective for summer weeds such as summer grass (*Digitaria* spp.), pigeon grass (*Setaria* spp.) and capeweed (*Arctotheca calendula*) without destroying the available feed.

Advantages

- Reduced weed seed numbers. The number of annual grass seeds in the soil can vary from 2000 to 60 000 plants per square metre (m^2). (The density of sown grass seed is only about 300/m^2.) Unless seeding is reduced the previous year, a 90% germination with the autumn break still leaves large numbers to germinate in spring after sowing to compete with the pasture seedlings.
- Reduced trash and sowing problems. Low trash residues reduce insect harbour, the carryover of the fungal disease pythium, and trash build-up on sowing machinery.

How to pasture top

Even head emergence: This is essential for effecting topping. Begin grazing the paddock during winter and keep it well grazed (that is, 2cm high). Graze heavily throughout spring until the soil begins to dry out and the days are warm to hot—some time between late September and early November. Once stock are removed all grasses will rapidly run to head.

Timing is critical: Apply glyphosate at early head emergence (50% heads emerged). Apply paraquat after complete head emergence until the oldest heads begin to hay off.

Surfactant: Low herbicide rates used for pasture topping mean extra wetting agent must be used. Add wetter at 200–300 mL/100 L of spray volume.

Herbicide rates: Glyphosate 240–360mL/ha; paraquat 500 mL/ha.

Earth mite control: Where earth mites are a regular problem, addition of a miticide to the topping herbicide will decrease the population capable of laying eggs during summer and reduce earth mite numbers the following autumn.

Grazing: This is essential to capitalise on the benefits of topping. Graze immediately after spraying with paraquat, as feed value begins to decline soon after spraying. By using glyphosate, feed quality is preserved, but it is preferable to

begin grazing after 21 days as the palatability of the feed is highest at this time.

In cold, high-altitude areas, which require early sowing, pasture top for two consecutive years if annual grass populations are high.

Spray fallow

In some situations, for example if you have either mixed annual weed species or insufficient grazing pressure, it might be difficult to achieve even head emergence. Use of heavier rates of glyphosate (up to 1L/ha) at full head emer gence of the earliest flowering plants will effectively control seeding of the entire sward.

Broadleaf weeds

Gramoxone applied at flowering prevents saffron thistle from setting seed. Glyphosate applied at flowering controls the seeding of capeweed.

Pre-emergence herbicides for legumes

Trifluralin can be applied before sowing lucerne and other legume crops in prepared seedbeds to control annual grasses and some broadleaf weeds. Full details are in *Weed Control in Lucerne and Pastures*.

Winter cleaning

This technique can be used on well grazed paddocks to remove annual grass weeds in winter the year before sowing. It is used mainly where *Vulpia* is a problem, in inland areas.

The major herbicide used for *Vulpia* control is simazine. Rates vary with weed density, soil type and timing. Simazine can be mixed with other grass or broadleaf herbicides to control a wider range of weeds.

Couch grass control

Couch grass can dominate ryegrass–clover pastures and lucerne stands in many parts of NSW. It is important to kill couch grass completely before sowing. A long-term plan of both summer and winter cropping is very important for its control.

For an April sowing, spray with glyphosate at 8 L/ha in December – early January. Leave for 1 month before cultivation or a follow-up spray with glyphosate. Scarifying or ripping the couch grass and bringing the runners to the surface is recommended. Rotary hoeing or discing buries the runners under the ground, where they can lie dormant for many months before reshooting. This is not recommended.

Cultivate soil November–February then sow a winter forage crop.

Sowing a vigorous summer fodder crop or maize crop before the perennial ryegrass – clover pasture can be advantageous if enough ground preparation time is allowed before pasture sowing. This is usually done a year before sowing because maize is difficult to cut for green chop before the end of March and hybrid forage sorghums grow into April. Shirohie or Japanese millet often finish before February, allowing sufficient ground preparation before the pasture sowing.

Pest control before sowing

Careful checking of the top 10 cm of soil and pasture residues is necessary before direct drilling. Slugs, snails, pasture cockchafers and black field crickets may be better treated by cultivation rather than chemical means. Planting pest-resistant lucerne varieties might minimise damage from spotted alfalfa, blue-green and pea aphids. Some subclovers have been selected for tolerance to red-legged earth mites.

Snails and slugs

Snails and slugs can cause significant seedling losses in direct-drilled and mulch-planted pastures in wet conditions or following cool wet summers.

The best method of checking for them is to put out bait stations before sowing. Squares of cardboard (30 × 30cm) held down by a stone or wet hessian bags are suitable. Place these near watercourses, in damp spots and near trees. If there are more than 2–3 snails or slugs at the bait stations, baiting with methiocarb is recommended. Where large numbers are found, thorough cultivation might be the best option for killing adults and eggs.

When herbicides have been used to kill existing pasture, and dry residue remains, burning before drilling can greatly reduce populations.

Earth mites

The most common pests of new pastures on the Tablelands and Slopes are red-legged earth mites and blue oat mites. They can cause enormous damage, especially if they attack the cotyledon, or seed leaf, of the germinating legume seedlings.

If direct-drilling or mulch plantings are to take place in autumn, early prespraying in spring and autumn can reduce numbers in areas where earth mites occur regularly.

Spring spray: Apply an appropriate miticide such as dimethoate or omethoate when spraying thistles, spray-fallowing or pasture-topping in late spring. This kills most of the year's final adult population and greatly reduces the number of over-summering eggs.

Autumn knockdown: When the autumn break coincides with maximum temperatures below 22˚C, the mites will hatch. Two or three weeks later the first generation will be mature and ready to lay eggs. If sufficient numbers are present and any weed spraying is being done, include a miticide at this time.

Black field crickets

These spasmodic pests of direct-drilled and mulch-planted pastures can be found under plant debris, in cracks in the ground and under clods. Field inspection before sowing is essential. They can be controlled by baiting before sowing or cultivation.

Pasture cockchafers

This group includes African black beetle, pruinose scarab and dusky pasture scarab. Larvae, or white curl grubs, can cause major losses of establishing grass and clover seedlings in direct-drilled and mulch-planted pastures. Adult African black beetles can also damage grass seedlings in late autumn and winter.

Larvae of the African black beetle are active from early summer to late February. Where these are the only scarabs, autumn planting from mid March onwards should avoid significant losses. Pruinose scarab and dusky pasture scarab larvae feed

actively from February to spring. Yellow-headed cockchafer numbers increase following dry springs and summers, particularly after a succession of dry years.

A thorough check of the top 10cm of soil before sowing is the only way to check for these pests. If white curl grubs are found, thorough cultivation will give easy control.

Further reading

Agfact AE.19, *Slugs and Snails*

Agfact AE.54, *African Black Beetle*

Agfact P2.5.13, *Lucerne Varieties 1995–96*

Agfact P2.5.16, *Subterranean Clover in NSW—Identification and Use*

Agfact P2.AE.1, *Scarab Grubs in Northern Tablelands Pastures*

Agfact P2.AE.6, *Field Crickets*

Agnote DPI 64, *Goulburn Subterranean Clover*

Agnote DPI 65, *Denmark Subterranean Clover*

Agnote DPI 66, *Leura Subterranean Clover*

Disease control before sowing

Selecting disease-resistant varieties, where they are available, is the most economic way of avoiding disease and gives the most productive and persistent pastures. Selecting diseaseresistant varieties of legumes will minimise damage from phytophthora root rot in lucerne and subclovers, crown rot and bacterial wilt in subclover, scorch in subclover, clover stunt in subclover, and rugose leaf curl in white clover. Selecting disease-resistant varieties of grasses will minimise damage from rust in ryegrass and from kikuyu yellows in kikuyu.

Crop rotations are very important in breaking the life cycle ofsome diseases. Growing a different species leaves no host for diseases to live on.

When a lucerne paddock thins out it is important to kill all lucerne plants and to introduce a grass crop before sowing lucerne again. The crop could be oats, barley, triticale, wheat, millet, forage sorghum or maize. Suitable species to follow a grass crop include lucerne, cowpeas and soybeans.

Planting more than one species will reduce the chance of significant loss of the pasture to disease, although there will be some diseases with a wide host range.

Further reading

Agfact P2.5.13, *Lucerne Varieties 1995–96*

Agfact P2.5.16, *Subterranean Clover in NSW—Identification and Use*

Agfact P2.AB.1, *Diseases of Lucerne*

Agfact P2.AB.2, *Diseases of Clover*

Agfact P2.AB.3, *Kikuyu Yellows*

Agnote DPI 64, *Goulburn Subterranean Clover*

Agnote DPI 65, *Denmark Subterranean Clover*

Agnote DPI 66, *Leura Subterranean Clover*

Agnote DPI 92, *Phytophthora Root Rot in Sub-Clover*

Conventional seedbed preparation

Timeliness of killing perennial weeds is very important in preparing a seedbed. Weeds can generally be categorised into winter annual weeds (which grow from March to October), summer annual weeds (which grow from October to February) and perennial weeds. Ploughing the paddock from March to May will greatly reduce the winter weed seed problem but it will not affect the summer and perennial weed seed problem. Summer weeds need to be tackled a year before a planned spring sowing.

Absolute weed control must be the ultimate aim of any seedbed preparation.

Seedbed requirements will vary according to the pasture species to be established. For example, lucerne and kikuyu require a very good seedbed, but ryegrass does not.

A good seedbed is a flat, uniform paddock with a small and even clod size (< 1 cm) and uniform soil moisture near the surface. There is a fine line between establishing a seedbed and overworking the soil. An overworked soil is very fine and can be prone to soil crusting and lack of surface moisture.

Soil should always be moist but not wet when worked, so that it crumbles. Ploughing wet or dry ground is pointless and can damage soil structure. Weeds will germinate in a moist soil after ploughing and will then be killed 2–3 weeks later when the soil is ploughed again.

The preparation of a paddock will take 2–5 workings. Make each working more shallow than the previous one. Initial workings, preferably with tined implements, will break up hardpans, increase water infiltration and minimise inversion of the subsoil. For autumn-sown pastures or spring-sown summer forage crops, allow at least 2 cultivations before sowing permanent perennial pastures.

A soil that has a major weed problem will need more workings over a longer period of time. It is important to use implements that will not overwork the ground. For example, a rotary hoe pulverises the soil—more than 2 workings will create a very fine seedbed and a loss of soil structure. Working with an offset disc, harrow or scarifier is preferable. It is important to minimise the number of cultivations.

Ploughing has a role, especially in heavier soils, in rough, pugged paddocks, and in paddocks with heavy burdens of tussocky grass. Always plough on the contour to minimise erosion. Ploughing is not recommended for shallow soils or steep slopes.

Secondary tillage can be done with discs, tines or heavy harrows. The aim is to even up the seedbed and to control germinating weeds.

Rolling can be useful to break up large clods or, before sowing, to firm a ‘fluffy’ seedbed, aiding accuracy of seed placement. Do not use a roller after sowing on soil that crusts on the surface.

Seedbed preparation with fodder crops

In many cases, one or two clean-up crops of oats, brassicas or short-term ryegrasses are used to help break down weed residues and seed burdens and to provide valuable fodder. Heavy grazing during summer will reduce winter-growing annuals and allow weed seeds to germinate and be killed. Paddocks selected for spring sowing should be heavily grazed in winter to reduce trash levels before thorough cultivation.

Herbicide use

Herbicides can be used to reduce the number of workings and improve the results on hard-tokill perennial weeds such as couch and bent grass. Spraying in autumn can control weeds and replace a cultivation if the seedbed is already fine enough. Pasture topping or chemical fallowing in spring will replace or delay the initial working.

Spring sowings often require herbicides to kill weeds and allow rapid seedbed preparation in late winter – early spring. Without the herbicide, most weeds are simply transplanted. After spraying with glyphosate, wait one day for annual weeds and 7–10 days for perennials before ploughing, to allow the herbicide to move through the weeds. It is important to spray the weed when it is growing actively to maximise the effectiveness of the herbicide.

Machinery

How to set up and operate your boom spray

Proper boom spray operation is essential for reliable and effective results. The following 8 factors must be considered.

Boom height

Correct height is essential for uniform spray coverage and depends on nozzle spacing, nozzle angle and the height of the target.

Most modern boom sprays have 110˚ flat-fan nozzles spaced 500 mm apart. These nozzles provide the correct double overlap when the boom is set 500mm above the target.

