NSW GOVERNMENT

Department of Primary Industries

Temperate perennial pasture establishment guide

Steps to ensure success

www.dpi.nsw.gov.au

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We would like to gratefully acknowledge the late Mike Keys (former Agronomist Special Projects, NSW DPI, Queanbeyan) who was responsible for writing and collating the first edition of the Prime Pasture Establishment Field Guide. That guide was a structured approach to planning, preparation and implementation of perennial pasture establishment. It was a product of the state-wide Prime Pasture Programme, implemented by NSW Department of Agriculture and funded by The National Soil Conservation Program. Mike led the Programme, in which he and Technical Officer, John O'Connor traversed the Slopes and Tablelands of NSW, sowing 101 paddock-sized demonstrations and holding numerous meetings and field days, with the aim of increasing the success rate of perennial pasture establishment. They developed and promoted a risk minimisation strategy and the 3As of: Absolute weed control, Accurate seed placement and Adequate soil moisture.

The current publication draws heavily on Mike's experiences, his knowledge and the principles embedded in his work, with revisions incorporated to address new issues associated with perennial pasture establishment in contemporary farming systems.

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Warnings & Disclaimers

Pasture improvements cautions

The Native Vegetation Act 2003 restricts some pasture improvement practices where existing pasture contains native species. Inquire through your office of Environment and Heritage or your Local Land Services for details.

Animal health issues

Pasture improvement may be associated with an increase in the incidence of certain livestock health disorders (e.g. bloat of cattle from clovers or lucerne). Livestock and production losses from disorders are possible. Management may need to be modified to minimise the risk. Consult your local veterinarian or advisor when planning pasture improvement.

Chemical use

ALWAYS READ THE LABEL

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

Pesticide residues may occur in animals treated with pesticides, or fed any crop product including crop waste that has been sprayed with pesticides. It is the responsibility of the person applying a pesticide to do all things necessary to avoid spray drift onto adjoining land or waterways.

Any product trade names used in this publication are supplied on the understanding that no preference between equivalent products is intended and that the inclusion of a product name does not imply endorsement by NSW Department of Primary Industries over any equivalent product from another manufacturer.

The information contained in this publication is based on knowledge and understanding at the time of writing (August 2016). However, because of advances in knowledge, and understanding users are reminded of the need to ensure that information upon which they rely is up to date and to check currency of the information.

Contents

Introduction

This publication focuses on the successful establishment of introduced temperate perennial pasture species. The establishment period extends from the initial planning two years before sowing, through to site preparation, the sowing process and until the pastures have survived their first summer. The high cost associated with sowing permanent pastures means that establishment must be successful. In order to recoup this cost, the sown species should persist and achieve the desired production and/or environmental outcomes for at least 10 years.

Points to consider when sowing perennials:

1. Most perennial species have slow-growing, weak seedlings compared with annuals. Consequently, weed competition is a common cause of establishment failure.
2. Pasture establishment is expensive. One bad outcome is a partial failure – where establishment is satisfactory and the newly sown pasture is too good to remove, but inadequate so that it will never achieve its productive potential.

How to use this manual

This manual focuses on the main factors that must be considered in the planning process and the establishment of perennial pastures.

The information is presented in three sections:

1. Planning and paddock preparation
2. Sowing
3. Post sowing management

The key points to consider are summarised in the 'Perennial Pasture Establishment Checklist' on page 2

The three factors that have been found to be critical to successful establishment are:

- **absolute weed and pest control**
- **adequate soil moisture**
- **accurate seed placement.**

Perennial pasture establishment checklist

This information highlights the **eight key stages** in the establishment of productive pastures. Complete each step before moving to the next.	
1	PLAN AND ASSESS PADDOCKS FOR PASTURE ESTABLISHMENT
	Identify goals and resources
	Assess existing pasture for species composition, ground cover, weeds and soil fertility
	Question reasons for sowing pasture and identify potential contribution to livestock enterprise(s)
	Budget check – assess costs and expected returns
2	IDENTIFY SOIL CHEMICAL AND LANDSCAPE ISSUES
	Conduct a soil test
	Identify soil and landscape constraints that may affect pasture production
	Select suitable pasture species
3	WEED AND PEST CONTROL IN YEAR(S) PRIOR TO SOWING
	Commence weed control program at least 2 years before sowing, using a range of techniques
	Calibrate boom spray and select appropriate pesticides
4	ABSOLUTE WEED AND PEST CONTROL AT SOWING
	Allow full weed germination after the autumn break
	Assess weed and pest levels, including wet areas for slugs
	Use appropriate herbicides/insecticides at label rates, OR cultivate to achieve a fine, firm and weed-free seedbed
5	ADEQUATE SOIL MOISTURE AT SOWING
	Do not sow on first autumn rains
	Soil profile should be moist to a depth of 20 cm
6	ACCURATE SEED PLACEMENT – USE QUALITY SEED
	Sow quality assured seed whenever possible; obtain a current certificate of seed analysis
	Use freshly inoculated and lime-pelleted seed whenever possible
	Direct drilled pasture should be sown into a furrow at an average depth of 2.5 cm. Do not use harrows to cover seed.
	Seed should be covered with no more than 1–2 cm of soil, but less than 1 cm for species with very small seed
7	MONITOR WEEDS AND PESTS AFTER SOWING
	Monitor newly sown pasture as soon as seeds begin to germinate 2 to 3 days after sowing
	Continue to monitor weekly and if required, treat as soon as possible
	Decontaminate spray equipment before spraying pastures.
8	GRAZING MANAGEMENT OF NEW PASTURES
	Only graze in the first spring if conditions are favourable, i.e. plants are well anchored, the soil is moist and plants are not stressed
	Allow pasture to set seed in the first year – do not cut for hay or silage.

Adapted from: NSW Agriculture (1996) Pasture Establishment Field Guide: Prime Pasture Programme

1 Benefits of perennials and the importance of legumes

Benefits of perennials

A successfully established, vigorous and well managed perennial pasture can be expected to survive and provide increased production and environmental benefits for many years. Environmental benefits include weed suppression, reduced soil erosion, reduced incidence of salinity and acidification, and improvements to soil structure and soil carbon levels.

Weed control

Persistent perennial species can provide long-term and sustainable weed control. Well managed, vigorous perennial pastures with good ground cover are less prone to weed invasion than poorly managed perennial or annual-based pastures. A competitive perennial pasture gives seedlings of invasive weeds such as thistles, Paterson's curse (*Echium plantagineum*), and capeweed (*Arctotheca calendula*) little opportunity to establish. Perennial pastures are also regarded as the best long-term option to minimise the impact of perennial grass weeds such as serrated tussock (*Nassella trichotoma*), African lovegrass (*Eragrostis curvula*) and Coolati grass (*Hyparrhenia hirta*).

Pasture cultivars with a prostrate growth habit are preferred to erect cultivars for weed control due to their greater ground coverage and persistence under grazing.

Soil erosion

Well managed perennial pastures form a stable ground cover which reduces the potential for wind and water erosion. Perennial pastures intercept soil and nutrients in run-off water, reduce overland flow and increase infiltration rates.

Dryland salinity

Perennial pastures help to reduce the risk of dryland salinity. They have deep root systems and have a longer growing season than annuals. They tend to use more water and are therefore more effective in lowering the water table and reducing deep drainage below the root zone.

Reduced soil acidity

The rate of acidification will be lower under a perennial grass-based pasture than an annual pasture. This is due to the long-lived, deeper roots actively utilising nitrogen that would otherwise leach below the root zone. Perennial grass-based pastures require 50–150 kg of lime/ha/annum to maintain their soil pH, while annual grass/ legume pastures require four to five times this rate.

Soil structure and fertility

Perennial pastures help maintain the long-term fertility of agricultural soils. The deep, fibrous root system of perennial grasses assist in maintaining or improving soil structure. The size and stability of soil aggregates and water infiltration rates are considerably higher under perennial grass-based pastures compared with rates for annual pastures and intensively cropped soils.

Perennial pastures usually have a higher root to shoot ratio and the roots decompose more slowly than the roots of either annual pastures or crops. In general, levels of soil organic carbon (SOC) are higher under vigorous pastures (both perennial and annual) than cropping soils, with the difference increasing as rainfall increases.

The importance of legumes

Legumes (both annual and perennial) are a very important component of productive pastures. Effectively nodulated legumes have the ability to fix atmospheric nitrogen through a symbiotic relationship with bacteria (rhizobia). The fixed nitrogen produced improves the production, quality and persistence of the perennial grass component of a pasture.

Not only does legume seed and foliage have a relatively high protein content and digestibility compared with grasses, the addition of legume to a diet will increase animal intake. Therefore maintaining an appropriate legume content in the pasture will improve the overall quality of the pasture and increase livestock production.

Further reading

Chan KY, Oates A, Liu DL, Li GD, Prangnell R, Poile G and Conyers MK (2010) A farmer's guide to increasing soil organic carbon under pastures. Industry & Investment NSW, Wagga Wagga, NSW.

2 Planning and assessing paddocks for pasture establishment

A comprehensive plan and thorough assessment of the existing pasture should be made before undertaking any pasture improvement program. The re-sowing of perennial pastures should be regarded as a long-term investment. Consider carefully if re-sowing is necessary – a better option may be renovation of existing pastures.

Planning and assessing pastures

Assess the potential of a paddock in relation to its significance within the whole farm, the specific benefits to the operation and constraints that must be overcome. Four aspects are worth of considering:

1. Personal goals, farm goals and resources

What are your goals regarding lifestyle, enterprises, costs and returns, debt and risk? You need to determine the required level of income to meet your personal and farm goals.

2. Proposed enterprises and feed requirements

The periods of high feed demand will depend on the enterprise. For example, in a breeding enterprise adjusting the joining, calving/lambing and weaning periods will shift the point of peak feed demand. Most sown temperate species have good winter and spring forage quality and production, but there may be a shortage of high quality feed in summer and early autumn. You may decide to grow a special purpose pasture to fill the feed gap. For example, in a temperate pasture system, lucerne is capable of producing high quality feed during summer and autumn. Alternatively, you may be able to conserve fodder in the spring as silage or hay to fill a summer or autumn feed gap.

3. Assess the current pasture for species composition and ground cover

It is essential that you learn to identify the species present in your paddock so that pasture assessments can be made. Keep in mind that composition will change throughout the year, so it is best to assess a paddock several times during the year, across a range of seasons, in periods of peak growth and times of critical feed supply.

Paddock assessment allows you to gauge the contribution each component of the pasture is making to ground cover, feed supply and quality. It also provides an indication of the condition of key species (and weeds) across seasons. The assessment will help guide decisions on, for example, weed control, fertiliser inputs and grazing strategy.

One of the quickest methods to assess pasture composition is to measure the species composition and ground cover (see *Appendix 1 – Assessing species composition and ground cover*). Identify useful pasture species and the plants considered weeds. Some plants such as barley grass (*Hordeum leporinum*) and capeweed (*Arctotheca calendula*) can be useful pasture components while they are in a vegetative stage, provided the proportion of space they occupy is within your accepted limits.

Assessing the current pasture composition is the first step in planning for investment in pastures.

Photo: L Ayres

The composition of perennial grass-based pastures will vary across seasons and targets will depend on your production and environmental goals. Using the pasture assessment methods described in *Appendix 1*, the botanical composition of a balanced, perennial grass-based pasture in spring would be:

- 60–70% perennial or sown grass
- 20–40% legume
- Less than 20% annual grass
- Less than 10% broadleaf weed
- Near 100% ground cover

If you are not satisfied with your current pasture composition then there are many techniques that can be used to improve it. A pasture assessment will not only provide you with valuable information on composition and the condition of the pasture, it will also help to determine the suitability of the various improvement options.

4. Review current management

Before investing in pasture improvement, determine whether the paddock can be rejuvenated by changing the way it is managed. In some circumstances improvement can be concentrated in affected areas of a paddock.

Consider the following:

- How much of the paddock is degraded?
- What issues should be managed, e.g. weeds, ground cover?
- Why has the pasture degraded? For example, are the sown species suited to the climate, aspect and soil constraints of the site?
- What desirable species are persisting?
- Can the existing pasture be either improved or rejuvenated by other means such as tactical grazing, the use of selective herbicides or fertiliser?
- Can production be increased using a simple, less costly, non-destructive technique such as over-sowing legumes into the existing pasture or fertilising?

Answers to these questions in combination with a visual assessment will help you to decide how good your pasture is, whether you need to take action; and, if action is warranted, whether it is preferable to rejuvenate the existing pasture or completely re-sow.

A high proportion of sorrel is an indicator of a degraded pasture.

Photo: N Ferguson

Reasons for pasture degradation

Whatever your plan for improvement, it is important to identify reasons that the existing pasture has degraded. Doing this will inform future management and improve persistence of the new pasture. There is often a combination of reasons for pasture degradation or low productivity, which may include: low soil fertility, drought, overgrazing, site factors such as limited soil depth, aspect, inappropriate species or variety choice, pest damage and weed invasion.

Techniques to improve pasture composition

Techniques aimed at improving pasture species composition and productivity range from simple and inexpensive options, such as grazing management to favour desired species, to total replacement. Although it may take several years for some management options to achieve a significant change in pasture composition, they may result in the largest return on investment. The following options and combinations of these may improve pasture composition and productivity sufficiently to avoid the need for costly re-sowing.

1. Fertiliser

Deficiencies of nitrogen (N), phosphorus (P), sulfur (S), potassium (K) and molybdenum (Mo) are common in many pastures. Fertilising to address nutrient deficiencies will ensure that desirable pasture species grow to their potential. In low fertility situations, useful pasture species tend to decline and low production weed species, such as vulpia species, catsear/false dandelion (*Hypochaeris radicata*) and sorrel (*Acetosella vulgaris*), can invade and dominate.

A vigorous, effectively nodulated legume component will provide N to the grass component and improve the persistence and production potential of the pasture. Without a vigorous legume component grasses will require N fertiliser in order to persist and produce to their potential. Legumes have a higher requirement for P, S and Mo than grasses.

2. Over-sowing an existing pasture

Many degraded pastures can be improved or rejuvenated by sowing new species into the existing pasture. This non-destructive approach can be the best option when you want to increase the proportion of the desired legumes or useful perennial grasses, but do not want to re-sow.

Legume and grass seeds can be broadcast or direct drilled into existing pasture. The success of such a technique is mixed and lower establishment often results from broadcasting legume seed, compared with drilling the seed into the soil. See *Chapter 14 – Sowing techniques and machinery* for more information

Depending on the situation, before over-sowing appropriate herbicides can be used to suppress the already established, useful species. Seek advice from an agronomist before using this technique.

3. Selective weed control

Unwanted species such as vulpia or Paterson's curse (*Echium plantagineum*) can be removed using appropriate herbicides. Before using herbicides, it is important to assess paddocks for species composition to determine the most appropriate herbicide option and the likely impact of removing the target weeds on ground cover. More details on weed management options are presented in *Chapter 7 – Weed control prior to sowing.*

A herbicide treatment may result in bare ground once the target weed is removed and make the pasture susceptible to weed re-invasion. If the pasture is made up of a large proportion of the target weeds, herbicide use is best combined with another change in management, such as grazing or over-sowing.

Herbicides can be used selectively to remove some weed species from pasture.

Photo: G Johnson

4. Grazing management

Assessing your grazing strategy may give clues as to why some species have thinned or disappeared from your pasture. Knowledge of phenology of the species (i.e. seasonal growth and development) is important in order to understand how your grazing system affects different pasture plants (both perennials and annuals) and how they respond to grazing pressure throughout the season. See *Chapter 16 – Grazing Management* and *Appendix 5 – Grazing systems* for more detail.

References and further reading

Leech F, Parker P and Clements B (2009) Rejuvenating perennial pastures. Primefact 906. NSW Department of Primary Industries.

3 Pasture establishment budgets

Sowing a new pasture or improving an existing pasture should be considered as an investment of resources over a predetermined period of time. Significant gains in productivity and profitability can be realised in grazing systems by sowing or improving pastures to achieve a desired outcome.

Factors influencing the economics of new pasture sowings

The amount of time required to obtain a return on an investment in pasture establishment depends on many factors including:

Climatic variables

Rainfall and temperature will influence the reliability of seasonal production, the amount of pasture grown (dry matter per hectare) and subsequently the number of additional stock that can be supported.

Landscape variables

Soil moisture levels and potential pasture production will vary across the landscape, depending on variables such as soil texture, soil depth and aspect.

Livestock enterprise

The time to recover the cost of sowing a pasture will vary, depending on the profitability of the livestock enterprise. When planning to sow pasture you need to consider:

- the type of enterprise being run or planned. (Will the planned new pasture match the livestock enterprise feed requirements and production targets?)
- the additional livestock or dry sheep equivalents (DSEs) that will be supported by the improvements to the pasture. (What is the estimated return on the investment?)

Carrying capacity

A new pasture should have the potential to support more stock. Therefore, the initial years following pasture establishment may result in lower cash surpluses or even deficits as more stock are either purchased or retained on farm.

Other factors

Pastures are often sown for more than just economic reasons and may not provide a clear financial advantage. For example, a new pasture may be sown for environmental reasons, specifically to reduce erosion or ground water recharge. These additional benefits need to be considered in conjunction with economics to make the best possible decision, with the available information.

Pasture establishment costs

Pasture establishment costs will vary from year to year. Table 3.1 provides an indicative cost of the inputs and operations, using prices as at June 2016.

A cash flow development budget is also needed to determine the time to recover the cost of establishing pasture. This will provide a comparison of extra costs versus extra income, over a number of years (typically 10 for permanent pasture) and take account of varying stocking rates. The stocking rate is zero in the first year (from the time the paddock is not available for grazing), rising to the expected potential by the fourth year. Interest charges on borrowed money, the cost of additional inputs (e.g. fertiliser) and the cost of purchasing the extra stock must all be taken into account.

Insecticides

In 'at risk' areas the budget should include two earth mite treatments before pasture emergence – one in the spring the year before an autumn sowing and possibly another after sowing.

Herbicides

Budget for a minimum of two herbicide applications prior to sowing; one in the spring the year before sowing and one just prior to sowing. The choice of herbicide and associated costs will depend on the weed spectrum and the level of infestation. For example, a tank mix of the broadleaf herbicide (e.g. dicamba) and a knockdown spray (e.g. glyphosate) can provide effective control of a wide range of hard-to-kill weed species.

Caution: *When using herbicides before sowing pastures check the herbicide labels for the recommended interval between herbicide treatment and sowing (i.e. the plant back period). Legume species are particularly sensitive to some residual herbicides and failure to observe plant back periods will result in establishment failure of sensitive species.*

Seed prices

Seed prices fluctuate from year to year and season to season, depending on availability. Ensure the species and varieties you are purchasing are the best possible choices for your paddock. Avoid sowing pre-mixed, cheap blends as these often contain varieties or species

Table 3.1 Indicative pasture establishment costs *.

Operation	Month	Machinery **			Inputs			Total cost $/ha
		Rate (h/ha)	Cost ($/h)	Total ($/ha)	Rate (per ha)	Unit cost ($)	Input cost ($/ha)	
Spring insecticide treatment for earth mite	Sept/Oct	0.10	28.25	2.72	0.1 L	25.00/L	2.50	5.22
Spring knockdown weed control e.g. glyphosate (450 g/L)	Sept/Oct	with above operation			1.5 L	5.30/L	7.95	7.95
Pre-sowing weed control e.g. glyphosate (450 g/L)	Mar/April	0.10	28.25	2.72	1.5 L	5.30/L	7.95	10.67
Pasture sowing operation	April/May	0.29	31.58	9.18				9.18
Seed: phalaris		with sowing operation			4 kg	10.75/kg	43.00	43.00
cocksfoot					2 kg	10.75/kg	21.50	21.50
sub clover (bare seed)					4 kg	7.84/kg	31.36	31.36
Legume inoculant					4 kg	0.22/kg	0.88	0.88
Fertiliser e.g. Granulock®					150 kg	700.00/t	105.00	105.00
Insecticide (bare earth)	April/May	0.10	28.25	2.72	0.1 L	12.00/L	1.20	3.92
Lime (applied 1 year in 10)		Contract spreading included in unit cost			2.5 t	70.00/t	175.00	175.00
TOTAL								**413.68**

** The costs should be used as a guide only and should be reviewed regularly and adjusted to take account of movements in prices, changes in seasonal conditions and individual farm characteristics.*

***Machinery assumptions:*

- *Machinery costs only include variable costs for the tractor and implements, i.e. fuel, oil, filters, tyres, batteries and repairs.*
- *The costs are based on a tractor with PTO power: JD6100D, 61kW (82 HP) and are based on hours/year work.*
- *Labour costs are not included*

that may not be suited to your soil types, location or the enterprise you wish to run.

Whenever possible use seed that comes with a current seed analysis certificate. Certified seed meets strict standards including germination rate and purity (e.g. weed seeds, damaged seed and other contaminants). See *Chapter 11 – Seed quality,* for more detail.

Seed treatments

Many retailers include seed treatments (coatings) in the price of the seed. These coatings may include fungicide, insecticide, inoculant and/or lime. Seed coating can add significant weight to the individual seeds and may require seeding rates to be adjusted to achieve the desired plant population. See *Chapter 12 – Seed treatments – inoculation, pest and disease control*, for more detail

If using precoated seed check the labels of all seed lots to ensure they comply with the industry code of practice. More information is available on the Australian Seed Federation website: http://www.asf.asn.au/

Inoculation of legume seed is a relatively very small cost in the whole budget and is recommended when sowing legumes – unless you are confident that the background population of effective rhizobia is adequate. If, in the last five years, a paddock has not had reasonable densities of legume species infected by the same inoculant group as needed by your chosen legume, then inoculation is required. See *Chapter 12 – Seed treatments – inoculation, pest and disease control*, for more detail.

Fertiliser

Fertiliser prices can also fluctuate greatly from year to year, depending on supply. Do not try to save money by reducing rates of fertiliser at sowing as this may compromise establishment and development of the new pasture. The nutrients most commonly applied to pastures are N, P and S. Mo is a micro-nutrient that is required by legumes for the N fixation process and is not included in most commercial fertilisers. See *Chapter 9 – Fertiliser at sowing*, for more detail.

Contractors

Contractor prices vary depending on the size of the paddock to be sown, travel and the cost to haul equipment. It will generally be cheaper per hectare to sow a larger area.

Machinery

Machinery costs can be variable, depending on the size of tractor. Factors such as fuel, oil, filters, tyres, batteries and repairs need to be included in budgets.

References and further reading

Blackburn AG and Ashby RG (2006) Financing your Farm: A practical guide to financial growth. Australian Bankers' Association

Malcolm B, Makeham JP and Wright V (2005) Cambridge University Press, Melb. The Farming Game: Agricultural Management and Marketing. Cambridge University Press, Melbourne

4 Soil testing

Soil testing is a valuable tool used to determine the nutrient or fertility status of a soil and to identify potential constraints that may limit production. It enables you to select pasture species that match the soil characteristics. Considered in conjunction with pasture or cropping history, fertiliser history and economic considerations, soil testing also allows you to make informed fertiliser decisions.

Why should I have my soil tested?

The main reasons for soil testing prior to sowing new pasture are:

1. to identify potential soil and nutrient constraints that may limit pasture establishment and persistence; and
2. to optimise the selection of pasture species to be sown.

How do I take a soil sample?

The accuracy of a soil test is only as good as the sampling procedure!

Soil samples are best taken using a soil testing tube which removes a 2.5 cm diameter soil core. These are often marked to give a fixed topsoil sampling depth (usually 10 cm). If the subsoil is being tested as well, remember to keep these samples separate from the topsoil samples. There are a number of methods used to sample soils for testing:

Transect method

The transect method uses a set line (e.g. 100–200 m in length) across a uniform soil type within a paddock. The start and finish points can be landmarks or GPS coordinates that can be easily found again.

Point sampling method

Point sampling involves sampling from a small area (not much bigger than a car) that is representative of a larger area, with similar soil type, depth, aspect, elevation, pasture history, etc. It is important that the person sampling is confident in being able to select a point that is representative. GPS coordinates of the sample points are recorded.

The transect or point sampling methods allow you to resample specific locations and monitor fertility changes over time using tools such as the 'Five Easy Steps'. See *Chapter 17 – Fertiliser requirements* for more details.

Random sample method

Traditionally soil samples have been taken from random points in a zig-zag pattern across the paddock. This method is no longer recommended as it is not repeatable, may not be representative of the whole paddock and is much less reliable in showing trends than the transect or point sampling methods.

Assessing problem areas

When sampling to assess problems in a paddock take samples from areas of both good and poor growth and have them analysed separately. Use the point sampling method in the affected area and use either the transect or point method to collect samples that are representative of the unaffected area.

Soil testing provides valuable information to guide your soil management program and the selection of pasture species.

Photo: N Ferguson

Soil sampling tips

- Sample at least three months before sowing to give time to obtain results and order fertiliser and other soil amendments (e.g. lime, gypsum).
- When monitoring trends, sample at the same time of the year to minimise seasonal variation.
- Avoid sampling in very wet, cold periods.

- Avoid sampling within six months of fertiliser applications. (N tests are the exception)
- Sample from representative areas of the paddock. Avoid sampling from stock camps, swampy patches, feed out areas, manure patches, dams, under trees, gateways, tracks, etc.
- Sample depth of 0–10 cm is the most common standard for pasture soils. Record the sampling depth to ensure that the results can be interpreted with confidence.
- If the paddock is made up of more than one soil type, sample and test each soil type separately.
- Collect at least 30 cores per sample area. Remove excess undecomposed organic matter from the soil surface before taking each sample, but take care not to disturb the soil.
- Label samples clearly and complete the field information sheet as fully as possible, as this will assist in the interpretation of results.
- Do not let the samples get hot. Ideally, put samples in an esky during the collection process and refrigerate them until they are sent to the testing laboratory, as soon as possible after sampling.
- **Always use a soil testing laboratory that is NATA accredited and ASPAC certified.** NATA (National Association of Testing Authorities) accreditation and ASPAC (Australasian Soil and Plant Analysis Council Inc.) certification ensures independent assurance of technical competence and provide confidence in the soil test results.

Interpreting soil tests

The presentation of soil test results varies between soil testing services, depending on reporting preferences and the methods used by the testing laboratory. Benchmark levels typical of soils from the NSW Tablelands are presented in *Appendix 2 – Benchmark levels typical of soil test results from the NSW Tablelands*. Discuss your soil test results with an agronomist.

Some notes on the common tests are outlined below.

pH

Soil acidity is measured on a pH scale from 0 (most acidic) to 14 (most alkaline), 7 is neutral. The scale is logarithmic, which means that, going down the scale from pH 7 (neutral), each unit is 10 times more acidic than the one before it. For example, a soil with a pH of 6 is ten times more acidic than soil with a pH of 7 (neutral) and a soil with a pH of 5 is one hundred times more acidic than a soil with a pH of 7.

It is important that you are clear which pH testing method is used for your soil analyses. The suffix Ca after the pH figure (i.e. pH_{Ca}) signifies that the pH was measured in a solution of calcium chloride ($CaCl_2$). This test is preferred by most soil scientists. When soil pH is measured in a solution of calcium chloride the pH_{Ca} is typically 0.5–0.8 units lower than if the pH was measured using the 1:5 soil: water suspension method. Results from tests using the water suspension method are usually expressed as pH_W. Note that most field pH testing kits use the water method.

Soil pH can be raised by applying lime to the soil. The optimal pH_{Ca} for many pasture and crop species is between 5.0 and 7.5. See *Chapter 5 – Soil issues affecting pastures*, for more information relating to the management of soil acidity.

Major soil nutrients

Phosphorus (P)

Phosphorus is a major nutrient essential for plant growth but is commonly deficient in Australian soils, with the exception of some basalt soils. Even paddocks with a long history of applied P may be deficient and benefit from P applications.

It is relatively immobile in the soil and is usually concentrated close to the surface. It is unlikely to be leached (except in very sandy soils) but can be lost with erosion.

Phosphorus can become unavailable to plants in acid soils when it is "tied up" with aluminium and iron in solution, so it is important to keep your soil pH_{Ca} at around 5 or above to maximise the benefit of applied P. Other factors that influence the ability of a soil to hold and/or fix P include: cation exchange capacity, organic matter content and iron levels.

There are three main tests for P in Australia: Bray, Colwell and Olsen. As they produce very different results, it is important to know which one is referred to in your report.

The Bray test is not suitable for soils with a pH_{Ca} higher than 7.0. Bray test results are most accurate at low soil pH.

The Colwell test is used extensively in NSW. Its critical value is determined by the Phosphorus Buffering Index (see below).

The Olsen test gives similar critical P values to those of the Bray test. It is not often used in NSW.

Phosphorus Buffering index (PBI)

The Phosphorus Buffering Index (PBI) is a relatively new test that is used to measure the P sorbing ability of a soil. Used in conjunction with the Colwell P test value, it improves the ability to interpret soil P status and to identify critical P values for maximum potential pasture growth across a range of soil types.

Nitrogen (N)

Australian soils are naturally deficient in N. In a well managed, grass/legume pasture, effectively nodulated legumes supply N to the grass component. This results in an overall increase in growth and an improvement in pasture quality (digestibility and protein content).

Nitrogen fixation by legumes varies, and is proportional to the amount of legume dry matter produced. There are some occasions when additional N may need to be applied; e.g. if the legume component of the pasture is poor; when sowing grass-based pastures, or when boosting pasture growth for fodder conservation.

Nitrogen is highly mobile and easily leached. As occurs with sulfur (S), N levels fluctuate widely, depending on the season, rainfall, and pasture composition. Useful amounts of N (and S) can be released throughout the year by the natural process of mineralisation. Particularly during warm and moist conditions, microbial activity may convert organic N to plant-available inorganic N.

Potassium (K)

Potassium is not mobile in soils. It is usually not limiting in the pastures of most extensive grazing systems, except in very sandy soils in high rainfall areas or where long-term hay or silage production has occurred. The critical Colwell K soil test values to achieve 95% predicted maximum pasture yield for sandy loam soils is 139 mg/kg and 161 mg/kg for clay loam soils (*Appendix 2*).

Applying a fertiliser test strip across a paddock is one way of determining if a pasture is likely to respond to K.