Set the height from the top of the target, not from the ground; to spray seedling weeds, the correct height is 500mm above the ground, but for weeds in an oat crop 150mm tall, the correct height is 650 mm.

Low boom height leads to uneven strips of spray. It is better for the boom to be slightly too high than too low.

Nozzle offsetting

Nozzles must **not** be set parallel to the boom but at an angle of 15˚. This prevents disruption of the spray pattern, which occurs if the sprays from adjacent nozzles hit together.

Some boom spray manufacturers provide a special tool to angle the nozzles. Otherwise, use a spanner, placing the nozzle tip in the jaws and turning the spanner until the shaft of the spanner is parallel with the boom. Some boom sprays have bayonet-type nozzles, which offset automatically.

Operating pressure

A reliable pressure gauge located in the main pressure line to the boom is essential. Operate at about 200–300 kPa (30–40 p.s.i. or 2–3 bars). Reducing operating pressure below this range is not a suitable way to reduce output. Buy a set of smaller aperture nozzles to apply low water volumes. Ensure that all nozzles are the same aperture and the correct size for the required droplet size and are suited to the operating pressure, speed and rate.

Operating speed

Most boom spraying is done at 5–12km/h. Changing the speed changes the application rate. Select a speed to suit the most difficult part of the paddock and operate at that speed over the whole paddock.

Water and chemical rates

Water rates of 60–120L/ha are commonly used. Lower volume spraying (30–50L/ha) requires a higher degree of application accuracy. Read the recommendations on the product label.

If the boom spray is calibrated to apply, say, 80L/ha, then a 600L tank will cover 7.5 ha (600÷ 80). The amount of herbicide to apply at, say, 2L/ha is 15L/tank (2L/ha × 7.5ha).

Mixing chemicals

When using tank mixes of chemicals, always check to ensure compatibility.

(Editor's note: Thanks to Mike Keys, of NSW Agriculture, Queanbeyan, and the Prime Pasture team for permission to reproduce material in this section from the *Pasture Establishment Field Guide*.)

Mixing some chemicals can reduce their effectiveness or increase the risk of pasture damage. Compatibility charts can be found in the NSW Agriculture publication *Weed Control in Lucerne and Pastures*.

Never mix the concentrates. Instead:

1. Fill the tank to one-third with water and start the tank agitation.
2. Add the first chemical.
3. Top up the tank to two-thirds with water.
4. Add the second and subsequent chemicals.
5. Add the final lot of water.
6. Always add wetting agent last.

Check the chemical labels for directions on tank mixing as some chemicals must be added in a particular order. For more information, see Agfact P7.3.1, *How Much Water to Mix with Herbicides?*

Spraying

When spraying, minimise spraying around corners as this leads to under- and oversprayed patches.

Some form of marking is essential for achieving full spray coverage and preventing costly overlaps and spray misses.

Take care and use proper protective clothing, especially when handling the chemical concentrates. Use a tractor with a fan-ventilated cab and appropriate air filters. Avoid spray drift to neighbouring paddocks.

Cleaning and storage

Careful selection of filters and regular cleaning will reduce the likelihood of nozzle blockages.

Always flush the boom spray unit with clean water after use. Do not leave unused chemical mixes in the tank. To prevent contamination between different sprays, always flush the unit with water and then, using a mixture of 2% cloudy ammonia (1L in 50L water), wash down the inside walls of the tank and run about 20L through the lines and nozzles. Finally, flush thoroughly with clean water.

Caution: Do **not** clean with cloudy ammonia after spraying with Ally® or Brush Off® (metsulfuron methyl) or Glean® (chlorsulfuron), as it can cause the release of poisonous chlorine gas. Use household chlorine bleach instead at 300mL in 100L of water.

When storing equipment at the end of the spraying season and after cleaning, run a mixture of water and miscible oil (the type used on lathes) through the pump and nozzles.

Boom spray calibration

Calibration determines boom spray output in litres per hectare. A properly calibrated boom spray is vital for effective weed and pest control. Poorly calibrated sprayers are costly:

Apply too little → Spray failure.

Apply too much → Pasture damage.

Calibration doesn't take long and is easy if you follow these 7 steps:

1. Part fill the tank with water (no chemical).
2. Start the tractor and set the engine revs to PTO speed.
3. Turn on the unit and ensure that all nozzles are spraying correctly (a full even spray in both directions with no drips or squirts).
4. Check that the pressure is in the correct range of 200–300kPa (approx. 30–40p.s.i.).
5. Using a plastic measuring cylinder

Boom spray output (L/ha) (nozzles 500 mm apart)

Speed km/h	Average nozzle output (mL/min)																
	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000	1100	1200
4	88	103	118	133	148	163	178	191	206								
5			94	106	118	130	142	154	166	177	188	200					
6				89	98	108	118	128	138	148	158	168	178	187	196		
7					84	93	101	110	118	127	135	144	152	160	168	186	202
8						82	89	96	103	111	118	125	132	140	148	160	178
9								85	92	98	105	112	118	124	130	142	154
10									83	89	95	100	106	112	118	130	142

with 20mL graduations, measure the output of each nozzle for one minute. Write down each result measured to the nearest 10mL.

6. Calculate the average nozzle output per minute. (Replace nozzles with an output varying by more than 20mL from the average.)
7. Use this average and the table above to obtain boom spray output in litres per hectare.

For boom sprays with nozzle spacings other than 500mm apart, use a calculator and the following formula to obtain L/ha output:

$$\text{boom spray output (L/ha)} = \frac{600 \times \text{av. nozzle output (mL/min)}}{\text{nozzle spacing (mm)} \times \text{speed (km/h)}}$$

When spraying, tractor speed must be constant for accurate application. Do **not** spray using a tractor without a tachometer. Install one or use another tractor.

Measuring the speed

If the speedometer doesn't work, or if non-standard tyres or wheels are fitted, you need to measure the speed:

1. Start the tractor and adjust the revs to PTO speed.
2. Select a suitable gear to give a comfortable speed of travel over the country to be sprayed. The spray boom shouldn't bounce up and down at this speed.
3. Begin travelling about 20m before a starting mark and start timing using a watch as you pass the start.
4. After 30 seconds, drop out a marker to mark the finishing point.
5. Measure the distance covered in metres.
6. Use a calculator to work out the speed:

$$\text{speed (km/h)} = \text{(distance covered in 30 sec)} \times 0.12$$

Record the speed and gears used on the dash with a spirit pen. It is worthwhile getting the speed for the gears above and below that selected initially.

Remember: Calibrate your spray unit before each major spray operation and after fitting any new equipment.

Setting up and calibrating the seeder

Accurate seed placement is possible only if care and time are taken in setting up the seed drill.

There are 8 steps to follow, although some don't apply to conventional sowing.

Seeder levelling

To ensure that all tines are sowing at the same depth, adjust the machine on a level

surface. If Caldow boots are fitted, ensure that the front tip is 6–8mm lower than the 'heel'.

Coulter alignment

Pull the machine into the ground to check alignment. Poor alignment results in 2 cuts in the undisturbed sod and can leave open furrows. If alignment is out, raise the machine, slightly loosen the nuts on the coulter assembly and reposition using a straight-edge and a heavy hammer. Recheck in the ground.

The next 4 adjustments must be made in the paddock after you have run the machine at the speed at which you propose to sow.

Tine tension

Correct tension allows the tine to vibrate, creating loose soil (tilth) while maintaining the correct point angle. Tine tension should be in the range 260–400N (60–90 lbs). Use lower tensions on sandy friable soils. Too much tension results in excessive point wear.

Depth

Sowing depth is not as critical as the amount of loose soil over the seed. Check the depth to the bottom of the furrow after travelling at least 200m. The rule of thumb for depth is: 'to the first knuckle of your index finger'. For early autumn or spring sowings, when warm, dry conditions after sowing are likely, this depth is necessary. In cold, wet winter conditions, sow more shallowly.

Tilth and speed

The amount of loose soil covering the seed is critical, regardless of the depth of the furrows. Aim for only 5–10mm of loose soil over the seed.

Warning: More seed fails to emerge by being buried under too much soil than by any other cause.

There is too much tilth if less than 5% of the seed and fertiliser is visible in the furrow. Speed must be increased (up to 12km/h) to throw more loose soil out of the furrow.

There is too little tilth if a high percentage of seed and fertiliser is visible in the bottom of the furrow. A single loop of heavy chain attached at either side of the seeder can be used to sweep soil from the edges into the furrow. Whatever device you use must follow the contour of the ground and not bulldoze loose soil on top of the seed.

In conventional seedbeds, deep seed burial is also likely, especially where the seedbed is loose and fluffy.

- Rolling to firm the seedbed before sowing is recommended for loose seedbeds.
- If using harrows, try to direct the seed tubes back so the seed lands in the last row of the harrows.
- When direct-drilling, a good rule of thumb is that 5% of the seed and fertiliser should be visible in the furrow.

Soil types and moisture

Often both soil type and moisture will vary within a paddock and as sowing proceeds. Try to sow different soil types in separate blocks and check the soil cover over the seed with changes in soil type. Pasture sowing is shallow, so large changes in moisture can occur throughout the day, necessitating constant checking of the cover.

Calibration

The simplest method of calibrating sowing rate when seed and fertiliser are mixed is to put a bag of fertiliser (50kg)

in the box, sow one fifth of a hectare, check the amount used and make adjustments if necessary.

When seed and fertiliser are sown from separate boxes, calibrate the seeder in the workshop using a jack and rotating the drive wheel. **Always calibrate the seed first and isolate the drive to the fertiliser box,** even if it is apparently empty.

1. Determine the number of wheel revolutions to travel 100m using the formula:

   revolutions = 16 ÷ wheel radius (m)
2. Turn the drive wheel a few turns to ensure that the seed or fertiliser is flowing down all tubes.
3. Place a tarpaulin under the seeder (or buckets under the hoses), then rotate the wheel the number of revolutions you calculated in step 1.
4. Check to see that all tubes have delivered similar amounts, then collect and weigh the total amount of material.
5. Compare the result with the amount required, which is easily calculated using this simple formula:

   amount required (kg) = sowing rate (kg/ha) × machine width (m) ÷ 100

Point maintenance

Seed placement and furrow profile can be adversely affected using worn points. Attention to point wear is essential, particularly when you are direct-drilling with narrow points that have to carve a channel through undisturbed soil. Expensive steel points can quickly become irretrievably ruined if they are not regularly hard-faced and maintained. An alternative in abrasive soils is the cast points produced by Primary Sales (Australia) Pty Ltd at Dubbo and referred to below under ‘Points for direct-drill pasture establishment’.

Direct-drill pasture sowing

Machines for direct-drilling small pasture seeds must be able to place seed accurately on moisture at a given depth and place a shallow cover of loose soil over the seed. Sowing when the soil is dry is not recommended as germination has to rely on follow-up rain, which may not fall.

The machines available for pasture sowing are many and varied.

Under good conditions, with proper attention to seed placement, most machines can be successfully used to sow pasture. However, when seasonal conditions are not ideal, some machines are far superior.

The ability of individual tines to follow the ground surface places all machines into one of two classes:

Machines with ground-following capability: These include triple discs, single disc seeders (and their conversions) and drills with trailing tines. All these machines can give a more precise sowing depth than the rigid-frame seeders and are preferred for sowing small pasture seeds.

Generally, tined seeders achieve precise placement and coverage better than disc seeders. The single disc seeder, in particular, produces poor results when direct-drilling is used in a moist seedbed soon after spraying. In these conditions, either the slot is left open and exposed or the sod falls back, burying the seed. Single disc seeders can be converted to fit Caldow points quite cheaply; conversion is recommended for these machines.

Rigid-frame machines: This class includes most combines, coil-tine, spring-tine or springrelease tine drills, and chisel seeders. The significance of a rigid frame is that, in selecting a sowing depth, a compromise is necessary to account for

localised ground variations, because all tines have a fixed position in relation to the frame. Average sowing depth is set at 25mm, but ground variations can produce furrows varying in depth from 10 to 40mm. It is important that the furrow walls don't cave in as the seed will be buried too deeply. Heavy rain soon after sowing can be a major problem for this reason.

Points for direct-drill pasture establishment

Burying pasture seed under large clods or too much soil is a major cause of sowing failure. Burial is particularly common in conventional seedbeds, and is the reason why seed is often simply dropped on the surface and 'covered' by light harrows or a roller. However, seed sown into a dry surface soil or, worse still, exposed on the soil surface, is still at risk. The type of sowing point is thus an important element in accurate seed placement. Narrow points with the leading edge only 6–10mm wide are preferred. A high wear rate is a problem with most narrow soil openers.