Sulfur (S)

Sulfur availability is closely associated with soil type. It is mobile and can be leached from the root zone. Sulfur is particularly important for legume growth. It is also a vital component of all proteins and is essential for wool growth in sheep.

The basalt, granite and sandstone soils of the NSW Tablelands are often deficient in S. It is most commonly measured by the KCl_{40} test and the critical minimum benchmark is 8 mg/kg.

Calcium (Ca) and Magnesium (Mg)

Calcium is usually the most dominant cation in the soil and is rarely deficient in pastures. Likewise magnesium is rarely deficient, except in extremely sandy soils. The Ca:Mg ratio can be used as an indicator of soil aggregate stability. Research has shown that a wide range of ratios are acceptable. However, soils with Ca:Mg ratios less than 2:1 are more likely to be prone to dispersion, whilst those with ratios greater than 25:1 may have problems with Mg deficiency. Cases of Mg deficiency in pasture do not often persist as the concentration of Mg increases at depth in most soils and is accessed by plants as roots grow into the subsoil.

Other elements

Molybdenum (Mo)

Molybdenum is a trace element essential for legumes, as it is required by rhizobia bacteria for N fixation. Deficiencies are common in most Tableland pastures. Molybdenum should be applied to acidic soils once every 3 to 5 years. It may be applied using 'Mo Super', as a seed treatment, or as a foliar spray. Refer to *Chapter 9 – Fertiliser at sowing* for more details.

Sodium (Na)

High Na levels (greater than 6%) can indicate sodicity problems with: (i) dispersive soils (particularly when the soil Ca:Mg ratio is also less than 2:1), or (ii) salinity (see Electrical Conductivity below).

Sodic and saline soils are discussed in more detail in *Chapter 5 – Soil issues affecting pastures.*

Aluminium (Al)

Although Al is abundant in soil, it is not a plant nutrient. In strongly acid soils (pH_{Ca} below about 4.7) 'exchangeable' Al is released into the soil solution. This form of Al is very toxic to most plants, even at low concentrations. Stunted, stubby root growth is the most common symptom of Al toxicity. Poor growth and vigour associated with Al toxicity is due to a combination of factors, including: (i) restricted root growth reduces the ability of affected plants to access nutrients, and (ii) low pH affects availability of nutrient (e.g. P, Mg, Mo).

Sensitive species such as lucerne and seedling phalaris perform poorly when Al levels are greater than 5% – as a percentage of the cation exchange capacity (CEC). The tolerance of key pasture species to Al is presented in *Chapter 6 – Pasture species selection.*

Recommendations for management of soil acidity are presented in *Chapter 5.*

Manganese (Mn)

Manganese is essential for chlorophyll production, photosynthesis, plant respiration, nitrate assimilation and for the production of enzymes. Deficiencies in pastures are rare and toxicity (or excess) is much more common. Legumes and other broadleaf plants are less tolerant of excessive levels of Mn than grasses. This is particularly so when Al levels are also high. Treatment with lime can reduce levels of available Mn (see *Chapter 5*).

Iron (Fe)

Plants require Fe to produce chlorophyll and to activate several enzymes, especially those involved in photosynthesis and respiration. Iron deficiency is not common in pastures and, if observed, is most likely to occur as a result of excessive lime applications and high pH. Excessive Fe can bind with P and reduce its availability.

Zinc (Zn)

Zinc has a role in the formation and activity of chlorophyll and in several plant enzymes. Deficiencies most commonly affect summer crops such as maize or sorghum growing in neutral or alkaline soil and those of basalt origin. Soils under pasture are not routinely tested for Zn.

Copper (Cu) and Boron (B)

Soils under pasture are not routinely tested for Cu or B. There have been isolated cases of deficiencies of these trace elements. Boron may be deficient in extremely sandy soils or where lime has been applied at high rates. Lucerne, canola and brassicas are sensitive to B deficiency, and seed production of clovers has been shown to be significantly reduced at deficient sites.

Animal health is usually the first indicator of Cu deficiency and may be caused by application of excessive rates of Mo. Seek veterinary advice.

Selenium (Se)

While not required for plant growth, Se is an important trace element for livestock health. Some NSW Tableland areas with a history of pasture improvement are notorious for Se deficiency, particularly on the lighter textured, less fertile soils. Light-textured, coastal soils are also prone to Se deficiency. Contact your local veterinarian for advice on how best to manage the problem.

Other soil tests

Cation exchange capacity (CEC)

Cation exchange capacity is a measure of the ability of the soil to hold and exchange nutrients (which are generally cations) for plant use. Cations, including Ca, Mg, K, Na and Al, are held in soil by clay and organic matter. Low CEC values often indicate sandy soils that have low fertility and contain very little organic matter. Conversely, high CEC soils may have more clay and organic matter, which 'hold' nutrients and, as a result, these soils are generally more fertile.

Some soil test reports include hydrogen (H) on the list of cations. In Australia, this element should not be included in the total CEC when interpreting a soil test.

Organic carbon

Soil organic carbon (SOC) is a measure of organic matter in the soil. It includes undecomposed plant litter, soil organisms and humus. SOC holds water, stores important nutrients, stabilises soil structure and is a food for soil microbes. If SOC is declining over time, then consider using green manure crops, or practices such as reduced tillage, mulching, or strategic grazing and fertilising to promote pasture production. There are several tests available to measure SOC, all of which differ slightly in the carbon fraction they measure. To calculate percentage organic matter (%OM) multiply organic carbon by 1.7.

Electrical conductivity (EC)

Electrical conductivity is a measure of salts in the soil. Production of most species is likely to be affected when soil conductivity is below 0.15 dS/m (deci-siemens per metre), but the critical EC value varies depending on soil texture. For example, critical values can be higher in a soil with a heavy texture and therefore, at a given EC level the degree of plant reaction to salt stress is less in clay soils than in sandy soils.

Salinity problems are usually caused by salty irrigation water or saline ground water. Salt can also be a symptom of dryland salinity – a natural geological phenomenon. Plants vary in their reaction to salt stress, from 'sensitive' to 'tolerant' (see *Chapter 6 – Pasture species selection*).

Soil test reports

There are several important things to consider while reviewing your soil test results, including:

- date of sampling – nutrient levels can vary throughout the year, particularly P. If you want to monitor change from year to year it is important that paddocks are sampled at a similar time each year.
- depth of sampling is important when comparing past results; and
- soil texture.

Laboratory tests are important but they will not identify soil compaction, structural decline, erosion or subsoil problems. These degradation issues (discussed in *Chapter 5*) are much harder to fix than a nutrient deficiency, and recognising the problem early can make a big difference to pasture establishment. When collecting your soil samples it is important to also take note of the following issues that may better inform your species selection and management approach:

- condition of the soil surface
- depth of the topsoil
- soil structure
- penetration of plant roots.

Tissue testing

If you suspect your soil has a trace element issue or wish to identify nutritional disorders observed in growing plants, a plant tissue test can help diagnose deficiencies or toxicities. Soil testing is not a reliable method to test for trace element deficiencies e.g. Mo, Zn, Mn and Cu.

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5 Soil issues affecting pastures

Landscape, soil acidity, salinity, sodicity and nutrient decline all have major impacts on establishment, persistence and productivity of pastures. It is important to identify constraints well before sowing a pasture to inform management and investment decisions.

Landscape factors

Soil depth, texture and water holding capacity

Soil depth and soil texture (i.e. the relative proportion of sand, silt and clay) determine the amount of water a soil can store.

Root growth and the amount of soil water plants are able to access is limited in shallow soils that overlay sub-surface rock layers and impediments such as hard pans. Restricted rooting depth is likely to affect the persistence of deep-rooted species such as lucerne.

Soil texture also influences the amount of water that is stored and available for plant growth. For example, when wet, a clay-rich soil is able to store more water than a loam (i.e. it has a high water holding capacity), but plants are less able to extract water from them as they dry. On the other hand, sandy soils have relatively low water holding capacity, but the water retained is readily available to plants.

Within any soil, it is a combination of the soil texture and plant rooting depth that determines the amount of water available to plants.

Aspect

Soil temperature, moisture and exposure to direct sunlight are all influenced by aspect. Consequently, aspect can have a strong impact on pasture production. For example, in summer a western aspect will be hotter and drier than a southern aspect due to exposure to northerly or westerly winds and the hot, afternoon sun. The western aspect is likely to have a shorter growing season due to moisture stress and is, therefore, unsuitable for long-season species such as ryegrass and late maturing sub clovers.

In winter, a north-eastern aspect will have a warmer soil temperature and therefore, potentially higher production than an adjacent south-western aspect. Soil moisture is not usually the most limiting factor on any aspect during winter.

Aspect can have a large influence on pasture production.

Photo: N Phillips

Acid soils

Many soils of NSW are naturally acidic, with pH_{Ca} of less than 5.0, while others have become more acidic as a result of many years of agricultural production. Soil acidity has major impacts on pasture production.

Acidity is relatively easily corrected if it is limited to the top 10 cm of the profile or within cultivation depth. On the other hand, subsoil acidity is very difficult and expensive to correct.

Effects of acid soils on pasture production

A soil pH_{Ca} in the range of 5.0 to 7.5 provides optimal growing conditions for most agricultural plants. The growth of species that are sensitive to acidity, such as lucerne, will be affected once pH falls below 5.0.

Several factors, and often a combination of these, may affect plants growing in acid soils, including:

- Al and Mn toxicity will affect susceptible plant species; levels of available Al and Mn decrease as soil pH increases (see Figure 5.1);
- reduced availability of P, Mo, Ca and Mg;
- poor response to fertilisers;
- increasing competition from weeds such as *Vulpia* spp., sorrel (*Acetosella vulgaris*), dandelion (*Taraxacum officinale*), bent grass (*Agrostis capillaris*) and onion grass (*Romulea rosea*);
- low plant water use;
- thinning of sensitive sown species due to shallow or stunted root growth;
- reduced soil biological activity; and
- survival and persistence of rhizobia, and therefore the efficiency of nodulation and N fixation in legume species.

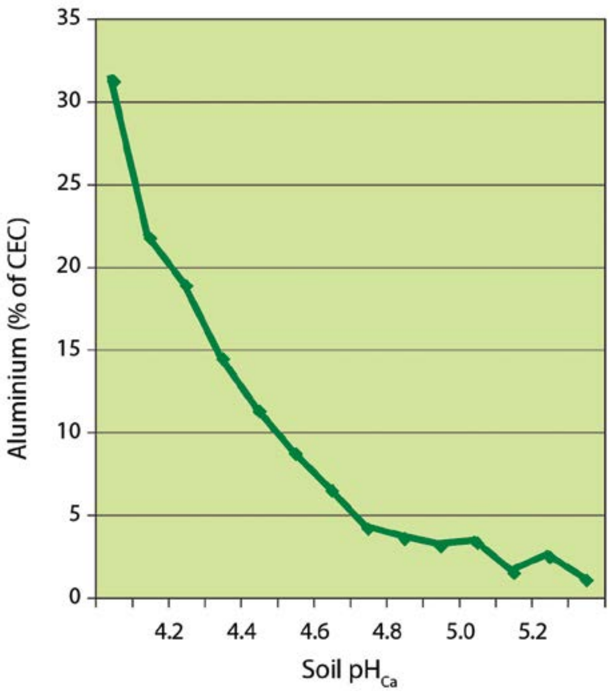

Figure 5.1 Soil test results from 700 Central Tablelands paddocks show that the level of available aluminium (% Aluminium) decreases as pH_{Ca} increases.

Causes of soil acidity

1. Leaching of nitrate nitrogen

Nitrate nitrogen is the main form of N taken up by a plant. It is very soluble and therefore easily leached. Soil pH will increase if nitrate nitrogen is leached out of the root zone before it is taken up by the plant, or before it is converted to ammonia (gas). The acid/alkali balance of the soil surrounding the roots remains in balance (and pH does not change) while the plants continue to take up all the nitrate nitrogen. Deep-rooted temperate perennial plants reduce the risk of leaching, which is most prevalent in autumn/early winter.

The N fixed by legumes is the main source of N in many perennial grass-based pastures, and will result in net acidification if the N is not used and is subsequently leached below the root zone.

2. Use of nitrogenous fertilisers

Acidity will only result from the use of nitrogenous fertilisers if the nitrate nitrogen produced from these fertilisers is leached before it is taken up by plants. The amount of acidification that results from using nitrogenous fertilisers depends on the fertiliser type, e.g. monoammonium phosphate (MAP) is significantly more acidifying than diammonium phosphate (DAP).

The use of superphosphate has an indirect effect on soil pH through stimulation of the growth of legumes.

3. Removal of produce

Grain and animal products are slightly alkaline and their long-term removal from a paddock can contribute significantly to the acidification of soils. Some production systems are highly acidifying because of the quantity and type of product removed. For example, 70 kg of lime would be required to neutralise the acidification effects of producing 1 tonne of lucerne hay, whereas the rate of acidification is much slower in a wool production system – i.e. 14 kg of lime for 1 tonne of wool produced (see Table 5.1).

Table 5.1 The amount of lime required to neutralise the acidification caused by removal of produce.

Produce	Lime requirement (kg/t of produce)
Milk	4
Wheat	9
Wool	14
Meat	17
Lupins	20
Grass hay	40
Clover hay	40
Lucerne hay	70

Source: Clements et al (2010), Industry and Investment NSW

4. Increase in soil organic matter

Although increasing organic matter has many benefits including improvement of soil structure; it can also increase soil acidity if the nitrogen in organic matter is mineralised and the nitrate nitrogen is then leached. Soil organic matter levels do not build up indefinitely and there is no further acidification once the organic matter stabilises at a new level.

The acidification caused by a build-up in organic matter can be reversed if the organic matter breaks down. However, if the topsoil containing the organic matter is eroded or removed, the net result will be acidification.

Reducing soil acidification

Soils acidify at different rates depending on soil type, climate and the amount of N and alkali lost due to leaching and/or product removal.

Strategies to reduce the rate of soil acidification:

- sow deep-rooted perennial species to utilise nitrogen before it is leached below the root zone;
- avoid using excessive rates of highly acidifying nitrogenous fertilisers, such as monoammonium phosphate (MAP) and sulfate of ammonia

- minimise soil disturbance to slow the breakdown of organic matter
- prevent erosion of the surface soil.

Managing soil acidity with liming products

Application of liming products, which contain carbonate, is the only way to raise the pH of acidic soils. Limestone and dolomite are the liming products most commonly used.

Limestone (calcium carbonate)

Lime moves very slowly through the soil. Therefore, the most effective and rapid pH response occurs if superfine grade lime is evenly spread and incorporated to the depth of the acidity problem (or as deep as is practical).

If lime is topdressed the response time is considerably longer, depending on soil type and rainfall. For example, lime applied to the surface of sandy soils in areas with an average annual rainfall of more than 600 mm may move to 10 cm in 2 to 3 years. However, lime movement will be slower as the clay content of the soil increases and rainfall decreases.

Surface applied lime moves slowly down the soil profile.

Photo: N Ferguson

The amount of lime required to raise soil pH will depend on the targeted soil pH, lime quality (fineness and neutralising value) and the cation exchange capacity (CEC) of the soil. Consult with your agronomist to determine a suitable rate for your paddocks.

In some situations the subsoil may also be acidic to depth, in which case responses to liming may be limited. If the aim is to increase subsoil pH, it is necessary to maintain the topsoil pH_{Ca} at 5.5. The 'lime effect' will then move slowly down the profile. Results from the NSW DPI long-term agronomic experiment on the South West Slopes of NSW (MASTER) showed that subsurface pH at 15–20 cm depth could increase by one unit over 20 years by maintaining pH_{Ca} in the top 10 cm at around 5.5.

Before undertaking a liming program it is a good idea to question the sensitivity and likely response of your preferred pasture species, both native and introduced, to a pH increase.

The economics and practicalities of a liming program need to be carefully considered on a case by case basis. Liming may not be a realistic option in hilly, steep, rocky landscapes. In these situations, management should aim to maintain and encourage the existing perennial species to reduce or slow the rate of acidification.

Dolomite (calcium/magnesium carbonate)

Dolomite (also known as maglime) is a naturally occurring rock containing calcium carbonate and magnesium carbonate. It is a useful liming material for acid soils where supplies of magnesium are low, but tends to be more expensive and coarser than lime. In most circumstances, fine agricultural lime will be the most cost-effective option.

Other liming products

From time to time various other liming products are available locally. Information on their liming quality, fineness and neutralising value should be obtained before deciding to use them.

Neutralising Value

Neutralising value is a measure of the reactivity of liming material and its relative ability to counteract soil acidity, which also depends on with the fineness of the product. Pure calcium carbonate (limestone), which has a neutralising value of 100, is used as the standard (Table 5.2).

Table 5.2 Neutralising value of some common liming materials.

Liming material	Neutralising value
Calcium carbonate	100
Dolomitic limestone	95–108
Agricultural lime	85–100
Burnt lime	150–175
Hydrated lime	120–135
Gypsum	nil
Basic slag	50–70

Source: Australian Soil Fertility Manual (2006)

Fineness

Fine grade liming materials are recommended because they provide superior distribution and react quickly. Fine grade lime products are therefore more efficient in neutralising acidity in the soil than coarse material. Most agricultural lime sourced from NSW crushers is fine grade lime with a particle size of less than 250 µm, i.e. at least 90% of the product will pass through a 250 µm sieve.

Information on neutralising value and particle size should be available for all liming products. This allows a comparison of the value of different liming materials by checking NV and fineness against spread cost as demonstrated in the example below:

Efficiency = (fineness × NV) ÷ 100

Comparative cost = (spread cost × 100) ÷ efficiency

Example	Lime A	Lime B
Fineness	50	100
NV	95	99
Cost, spread	$55/tonne	$70/tonne
Efficiency	(50 × 95) ÷ 100 = 47.50	(100 × 99) ÷ 100 = 99
Comparative cost	($55 × 100) ÷ 47.50 = $115.79/tonne	($70 × 100) ÷ 99 = $70.71/tonne

Although the fine grade Lime B is more expensive on a per tonne basis than coarser Lime A, it is comparatively cheaper because it is more effective in neutralising acidity and will therefore provide a more rapid return on investment.

Soil salinity

Salinity has always been part of the Australian landscape. However, an increase in the incidence of saline areas has been attributed to the advent of agriculture, mainly as a result of land clearing and the removal of perennial vegetation.

Dryland salinity develops where upper slope (recharge) areas are cleared, resulting in increased soil water discharges on the lower slopes and concentration of salts at the soil surface. Soil acidity can contribute to soil salinity problems through inefficient water use by plants, which results in greater 'leakage' of soil water to groundwater.

Effects of soil salinity

Salinity has a major impact on the overall condition of a catchment through reduced water quality and damage to infrastructure such as roads and buildings. Visual signs of soil salinity include:

- leaves of affected plants look darker than normal and often appear wilted;
- leaf margins are scorched;
- susceptible plants die – death of well established trees is an early symptom;
- pasture composition changes with the loss of clovers and invasion of water tolerant species such as rushes and then salt tolerant species such as sea barley grass (*Hordeum marinum*), couch grass (*Cynodon dactylon*), annual beard grass (*Polypogon monspeliensis*) and cumbungi (*Typha domingensis*);
- water in dams may change from muddy to clear with white salt crystals appearing above the water line; and
- areas of bare ground develop and when these dry they are covered with salt crystals. Animals tend to concentrate on these areas to lick the salt.

Indicators of soil salinity include the presence of salt tolerant species such as sea barley grass and couch and areas of white salt crystals on the soil surface.

Photo: H Warren

Reducing the impact of salinity

Salinity is best managed by first identifying the possible causes and then addressing the problem on a whole farm or catchment basis. Deep-rooted perennial pastures (e.g. lucerne and phalaris) and trees should be planted on the recharge areas to minimise deep drainage and prevent salinity problems developing in the lower slope areas.

Saline areas should be fenced to control grazing stock and encourage re-vegetation. Moderately saline discharge areas can be sown to salt-tolerant species to encourage ground cover and increase productivity, e.g. tall wheat grass (*Thinopyrum ponticum*), puccinellia (*Puccinellia ciliata*), balansa, strawberry and gland clovers (*Trifolium michelianum*, *T. fragiferum* and *T. glanduliferum*) and old man saltbush (*Atriplex nummularia*). See *Chapter 6 – Pasture species selection* for more information on species tolerance to salinity.

Sodic soils and poor soil structure

Soils with high levels of exchangeable sodium (Na>6% of the CEC) are known as sodic soils. Excessive Na has the effect of dispersing clay particles, resulting in undesirable physical properties, including poor aggregate stability.

Characteristics of sodic soils

Sodic soils lack structure and set hard when dry. They are:

- structurally unstable and 'collapse' when wet;
- highly erodible, particularly when disturbed (soils with exposed sodic subsoils are prone to gully erosion);
- prone to waterlogging and have poor internal drainage;
- lacking in pores, and so there is poor air movement and few cracks for roots to penetrate;
- not trafficable when wet;
- prone to compaction and pugging (trampling of the soil's surface by sheep and cattle hooves) when wet; and
- liable to form a surface crust, which reduces water infiltration and can affect seedling emergence.

Note: *Sodicity should not be confused with salinity. Sodic soils have excessive amounts of sodium attached to the clay, whereas saline soils have excessive amounts of salt (sodium chloride) dissolved in the soil water.*

Exposed sodic subsoils are highly erodible.

Photo: B Stein

Reducing the impact of sodic soils

Gypsum (calcium sulfate) and lime (calcium carbonate)

Gypsum is the product most commonly used for ameliorating sodic soils and is often promoted as a 'clay breaker'. Gypsum only improves the structure of soils that are high in sodium by replacing the excess sodium with calcium, and may need to be re-applied within 2 to 3 years. It will not improve the structure of soils that are not sodic (Na<6%) or soils with low clay content.

In cases where soils are both sodic and acidic, and when lime is relatively cheap compared with gypsum, lime is a better choice of product. Lime contains twice as much calcium as gypsum and will improve the structure of sodic soil while also increasing pH.

Once the gypsum or lime has improved the physical condition of the soil, the best way to maintain the improved soil structure is to adopt management practices such as minimal soil disturbance and establishment of vigorous pastures to increase organic matter levels and thereby improve the structural stability of the soil.

Soil nutrient decline

Soils fertility varies with soil type (the inherent soil fertility), fertiliser history and product removal.

A sustainable production system requires that nutrients exported in agricultural products are replaced. Failure to replace nutrients is really a form of mining. For nutrients such as iron, there may be hundreds of years of supply in a typical soil. However, for some important nutrients, such as N, K and S, soil reserves can be quickly exhausted within a few years.

The amount of nutrient removed in agricultural products is shown in Table 5.3.

Table 5.3 Quantity of nutrient – nitrogen (N), phosphorous (P), potassium (K), sulfur (S) – removed per tonne of product.

Product	Kilograms of nutrients removed per tonne of product			
	N	P	K	S
Beef or lamb	22	7.0	2.0	2.0
Greasy wool	135	0.3	17	28
Pasture hay	25	2.5	17	2.5
Cereal grain	20	3.0	4.0	2.0

Source: Clements et al (2010), Industry and Investment NSW

Symptoms of soil nutrient decline

Nitrogen deficiency

- Reduced pasture growth
- Yellowing and premature death of older leaves; N is concentrated in the younger, darker growth.

Phosphorus deficiency

- Poor root development, stunted growth, spindly stems, delayed maturity
- Purplish colouration on older leaves
- Poor seed production
- Legume growth is poor, leaves are very dark green
- Legume content will decline

Sulfur deficiency

- Yellowing of leaves, but unlike N deficiency, the new growth is not darker green.

Potassium deficiency

- Pale spots on the leaves of legumes
- Yield reductions, especially in paddocks with a history of hay or silage production
- Poor seed production (especially in legumes).

Molybdenum deficiency

- Symptoms similar to N deficiency
- Poor or ineffective nodulation in legumes, as indicated by a white (not pink) colour inside the nodules.

Soil erosion

Soil erosion is a very important sustainability issue. There are three main types: stream bank/gully erosion, sheet/rill erosion and wind erosion.

Stream bank and gully erosion are often quite spectacular but tend to be site specific. They occur where large volumes of surface run-off are concentrated. Management options need to target reducing or diverting the surface run-off. Particular care should be taken not to disturb soils in flow lines, especially those with dispersive (sodic) subsoils.

Sheet erosion and erosion caused by wind is less visible but removes valuable topsoil, which can have a major impact on soil fertility.

It can take up to 100 years to form 1 mm of soil, which is equivalent to 0.14 t/ha/year. Losses from erosion can range from 0.24 t/ha/year under pasture with more than 70% ground cover, to more than 60 t/ha/year from bare fallows.

Erosion also has major off-site effects on air and water quality (turbidity and nutrient loads). Reduce soil erosion by maintaining ground cover at a minimum of 70% and minimise soil disturbance by adopting minimum tillage practices.

Well managed perennial pastures have a role in managing gully erosion.

Photo: L Ayres

Acid sulfate soils

Acid sulfate soils are typically only found in landscapes less than 5 m above sea level. These soils contain naturally high levels of iron sulfide. When disturbed and drained, the sulfide oxidises to form sulfuric acid, which then acidifies surface and groundwater.

Effects of acid sulfate soils

- Severely limit plant growth due to toxic levels of iron and aluminium in the soil
- Cause acidic run-off into waterways
- Corrode concrete, iron, steel and some alloy structures.

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6 Pasture species selection

The species and varieties selected can affect pasture persistence and production. Establishment costs may take many years to recoup, so it is important to select species and varieties that persist. The cost of seed alone is a poor basis for selecting a species or variety. Consideration should be given to climate, soil type, landscape, enterprise type and desirable plant traits.

Climatic considerations

Rainfall

Select pasture species and varieties with growth patterns that match your regional rainfall. Total rainfall and seasonal incidence (uniform, summer- or winter-dominant rainfall patterns) dictate the growth and production potential of a given species. Other factors such as soil depth and water holding capacity, aspect, steepness of land and ground cover should also be considered as these will influence effective rainfall, i.e. how much of the total rainfall is available for pasture growth and how much is lost via evaporation or as run-off.

Drought tolerance

Annual species with shallow root systems are less likely to survive severe droughts compared with annuals or perennials, which have more developed root system. Plant dormancy is an important characteristic that enables plants to survive through prolonged dry periods (dormancy is discussed later in this chapter). Soil fertility status and grazing management can also influence the survival of a species during drought periods.

Temperature and frost tolerance

Temperate pasture species are adapted to a wide temperature range but favour temperatures between 12°C and 30°C. Growth rates increase as temperatures increase, provided there is adequate moisture. Although many temperate species are tolerant of frost and will remain green over the winter months, their growth rate is minimal once temperature drops below 8°C.

Temperate grasses produce higher quality feed compared with tropical grasses – at the same growth stage.

Tropical pasture species are most productive during warmer months. Their distribution and productivity in NSW is limited by low temperatures, frost and low effective rainfall during summer. Tropical pastures are best suited to all the coastal districts and the northern and central inland areas of the lower slopes and plains of NSW. Establishment opportunities outside these regions are limited by spring and summer rainfall, soil temperature and the length of the frost-free period.

Note: *All pasture growth is restricted below 8°C.*

For further information on growing tropical species, refer to the booklet "*Tropical Perennial Grasses for Northern Inland NSW*".

Altitude

Altitude has a marked effect on pasture growth. In general, as altitude increases, temperatures are lower and rainfall higher. However, severe winters (including snowfalls) in high altitude areas limit pasture growth.

Soil and landscape factors

Soil pH and acidity

Soil acidity is a widespread issue that affects the growth and persistence of many pasture species. Species vary in their tolerance to soil pH and levels of available Al and these should be a major consideration when selecting species. Acid sensitive species such as lucerne and phalaris (seedling stage) grow poorly or fail to persist if sown on soils with low pH and high levels of Al. Liming is effective in ameliorating acidity in the topsoil (0–10 cm), but acid tolerant species such as cocksfoot should be used where soils are acid at depth.

Every effort should be made to preserve acid tolerant native species such as weeping grass (*Microlaena stipoides*), wallaby grass (*Austrodanthonia* spp.) and spear grass (*Austrostipa* spp.) on soils which have acidity problems at depth (Table 6.1).

Table 6.1 A guide to the aluminium sensitivity of some pastures and suggested exchangeable aluminium (ECEC Al. ex %) upper limits. Potential dry matter production will be reduced by at least 10% above these levels.

Sensitivity	Exchangeable aluminium	Species affected
Highly sensitive	1–5%	Barrel, strand and burr medics; lucerne; strawberry, berseem and persian clovers; tall wheat grass
Sensitive	5–10%	Murex and snail medics, red clover, phalaris seedlings, Madeira yellow serradella
Moderately sensitive	10–15%	Sub clover, white clover, balansa clover, ryegrass, tall fescue, phalaris (established)
Tolerant	15–20%	Some species of yellow and french serradella, biserrula, Maku lotus, cocksfoot, weeping grass (*Microlaeana stipoides*), wallaby grass (*Austrodanthonia* spp.), kangaroo grass (*Themeda australis*)
Highly tolerant	20–30%	Some species of yellow and French serradella, spear grass (*Austrostipa* spp.), wire grass (*Aristida* spp.)

Waterlogging and salinity

Species differ in their tolerance to waterlogging and salinity. Deep-rooted species such as lucerne require relatively deep, free-draining soils, while other species, such as tall fescue, are tolerant of extended periods of waterlogged conditions. Table 6.2 shows the tolerance of commonly grown pasture species to waterlogging and salinity.

Species tolerant to waterlogging and /or salinity should be selected for paddocks that are poorly drained. For example *yaninnicum* sub clovers, such as the variety Riverina, are well suited to soils prone to waterlogging, while strawberry clover and tall fescue are recommended if salinity is also an issue.

Table 6.2 Tolerance of common pasture species to salinity. ECe level where yield reduced by 10%.