Triple disc soil openers have relatively low wear rates and accurate sowing depth. Operate the coulter disc 5–10cm below the sowing discs. In heavier wet clay soils the discs cause smearing and compact the soil at the bottom of the furrow or leave the furrow open with the seed exposed.

Single disc soil openers are generally not recommended for direct-drill pasture sowing as it is difficult to get a tilth for seed coverage until the sod has died and the soil is dry.

Chisel points are 50mm wide and fracture the sod along both sides of the point, forming an open furrow and leaving the seed exposed. Long strips of sod are peeled out and thrown in all directions, some going back in the furrows, burying the seed. Trailing chains behind each tine are essential.

Steel lucerne points are less expensive but must be hard-faced. Wear and maintenance are excessive in most soils. These points perform best on light spring tines, where plenty of vibration can produce a good tilth.

Baker boots (inverted 'T' soil openers). These points were designed to permit sowing in slightly less than ideal sowing conditions. The Baker boot produces a flat-bottomed, inverted 'T' (⊥) furrow, protecting the seedling from moisture stress if dry conditions occur after sowing. In many low-clay Australian soils, the side walls fall back, burying the seed, and the large blade becomes quickly worn.

Caldow 'T' boots are a development of the Baker boot but are designed to reduce the amount of wearing surface, to produce a 'V' shape at the bottom of the furrow and to throw more soil out of the furrow. The 'V' bottom is achieved by pitching the point forward so the leading tungsten-protected tip is 6–8mm lower than the rear of the wings. The wings then produce tilth scraped from the sides of the furrow.

The Caldow 'T' boot is a great improvement, but wear rates are still a problem in abrasive soils. Extra tungsten can be applied to the wings but cost escalates. Regular hard-facing maintenance is still required to preserve the unprotected parts of the blades.

Cast points. These hard-wearing alloy points are available in Baker boot and Caldow 'T' boot designs. NSW Agriculture found that the cast points cost 50% less and were 65% more hard-wearing than triple-tungsten-protected steel Caldow points, and required no maintenance (hard-facing). More than 250ha of abrasive granite soils have been sown with cast Caldows.

Super seeder points are made of the same cast alloy as the cast Caldow point. They were originally developed for direct-drilling crops. Their cross-section is similar in shape to an inverted ‘T’. As well as having good wear rates, these points can be bolted directly to most tines, thus doing away with the need for the expensive adaptor needed for ‘T’ boots.

Band-seeders are strongly recommended in ploughed seedbeds.

Fertilisers for sowing pastures

It is important to ensure that sufficient nutrients are available to the young pasture in the early stages of growth. Seedlings need nitrogen, phosphorus, sulphur and molybdenum to be available nearby.

When sowing into a prepared seedbed, the fertiliser is often sown with the seed. When heavier rates of fertiliser are required, they can be prespread or applied soon after the pasture has effectively established.

High rates of nitrogen or potassium fertiliser placed in contact with or very close to the seed can restrict germination and reduce establishment.

Nitrogen

Small amounts of nitrogen at sowing (10–20 kgN/ha) can be beneficial for establishing pasture seedlings, especially on lighter-textured soils. The nitrogen stimulates early growth of pasture seedlings and helps their rapid establishment. Additional nitrogen can be topdressed soon after establishment to continue the rapid growth of grass-based pastures.

Previous nitrogen fixation by legume-based pastures will add to the nitrogen supply available in the soil for pasture establishment and growth. As shown in the table at the bottom of this page, different legumes vary in their capacity to fix nitrogen. A high proportion of this fixed nitrogen is avail-able for cycling and and can stimulate the establishment and growth of the pasture.

Nitrogen fixed by various pasture legumes

	N fixed (kg/ha/y)	
	Typical	Range
Lucerne	217	56–504
White clover	115	70–200
Red clover	128	85–189
Cowpeas	100	64–129
Vetch	90	90–154
Peas	80	33–156
Soybeans	112	65–180

Phosphorus

Phosphorus is taken up rapidly in the early stages of seedling growth. It should therefore be applied near the establishing seedling. Phosphorus fertilisers can be drilled in contact with seed. The rhizobia in legume inoculum can be killed when mixed with acidic phosphorus fertilisers, but lime-pelletting inoclated seed protects them from damage.

Phosphorus is more readily available to establishing pastures when placed in a drill row than when broadcast. Follow-up topdressings are effective when applied in subsequent autumns and springs.

Soil tests help in deciding the best rate of phosphorus to apply. Take samples as close as possible to the planned sowing date.

Potassium

Potassium is not usually applied in the drill row at sowing as it can reduce germination if placed in close contact with the seed. Potassium-deficient soils are best treated with a separate application before or after sowing with muriate of potash (potassium chloride). The rate will vary from 62 to 125 kg/ha, depending on the deficiency and the soil type.

Molybdenum

Molybdenum (Mo) deficiency in young legume seedlings inhibits rhizobia and reduces nitrogen fixation, leading to

Recommended rates of phosphorus for sowing pastures. *(These rates must be reduced by up to 20% in direct-drilled pastures as fixation of phosphorus is reduced.)*

Soil P status	Colwell P soil test (mg/kg)	Phosphorus rate (kg/ha)	Single super equivalent (kg/ha)
Low	≤ 15	30–40	341–454
Medium	16–30	20–30	227–341
High	31–45	10–20	114–227
Adequate	> 45	10	114

nitrogen deficiency.

Molybdenum can be applied in prepared mixes with superphosphate and other fertilisers. Super Mo 0.02 at 250kg/ha and Super Mo 0.04 at 125 kg/ha both supply 50g/ha of Mo (the required rate).

Treating legume seed to apply 100g of molybdenum trioxide per hectare is an effective method of applying Mo that guarantees sowing the seed in contact with the Mo. A foliar spray of sodium molybdate at 420g/ha will overcome molybdenum deficiency. **Do not use sodium molybdate to coat seeds** as it kills rhizobia.

Sulphur

Certain soils, for example those derived from basalt, are low in sulphur (S). Apply sulphur fertiliser at sowing to meet deficiencies. Sulphur is more likely to be needed for direct-drilling than when conventional cultivation has been used to prepare a seedbed. Apply at least 10kg/ha of sulphur at sowing.

Sulphate S, such as in gypsum, is more quickly available than elemental yellow sulphur, which has to be changed to sulphate by microorganisms before it becomes available. This change takes longer.

Fertiliser placement

Place the fertiliser under the seed, where the roots of the seedlings can use it. Fertiliser burn of seedlings can be caused by direct osmotic effects (because of high concentrations of dissolved salts in the soil solution) and specific ion effects (for example, ammonium from urea or DAP). Different fertilisers have different effects on soil pH in the immediate vicinity of the granule when they dissolve. Some products form an acidic solution, and might induce aluminium or manganese toxicity in seedlings on soils that are already strongly acidic.

Fertiliser burn is most likely to occur with nitrogen, then potassium, then phosphorus fertilisers. To avoid fertiliser burn, don't exceed 20kg/ha of N or 10kg/ha of K when seed is in direct contact with the fertiliser. Potassium is usually not used near the seed when establishing pastures. The salt effects of nitrogen and potassium fertilisers are additive.

Rhizobia and fertiliser

Rhizobia bacteria can be killed when the seed is mixed directly with fertiliser. They are suceptible to phosphate fertiliser, nitrogen, sulphur as sulphate of ammonia, and potassium.

Lime-pelleting legume seed will improve rhizobium survival, the nodulation of the seed and the growth of young seedlings. Lime-pellet and inoculate legume seed not more than 24 hours before sowing.

Commercial fertilisers

A wide range of fertilisers is available from the various fertiliser companies for establishing pastures. Fertilisers and rates

Nutrient application rates for a range of products

Product	Application rate (kg/ha)	Nutrient supplied (kg/ha)			
		N	P	S	Ca
Superphosphate	125–250		11–22	14–28	25–50
Trifos	50–100		10–21	0.5–1	8–15
Goldphos	100		18	10	
Pasture Starter	75–125	58	10–17	6–11	7–12
Starter Fos	50–100	510	11–22	12	
Starter 15	75	10	10	8	
DAP	50	9	10	1	

125 kg/ha≈ 1 bag per acre; 250 kg/ha≈ 2 bags per acre; 1 bag = 50 kg

are chosen on the basis of the nutrients required to successfully establish the pasture, and on the cost to buy the fertiliser, deliver it to the farm and apply it.

The table below shows several fertilisers available from the major fertiliser suppliers Incitec, Pivot, Hi-Fert and W. Paton.

Fertilisers from various manufacturers and their analysis for NPK (3 numbers) or NPKS (4 numbers)

Incitec	W. Paton	Hifert	Pivot	Comments
Single Superphosphate 0:9:0:11	**Superphosphate** 0:9:0:11	**Superphosphate** 0:9:0:11	**Superphosphate** 0:9:0:11	Phosphate fertiliser
Double Super 0:16:0	**Double Super** 0:16:0		**Double Super** 0:16:0	Phosphate fertiliser where S is not important
Greenleaf Trifos 0:20:0	**ABO Triple Super** 0:19:0	**Triple Superphosphate** 0:20:0		Phosphate fertiliser where S is not important
		Goldphos 0:18:0:10 0:16:0:20		Phosphate + sulphur fertiliser
Starter 15 15:13:0	**Starter 15** 15:13:0	**Hifert** 15:13:0	**Pivot 15** 15:13:0	Sowing with seed
Starter NP 18:20:0	**DAP** 18:20:0	**DAP** 18:20:0 **DAP Sulphur** 16:18:0:12	**DAP** 18:20:0	Sowing with seed
Greenleaf Pasture 13 0:6:12:8 **Greenleaf Pasture 16** 0:5:16:7 **Greenleaf Pasture 25** 0:4:25:5		**Phosphorus-Potash** 0:6:35 0:10:26 0:12:20 0:13:18 0:14:15 0:16:10	**Super Potash** '1+1': 0:4:25:5 '2+1': 0:6:17:7 '3+1': 0:7:13:8 '4+1': 0:7:10:9 '5+1': 0:7:8:9	Topdressing lucerne pasture
Greenleaf Greentop K 32:0:10:3		27:0:21 23:0:25 33:0:11	20:0:16 27:0:21	Topdressing ryegrass, clover, kikuyu on K-deficient soils

Which fertilisers are the best buys?

A fertiliser can be valued by estimating the quantities of N, P, K and S and then valuing the components at current market prices. For example, calculate the value of each in terms of the nitrogen it contains. Another way is to value all of the components and then estimate the value of the most important one.

The following table shows typical examples. The two most popular NP fertilisers are DAP and Starter 15.

Brand	Analysis (NPKS)	Cost ($/t)	Value ($*)	Comments
DAP	18:20:0:0	500	674	High P and N fertiliser. On high P soils, use 187 kg/ha. The big problem is DAP's lack of sulphate sulphur, an important nutrient on some soils.
Starter 15	15:13:0:11	459	479	More suited to high P soils that respond to sulphur.
Starter 18	18:7:0:17	430	369	Suited to high P soils that respond to sulphur. Not price-competitive.
DAP Sulphur	16:18:0:12	500	610	Similar to DAP with the bonus of sulphur.
Grower 12	11:8:14	440	428	Recommended rate is 250 kg/ha. On low K soils, broadcasting muriate of potash (potassium chloride) at 62 kg/ha and sowing with DAP might be a better option.

* Value as if each were a nitrogen fertiliser. Valuing in terms of, say, phosphorus content might give a different result.

Weed control at sowing

For a complete listing of herbicides for weed control in lucerne, see the NSW Agriculture publication *Weed Control in Lucerne and Pastures*, which is included in this manual.

Sowing into existing good pasture

It is possible to add ryegrass and clover to an existing pasture by direct-drilling or mulch planting without the need to spray or kill the existing pasture. This technique is useful if the pasture is legume-dominated or too good to kill. The aim is to thicken up the pasture or to add a grass to legume-dominated pastures. The technique is suitable only for annual and perennial ryegrass, lotus, white clover and subclover; it will not work with phalaris, cocksfoot, fescue or lucerne.

To use this technique there should be no more than 50% ground cover. Graze the paddock as hard as possible immediately before broadcasting or direct-drilling the ryegrass and clover seed into a moist soil. Then slash or mulch as close to the soil surface as possible without damaging the existing pasture (1–2 cm).

Slash mulch-planted kikuyu or paspalum pastures as short as possible after broadcasting or direct-drilling—even to the soil surface. Delay sowing winter-growing pastures into these pastures until active growth has stopped (for example, on the South Coast after late March) to avoid seedlings being swamped by summer-growing species. Earlier sowings will be swamped by summer-growing species.

Using herbicides to kill at sowing before direct-drilling or mulch planting

Where the existing pasture is poor, weedy or not wanted, the pasture can be killed with glyphosate (for example, Roundup®) at or before sowing. This technique is often used on kikuyu, paspalum, carpet grass, tussock grass and annual summer grasses.

After heavy pre-grazing or slashing, allow the summer-growing grasses to regrow 5–7 cm and then apply glyphosate. Plants must be actively growing for this to work.

Where poa tussock grass or bergalia tussock is present, graze heavily and then apply glyphosate at or immediately before sowing. Direct-drill or broadcast pasture seeds immediately after spraying.

Rate of glyphosate product (L/ha) to control various plants

Species	Rate of glyphosate product (L/ha)
Tussock grass (*Poa sieberiana*)	3
Bergalia tussock (*Carex longibrachiata*)	4
Paspalum	3
Kikuyu	3–6
Annual summer grasses	1.5–3
Couch grass	9

See also the NSW Agriculture publication *Weed Control in Lucerne and Pastures*.

Reducing competition but not killing existing perennial pastures

When direct-drilling or mulch planting into an existing perennial pasture, you can reduce competition by using herbicides at sowing. The two most used are low rates of glyphosate in kikuyu and paspalum, and paraquat + diquat (for example, Spray-Seed®) in temperate pastures and summer-growing perennials.

In paspalum, following heavy grazing use 2L/ha paraquat + diquat. Early direct drilling into kikuyu or paspalum before early April requires the use of herbicides to reduce competition and to allow successful pasture establishment.

In temperate perennial pastures, paraquat + diquat can be used to kill annual grass weeds, broadleaved weeds and competition from existing perennial pastures. Apply 1–2L/ha and direct-drill immediately.

Pest control at sowing

If you have found pests when checking the topsoil or crop residue, or if there a historical risk of pests, you can treat immediately before sowing for seed-harvesting ants, red-legged earth mites (blue oat mites), slugs, snails and cockchafers.

Seed-harvesting ants

To prevent seed loss by seed-harvesting ants, treatment with bendiocarb (for example, Ficam®) or permethrin (for example, Coopex®) is essential for all grass and small legume seed that will be surface-sown. This treatment does not affect rhizobium survival on inoculated seed.

Red-legged earth mites (blue oat mites)

These mites can cause regular and severe damage on the Slopes and Tablelands and spasmodic outbreaks in coastal areas. When damage is regular it is common to prespray or treat seed before sowing both conventional seedbeds and by direct-drill.

Seed can be bought pretreated (for example, N•Dure Plus® or AgriCOTE®) or can be treated on-farm before sowing with omethoate (for example, Le-Mat®); or seedlings can be treated with an appropriate insecticide applied by boomspray after germination.

To prepare the seed dressing, mix it in a cement mixer. Mix omethoate with about half the suggested water volume, then add it to the seed. Add the remaining water slowly to obtain full coverage of the seed. Continue mixing until the seed is dry. Store under cover. Seed dressings will give 3–6 weeks' protection depending on mite numbers and growth. For additional protection, follow-up spraying might be needed after sowing.

When applying glyphosate before sowing, add dimethoate (for example, Rogor®) or omethoate to the spray mix. This will give 2–3 weeks' protection depending on rainfall. Mites are usually a problem only in mild winter weather.

To inoculate omethoate-treated legume seeds, treat with omethoate and let stand for 24 hours. Then apply inoculant and sow on the same day. (See section 2.5 for how to inoculate.) Destroy treated seed not used for sowing.

Do not sow into dry soil or where germination might be slowed.

Do not mix omethoate directly with inoculant.

Do not treat seed more than one season old.

Do not store treated seed for more than one week.

Do not store treated seed near foodstuffs or where it is likely to prove hazardous to humans or animals.

Decreased efficiency can occur when heavy rain falls after sowing but before emergence, and where weed control has not been adequate.

Slugs and snails

The best method of checking for slugs and snails is to put out bait stations before sowing. Squares of cardboard (30 × 30cm) held down by a stone are suitable. Place these near watercourses, in damp spots and near trees. If there are more than 2–3 slugs or snails at the bait stations, baiting with methiocarb (for example, Mesurol®) is recommended.

Slugs and snails can be controlled by cultivation or, in direct-drill or mulch planting situations, by applying a bait

containing methiocarb at or immediately before planting. Where slugs and snails are readily found, rates of 5.5–22kg/ha could be necessary.

Consider routine baiting with 2–3kg/ha in wet situations by broadcasting or dropping the pellets above the drill row. A pesticide permit will be needed for low rates of application. Apply to your local office of the EPA for this.

Further reading: Agfact AE.19, *Slugs and Snails*.

Pasture cockchafer

Larvae of African black beetle, pruinose and dusky pasture scarab and Argentine scarab can severely damage direct-drilled pastures at establishment. Where these larvae are present in populations below approx. 15 per m^2, pasture establishment can be doubled by treating the grass seed before sowing as outlined in the table below. Where populations are greater, consider cultivating before sowing.

Products	Where to use	Pests	Rate	Critical comments
250 g/kg chlorpyrifos seed dressings (e.g. Lorsban® 250)	Direct-drilled ryegrass and clover pastures	Root-feeding scarab larvae, wireworms and seed-harvesting ants	10 g product per kg seed	Mix thoroughly and evenly with the seed immediately before sowing
500 g/kg chlorpyrifos seed dressings (e.g. Lorsban® 500)			250 g product + 250 g talcum powder per 50 kg seed	If inoculant is required for nodulation of clover seedlings, apply as a water-injected slurry alongside the treated seed

Further reading: Agfact AE.5, *African Black Beetle*; Agfact P2.AE, *Scarab Grubs in Northern Tablelands Pastures*.

Black field crickets

Crickets can be controlled by cultivation before planting, or by baiting before direct-drilling, mulch planting or broadcast sowing.

Field crickets can be controlled with a bait made up of wheat grains treated with maldison (17 kg wheat treated with 560mL of 500g/L maldison concentrate, per hectare). This use is not registered under the Pesticides Act 1978, but has been authorised by permit by the Registrar of Pesticides for field cricket control in pastures and cereals, on seed crops and on seed and pod vegetables.

Prepare the bait by mixing the wheat and the maldison together thoroughly and storing it overnight. Scatter it over the affected area late on the following afternoon.

Treated seed must not be used for animal or human consumption. Do not allow treated seed to contaminate grain intended for animal or human consumption. If storing treated grain, keep it apart from other grain and clearly mark the bags or other containers holding it to show that the contents have been treated.

No guarantee is given by the Registrar of Pesticides as to the effectiveness, safety, or any other thing of this advice or information; and no responsibility is accepted by the Registrar of Pesticides as to the effectiveness, safety, or any other thing which may, or may not, occur as a result of preparing the pesticide for use, using the pesticides, and/or making a claim that the pesticide may be prepared for use and/or used.

Further reading: Agfact P2.AE.6, *Field Crickets*.

Disease control at sowing

Two diseases can be treated at sowing: damping-off of lucerne, subclover and red clover, and smut of prairie grass.

Damping-off

Damping-off of seedling clover is caused by the fungi *Pythium irregular* and *P. ultimum*. It can cause serious losses in subclover, red clover and lucerne. Losses are worse in very wet conditions, on acidic soils, or on soils that have been used to grow these pastures for years, allowing a build-up of fungi.

Seed can be treated with Apron 350 SD at 200 g/100 kg seed before or at inoculation.

Head smut of prairie grass

The most common disease of prairie grass is head smut (*Ustilago bullata*). This causes serious losses in dry matter yield and complete loss of seed at heading. Head smut is readily prevented. Seed **must** be treated before sowing by dusting or slurry-treating with benomyl (for example, Benlate®) at 10 g/kg seed or Baytan® F-17 Seed Dressing at 1.7 g/kg of seed. Insist on treated seed from your merchant.

Inoculation of legumes

Inoculation of legumes is essential. Inoculation of legume seed is the application of nitrogenproducing *Rhizobium* bacteria (rhizobia) to the seed to ensure the production of nitrogen in nodules on the plant roots. Seed can be bought already inoculated, or can be inoculated on-farm.

With normal inoculation, sow seed as soon as possible or within 5 days. See Agfact P2.2.7, *Inoculating and Pelleting Pasture Legume Seeds*, for details.

Pre-sale inoculation

Many produce merchants will inoculate seed before purchase. Two companies also offer pretreated seed with extended shelf-life:

N•Dure (Wrightson Seed Group of Companies): Rhizobium shelf-life is extended from 3–5 days to 12 weeks. Seed has a lime-based coating and molybdenum is included. Seed can be sown at the same rate as unimproved raw seed.

N•Dure Plus (Wrightson Seed Group of Companies): Rhizobium shelf-life is extended from 3–5 days to 12 weeks. This treatment protects seedlings against red-legged earth mite attack for 4–6 weeks after sowing. The seed must be covered by soil, and the pasture cannot be cut or grazed within 6 weeks of the sowing date.

AgriCOTE is a patented process of pre-inoculating seed from the Heritage Seeds company. The rhizobia remain viable in the AgriCOTE seed coating for at least 4 weeks after the seed has been coated. The AgriCOTE seed has the correct rhizobial strain, major and minor plant nutrients and Apron® fungicide (where registered for use) to protect young seedlings from damping-off caused by *Pythium* and *Phytophthora*.

Molybdenum trioxide

Where necessary for acidic soils, molybdenum trioxide can be added when you are inoculating. Work out a rate that applies 100 g/ha.Adding molybdenum trioxide guarantees that the young seedlings have molybdenum, which is important for nodulation of legume roots and subsequent nitrogen production.

Do not use sodium molybdate to coat seeds as it kills rhizobia.

Further information

Agfact P2.2.7, *Inoculating and Pelleting Pasture Legume Seeds*

Sowing

Successful pasture establishment requires manipulation or control of several factors at the time of sowing:

- **Competition**—Total or partial removal or manipulation to prevent competition for light, moisture and nutrients from existing plants to allow seed to germinate and establish. This can be achieved through cultivation, herbicides, grazing, mulching or slashing. See section 2.2.
- **Soil moisture**—There needs to be sufficient soil moisture available (for dryland sowings) or supplementary irrigation to allow for establishment. Reliability of soil moisture can be improved by using a fallow period (by cultivation or chemical) before sowing, sowing in the most reliable rainfall period, or sowing in autumn, when evaporation is declining and the available soil moisture is more effective.
- **Seed placement**—Pasture seeds require shallow sowing as they are small and often have little seedling vigour. See section 2.6.
- **Insect pest control** —See section 2.3.

Sowing methods

Conventional (broadcast) sowing

In conventional sowing, seeds are broadcast or dropped on the ground and then covered using a pasture harrow or rolling to ensure effective contact between seed and soil so that the seed can take up moisture for germination.

Drilling

A band seeder attached to the combine's small seedbox, or a standalone seedbox – band seeder – roller assembly, is the best sowing equipment. If the combine tines are working in the soil, it is essential to use levelly bars in front of the band seeder. The band seeder creates a groove 10 mm deep and places the seed in it.A trailing chain then covers the seed. Use a rubber-tyred roller to firm the soil to help germination, except on soils that develop a surface crust. (Alluvial soils containing silt are prone to surface soil crusting. Gypsum will reduce the crusting of soils that contain at least 30% clay. It is important that these soils be moist at sowing and be kept moist for the first 3 weeks after sowing.)

Do not plant small-seeded species such as white clover too deeply. It can be more effective to broadcast white clover on the surface, provided the seed is covered by covering harrows and rolled, and drill the ryegrass into rows.

Drilling allows you to band fertiliser close to the seed, where it can be readily available to the germinating seedling. Don't apply high rates of soluble fertiliser, such as nitrogen or potassium, too close to the seed because the high salt concentration may kill the seedlings.