Salinity	ECe (dS/m)	Species
Slightly saline	2–4	Most clovers, vetch, lucerne
Moderately saline	4–8	Phalaris, tall fescue, perennial ryegrass, balansa clover, strawberry clover
Severely saline	8+	Tall wheat grass, Puccinellia

Plant characteristics

Matching plant characteristics to environmental conditions and production targets will ensure that the species and varieties sown are adapted and meet production and persistence objectives. The key features of the major temperate pasture species are summarised in Tables 6.3 to 6.6 – Table 6.3: *The key features of the major temperate grass pasture species*; Table 6.4: *The key features of the major temperate annual legumes*; Table 6.5: *The key features of temperate pasture herbs*; Table 6.6: *The key features of the major temperate perennial legumes.*

Plant maturity and flowering time

The time of year when a cultivar switches from vegetative to reproductive growth is critical in determining the pattern of pasture production and quality during its growing season. Production from annual plants depends on timing of the autumn break, and their maturity. Time to reach maturity can vary between species and also between varieties of a particular species, e.g. sub clover.

In a region with a long growing season, late maturing cultivars can grow through spring, produce high total dry matter yields and still successfully flower and set seed. An early maturing variety is better suited to regions with a short growing season, including low rainfall areas or those with very shallow soils or exposed ridges. They have potential to flower and set seed before moisture becomes limiting.

Plant maturity is an important trait of sub clover varieties. Very early maturing varieties may flower in July, while late maturing varieties may not start flowering until September or early October. Where spring rainfall is erratic, or where landscape factors affect growing season length it is advisable to mix an early maturing clover variety with a later maturing one.

Perenniality

Perennials are plants that live for more than two years. Some perennial species may live for decades under appropriate management. Biennials are plants that take up to two growing seasons to complete their life cycle. Annuals are plants that complete their life cycle in less than 12 months (one growing season) and are therefore dependent on setting seed in order to regenerate in the following year.

Perennials are an important component of pastures as they ensure pasture stability and longevity. Their root systems are large compared with those of annuals.

Seedling vigour

Seedling vigour is a characteristic which contributes to the 'Establishment ease' rating given to pasture and herb species in Tables 6.3 to 6.6. It can be associated with seed size, but there are exceptions, e.g. phalaris is considered as the perennial grass species with the least vigorous seedlings, although its seed is twice the size of cocksfoot seed (Table 13.1).

Fertility status and soil moisture availability during growth and seed development can influence the size of seed produced.

Plant growth habit

Plants with a prostrate growth habit tend to be more competitive with weeds, and once established, more tolerant of heavy grazing and more persistent then erect types. However, these plants can be less productive in winter compared with erect types. Erect species require careful grazing management if persistence is a priority.

Some plants have the capacity to spread vegetatively with rhizomes or stolons e.g. white clover. Species with tap roots, such as chicory or lucerne, may require deeper soils compared with those with fibrous root systems, e.g. cocksfoot or tall fescue.

Hard seed levels

Hard seed protects a species or variety against depletion of the seed bank when summer storms and false autumn breaks cause a succession of early germinations. Hard seed also provides a bank of seed capable of germinating over one or more seasons when seed set has failed.

Many legume species are described as having a certain level of hard seed (Tables 6.4 and 6.6). Hard seeds are impermeable to water and will not germinate until the seed coat breaks down and becomes permeable. The level of hard seed produced can vary from season to season, with a higher proportion formed if soil moisture levels are marginal when the plants are producing and setting seed.

Ploidy

Ploidy is a term used to describe both tetraploid and diploid ryegrasses. Tetraploid types have double the number of chromosomes as diploid types. Tetraploid varieties tend to be higher in quality than diploid varieties, e.g. more leaf and higher sugar levels.

Dormancy and seasonal production

Many pasture species exhibit a dormancy mechanism that enables them to survive during periods of extreme conditions, e.g. winter dormancy to avoid severe cold, and summer dormancy to survive periods of heat and drought stress. Different terminology is used to describe dormancy within a given species, e.g. dormancy is used to describe the relative seasonal production of varieties of lucerne.

Lucerne

Lucerne varieties have growth patterns ranging from winter dormant to highly winter active, although all varieties become dormant under moisture or severe heat stress. Dry matter production of all varieties peak between late spring to early autumn, when moisture is available. In Australia, dormancy of lucerne varieties is rated on a scale of 1 to 10 (1 = winter dormant, 10 = highly winter active).

- **Winter dormant (1–4 rating).** This group is able to withstand very low temperatures for long periods. These varieties have a distinct dormancy period, which is triggered by day length.
- **Semi-dormant (5 rating).** These varieties grow significantly slower in winter than in summer. Growth may stop for a short period or it can be restricted (depending on the climate). Autumn and spring growth will be quicker than that of winter dormant varieties.
  Winter dormant and semi-dormant types tend to have better persistence under grazing than winter active types.
- **Winter active (6–7 rating).** Growth of these varieties will slow in winter but they will not become totally dormant. Their recovery after cutting or grazing is faster than the dormant varieties. Growth is not affected by day length, provided temperatures are suitable. Winter active varieties tend to have fewer tillers and bigger leaves compared with winter dormant varieties. They also have narrower and higher crowns, which mean that these varieties are more susceptible to overgrazing.
- **Highly winter active (8–10 rating).** Highly winter active varieties are generally more productive than semi-dormant and dormant varieties during the first three years. Their seedling vigour, growth and

recovery after grazing and hay cutting is superior to less active varieties. They lose quality more quickly as they reach maturity and they are less resilient under heavy grazing.

Perennial grasses – fescue, cocksfoot and phalaris

A key trait to consider when selecting a perennial grass is the degree of summer or winter dormancy. For cocksfoot and phalaris, the degree of summer dormancy is used to separate varieties into three categories:

- **Winter active or Mediterranean types.** Dormancy of winter active plants is triggered by rising temperatures and declining soil moisture towards the end of spring. Varieties in this category will not respond to summer rainfall and will only become active once temperatures decline, towards the end of summer. These types e.g. 'Atlas PG' phalaris and 'Kasbah' cocksfoot, are well adapted to areas typified by low and unreliable summer rainfall, and prolonged dry periods. They are sometimes described as highly summer dormant.
- **Intermediate dormancy.** Plants with an intermediate dormancy rating will 'shut down' once soil moisture is limiting, but will begin active growth in summer if significant rain falls. These varieties need reliable climatic conditions for persistence, and are suited to areas that do not have periods of intense summer moisture stress and where there is a low incidence and intensity of drought. This group includes most varieties of phalaris, and cocksfoot varieties such as 'Currie' and 'Porto'.
- **Summer active or temperate types.** These varieties have no summer dormancy and will attempt to grow regardless of moisture or temperature conditions. They are unlikely to persist when moisture remains low for an extended period of time. These varieties are suitable for areas with high overall rainfall with a slight summer dominance. They will not tolerate drought.

Note: *Dormancy ratings are 'continuous', which means that some varieties described as 'summer dormant' can still respond to summer rain, whereas others in the same category remain absolutely dormant regardless of rainfall.*

Pest and disease tolerance

Reaction to pests and diseases is an important consideration when selecting a variety. For example, in coastal or humid regions, in irrigation districts or in waterlogged areas, diseases such as rusts, root rots and anthracnose can proliferate and therefore, resistance is a desirable trait.

Tolerance to pests such as scarabs, redlegged earth mites, aphids, and lucerne flea should also be a consideration when selecting a variety.

End uses – hay/silage or grazing

Consideration should be given to the end use of the pasture. Some species have been specifically bred for hay/silage production, e.g. some Persian clover varieties, and lucerne varieties with a high winter activity rating. Other pasture species are described as 'dual purpose' and were bred for both grazing and silage/hay production.

Livestock enterprise

Some plant species and varieties within species are more suited to cattle than sheep or vice versa, due to characteristics such as leaf size, tolerance to grazing, crown height and animal/plant interactions. Consider when peak feed demand occurs for the livestock enterprise, such as lambing, calving, and joining.

Pastures for horses need to be based on perennial species, e.g. phalaris, although it is difficult to maintain a working horse without supplementary feeding. Goats and alpacas require high roughage and lower moisture content pastures than do sheep. They tend to 'do' poorly on clover dominant pastures.

Supplementary feeding may be required across all livestock enterprises when feed requirements are not met by pastures.

Enterprise type is an important consideration when selecting pasture species and varieties.

Photo: NSW DPI

Compatibility with herbicides

It is important to consider the herbicide compatibilities of species to be included in the sowing mix. If mixtures are complex and include many different species, it can be difficult to control some weeds without compromising the survival of some of the sown species. In addition, if a paddock has a known weed history it can be advisable to avoid sowing some species. For example, if a paddock has a history of thistles it would be wise not to include chicory or plantain in a mixture for that paddock as they would be killed or damaged by the herbicides used to control thistles.

Table 6.3 Key features of the major temperate pasture grass species.

Species	Sub group	Persistence	Establishment ease	Waterlogging tolerance	Drought tolerance	Fertility needs	Salinity tolerance	Soil acidity tolerance	Minimum rainfall
Introduced grasses									
Cocksfoot	Summer dormant	*****	****	*	*****	**	***	*****	400
	Intermediate	*****	****	*	***	**	***	*****	600
	Summer active	*****	****	*	*	**	***	*****	700
Phalaris	Summer dormant	*****	**	***	*****	****	***	** sensitive in seedling stage	400
	Low summer dormancy	*****	**	***	****	****	***	** sensitive in seedling stage	500
Ryegrass (perennial)		***	*****	**	*	*****	***	****	700
Tall fescue	Summer active	**	***	****	**	****	***	***	650
	Winter active	**	***	****	**	****	***	***	550
Brome grass		***	*****	*	*	****	*	****	600
Puccinellia		****	**	*****	*	**	*****	*	400
Tall wheat grass		****	**	****	*	**	****	**	400
Timothy grass		*	***	*	*	*****	*	*	800
Native grasses									
Wallaby grass (*Austrodanthonia* spp.)		*****	*	*	*****	**	*	*****	400
Weeping grass (*Microlaena* sp.)		*****	*	*	*****	***	*	*****	500
Common wheat grass (*Elymus scaber*)		***	*	*	***	***	*	***	400

*Note: * = very low; *** = moderate; ***** very high*

Note: The 'Persistence' and 'Establishment ease' ratings assume that the species/varieties sown are selected on the basis of prevailing environmental conditions, soil type and landscape.

Table 6.4 Key features of the major temperate annual pasture legumes.

Species	Hard seed level	Establishment ease	Waterlogging tolerance	Fertility needs	Salinity tolerance	Soil acidity tolerance	Minimum rainfall
Annuals							
Arrowleaf clover	****	*****	**	****	*	****	400
Balansa clover	***	*****	*****	****	*	****	350
Berseem clover	*	*****	***	*****	**	**	600
Biserrula	*****	*****	*	***	*	*****	350
Bladder clover	*****	*****	**	****	*	****	350
Crimson clover	*	*****	*	***	*	****	450
Eastern star clover	****	*****	*	***	*	****	350
Gland clover	****	*****	****	***	*	****	375
Persian clover var. *resupinatum*	**	*****	****	*****	**	**	450
Persian clover var. *majus*	*	*****	****	*****	**	*	450
Purple clover	***	*****	****	*****	*	***	550
Rose clover	**	*****	*	****	*	**	400
Serradella[1] (pink/French)	****	*****	**	****	*	****	350
Serradella[1] (yellow)	****	*****	**	***	*	*****	350
Sub clover (*ssp. subterraneum*)	**	*****	**	****	*	****	400
Sub clover (*ssp. yanninicum*)	**	*****	****	****	*	****	400
Sub clover (*ssp. brachycalycinum*)	**	*****	**	****	*	***	400
Barrel medic	****	*****	**	****	*	*	275
Burr medic	****	*****	***	****	**	*	350
Disc medic	****	*****	**	****	*	*	350
Murex medic	***	*****	**	****	*	***	500
Snail medic	****	*****	**	****	*	*	400
Sphere medic	***	*****	**	****	*	**	350
Strand medic	****	*****	**	****	*	*	275

** = very low; *** = moderate; ***** very high*

[1] *Significant differences in hard seed levels exist between varieties.*

Note: The 'Establishment ease' rating assumes that the species/varieties sown are selected on the basis of prevailing environmental conditions, soil type and landscape.

Table 6.5 Key features of the major temperate pasture herb species.

Species	Persistence	Establishment ease	Waterlogging tolerance	Drought tolerance	Fertility needs	Salinity tolerance	Soil acidity tolerance	Minimum rainfall
Herbs								
Chicory	**	****	*	**	****	*	***	600
Plantain	**	****	*	**	****	*	***	600

*Note: * = very low; *** = moderate; ***** very high*

Note: The 'Persistence' and 'Establishment ease' ratings assume that the species/varieties sown are selected on the basis of prevailing environmental conditions, soil type and landscape

Table 6.6 Key features of the major temperate perennial pasture legumes.

Species	Hard seed level	Establishment ease	Waterlogging tolerance	Fertility needs	Salinity tolerance	Soil acidity tolerance	Minimum rainfall
Annuals							
Lotus	**	****	*	****	***	****	700
Lucerne	–	***	*	*****	*	*	375
Red clover	*	****	**	*****	*	**	700
Strawberry clover	–	***	****	****	***	*	600
Sulla	***	****	*	*****	*	*	400
Talish clover	***	*****	***	****	*	****	500
White clover	*	*****	***	*****	*	***	700

*Note: * = very low; *** = moderate; ***** very high*

Note: The 'Establishment ease' ratings assume that the species/varieties sown are selected on the basis of prevailing environmental conditions, soil type and landscape

References and further reading

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7 Weed control prior to sowing

A weed-free seedbed is **essential** to ensure the success of a new pasture. A variety of strategies can be used to control weed populations. For best results, planning should begin two years prior to sowing.

Weed identification the first step

Identify the weeds present and understand their life cycle in order to choose the best management options. This should begin at least two years prior to establishing new pasture.

Annual grasses such as barley grass (*Hordeum leporinum*), vulpia (*Vulpia* spp.), ryegrass (*Lolium rigidum*) and brome grasses (*Bromus* spp.) are particularly difficult to manage due to their prolific seeding and staggered germinations. There are no herbicides available to control these weeds in seedling grass pastures so they must be targeted to prevent seed set and avoid a build-up of the weed seed bank.

A control program commencing two years prior to the new pasture being established is also recommended for heavy infestations of hardy **perennial grass** weeds such as couch grass (*Cynodon dactylon*), bent grass (*Agrostis capillaris*) and serrated tussock (*Nassella trichotoma*).

Weed species that produce hard seeds, such as thistles and sorrel (*Acetosella vulgaris*) may need a longer term strategy as the seeds can remain viable in the soil for more than five years. Even the hard seed of desirable species such as clover can be an issue if seed numbers are high and they compete with less vigorous grass or lucerne seedlings.

Weed control prior to sowing

Two years prior to sowing

A weed control program starting two years prior to sowing will run down weed seed banks and reduce weed populations in the establishing pasture. There are a number of chemical and non-chemical techniques that can be used.

Caution: *If herbicides are to be included in your weed management program:*

- *Boom sprays should be calibrated regularly to ensure accuracy of pesticide applications – see Appendix 3.*
- *Check herbicide labels for plant back periods for pasture species if residual herbicides are used.*
- *Check herbicide labels for stock withholding periods.*

1. Spray topping or pasture topping

Spray topping or pasture topping is an effective, low-cost technique that involves the application of a low rate of a non-selective herbicide (either paraquat or glyphosate) after head emergence to sterilise the seed. It is used to reduce the seed set of a number of annual grass weeds (barley grass, vulpia species, annual ryegrass and brome grass) and some broadleaf weeds, such as capeweed (*Arctotheca calendula*), saffron thistle (*Carthamus lanatus*). There will be limited effect on the quality and quantity of available feed.