Direct-drilling

Direct-drilling or minimal tillage is the most popular technique for establishing winter pastures: it saves time; the soil organic matter is improved after 3 years, which means less nitrogen fertiliser is required and more soil moisture is conserved; and the pasture is more productive because it is available for

grazing. However, in the first 3 years the pasture requires more nitrogen, the crop runs out of moisture quickly, and it is susceptible to competition from weeds, especially couch grass.

When to sow

There are two general guidelines:

- Winter-growing annuals such as subterranean clover need to be sown by mid winter to ensure that they set sufficient seed to regenerate next autumn.
- Perennial species can be sown in autumn or spring depending on reliable soil moisture.

Autumn sowing is less risky because seedlings are growing in a cool, moist period. However, the unreliable and often late autumn break in many regions and years means that plants have to battle through cold, wet conditions as very small and vulnerable seedlings. On the Tablelands, try to avoid July sowings.

Late winter – early spring sowings can be very successful, provided the sowing takes place early August – mid September. By the time the seedlings emerge, the temperatures are beginning to warm up, and the seedlings develop rapidly with ample soil moisture.

Ryegrass–clover pastures are best sown in March–June. If the pasture is required for winter feed, sow in March–April. If the paddock has a history of winter weed competition, sow in May–June.

Lucerne, clovers, vetches and lotus: Generally an autumn sowing is prone to competition from broadleaf weeds and ryegrass. A spring sowing is prone to summer grass invasion. Use trifluralin as a pre-emergence herbicide to stop grass and wireweed competition in the first 12 weeks of growth. Sow winter-active lucerne varieties in the coolest months. Note that because Maku lotus has very poor winter growth, August sowing is recommended, but autumn sowing is also acceptable.

Kikuyu requires warm soil temperatures. The biggest problem is that annual summer grass weeds also germinate at this temperature. Sow late February – early March on the Central Coast.

Brassicas: Spring plantings can begin as early as September but sowing time will depend on crop selection and feed requirements.

Soil moisture

Soil moisture losses are greatly reduced if weeds are removed. Most rainfall or irrigation that falls on a bare fallowed paddock is saved.

The correct sowing time is when adequate soil moisture is present. The rate of germination and growth will then depend on temperature.

The aim is to have sufficient moisture at the surface when the seed is sown to achieve immediate germination, as well as moisture down to 200mm to permit seedling survival if further rain doesn't fall or irrigation isn't available.

Winter weeds germinate with the first autumn rain. This is especially important with direct drilling. This will create a problem if sowing takes place on the first rain. It is preferable to control these weeds and wait for subsequent rain before sowing. However, in recent years, dairy farmers who have sown on the first rain have produced winter feed, while others have missed out. There is an advantage in producing good winter feed by direct-drilling on the first autumn rain. The disadvantage is competition from winter weeds. Good weed control is essential.

Sowing into moisture gives the slower-growing perennial pasture seedlings an

even start with vigorous annual weed seedlings, which can often germinate from a greater depth, where moisture is present.

Frost

'Frost lift' will kill seedlings sown into ploughed ground in higher parts of the Tablelands. It kills by tearing the plants in two as the surface soil freezes, expands and separates from the soil below. Direct-drilled pastures are rarely affected by frost lift.

Except in very dry conditions when seedlings are under moisture stress, –4˚C frosts will not harm pasture seedlings. On the Southern Tablelands young pastures have survived –8˚C frosts for more than a week.

Sowing rates

Sowing rates of fodder crops suited to a pasture improvement program

Forage type	Sowing rate (kg/ha)		Sowing time	Uses	Time to first grazing (weeks)	Min. grazing height (cm)
	Dryland	Irrigated				
Japanese millet	20	25	late Sept – Jan	grazing	5–6	15–30
Pearl millet	8	15	late Oct – Dec	grazing	6–8	30–60
Hybrid millet	8	15	late Oct – Dec	grazing	5–7	30–60
Hybrid sudan grass	8–10	15–20	late Oct – Dec	grazing	6–7	100
Sorghum × sudan grass	10	15–20	late Oct – Dec	grazing	6–7	80–100
Sweet sorghum and hybrids	8	15	Nov–Jan	silage, autumn standover	7–8 or left for silage or stand-over feed	150
Cowpeas	30			grazing, silage, hay	12	
Chicory		2–4	spring–autumn	grazing, silage	8	Any
Rape	2–3 drilled, 4–5 broadcast		Sept–Jan	grazing	12	
Turnips	1–1.3		Sept–Jan	grazing	12	
Maize	18	25	mid Oct – Jan	grain, silage	13–18	20–30
Oats	60	120	late Feb – Jun	grazing, hay	6–8	15
Annual ryegrass	15	25	late Feb – early Apr	grazing	6–7	10
Balansa clover	2	4	Mar–Apr	grazing, silage, hay	8–10	10
Persian clover	4	8	Mar–Apr	grazing, silage, hay	8–10	10
Berseem clover	15	25	Mar–Apr	grazing, silage, hay	8–10	10
Lablab	15	30	Nov–Jan	grazing, silage, hay	12	150
Soybean	15	30	Oct–Dec	grazing, silage, hay	12	80
Pinto	15	20	Nov–Dec	grazing, silage, hay	12	80

Crop	Seeds per kilogram
Perennial ryegrass	295 000–640 000 (av. 500 000)
White clover	1 500 000
Red clover	500 000
Lucerne	400 000
Subclover	90 000–160 000
Kikuyu	50 000–400 000

Sowing equipment

Direct-drill pasture sowing

Machines for direct-drilling small pasture seeds must be able to place seed accurately on moisture at a given depth and place a shallow cover of loose soil over the seed.

Sow pasture seed no deeper than 25 mm. Because of the unevenness of ground the depth will vary from 10 to 40 mm. At the greater depth it is important that the furrow walls don't cave in as the seed will be buried too deep.

Direct-drilled seed is sown deeper than in a conventional ploughed seedbed.

Do not use harrows or a roller behind sowing equipment when direct-drilling as there will be a greater burial of seed resulting from filling the furrows in.

What's the best direct-drill seeder?

The coastal dairy area of NSW is dominated by kikuyu, couch and paspalum pastures. A direct-drill seeder must have a coulter (disc) to cut through the kikuyu and couch. The two most popular types are:

Tine coulter drill: Suited to smaller paddocks and paddocks that are prepared properly. Fitted with the inverted T Baker boot they provide an ideal seedbed.

Triple disc seeder: With a greater ground speed, can sow large areas quickly. On heavy wet clay soils smearing of the furrow may be a problem. Greater weight makes it ideal in rough country.

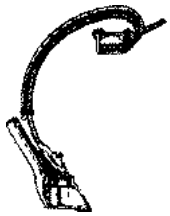
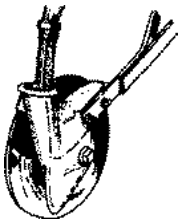
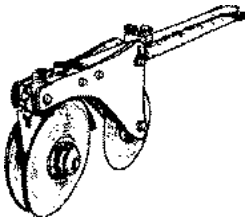
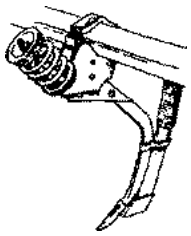
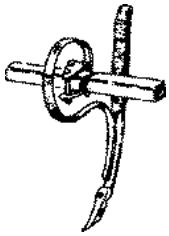
Seed machinery options. The table on the next page shows some of the sowing machinery that can be used for direct-drilling pastures. Machinery needs to be suited to your soil type and condition at sowing time.

Further reading

Agfact P2.2.6, *Nine Steps to Successful Pasture Establishment*

Agfact P2.2.3, *Pasture Establishment*

Agfact P2.E.1 *Band Seeders for Pasture Establishment*.

	Machine	Points to note
	**Trailed tine drill** Caldow Grassliner Begg TD 150	Good ground-following and depth control. Suitable in rocky or tussocky ground. Caldow points on Grassliner.
	**Disc seeder** Connor Shea Super Seeder Massey 500 Disc Seeder Shearer Disc Seeder	Handles sticks and stones. Dry soil, full root release and fast speed critical to prevent soil either ribboning or being thrown out of the slot. Most machines suited to conversion to Caldow points.
	**Triple disc drill** Duncan 730/734 Multiseeder	Good ground-following and depth control. Suitable in stony or tussocky ground. Suited to higher ground speed (10–12 km/h). Can sow large areas quickly. Slot walls can become glazed in moist or heavy soils.
	**Coil tine seeder** Connor Shea Coil Tine Aitchison Seedmatic Agrowdrill	Fitted with Baker boots. Poor trash clearance in some makes. Excessive wear on points in abrasive soils.
	**Spring-release rigid tine** John Shearer Tine Drill CSN Tine Drill	Inverted T or bolt-on points. Tungsten tip on blade gives better wear. Cast points are even better. Rugged stump-jump action is severe on points in rocky ground.
	**Spring tine drills** Duncan 750 Till Drill Spring tine combines	Flexible machines for sowing crop and pasture. Flexible tines can create excessive disturbance.

Plant populations

A newly sown pasture should contain only the species and varieties sown. The germination of the paddock should be uniform.

Plant populations at sowing

Species	Nº seedlings per m^2			Comments
	Min.	Opt.	Max.	
Ryegrass	170	340	450	NZ and cooler climates
Kikuyu	10	100	300	
Lucerne	50	100	300	
Clover	70	150	350	Clover plants are difficult to count but their growth can be assessed by their cover.

In the first spring, a good perennial ryegrass – clover stand will have 140 ryegrass plants per square metre. After 2 years, 30–50/m^2 will survive, more in cooler climates. Counting ryegrass plants after the first 3 months can be deceiving as they produce tillers, having up to 25 each.

Careful management is required to maintain the balance between legumes and grasses to sustain the productivity of a mixed pasture. The best grass–clover balance for productive perennial pastures is about 60% grass and 40% white clover. This should give sufficient nitrogen fixation by the clover to sustain the productivity of the grass. Increasing the clover content further will increase the feed quality but will reduce the total amount of dry matter produced and the stability of the pasture.

Lucerne is often sown with ryegrass and clover because of its summer growth. However, it competes against them for moisture, and selecting a grazing and irrigation interval that is suitable for all three is difficult. On the other hand, ryegrass dominates lucerne, and heavy ryegrass sowings will reduce the establishment of the lucerne.

Potential losses at establishment

Serious losses in pasture production can occur very quickly. This can mean not enough high quality feed for the milking herd. For example:

- slugs can eat out a very high proportion of clover seedlings in direct-drilled pastures
- cutworms and armyworms can cause serious productivity losses
- broadleaf weeds can establish with pasture seedlings and exclude the sown plants.

Provided treatments are applied at the correct time, all these problems can be controlled effectively. **Frequent careful observation** for potential problems, and timely remediation, can dramatically increase pasture productivity.

Regular inspections

Inspect the pasture regularly for any potential problems. Continue this observation for the life of the pasture. Inspect the establishing pasture at least weekly in the first 6 weeks. Proper management of problems diagnosed in this period can substantially increase the effective establishment of the pasture and hence its productivity.

Learn to read the pasture by asking many questions, including:

- Is the pasture growing as quickly as would be expected under the current conditions?

- Would the pasture respond to fertiliser application?
- Are there any obvious nutrient deficiencies?
- Are there any insects causing enough damage to the pasture to reduce Production? Check underground too.
- Is the pasture infested by disease?
- Is the grass–clover balance correct?
- Is the pasture at the correct stage for grazing?
- Should I graze or make hay or silage?

The only way these questions can be answered satisfactorily is by regularly checking the pasture in detail. Regular inspections can provide early warning of potential serious problems and allow for timely remediation.

The seedlings have germinated. What will help them to establish successfully?

- **Control weeds** while they are young with selective herbicides. Competition can severely reduce the establishment and survival of the pasture species.
- **Control pests** such as slugs and snails, which can severely reduce the number of seedlings.

Control of diseases, companion species and competition between annual and perennial ryegrasses is difficult by this stage. Using disease-resistant varieties and seed treatments for disease and the right sowing rate is the best prevention.

The seedlings have successfully established. What will maintain the population of grass and clover?

- **Control weed competition** later in the development of the pasture where possible with selective herbicides or mechanically. Larger and older broadleaf weeds are much harder to kill, and the herbicides used to control them can damage clovers.
- **Monitor pest and disease damage** and implement control procedures promptly where effective methods are available.
- **Manage competition between the sown species.** The grass seedlings will grow faster than the clover seedlings. Control grass growth by judicious grazing, which will allow light in to the clover seedlings. Section 3.6 describes this in detail.
- Stresses caused by weather can have a large effect on the maintenance of the grass–clover balance. Prolonged dry spells can reduce clover populations substantially.
- Provide adequate nutrition for both legumes and grasses. Apply fertilisers throughout the year so that sufficient nutrients are available for periods of rapid growth. Rectify all existing nutrient deficiencies. Reduce severe soil acidity with lime.

Fertilisers

Nitrogen

Nitrogen (N) is important for leaf growth and is one of the essential building blocks of all proteins. It has an important effect on the quantity and quality of pastures.

Nitrogen is found in the soil as nitrogen gas, oxides of nitrogen (nitrate, nitrite, nitrous oxide and nitric oxide), ammonia, ammonium and organic nitrogen. Nitrate is the form required by most plants. Soil water content, pH, temperature, organic matter and microorganisms determine its rate of formation.

There are many different forms of nitrogen fertiliser:

Organic: Dairy manure, poultry manure, urea. Chicken manure is often used to increase pasture production. In cool climates it is applied in early autumn to provide winter feed. However, because of its high NPK content and because it's an organic fertiliser, it is best applied in spring.

Inorganic: Sulphate of ammonia, ammonium nitrate (Nitram), potassium nitrate, sodium nitrate, monoammonium phosphate (MAP), diammonium phosphate (DAP).

There are several NP (nitrogen and phosphorus) fertilisers; for example, DAP, Starter 15, Starter 18 and DAP Sulphur. The choice will depend on the phosphorus status of the soil and the amount of nitrogen required. As a general rule, sow 20 kg N/ha with the seedA hundred kilograms per hectare of DAP with an analysis of 18:20:0 will provide 18kgN/ha.

Heavy rain at or just after sowing will cause leaching and thus loss of nitrogen. Some dairy farmers prefer to sow with molybdenum and phosphorus and then broadcast nitrogen as urea or nitram after germination.

Urea and ammonium nitrate will last only 6–8 weeks in the soil. It is important to observe the pasture to determine its nitrogen status. Blanket applications of nitrogen fertilisers every 6–8 weeks are not recommended for perennial ryegrass – clover pastures because they will alter the balance between grasses and clovers. For other pastures, a small dose of 30–60kgN/ha every 6 weeks is ideal.

Choosing between urea and ammonium nitrate will be determined mainly by the price. Compare the cost of 1kg of nitrogen from both. Ammonium nitrate is more suited to drier conditions and provides a slightly quicker response.

For every 1kg of nitrogen applied to a pasture, approximately 10kg dry matter results. For a ryegrass pasture, 1kgN will produce the following amounts of dry matter (kg/ha):

Climate	Dry matter produced, by season (kg/ha)		
	Autumn	Winter	Spring
Cool	10–12	5–8	20
Moderate	15	10–12	23
Warm	20	15	25

Phosphorus

Phosphorus (P) fertiliser will be required each year to sustain a healthy and productive pasture. P deficiency can be one of the greatest constraints on pasture production. As stocking rate and intensity of production increase, the demand for P fertiliser will also increase.

The availability of phosphorus to pastures is reduced by:

- formation of sparingly soluble iron and aluminium phosphates in acidic soils
- formation of sparingly soluble calcium phosphates in alkaline soils
- adsorption* on soil particles
- transfer in dung to the unproductive areas on the farm such as laneways
- immobilisation in plant residues
- immobilisation in dung
- incorporation into the organic matter in slowly available forms
- run-off.

We can budget the annual phosphorus gains and losses:

Phosphorus budget for a model farm with a stocking rate on milking area of 2.5 cows/ha and milk production of 5000 L per head per lactation

		kg P
Inputs:	Concentrate	10.6
Losses:	Product	17.0
	Transfer	2.9
	Dung unavailable	9.6
	Run-off	2.0
	Residue unavailable	11.6
	Soil P sorption	See next
	Total	43.1+
Deficit (equivalent to 369 kg/ha of single super)		32.5+

* Adsorption is attachment by chemical reaction to a surface. Absorption is soaking into something. Together these are referred to as sorption.

This phosphorus budget does not take into account losses through reactions between the soil and the freshly applied fertiliser because the amount of P sorbed varies markedly between soil types. Soils with a high iron content, such as the red krasnozems, have a high capacity to sorb P and will have a higher requirement for P fertiliser than a low sorbing sandy soil. Organic matter in the soil also reduces P availability. Therefore more P than this budget indicates must be applied. The total fertiliser P required then could vary from 43 to 73 kg P/ha/year at the production levels used in this P budget.

Note that the capacity of the soil to sorb P reduces as more P is applied, so the annual requirement could approach the amount in the budget.

The amount of P lost will vary with stocking rate and milk production. The table on the next page shows this.

Frequency of application

P fertiliser must be applied every year to sustain the high level of production that dairy farming systems demand.

Pasture plants take up P early in the growth cycle. Seedlings in particular take up large amounts. Freshly applied fertiliser can supply seedlings effectively with their P requirements. This P is more readily available than the P already in the soil. Apply the P near the seed so that the seedling can extract it efficiently from the soil.

The P taken up by the plant can be mobilised rapidly to supply the growing parts of the plant. P is moved from old leaves to new leaves very efficiently. Therefore, if the plant can take up large amounts of P early in its life then it can mobilise the P when soil moisture stress (too little or too much moisture) makes it hard for it to get P from the soil.

Application of P is required close to

P losses at different stocking rates, and rates of superphosphate required to replace the P for different soils

Stocking rate (cows/ha)	P loss (kg/ha)	P fertiliser required					
		High sorbing soils		Medium sorbing soils		Low sorbing soils	
		P (kg/ha)	Super (kg/ha)	P (kg/ha)	Super (kg/ha)	P (kg/ha)	Super (kg/ha)
1.5	25	65	740	50	568	35	398
2.0	29	69	784	54	614	39	443
2.5	33	73	830	58	659	43	489
3.0	43	83	943	68	772	53	602
3.5	52	92	1050	77	875	62	705
4.0	61	101	1148	86	977	71	807

periods of rapid pasture growth. Applications in autumn are essential to stimulate autumn growth and to start the perennial ryegrass – white clover growth cycle. Spring applications also supply readily available P just before rapid growth starts in spring. Early summer applications can also ensure that the clover and ryegrass have enough P to help them survive before they enter a period of stress during summer.

Phosphorus can be applied in association with frequent dressings of nitrogen or potassium. However, it might not always be possible to apply all the smaller dressings in some years because of unfavourable weather, and pasture productivity could suffer through P deficiency. Therefore the main autumn and early spring applications will still be essential to ensure that the plants can take up large amounts of P at these times. The P can then be mobilised when the plant needs it in the future.

Sulphur

Superphosphate contains 11% sulphur, which is mainly as immediately available sulphate. Rates of superphosphate sufficient to meet the P requirements of pastures in most districts will also meet the S requirements on moderately S-deficient soils. However, concentrated forms of P fertiliser, such as triple super and DAP, often cannot meet the S requirements in some soils. These fertilisers can be fortified with S by mixing in elemental (yellow) sulphur. This form of S has to be converted to sulphate by organisms in the soil before it can be used by pasture plants; this can delay the availability of sulphur to the plants.

Timing the application of fertiliser containing elemental S can be important. Because the S has to be converted by microorganisms, it should be applied well before periods of rapid growth when S deficiency in plants is likely to occur. When the S is required quickly after application, particularly after cold periods, which slow the rate of conversion, use fertilisers with sulphate S.

Which source of P should I apply?

This will be influenced by various factors:

- The relative price of the N, P and K components from the various fertiliser sources.
- The number of applications required to deliver the total fertiliser.
- The cost (bag fertiliser is dearer than bulk fertiliser).

Forms of P for application of annual dressings *(N = nitrogen, P = phosphorus, K = potassium, S = sulphur)*

P fertilisers	N:**P**:K:**S**	Comments
Superphosphate		
Single superphosphate	0:**8.8**:0:**11**	Sulphur content valuable in soils with S deficiency
Double superphosphate	0:**18**:0:**4**	Will require additional S in S-deficient soils
Triple superphosphate	0:**21**:0:**1**	
Compounds		
Monammonium phosphate (MAP)	10:**22**:0:**1.5**	These supply N but very little S
Diammonium phosphate (DAP)	18:**20**:0:**1.6**	
Mixtures		
Super Potash 1 + 1, Pasture 25	0:**4.5**:25:**5**	Superphosphate + potash
Super Potash 2 + 1, Pasture 16	0:**6**:16:**7**	
Super Potash 3 + 1, Pasture 13	0:**7**:13:**8**	
NPK mixtures		Wide range available from all the major fertiliser companies. Many developed for specialised situations in pasture development. Specialised mixtures can be made to suit individual needs.
Hay Booster®	12:**5**:24:**5**	Examples from Pivot
Pasturebooster®	24:**4**:13:**4**	
Poultry manure	~2% P	Variable product. 7.5 m^3/ha will supply ~50 kg P/ha. Soils that have had frequent applications of poultry manure can have very high soil test values for P, but how effective this P is in supplying pasture plants is unclear.

To decide which source to use, you need to determine the amount of nutrients inkg/ha that you plan to use over a year:

- Estimate thekg/ha of N, P and K required for each paddock for the whole year.
- Adjust for other nutrients such as sulphur, molybdenum and trace elements.
- Decide the timing of application for each nutrient.

A combination of the price of the fertiliser types that can supply the required nutrient amount and the cost of applying it will decide the most efficient combination of fertiliser types to use.

Potassium

Potassium (K) is usually deficient in dairy pastures. This is because cows transfer K in their urine and manure to unproductive parts of the farm, dairy farmers remove it in hay and silage, and the milk leaving the farm takes the K with it.

Keep the following points in mind when applying K:

- Potassium will burn seedlings if it is applied at more than 62kgK/ha. Broadcast the K before sowing and work it in, or sow a maximum of 30kgK/ha with the seed.
- Potassium has a big effect on the ultimate population of clover and lucerne stands. Application of K before

sowing will produce a good plant population. Application of K when clover and lucerne populations decline gives a poor response because the reduced plant population cannot compensate.

- Lighter or sandy soils are more prone to K deficiency.
- Dairy wastewater is high in K.
- Pasture can take up excess applied K; this can cause milk fever in freshly calved cows.
- Excess applied K can be leached out of the soil and wasted on sandy soils.
- Calcium and magnesium compete with K for entry into plants. A soil high in one or both of these will require extra K for satisfactory crop nutrition.
- Conversely, high amounts of K can reduce the uptake of magnesium and thus cause grass tetany, particularly when K fertiliser is applied with N fertiliser in early spring.
- Responses to K can be disappointing if N and P are deficient.

Recommended potassium rates at sowing

Soil test result (meq K/100 g)	Potassium needed (kg/ha)	Rate of muriate of potash (kg/ha)
> 1	0	0
1–0.5	15	30
0.5–0.3	30	60
< 0.3	60	120

Using fertiliser blends

Fertiliser blends can be useful for applying small amounts of K regularly:

N+P+K: Used mainly for summer crops. Can be used for pastures where K is deficient and N is required.

P+K: Very good for pastures that have a high clover component.

N+K: Ideal for topdressing a pasture. Maintains a balance of N and K and ensures that the grasses do not dominate the clovers.

The balance of K and P is critical if a blended fertiliser is to be sown with the seed. The balance will depend on soil concentrations and paddock history. The most important consideration is that excess K will burn seedlings.

Nutrient deficiencies

In the early stages nutrient deficiencies might be evident.

Nitrogen deficiency

If clovers and lucerne are growing actively but grasses are light green to yellow then nitrogen is deficient. Heavy rain at sowing can leach nitrogen below the root zone. Topdress with urea at 125kg/ha or nitram at 187kg/ha.

Forms of potassium fertilisers

Form	% K	Salt index*	Comments
Potassium chloride (KCl)	52	2.1	Sold as muriate of potash. By far the most widely used K fertiliser.
Potassium sulphate (K_2SO_4)	54	0.85	17% S
Potassium magnesium sulphate (K_2SO_4, $MgSO_4$)	18	1.97	11% Mg, 22% S. Frequently included in mixed fertilisers.
Potassium nitrate (KNO_3)	37	1.58	13% N

* Salt index is the ratio of the increase in osmotic pressure produced by the fertiliser to that produced by the same weight of sodium nitrate.