The success of the technique relies on correct timing of the herbicide application (see below for details). Evenness of head emergence is essential for effective topping. This can be achieved through heavy grazing or slashing during winter and spring. Stock should be removed 2 to 3 weeks prior to the targeted growth stage of the dominant weed species.

Capeweed and Paterson's curse are common broadleaf weeds of temperate pastures.

Photo: A Johnson

Herbicides used for spray topping

The herbicide is applied at a low (sub-lethal) rate, so in order to prevent development of viable seeds, it is critical that the time of application to coincides with the vulnerable stage of the weed. There should be a 2 to 3 week spray window. Read herbicide labels!

1. Glyphosate (e.g. Roundup®) must be applied at flowering for capeweed and annual ryegrass and from early head emergence (50% heads emerged) to milky dough stage of seed development for other grasses, in order to sterilise seed. Spraying too early may result in regrowth, and too late will reduce the effectiveness of control as many viable seeds will still be formed.

2. Paraquat (e.g. Gramoxone®) is a more appropriate choice of herbicide if the target weed has developed beyond the flowering stage. However, timing is critical – it must be applied when all heads have emerged and there are initial signs of haying-off. This narrow spray window means that paraquat is not ideal in situations where several weed species are being targeted or in paddocks where landscape variability results in uneven maturity.

Annual grass weeds

Barley grass and brome grass

- Glyphosate is a good option for barley grass as the species often produces seed heads over an extended period of time. It should be applied after the seed heads have emerged, but prior to dough stage in the grain.
- Paraquat should be applied after flowering.

Control of annual grass weeds such as barley grass and brome grass should begin up to two years before the pasture is sown to avoid competition with sown species.

Photo: B Stein

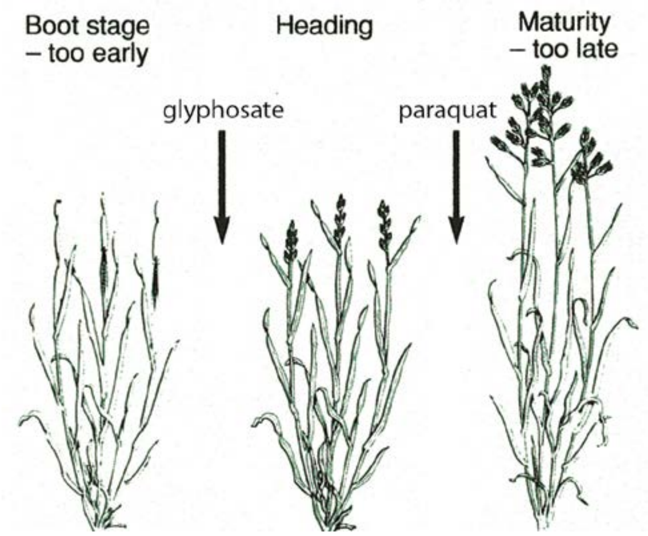
Vulpia species

Timing is particularly critical for paddocks with vulpia infestations as plants progress very quickly from flowering to seeding once they are moisture stressed.

- Apply glyphosate at the early head emergence stage.
- Paraquat should be applied just prior to haying-off.

Annual ryegrass

- Glyphosate needs to be applied during flowering and when all tillers are in head.
- Paraquat should be applied when seed in most heads is in the dough stage.



Annual grass growth stages for spray topping.

2. The "spraygraze" technique for broadleaf weeds

Spraygraze is an option for management of a range of broadleaf weeds in established pastures. It can be very effective against weeds such as: thistles, shepherd's purse (*Capsella bursa-pastoris*), Paterson's curse (*Echium plantagineum*), charlock (*Sinapis arvensis*), mustards (*Sisymbrium* spp.), wild radish (*Raphanus raphanistrum*), dock (*Rumex* spp.), sorrel (*Acetosella vulgaris*) and capeweed (*Arctotheca calendula*).

The technique involves the use of sub-lethal rates of herbicide such as MCPA or 2,4-D amine, in combination with tactical grazing. The target weeds should be sprayed no more than 6 to 8 weeks after germination, when they are still in the rosette stage and actively growing. Any clovers present need to have at least 4 trifoliate leaves to tolerate the herbicide. Spraying smaller, less developed clovers will severely affect their capacity to recover.

Once the stock withholding period (7 to 10 days) of the herbicide has passed, the paddock should be stocked with at least 5 times the normal stocking rate for a short period, using older or non-breeding stock. Sheep are more effective than cattle with this technique.

The herbicides cause the broadleaf weeds to wilt. Plant sugars levels rise and the target weeds become more palatable and attractive to stock. The herbicide also promotes more erect growth, making the weeds' growing points more accessible to grazing and damage by stock.

This technique relies on the combination of sub-lethal application of herbicide, high grazing pressure and subsequent pasture competition to kill the target weeds. Weeds are likely to recover if the paddock is not heavily stocked. The technique works best on smaller paddocks, i.e. less than 20 ha.

Caution:

- *Check herbicide labels and seek advice from an agronomist before using the spraygraze technique on lucerne and medic based pastures. MCPA herbicides may damage lucerne and medics plants.*
- *Improved palatability and greater intake of some broadleaf weeds may cause livestock health issues when animals graze potentially poisonous plants such as Paterson's curse, variegated thistle (Silybum marianum) and caltrop (Tribulus terrestris).*

3. Winter cleaning for vulpia control

Winter cleaning can be used to selectively remove *Vulpia* spp. (silver grass) in the winter two years prior to sowing. Best results are achieved when pastures are grazed short and are free of dry residue from the previous spring. Simazine is the main herbicide used for vulpia control, with application rates varying depending on weed density, soil type and plant development. Application should occur when the clover has at least 3 trifoliate leaves, 6 to 10 weeks after germination. Simazine can be mixed with other grass or broadleaf herbicides to control a wide range of weeds.

This technique is not recommended if winter feed is likely to be limited as there may be a short-term effect on the growth of some legumes and desirable grasses.

4. Slashing

Slashing paddocks in the spring up to two years prior to sowing begins the process of reducing dry matter and reducing weed seed set. This technique can be used in paddocks that contain weeds that are of low feed value and not worth conserving for fodder. Slashing can reduce the amount of weed seed set, but regrowth must be managed in order to significantly reduce the number of seeds that will add to the soil seed bank. Heavy grazing, a follow-up herbicide or additional slashing may be required in this situation.

5. Fodder conservation

Strategic cutting of paddocks for silage or hay production can very effectively reduce weed seed set, particularly when used in combination with grazing or a follow-up herbicide treatment to manage weed regrowth and late seed set.

6. Forage and fodder crops

Growing forage and fodder crops such as forage brassica, forage sorghum or winter cereals in paddocks before sowing pasture can very successfully reduce weed competition in newly sown pastures. Vigorous, dense crops compete with annual weeds and help to reduce the weed seed bank. Refer to the appropriate NSW Department of Primary Industries publications for management guidelines for the desired crop.

Weed control in the year before sowing

Aim for **complete** weed control in the year before sowing to stop seed set and to accumulate soil moisture. There are a number of options to manage weeds in the months prior to sowing.

1. Chemical spray fallowing

A chemical spray fallow is the preferred option in the spring prior to sowing, as it gives absolute weed control, but leaves organic matter to protect the soil surface over summer. A knockdown herbicide (e.g. glyphosate) will give effective control of most annual weeds, if it is applied before they flower and set seed.

Caution: *Check herbicide labels for plant back periods for pasture species if residual herbicides are likely to be used in conjunction with the knockdown herbicide.*

2. Cultivated fallow

Cultivation should only be used if there is a reason to cultivate, e.g. to reduce excessive levels of plant material. It is not the preferred option for spring fallow weed control as it leaves the paddock exposed to wind and water erosion. If the soil is moist, cultivation may not kill all weeds, as a proportion may be transplanted and will require further cultivations for effective control.

Forage crops are an ideal way to clean up weedy paddocks.

Photo: L Ayres

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8 Pests of pastures

There are a number of invertebrate pests which can cause significant damage and may completely destroy a new pasture. An integrated approach to pest management is recommended to reduce reliance on pesticides and to encourage populations of beneficial insects.

Pastures should be monitored for the presence of pests before and after sowing. Major pests of temperate pastures are: earth mites, snails, slugs and pasture cockchafers.

Integrated pest management (IPM)

IPM uses a combination of control tactics (cultural, host plant resistance, biological and chemical) to keep pest numbers below the level that will result in economic damage. The basis of an effective IPM plan is sound knowledge of pest life cycles, which is needed to determine critical control points. The objective is to reduce reliance on pesticides, minimise the harm to populations of beneficial insects (natural pest enemies), and achieve a balance between treatment cost and impact on the establishing pasture.

IPM requires regular monitoring, the identification of pests and beneficial insects, and making strategic chemical control decisions according to acceptable damage thresholds. IPM strategies used in pastures rely on biological control of pests and protecting and encouraging natural enemies. See *Chapter 15* for more details on eneficial insects in pastures.

Control options available include:

- cultural methods, such as farm hygiene, weed control, cultivation, physical barriers, quarantine areas, planting times, crop rotations and maintaining plant vigour;
- manipulation of the micro-environment to create conditions unfavourable for pests or more favourable for the beneficial insects (e.g. planting density, row spacing, row orientation, grazing);
- host plant resistance, such as genetic resistance (e.g. redlegged earth mite resistance in sub clover) or physical features that repel attack;
- genetic control measures such as the release of sterile male insects;
- use of pheromones to disrupt mating or aggregation;
- use of microbial pesticides such as insect-pathogenic viruses (e.g. Nuclear Polyhedrosis Virus or metarhizium fungi); and
- use of selective pesticides as a last resort. Using 'soft' chemicals or pest-specific chemicals in preference to broad spectrum pesticides promotes beneficial pest populations. For many species, it is very important to apply pesticides at the correct time of day, e.g. in the evening when grubs are feeding and exposed, otherwise the application will be ineffective.

Caution: *Check pesticide labels before use and pay particular attention to livestock withholding periods.*

Major pest threats to new pastures

1. Earth mite

Description

"Earth mite" is a collective term used for both redlegged earth mite (RLEM) (*Halotydeus destructor*) and blue oat mite (BOM) (*Penthaleus* spp.). They may occur in mixed or separate populations within paddocks. Over-summering eggs of earth mites typically hatch after late autumn/early winter rains. Adult populations are highest during May–June and September–October.

Redlegged earth mites have black bodies, eight bright orange legs and are about the size of a pin head.

Redlegged earth mite.

Photo: L Turton

The blue oat mite is often a more blue/black colour and can be distinguished from redlegged earth mite by an orange dot on its body.

Blue oat mite.

Photo: L Turton

Damage

Both species of mite can cause serious damage and the death of pasture seedlings. Autumn hatching is stimulated by 15–25 mm of rain in combination with temperatures below 20 °C over several days, which coincides with conditions ideal for seedling emergence. Damaged plants have silvery/whitish leaves; they are stunted, weak and slow to establish. Severely damaged plants are distorted and may die. Heavy mite infestations can result in patchy or failed establishment.

Control

While redlegged earth mite and blue oat mite are very similar, the blue oat mite is known to be tolerant (but not resistant) to some common miticides. Therefore it is important to confirm which species are present.

Control of redlegged earth mite prior to sowing can commence with an application of an appropriate miticide with the spray fallowing operation in the previous spring. This controls the majority of the spring adult population and greatly reduces production of over-summering eggs.

The timing of this spray can be optimised using the Timerite® program. Timerite® was developed by CSIRO and is used to control the adult redlegged earth mites before over-summering eggs are formed. It uses location-specific information to predict the optimum time to spray to kill the mites, before they begin to produce eggs that stay dormant over summer. Unfortunately, Timerite® does not work on blue oat mites as they produce a combination of over-summering eggs and normal eggs throughout their life cycle.

Combining a residual miticide (registered for both species) with the knockdown herbicide used for the weed control operation immediately before sowing is strongly recommended. This will provide 2 to 3 weeks' protection for emerging seedlings, at a time when they are most susceptible and likely to be killed by mite. The period of protection varies with rainfall.

If mites are still present or the invasion of mites from neighbouring paddocks is expected post sowing, consider applying a bare earth insecticide for longer term protection – either as an overall or perimeter spray.

Caution: *Current control tactics are heavily reliant on pesticides and some mite populations have developed resistance. Avoid pesticide resistance through:*

- *good understanding of the mites' life cycles to maximise the effectiveness of a spraying program; and*
- *rotating pesticide options.*

2. Slugs and Snails

Description

Slugs are a more common pest of pastures in NSW than snails, which tend to be confined to alkaline soils or soils containing free lime. The build-up of slug and snail populations is favoured by ground cover and cool, wet summer conditions.

Damage

Slugs mostly feed at night and shelter during the day. They preferentially attack legumes and dense populations can consume large numbers of emerging shoots and seedlings (both above and below ground).

Control

A combination of grazing and/or burning before sowing will remove habitat, and cultivation will help to control populations. Direct drilled pastures and those sown after a short fallow are at greater risk of attack than those sown after a long, weed-free fallow. Late sown pastures are also more susceptible as autumn rains trigger activity, feeding and egg laying.

If slug or snail infestations are expected, check paddocks prior to sowing by placing bait stations at several locations. Squares of weighed down cardboard are suitable. Position these near sheltered areas, trees or in damp spots. If there are more than 2–3 snails or slugs at each station, baiting at sowing is recommended, but may be limited to the areas of infestation. Check slug or snail levels about 7 to 10 days after baiting. If infestations are heavy, a follow-up bait may be needed to protect establishing seedlings. An effective bait program early in the season will minimise damage and prevent population build-up.

There are a number of chemicals registered for control of slugs and snails in pastures. When selecting, consider weather resistance of the bait and coverage. Small, even-sized baits applied at label rates will ensure a relatively high number of baits per hectare, which will increase the likelihood of a slug or snail encountering a bait.

3. Pasture cockchafers (scarabs)

Description

There are two main types of cockchafers – the blackheaded (*Aphodius tasmaniae*) and the redheaded (*Adoryphorus couloni*) pasture cockchafer. The adult blackheaded pasture cockchafer (scarab) is a shiny dark brown or black beetle 10–12 mm long.

The larvae have a 10–20 mm long, whitish soft body. The redheaded pasture cockchafer has a reddish-brown head and is up to 30 mm long.

Both species remain in the soil in larval form until autumn rain softens the ground and encourages pasture growth.

Blackheaded pasture cockchafers.

Photo: L Turton

Damage

The first evidence of blackheaded pasture cockchafer is often areas of bare ground with many small piles of fresh soil seen on the surface after rain. Larvae feed on foliage (particularly legumes), whilst the redheaded pasture cockchafer will feed on the root system, placing stress on establishing plants. Bird activity is also an indication of cockchafer. Birds may cause further damage to seedling pastures as they attempt to feed on the larvae.

Redheaded pasture cockchafer larvae.

Photo: L Turton

Control

The blackheaded cockchafer can be controlled by insecticides as they are surface feeders. However, there are no chemical control options for the redheaded cockchafer, which feeds solely underground.

A spray program is recommended if two or more blackheaded cockchafer grubs are found in each spade of soil dug up across the paddock.

Insecticides are registered for the control of the blackheaded pasture cockchafer. For best results spray before July, ideally just before 5 mm or more rain. The larvae mature and stop feeding from about mid-winter.

Resowing may be the only option for redheaded cockchafer infestations. Cultivation will assist in reducing the population through physical damage to the larvae and exposing them to predation by birds.

Other pests

4. White fringed weevil

Description

The white fringed weevil (*Naupactus leucoloma*) is the most common and damaging insect pest of lucerne stands. The larvae, is creamy white, grows from 1–13 mm long and can be found below ground in the cooler months of the year. It can cause serious damage to lucerne plants.

White fringed weevil larvae.

Photo: L Turton

Adult weevils are 10–13 mm long and dark grey/brown/black. They usually emerge in the spring/summer months to feed on the leaves, but rarely do any significant damage.

Adult white fringe weevil.

Photo: L Turton

Damage

Symptoms of white fringed weevil damage are often not evident until the plants are under moisture stress. Individual plants or groups of plants within a paddock may appear stunted and yellow, and affected plants may die over time. Larvae burrow into the top 20 cm of the tap root and large lateral roots, producing distinctive vertical furrows, which can be easily seen in affected plants.

Seedling lucerne can be completely destroyed and the life expectancy of established stands will be reduced if white fringed weevil numbers are high.

Control

Control of this root-feeding insect is difficult. Remove unproductive, older stands and sow a cereal 'break' crop, free of broadleaf weeds and legumes for a minimum of three years before returning it to lucerne. New lucerne stands should not be sown beside older, established lucerne stands.

5. Armyworm

Description

The three main species of armyworm found in pastures are common armyworm (*Leucania convecta*), southern armyworm (*Persectania ewingii*) and inland armyworm (*Persectania dyscrita*). The caterpillar of all these species can be green, brown or yellow with three light stripes running the length of their back and sides. They are smooth, grow to 40 mm and curl when disturbed. Caterpillars usually shelter near the ground during the day and feed on leaves at night.

Armyworm populations commonly build up when substantial rain follows periods of drought.

Southern armyworm caterpillar.

Photo: L Turton

Damage

Mature armyworm larvae can cause extensive damage. They defoliate young plants and may kill seedlings.

Control

Spraying may be necessary to control outbreaks. Smaller armyworms are more susceptible to pesticides than larger ones, and should be controlled before they cause serious damage.

The larvae are most active late in the afternoon and at night, so pesticides applied in late afternoon or evening will be most effective.

6. Cutworm

Description

Cutworm caterpillars are the larvae of several moth species (*Agrostis* spp.) and can grow up to 50 mm long. They are smooth and vary in colour from grey, brown, green to nearly black.

Damage

Cutworm activity is usually concentrated in patches. They are a sporadic pest and may eat out or thin large areas of seedlings. The larvae shelter in the soil during the day and feed at night. They feed on leaves and stems of young seedlings and established plants by cutting through plants at ground level.

Cutworm larvae.

Photo: NSW DPI

Control

Controlling weeds on the perimeter of the paddock for at least one month prior to sowing will help reduce the incidence of cutworms. Inspect paddocks late in the evening or at night when they are active.

7. Aphids

Description

There are several aphid species that can infest lucerne and clover stands. Identification will help guide management decisions. The main species affecting pastures in temperate Australia are:

- spotted alfalfa aphid (*Therioaphis trifolii*)
- bluegreen aphid (*Acyrthosiphon kondoi*)
- green peach aphid (*Myzus persicae*)
- pea aphid (*Acyrthosiphon pisum*)

Green peach aphid.

Photo: M Steiner

Damage

Aphid infestations are most likely to occur in spring but populations can build-up and also cause damage in autumn and winter, when conditions are favourable. They usually attack new growth, sucking sap from buds, stems and leaves. They cause stunting, leaf distortion, wilting, yellowing and leaf drop and heavy infestations may result in the death of establishing plants.

Control

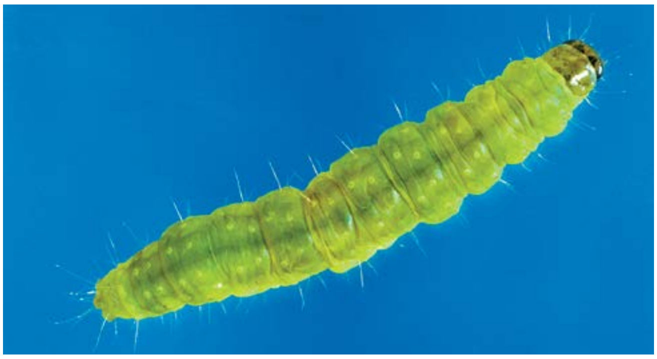
Aphids are attacked by a number of beneficial insects, so an IPM approach will minimise the impact of aphids on establishing pastures. It is important to monitor pastures and consider all control options included below, before resorting to chemical control.

- Select varieties with good resistance to aphids;
- maintain vigorous stands through good nutrition, weed management and watering (if irrigated);
- monitor pastures regularly in seasons favouring aphids;
- cutting or quick, intense grazing of lucerne or clovers can effectively reduce aphid populations;
- spraying should be considered to prevent thinning of seedling stands and production loss when there are two or more aphids per growing point;
- infestations often occur in patches so the whole paddock may not require treatment; target only areas of heavy infestation to minimise the damage to beneficial insects.

8. Lucerne leafroller

Description

The lucerne leafroller (*Merophyas divulsana*) is native to Australia and widely distributed. The pest is the larval stage of a tortricid moth. Young larvae are pale yellow in colour, then become greenish, with a dark head and grow to about 15 mm in length.



Lucerne leafroller larvae.

Photo: L Turton

Lucerne leafroller moth.

Photo: L Turton

The moths lay eggs on the upper surface of leaves during spring and summer. Once hatched the larvae immediately commence rolling and webbing the terminal leaves together. After four or five weeks the fully grown larvae pupate within the leaf rolls. The pupal period is shorter (approximately one week) during summer. When the moths emerge from the pupae they establish the next generation.

Damage

Leafrollers can attack lucerne (and occasionally clover) at any stage of growth, but are more commonly found in the warmer spring and summer months in paddocks that have not been grazed recently. The larvae skeletonise leaves from within the shelter of the leaf rolls. By rolling terminal shoots the larvae prevent new growth from these points, reducing yield and quality.

Control

Leafrollers are not known to have any natural enemies. Insecticides are registered for their control but they can lead to other problems such as chemical residues in lucerne.

Spraying advanced crops for lucerne leafroller is not recommended (or economical) if cutting or grazing is a practical alternative. If infestations are significant after 3 weeks of regrowth (more than 25% of stems affected) cutting or grazing slightly earlier than scheduled is recommended, instead of applying an insecticide. If this level of infestation occurs in the first 3 weeks of regrowth then insecticide control may be necessary. Leafroller numbers usually peak about every 4 to 5 weeks in late summer/autumn. It is possible to manage populations by adjusting harvest time so it occurs just prior to the expected peak in larval activity.

9. Lucerne flea

Description

Lucerne flea (*Sminthurus viridis*) are wingless, globular insects up to about 3 mm long. They are grey-green or yellow-green with dark patches and have a distinctive jumping action when disturbed.

Lucerne flea is an occasional pest of lucerne and other pasture legumes from autumn to spring when temperatures are consistently below 17 °C. There may be 3 to 5 generations in that period.

Damage

Very young nymphs feed on the underside of leaves, creating clear membranous windows while older nymphs and adults eat out larger patches. Badly affected stands may appear whitish and total defoliation can occur. Plants are most susceptible during the seedling stage, when severe infestations can stunt or kill plants.

Control

There are no pasture varieties with tolerance specific to lucerne flea. Fallow weed control prior to sowing can reduce numbers, however if the infestation is severe then an insecticide spray may be required. Spot or border spraying may be adequate as infestations are often in patches or begin on borders with infested neighbouring paddocks.

Timing is important to ensure populations are targeted early in the season. Spray when the first generation has hatched and before they mature and start laying eggs. This is usually about 3 weeks after they are first detected. A follow-up spray about 4 weeks later may be needed. Cutting may help reduce numbers, but it is not as effective as heavy grazing by sheep and dry conditions.

10. Pasture webworm

Description

Pasture webworm (*Hedonta* spp.) larvae have a smooth green-brown body, shiny dark head and grow to about 20 mm. Larvae shelter in web-lined tunnels in the soil during the day and emerge to feed at night.

Pasture webworm larvae.

Photo: N Ferguson

Damage

Larvae feed on grasses and can cause severe losses in establishing pastures. As they feed they often pull plant material into their tunnels. This is a distinguishing feature that can assist in identification.

Control

The greatest damage occurs in pastures that are direct drilled into an infested paddock, or which follow a short fallow. Inspect newly sown pastures 4 to 5 days after emergence.

11. Sitona weevil

Description

The adult sitona weevil (*Sitona discoideus*) is about 5 mm long, dark-greyish brown with 3 light stripes on the thorax. The larvae are small, slightly curved white grubs (1–2 mm long) with dark heads. They mainly occur in the top 10 cm of soil.

Damage

Sitona weevil is a pest of lucerne and medics. Early stage larvae feed within or on the root nodules of lucerne plants. Older larvae feed on lateral roots and tap roots. Adults make scallop-shaped notches along the leaf margins and also chew stems of seedlings and established plants. Heavy infestations can defoliate established plants, causing yield loss, and may kill seedlings and young plants.

Adult sitona weevil.

Photo: L Turton

Control

No chemical treatment is available for the larvae. Egg laying can be greatly reduced or prevented by controlling adult infestations in April-May. Check seedlings and first year stands regularly. Spray established stands only if weevil numbers are high and the damage is worsening.

12. Other pests

Other pests that can occur sporadically and damage establishing pastures include the mole cricket (*Gryllotalpa* spp.), thrips (*Thrips* spp.) and lucerne seed web moth (*Etiella behrii*). The wingless grasshopper (*Phaulacridium vittatum*), plague locust (*Chortoicetes terminifera*), heliothis (*Helicoverpa armigera*), and wireworm (*Elateridae* spp.) may also cause problems in isolated instances. The important thing to remember is to be vigilant and inspect the paddock regularly.

References and further reading

PestFacts

PestFacts is a free electronic service designed to keep consultants, growers and researchers informed about pest outbreaks, effective controls and current information about relevant research findings as they emerge. The PestFacts service draws on field observations of consultants, growers and industry specialists across south eastern Australia.

The information generated by PestFacts can also be used to gain an idea of the occurrence and location of pest problems. The service is supported by GRDC and is available at: http://www.cesaraustralia.com/sustainable-agriculture/pestfacts-south-eastern/

Anon (1997) Guide to the key insect pests of pastures. Agriculture Victoria

Hertel K, Roberts K and Bowden P (2013) Insect and Mite Control in Field Crops. NSW Department of Primary Industries

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9 Fertiliser at sowing

Most Australian soils are naturally deficient in phosphorus, sulfur and nitrogen. Fertiliser applied at sowing will ensure rapid, healthy and vigorous seedling growth.

Nutrient requirements at sowing

Knowing the nutrient status of your soil is essential prior to sowing. A soil test before sowing will help to identify potential soil and nutrient constraints and indicate fertiliser requirements. For more information see *Chapter 4 – Soil testing*.

Caution: *High fertiliser rates drilled with the seed can reduce seedling germination and cause 'fertiliser burn'. The potential for damage from high fertiliser rates will be greatest in lighter soil types or when sowing into cool conditions and marginal soil moisture.*

Phosphorus (P)

A soil test is the only way to confirm the amount of P required at sowing. Typically 10–20 kg P/ha should be used, depending on your soil P status (see Table 9.1). Some sowing equipment may limit the rate fertiliser can be applied, in which case additional P may need to be applied, either before or after the sowing operation.

Table 9.1 Recommended phosphorus rates (kg P/ha) for a range of soil P levels (low, medium and high) based on Colwell and Bray P soil test results.

Soil P status	Colwell P test (mg/kg)	Bray P test (mg/kg)	P rate (kg/ha)
Low	15 or less	less than 8	15–30
Medium	16–27	9–14	10–20
Adequate	28 or more	15 or more	10–15

Sulfur (S)

Sulfur is particularly important for legumes. Sulfur in the sulfate form is readily available to plants. Therefore, in situations where S is deficient or low, products containing S in the sulfate form are recommended. They will provide S to the establishing pastures more quickly than products containing the elemental S form. That form of S is insoluble and slow to become available to plants.

Nitrogen (N)

Nitrogen is often supplied in the form of a 'starter' type fertiliser at sowing. Excessive amounts of N applied with the seed can affect germination. As a general rule, do not apply more than 20 kg N/ha with the seed when sowing on 15 cm row spacing.

Note: *Nodulation of legumes is suppressed by presence of soil mineral N. In most situations there is no reason to use 'starter' N when sowing legumes.*

Molybdenum (Mo)

Molybdenum is a trace element that is essential for legume nodulation and N fixation. As soils acidify, Mo becomes less available to plants. It should be applied to soils with a pH_{Ca} of less than 5, every 3 to 5 years.

Molybdenum can be applied using one of the following methods:

1. *Mixed with herbicide applications*: mix sodium molybdate in the spray tank with the herbicide used for e.g. the pre-sowing weed control operation. Use a rate of 139 g/ha sodium molybdate. Application of Mo via a boom spray will ensure even distribution across the paddock.

   Caution: *Check the compatibility of the herbicide with Mo.*

2. *As a seed dressing*: molybdenum can be mixed either with the inoculant solution or dry with the liming coating material.
   Use either molybdenum trioxide (66% Mo) or ammonium molybdate (54% Mo). For soils deficient in Mo use a minimum of 50 g Mo/ha – i.e. 76 g/ha of molybdenum trioxide or 92 g/ha of ammonium molybdate.

   Caution: *Sodium molybdate is toxic to rhizobia and must not be used as a seed dressing.*

3. *Applied in single superphosphate fertiliser at sowing*: use 0.05% Super Mo product (or equivalent) when applying superphosphate at a rate of 125 kg/ha or the 0.025% Super Mo product when applying superphosphate at a rate of 250 kg/ha.

Potassium (K)

Sandy loam soils and those with a history of hay or silage production are most likely to be low in K. It can be applied in the form of potash prior to sowing, post sowing or during the first spring. Do not drill potash with the seed as it can affect seed germination.

Note: *For additional information on other soil nutrients see Chapter 4 – Soil testing.*

Fertiliser and establishment method

The most suitable type of fertiliser to use and the rate at which it is applied will depend on the method of pasture establishment. There are many compound fertilisers available that provide a balanced ratio of N, P and S (see Table 9.2).

Note: *fertiliser drilled into the soil at sowing is 40% more efficient than fertiliser broadcast onto the soil surface.*

Table 9.2 Suggested rates of fertiliser (kg/ha) when establishing pasture in conventional cultivation or direct drill (nil cultivation) systems.