Phosphorus deficiency

Clovers are slow to establish. In extreme phosphorus deficiency grass leaves become purple. Apply any P fertiliser at 30kgP/ha.

Potassium deficiency

Hard to detect in the early stages. Clover and lucerne plants die out in the first 12 months. Apply potassium chloride before sowing or at 125kg/ha when symptoms first appear.

Molybdenum deficiency

Often seen on lighter soils. The young clover and lucerne seedlings have red stems. The plants remain stunted, the reddening affects the leaves and the young plants die.

Molybdenum deficiency causes nitrogen deficiency. Because molybdenum is necessary for nodulation of the roots, the plant is unable to produce nitrogen. Spray with sodium molybdate at 100g/100L applied at 70L/ha, or apply either urea at 125kg/ha or nitram at 187kg/ha with either Mo single superphosphate at 250kg/ha or Mo Goldphos at 125 kg/ha.

Fertilisers and the environment

There is concern that fertiliser use in intensive farming systems could pollute surface water and groundwater. The Agfact *Fertilisers and the Environment* (AC.21) discusses this problem. A copy was included in this manual.

Weed control after sowing

Weeds can compete severely with a new pasture and stop it establishing well. Effective weed control is a combination of careful planning in the year before the pasture is established and judicious use of herbicides, grazing or mechanical control.

Most aspects of weed control in pastures after sowing are covered in the NSW Agriculture publication *Weed Control in Lucerne and Pastures*, which should have been included in this manual. If it wasn't, please ask your local NSW Agriculture office for a copy.

Controlling broadleaf weeds in seedling grass–legume pastures

Broadleaf seedlings can be controlled with selective herbicides without killing the clover if you follow these important principles:

- Use only herbicides recommended for the target weed in the current situation.
- Use the correct rate.
- The legume seedlings must be past the first trifoliate leaf stage, but before the 8th trifoliate leaf stage for some herbicides.
- High temperatures will increase the susceptibility of legume plants to some herbicides. For example, temperatures above 20˚C will increase the risk of killing legumes with bromoxynil.

Controlling grass weeds in seedling grass–legume pastures

The grass weeds that cause the greatest problem are annual summer-growing grasses such as summer grass and pigeon grass. It is very difficult to control grass weeds in an establishing grass–legume pasture with selective herbicides. The most effective way to control potential grass weeds is to control their seeding in the year before the new pasture is established.

Spray-topping before the problem weed has seeded, usually in spring or early summer, will minimise the production of fresh weed seeds and thus reduce the potential for the weeds to germinate the following year. In spray-topping the soil is cultivated to encourage the target weeds to germinate; the weed seedlings are then killed by herbicide or cultivation when they emerge, or they are out-competed by a vigorous crop. See *Weed Control in Lucerne and Pastures* for rates.

Rainfast and withholding periods for pasture herbicides

When using herbicides, observe the withholding periods for the entry of livestock after application so that livestock products are not contaminated. *Weed Control in Lucerne and Pastures* gives details.

Pest control after sowing

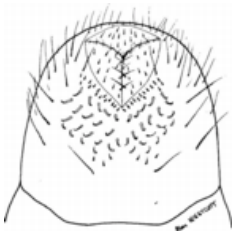
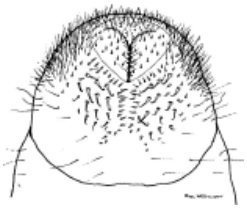
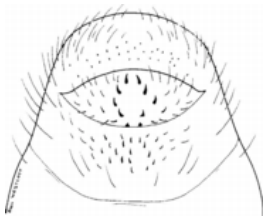
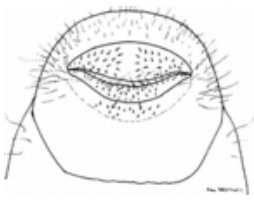
Pasture plants are susceptible to insect attack after they have been established and during their productive growth. You must take care to correctly identify the insect that is causing the damage. The most important insects are discussed in the following table. Damage must be sufficient to warrant the use of insecticides.

Pest	Description	Activity	Control
Red-legged earth mite	~1 mm long. Black body and red legs.	Eggs are produced and carried over summer and hatch in late autumn after rain and when the soil temperature cools.	Best control is spraying 2–3 weeks after hatching and before egg laying. Do not allow the mites to lay eggs in spring. Spray miticide along fences.
Lucerne flea	Pale green and round. 3 mm long. Will hop when disturbed. Eat holes in leaves until a thin skin remains on one side.	Most active in cool wet weather. Several generations during the year.	Inspect weekly after the autumn break. Spray when numbers increase sharply. Two foliar sprays a few weeks apart might be needed.
Spotted alfalfa aphid	Adults yellow to green, ~2 mm long, with rows of dark dots along their back. Some adults winged, others wingless.	Most active spring–summer.	Monitor lucerne stands. Cut for hay when the aphids become a problem. Spray if lucerne wilts.
Blue-green aphid	Blue to green and ~3 mm long. Some adults winged, others wingless. Two long slender projections at the rear of their body.	Most active autumn–spring. Leaves can turn yellow and die prematurely.	Predatory insects such as wasps and ladybirds are important in keeping numbers down.
Lucerne leaf-roller	Two types: one in the south of the state and another in the north.	The small caterpillar rolls the leaf with a web. The caterpillar pupates in the leaf.	Cut the lucerne for hay. Spraying should not be necessary.
White-fringed weevil	Larvae ~13 mm long, legless and creamy white. Attack lucerne, burrowing around the taproot and leaving deep grooves.	Larvae most active spring–autumn. Adults common January–March.	Crop rotation with cereals. Do not sow lucerne in land that has been infested with the weevil for the last 2 years. Adults can be killed with insecticides.
Sitona weevil	Grey-brown, 3–5 mm long with a brown snout. They do not move when disturbed. They eat U-shaped notches out of the leaves.	Adults emerge from the soil October–November; become dormant after feeding until late autumn, when they resume feeding and lay eggs within 1 week. Larvae develop into adults September–October.	Spraying must be completed within a week of renewed activity in autumn to stop egg laying.

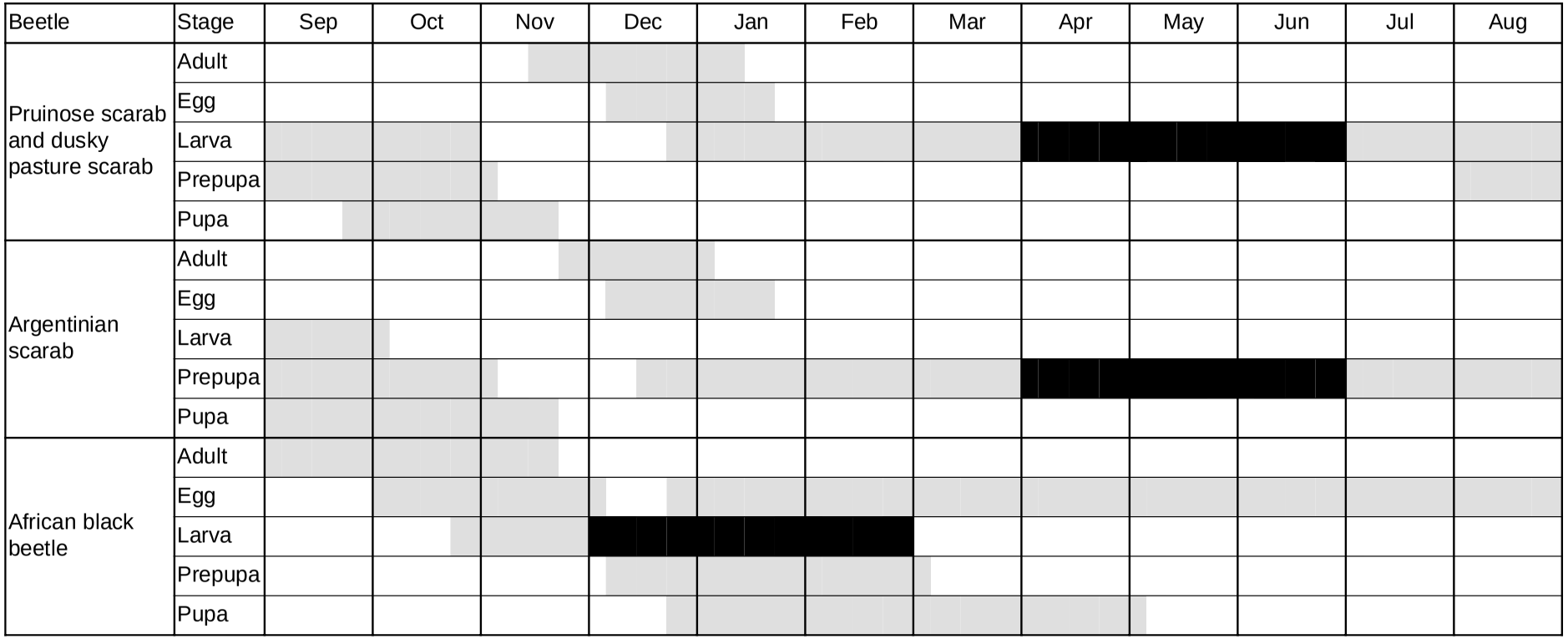
Pest	Description	Activity	Control
Cutworms	Eat through stems of young pasture plants near ground level. Difficult to detect. 25–50 mm long. Colour ranges from grey to pink to brownish black.	Feed at night and hide in the soil during the day.	Inspect the pasture in late afternoon or evening. Best treated with insecticide when feeding.
Armyworms	Caterpillars vary in colour. Often have a dark-edged, broken white line down the centre of the back and a dark line along the inner margin of a white line down each side of the back. 35–45 mm long.	Usually occur in warm weather after heavy rain. Spread from areas where eggs were laid by moths.	Monitor paddocks. Spray when armyworms first appear.
Slugs and snails	A problem mainly in perennial pastures where there is plenty of organic matter. Snails take ~2 years to reach maturity. Slugs mature in 1–2 years and can live for several months to a few years.	Worst in young pastures in autumn and winter.	Baits containing methiocarb.

Beetle identification

Scarabaeid pests of coastal dairy pastures. Scarabs can cause serious damage to pastures as both adults and larvae. The four scarabaeid pests are shown below. They all have 1-year life cycles and 7 life stages: egg, 1st, 2nd and 3rd instar larvae, prepupa, pupa and adult. The larvae of each of the 4 look similar. The 3rd instar larvae are white or creamy white soft-bodied grubs about 25–35 mm long.When resting they are C-shaped. They have hard brown or yellowish brown head capsules, strong biting mouthparts and 3 pairs of legs. Second or 3rd instar larvae can be distinguished by the shape of the anal opening, the raster (the arrangement of spines and hairs on the underside of the last body segment) and some other features with a low-power (× 10) hand lens). As the second table shows, the life cycles occur at different times of the year. Understanding when the grubs and beetles are active will help you develop management strategies to control them.

Name	Adult	3rd instar larvae	Other comments
Pruinose scarab (*Sericesthis geminata*)	 Length 11–16 mm	 Anal opening Y shaped	Problem in cooler highland pastures. Kills established pastures in winter.
Dusky pasture scarab (*Sericesthis nigrolineata*)	 Length 10–13 mm	 Anal opening Y shaped	Problem in cooler highland pastures. Kills established pastures in winter.
Argentinian scarab (*Cyclocephala signaticollis*)	 Length 13–15 mm	 Anal opening transverse	Problem in the Sydney area. Causes damage to pastures after African black beetle, April–June.
African black beetle (*Heteronychus arator*)	 Length 10–13 mm	 Anal opening transverse	Causes problems in maize crops (October–November) and early sown pastures (February). Mainly coastal.

Life cycles of scarabaeid pests of pastures *(grey = active or present; black = most serious)*



Disease control after sowing

For many plant diseases the only suitable control is to sow resistant or tolerant varieties. Chemical control of diseases in pastures is usually expensive and is seldom used except in specialist situations such as seed crops.

- Keep plants healthy and reduce stress by giving adequate moisture and nutrients.
- Correct any nutrient deficiencies. Appropriate fertiliser rates and timing will help plants to resist diseases.
- Don’t let pastures become rank as disease can build up. The increased humidity within the canopy also helps disease development.

Good grazing management can help in slowing disease development:

- Do not move stock directly from infected areas to clean areas.
- Removing the diseased tissue by grazing can often help to restrict disease spread.

Correct identification of the disease is important.

First-year management of newly sown pasture

Key management goals

Graze early to control competition from ryegrass

Ryegrass seedlings are much more vigorous than clover seedlings and will quickly smother out the clover unless they are controlled. To reduce the grass and allow light in to the clover seedlings, and to stimulate tiller development in the ryegrass, graze the pasture as soon as the grass seedlings cannot be pulled out easily by hand. They should be 10–15 cm tall; this is usually 4–6 weeks after sowing, depending on weather.

Graze intensively

Graze the pasture down to leave 4–6 cm stubble and repeat the grazing whenever the grass reaches the 3-leaf stage of development. This should give effective competition control for the clover and maximise ryegrass growth.

Remove the seed heads and flowering tillers in spring to stimulate new vegetative tiller development so that effective ryegrass production can continue into the next year. Pasture topping, cutting for silage or heavier grazingwith dry stock might be required. Reproductive tillers have no further growth potential after they have set seed, they produce low quality feed, and they drain nutrients away from the productivity of vegetative tillers. While reproductive tillers are present on the plant there is no stimulus for the plant to produce new vegetative tillers. Removal of reproductive tillers will also reduce the potential for ryegrass staggers from high-endophyte ryegrass cultivars.

Don't damage the new pasture

Set the stocking rate to reduce the pasture height from 15cm to 4cm in 24 hours with strip grazing using an electric fence. Back-fencing is preferable to ensure that the pasture is not grazed for more than 3 days. Pasture growth will be seriously restricted if stock are allowed to graze over an area that has already been grazed. The vigour of the young seedlings will be reduced through loss of leaves that emerge after grazing and reduction in carbohydrate availability to the young plants.

Avoid trampling and pugging damage

New pasture seedlings are vulnerable to trampling and pugging damage. When soil is wet and susceptible to pugging damage, use young stock for the first grazing; they cause less damage than milkers or dry cows. If the soil is dry, use cows.

No silage or hay production in the first year

Attempting to produce silage or hay from a new pasture in its first spring will be detrimental to both ryegrass and clover survival and production. Where possible, avoid hay and silage making in the first spring. Shutting the paddock up for silage will produce grass that is much taller and more competitive with clover than under effective grazing. Damage can be reduced and quality of silage can be enhanced by using 4-week shut-up periods before harvest.

Clover runners can be extensively damaged by being cut close to the ground

for silage. The growing points of many of the vegetative tillers of ryegrass can also be removed, and the potential for further production from those tillers would be lost. The plant would have to produce new tillers to remain productive. This is a much slower process than regrowth from an existing tiller. The ryegrass has little potential to produce new tillers in summer. Take care to ensure that as many tillers as possible survive in spring and summer so that they are present in autumn to begin rapid growth, when the weather is ideal for ryegrass growth.

Allowing dryland perennial grass pastures to seed in the first year will allow regeneration from seed should the perennial grass die from lack of summer rain in the first year.

Irrigation

An irrigation system should apply sufficient water, without waste, at the correct time, to maintain vigorous pasture growth. The best irrigation system is capable of keeping the top 5 cm of soil moist for the first 3 weeks after sowing, and not causing damage to the young seedlings. In the drier, hotter areas where rainfall is low, irrigation design is essential.

There are several different sprinkler irrigation systems available:

Hand-move systems are cheap in capital and running costs, but have a high labour requirement, needing a sprayline shift every 5–6 hours and 1.6 man-hours per hectare.

Side-roll–end-tow: Similar to a hand-move system, this system reduces labour to about 0.5 man-hours per hectare. Suited to flat, rectangular paddocks.

Bike-shift or long lateral: A network of underground pipes, with sprinklers that can be towed by a 4-wheel bike. This system can apply 25 mm of water every 4–6 days. Each sprinkler must be moved twice a day. Ideally suited to odd-shaped paddocks and uneven hilly paddocks.

Travelling irrigators irrigate a rectangular strip. The strip can be 40–100m wide, depending on the size of the sprinkler or boom, and 200–800 m long, depending on the length of hose. This system can apply about 25mm of water in 11 hours. The labour requirement is about 1.5 man-hours per hectare. On young pastures, poor irrigation uniformity due to wind drift, droplet size and the dragging of the hose along the new seedbed can affect germination and seedling vigour. Suited to uneven paddocks.

Centre pivots consist of a single sprinkler lateral supported by a series of towers. The towers are self-propelled, so that the lateral rotates around the pivot point in the centre of the irrigated area. Centre pivot systems are easy to run: when they are set

Irrigation system	Area (ha)	**Capital cost ($/ha)**	Annual costs ($/ha)						Suitability for pasture germination
			Depreciation	Interest	Pumping	Repairs	Labour	**Total**	
Hand-move	25	**1500**	78	128	100	50	120	**476**	good
Powered side-roll	25	**2600**	140	220	110	85	50	**605**	good
Bike-shift	25	**1500**	78	128	80	50	20	**356**	good
Travelling irrigator—soft hose	25	**2400**	125	205	190	90	38	**648**	poor
Travelling irrigator—hard hose	25	**2900**	150	245	190	100	30	**715**	reasonable
Travelling irrigator—fixed boom	25	**3200**	175	270	140	115	40	**740**	poor
Centre pivot	60	**2400**	150	205	75	105	6	**541**	good
Linear move	200	**1325**	90	115	65	65	5	**340**	good

up and operating correctly, very little can go wrong. Their drawback is that the outside sprinklers have to apply high volumes of water because they are irrigating a larger area than the centre sprinklers. Soil water intake rate and soil load-bearing capacity must be taken into account. Water intake rates of at least 10mm an hour are desirable, thus limiting use to light soils.

Linear move: Similar to centre pivot, but self-propelled laterally, making it suitable for rectangular paddocks. Linear moves are hydraulically more efficient and can operate at lower pressure than centre pivots. Tracking problems can occur on heavy soils of poor load-bearing capacity where wheel tracks develop into deep gutters. They require high capital investment but have low irrigation labour requirements. Suited to flat areas with minimal slope.

When to irrigate

The table below describes a number of practical measures to use to determine the best time to irrigate. Simply watering when a pasture is wilted is not good enough; white clover, for example, does not wilt until production has already fallen by 80%.

How much and how often?

This will depend on climate, the soil's capacity to store and release water, the root depth, and the water requirements of the particular pasture species. Water should be applied before the most easily stressed plant or the one with the shallowest root depth wilts.

The maximum amount of water to apply is calculated as:

average holding capacity of soil (mm/m)
× root depth (m)

Soil water status for surface soils and subsoils

Available water	Sands & sandy loams	Loams, clay loams & clays	Comments
Above field capacity	On squeezing, free water is expressed from the ball of soil.	Soil very sticky and sloppy. When squeezed, oozes water.	Soil waterlogged: no air can get to the roots.
100% (field capacity)	No free water appears on the soil when the ball is squeezed but a wet outline is left on the hand.	Soil sticky. No free water appears on the soil when the ball is squeezed but a wet outline is left on the hand. Possible to roll long thin rods 2.5 mm in diameter between finger and thumb.	Plenty of water and enough air available to the plant.
75%	Slightly coherent. Will form a weak ball under pressure but breaks easily.	Soil coherent. Has a slick feeling and ribbons easily. Will not roll into long thin rods 2.5 mm diameter.	Adequate water and air; plant grows well.
50%	Appears dryish. Tends to ball under pressure but seldom holds together. Close to the refill point.	Soil coherent. Forms ball under pressure. Will just ribbon when pressed between finger and thumb. Close to refill point.	Just enough water available to the plant.
25%	Appears dry. Will not ball under pressure.	Somewhat crumbly but will form a ball under pressure. Will not ribbon between finger and thumb.	Past refill point; growth has ceased.
0% (wilting point)	Soil is dry and loose and flows through fingers.	Crumbly–powdery. Small lumps break into powder. Will not ball under pressure.	Desperately needing water; plants will die soon.

For a ryegrass–clover pasture on a clay loam soil with a root depth of 20cm, the maximum irrigation application would be:

$$80 \times 0.2 = 16 \text{ mm}$$

Average available water-holding capacities

Type of soil	Average holding capacity (mm/m)
Sand	25
Fine sand	40
Sandy loam	55
Fine sandy loam	70
Loam	80
Silt loam	90
Light clay loam	90
Clay loam	80
Heavy clay loam	75
Clay	70

Typical range of effective root depths of species. Actual root depth will depend on soil structure and depth

Species	Root depth (cm)
Clover	15–30
Ryegrass	25–45
Paspalum	30–50
Kikuyu	30–60
Oats	30–60
Lucerne	50–70

Net applications for some pasture species

Species	Sandy loam (mm)	Loam (mm)	Heavy clay loam (mm)
Clover	10–15	10–25	10–20
Ryegrass	15–25	20–40	20–35
Kikuyu	15–30	25–50	25–45
Paspalum	15–30	25–40	25–40
Oats	15–30	25–50	25–40
Lucerne	25–40	40–55	–

Irrigation interval—how often to irrigate—depends on evapotranspiration. This is the amount of water a crop and its soil lose, and is calculated as evaporation × crop factor. Crop factor is the amount of water that a plant transpires as a proportion of free evaporation, and depends on crop and season. The 2 tables below show free evaporation in 4 towns in NSW, and crop factors for 3 crops:

Evaporation (mm)

Month	Bega	Richmond	Alstonville	Forbes
January	127	150	180	250
February	102	120	141	175
March	102	100	135	150
April	76	75	107	100
May	51	50	83	60
June	38	40	77	45
July	38	40	88	42
August	43	50	113	60
September	64	75	137	85
October	89	100	158	125
November	127	130	170	160
December	127	140	188	225
Total	984	1070	1577	1477

Crop factor

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lucerne	0.95	0.9	0.85	0.8	0.7	0.55	0.55	0.65	0.75	0.85	0.95	1.0
Pasture	0.7	0.7	0.7	0.6	0.5	0.45	0.4	0.45	0.55	0.65	0.7	0.7
Maize	0.7	0.7	0.7							0.7	0.7	0.7

If the evapotranspiration rate is 4mm a day, then the irrigation interval will be:

16mm ÷ 4mm/d = 4 days

Extending the irrigation frequency to 8 days would result in a 50% production loss in the white clover.

The following table gives the irrigation interval for four towns in January:

Town	Daily evap. in January (mm)	Crop factor	Evapotranspiration (mm)	Irrigation interval (days)
Bega	4.10	0.70	2.9	6
Richmond	4.84	0.70	3.4	5
Alstonville	5.81	0.70	4.1	4
Forbes	8.06	0.70	5.6	3

Common pasture problems

Problem	The most common causes
Cows are pulling out ryegrass plants	• Weak root system from repeated grazing • Fungal diseases • Scarabs • Soil compaction • Variety of ryegrass
Clover seedlings have disappeared	• Slugs • Damping-off • Molybdenum deficiency (leaves turn red or purple first)
Oversowing of ryegrass into clover was unsuccessful	• Competition—it is important to graze heavily • Timing—sow the ryegrass when clover is not growing
Oversowing of white clover into grass pasture was unsuccessful	• Competition—it is important to graze heavily and spray with glyphosate **or** paraquat to suppress the grass • Clover is best dropped on moist ground with harrows and rolled. Moisture **must** be maintained in the topsoil
Pasture is yellow and lacks growth and vigour	• Waterlogging • Nitrogen deficiency • Cold • Disease
Pasture seedlings are stressed. The grass leaves are dry. Some plants have turned white	• Red-legged earth mite • Blue oat mite
Poor legume growth	• Seed must be correctly inoculated before sowing
Lucerne and clover seedlings turn red or purple and die	• Molybdenum deficiency • Incorrect inoculation of the seed—e.g. using sodium molybdate instead of molybdenum trioxide
Within 6 months of establishment, pastures thin out, especially clovers and lucerne	• Potassium deficiency
White clover growth been disappointing	• Dry winter weather affects the most popular white clover, Haifa, which relies on good winters and springs before seeding down
Poor clover growth in a pasture mix	• Phosphate deficiency
Cows suffer nitrate poisoning when they graze oats or ryegrass in winter	• Too much N fertiliser when overcast weather prevails • Molybdenum is deficient and the plants cannot incorporate N into their tissues. Instead, they store N, and nitrate poisoning results