Sowing method	Conventional cultivation		Direct drill
Fertiliser	Single super	Granulock®	Pasture starter
N	–	*11.0%*	*6.7%*
P	*8.8%*	*21.0%*	*13.5%*
S	*11.0%*	*4.0%*	*7.9%*
Soil P status			
Low	175–350	75–145	>240
Medium	125–250	50–100	120–240
Adequate	125	50	120

1. Conventional cultivation

Cultivation stimulates mineralisation of organic matter. This process converts organic forms of nutrients, such as N and S, to mineral forms that are readily available to plants. Therefore, less of these nutrients is required if the seedbed is cultivated before sowing. However, mineralisation does not affect the availability of phosphorus. Fertilisers recommended for use in conventional cultivation systems include:

- Single superphosphate: contains moderate levels of P and S
- 'Starter fertilisers': contain high P levels, some N to boost seedling growth of non-legumes, but are usually low in S
- Compound fertilisers: contain a combination of N, P and S. A range of products are available.

2. Direct drilling

Pastures sown in direct drill systems do not have the advantage of the early nutrient boost from mineralisation. In the absence of cultivation, only low levels of N and S are likely to be available to the seedlings, and therefore pastures established by direct drilling require more added nutrients for early growth

The risk of seedling death as a result of seed being placed in contact with fertiliser is increased in direct drill systems, particularly when high fertiliser rates are drilled with minimum soil disturbance (e.g. disc drill seeding machinery). Some seeders have the capacity to separate the fertiliser and seed. Ideally fertiliser is placed 1–2 cm below the seed.

Fertiliser and inoculated seed

Some fertilisers are toxic to rhizobia, because of their acidity. The survival of rhizobia can be improved by lime pelleting legume seed after inoculation to minimise contact with fertiliser. For more information refer to *Chapter 12 – Seed treatments – inoculation, pest and disease control.*

Alternative fertiliser sources

Organic materials contain a range of nutrients and can be a cost-effective alternative to the more commonly used inorganic fertilisers. However, they are often bulky, and can be difficult to handle and spread. When assessing the value of these fertilisers:

- consider the nutrient requirement of the product; and
- check the nutrient analysis of each batch as nutrient levels of organic materials can be highly variable due to differences in inputs, processing, waste treatment, moisture content and storage time.

For more information refer to the *Chapter 17 – Fertiliser requirements.*

Follow-up fertiliser applications

Follow-up fertiliser requirements will depend on soil fertility and production targets (see *Chapter 17 – Fertiliser requirements*). Soil tests will indicate the impact of fertiliser applied at sowing on soil fertility and should be used as a guide to further nutrient requirements. Allow about six months between the last fertiliser application and soil sampling.

Comparing fertiliser costs

When buying fertiliser compare the cost of each product based on the nutrients identified as most limiting to the pasture. Compare prices on a cost per kilogram basis for the limiting nutrients to determine the most cost-effective product, as shown in the following example:

1. Calculate the number of kilograms of nutrient e.g. P in each tonne of product.
2. To calculate the cost per kilogram of nutrient divide the price per tonne by the number of kilograms of nutrient in each tonne of product.

Example:

Single superphosphate is 8.6% P

1. 1 tonne contains 86 kg of P (1,000 kg × 0.086)
2. Assuming the cost is $450/tonne, the cost of each kg of P is $5.23 ($450 ÷ 86 kg)

A true comparison should be the cost per kilogram of nutrient delivered and spread.

Reference and further reading

Anon (2011) Guidelines for suggested maximum rates of fertiliser applied with the seed in winter crops. Incitec Pivot Fertfacts

Havilah E, Warren H, Lawrie R, Senn A and Milham P (2005) Fertilisers for Pastures. NSW Department of Primary Industries

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10 Weed and pest control at sowing

Seedlings of most perennial grasses and legumes are not vigorous, so it is essential to effectively manage competition from weeds and damage from pests to maximise the potential for successful pasture establishment.

Weeds

Forward planning is the key to minimising the impact of weeds on establishing pasture. An effective weed control program in the two years prior to sowing will control perennial weeds and reduce the seed bank of annual weeds. By following this approach the only weeds that may pose a threat to establishing seedlings are young annual weeds that can be easily controlled by a knockdown herbicide applied just before sowing. This is the only possible way to achieve absolute weed control, and so eliminate one of the major threats to pasture establishment – weed competition.

The traditional approach that relied on a single application of a broad-spectrum knockdown herbicide the week before sowing is not recommended. This practice depends on a significant 'autumn break' and carries a high risk of failure, particularly when paddocks have infestations of perennial weeds and carry a large burden of annual weed seeds.

Do not sow on the opening autumn rain.

An 'autumn break' of more than 15 mm of rainfall and cooling temperatures should stimulate the germination of annual grass weeds and some broadleaf weeds. Inspect the paddock two weeks after "the break" for other weeds, including hard-to-kill perennials, such as established sorrel.

The three methods used to control weeds immediately prior to sowing are listed below. The first two methods rely on the use of non-selective knockdown herbicides and provide the best control:

1. Glyphosate application – with no cultivation at sowing (minimum disturbance);
2. Paraquat and diquat (Sprayseed®) application – with either minimum disturbance or full cultivation at sowing;
3. Sowing with a full cultivation.

A selective hormone herbicide may be mixed with glyphosate to target broadleaf weeds. This will delay sowing by 1 to 3 weeks because a plant back interval (the time between spraying and sowing a sensitive species) is required to allow for the residual effects of the hormone herbicides to break down. It may be worthwhile including an insecticide in the herbicide mix to control earth mite. Refer to *Chapter 8 – Pests of pastures*.

Note: *Check herbicide labels for chemical compatibility and plant back periods.*

Invertebrate pests

The main invertebrate pests of pastures and their control have been discussed in *Chapter 8*. Implementing an integrated pest management (IPM) program prior to sowing will reduce the risk of damage from pests to establishing pastures.

Pest infestations are not predictable as populations are transient and life cycles are determined by environmental conditions. Therefore, to ensure successful establishment t is essential to monitor paddocks regularly. This includes checks every two to three days for the first three to four weeks after sowing, when the pasture is most susceptible, and ongoing monitoring until the pasture is established.

A proactive management approach such as Timerite® will assist in the management of redlegged earth mite. For other pests monitoring paddocks and maintaining good records in the season prior to sowing will provide an indication of potential pests.

The decision to use a pesticide should only follow identification of the pest and consideration of the impact of the recommended pesticide on beneficial insects, which have an important role in controlling pest species. Seek advice to determine which strategy best suits your farming system, pest populations and risk profile.

There are two methods of chemical control used:

- Knockdown
- Bare earth

Knockdown pesticides tend to be a 'softer' option as they only kill pests present at the time of spraying. This option allows insects, both beneficial and pests, to re-enter the area, causing re-infestation to occur quickly. Identification, assessment of damage and monitoring of insect activity, in and around the target area, before and after the pesticide application, is essential for effective control when using knockdown insecticides.

Bare earth treatments generally use broad spectrum insecticides that kill both pests and beneficial insects. They have a residual effect ranging from days to weeks. Bare earth treatments can offer a sense of security because pests are controlled over an extended period. However, continued monitoring is essential as pest populations may still rebuild quickly, before the pasture is established. There is usually a lag period for the recovery of the beneficial insect populations during which time the pest populations will not be checked by natural predators.

11 Seed quality

Seed quality is one of the most important aspects of sowing a new pasture. Whenever possible, purchase Certified Seed or Quality Assured Seed to ensure that it is true to type for the nominated variety and has high germination capacity and physical purity. Ask for a current certificate of seed analysis when purchasing seed. These certificates are available for any seed from reputable merchants and provide details of the germination, physical purity, and lists weed seeds found in a representative sample. Insist on seed that has a high germination percentage and high level of physical purity.

Varietal purity

The only way to ensure that the seed purchased is the correct variety is by purchasing seed that is supplied under a Certified Seed or Quality Assured Seed Scheme where varietal purity is carefully managed. This will provide confidence that the seed is the correct variety and that it has been properly sampled and tested for physical purity and germination. Check that the seed lot or line number listed on the certificate matches the lot number on the bag purchased.

Physical purity

Purity information is presented on the certificate of seed analysis as the percentage weight of 'Pure seeds' and contaminants – i.e. 'Inert matter' and 'Other seeds':

- *Pure seeds* – provides an indication of whether the lot is 'true to type', e.g. 99.1% sub clover (species but not variety).
- *Inert matter* – includes broken seed and non-seed material such as dirt, plant residue and fungal material.
- *Other seeds* – includes seed of all other plants found in the sample, including weeds. Check the list of 'other seeds' on the certificate and reject seed lots that contain the seeds of weeds you do not want introduced to your farm.

Germination percentage

The germination percentage on a certificate is broken down into several categories:

- *Normal seedlings* – is the percentage of germinating seeds that will progress to develop 'normal seedlings'. It is an indication of the percentage of seeds that will germinate in the year of establishment. Ideally this should be more than 80%.
- *Hard seed* – is the proportion of seed in the sample that is dormant. The hard seed levels of legumes can vary considerably between species and varieties.
- *Fresh ungerminated seed* – are found commonly in tropical grass species and are either immature or dormant seeds.
- *Abnormal seedlings* – are those produced by seed that germinates but is damaged in some way. These seeds are unlikely to produce healthy plants.

The germination test results are valid for up to 12 months provided that the seed is stored under suitable conditions – i.e. cool, dry and free of insect infestations

Sowing seed harvested on farm

Seed viability and germination percentage is affected by moisture levels at harvest and subsequent storage conditions. A seed test analysis from a reputable seed testing laboratory will provide an accurate estimate of germination percentage and assist in calculating seeding rates.

Contact details of reputable seed testing laboratories and more information about seed quality and quality assurance programs are available at the Australian Seed Federation website: http://www.asf.asn.au/

12 Seed treatments – inoculation, pest and disease control

A number of seed treatments are available for legumes and grass species. Some of these are essential for successful establishment and the long-term productivity of the pasture.

Legume inoculation

All legume seed should be inoculated with N fixing rhizobia bacteria before sowing. Using the inoculant group (rhizobia strain – Table 12.1) that is specific to the pasture species will ensure compatible rhizobia are close to the emerging root for effective nodulation and N fixation . Nodules with pink centres found close to the crown of the plant indicate that the inoculation process was successful. White nodules indicate ineffective nodulation and are unlikely to fix N.

Effectively inoculated legumes have numerous pink coloured nodules close to the crown of the plant.

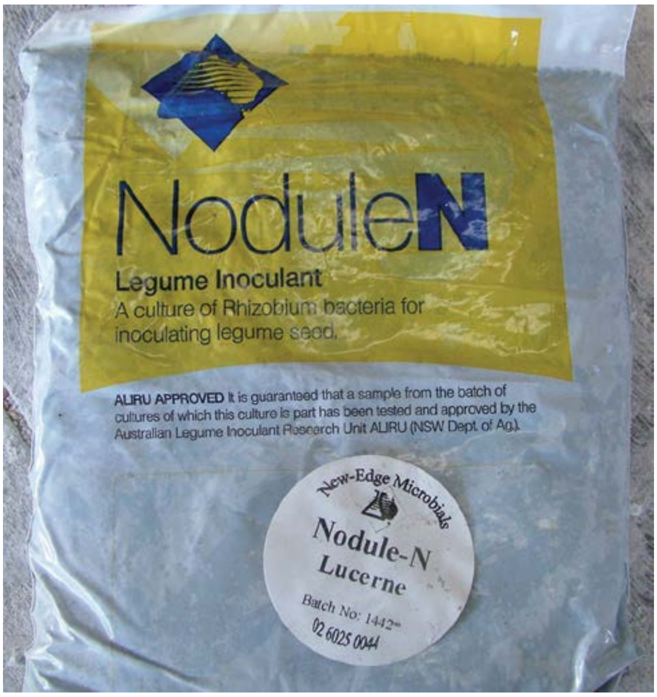
Photo: NSW DPI

Table 12.1 Inoculant groups used for legume pasture species.

Group	Species
AL	Lucerne, strand and disc medics
AM	Medics (except strand and disc)
B	Ball clover, berseem clover, cluster clover, red clover, strawberry clover, suckling clover, white clover.
C	Arrowleaf clover, balansa clover, bladder clover, crimson clover, eastern star clover, gland clover, purple clover, rose clover, sub clover,
D	Lotus
E	Woolly pod vetch, purple vetch
S	French and yellow serradella
Special inoculants	Caucasian clover, desmodium, desmanthus, leucaena
Biserrula special	Biserrula

Inoculant formulations

Inoculants contain *live* rhizobia and come in several formulations including fresh or slurry inoculants (e.g. peat, freeze-dried powder and liquid inoculants) and long-life formulations (e.g. granular inoculants and preinoculated seed). The 'Green Tick Logo' program of the Australian Inoculants Research Group (AIRG) provides quality assurance of legume inoculants and, when the inoculant is applied at the recommended rate, an adequate number of rhizobia should be delivered to ensure effective nodulation. Follow manufacturers' storage and handling instructions to maximise rhizobia survival and nodulation.



Peat inoculants are a high quality, cost-effective option for successful nodulation.

Photo: L Ayres

Slurry inoculants

Peat inoculants are the most commonly used formulation and, along with freeze-dried, are usually applied as a slurry onto the seed. They may also be injected into the furrow, close to the seed at sowing. Treated seed should be sown on the day of inoculation as rhizobia numbers decline quickly after 48 hours.

The peat and freeze-dried inoculant formulations are sensitive to desiccation and are therefore most effective when seed is sown into moist soil.

Dry sowing of inoculated seed is not recommended. In such circumstances, nodulation may only be satisfactory if the paddock has a recent history of effective nodulation of the same legume. Survival of rhizobia introduced on the dry-sown seed cannot be guaranteed and nodulation will depend on the 'background' rhizobia population surviving in the soil.

Inoculated seed is often lime-pelleted to improve rhizobia survival. Lime-pelleting is recommended when sowing into acid soils ($pH_{Ca} < 5.5$) or when seed is sown in contact with fertilisers.

Inoculating and lime-pelleting legume seeds using a slurry inoculant involves the following steps:

1. Prepare a 1.5% methyl cellulose glue solution by dissolving 15 g methyl cellulose in 200 mL hot water (80 °C), then adding 800 mL cold water.
2. When cool mix 250 g inoculant with 1 litre of the glue solution using an electric drill and stirrer. Pour the inoculant mix over the legume seed while rotating in a cement mixer – either 25 kg of small seed (e.g. white clover, red clover or lucerne) or 50 kg of medium sized seed (e.g. sub clover)
3. Add 12.5 kg fine lime and roll for 1–3 minutes. **Do not use builders lime, e.g. hydrated or quick lime.**
4. Sow inoculated seed as soon as possible (within 48 hours).

Cement mixers are commonly used to inoculate and lime pellet legume seed.

Lime pelleted seed should be an even size and firm.

Uneven size and powdering creates problems when sowing poorly pelleted seed.

Photos: L Ayres

Granular inoculants

Granular inoculants are either clay or peat-based granules impregnated with rhizobia. Separation of the seed from the rhizobia means that seed can be treated with fungicide and insecticides that are toxic to rhizobia, without affecting rhizobia survival. They are easy to use, but contain fewer rhizobia per gram of product and therefore require higher application rates and are more expensive than slurry formulations.

Shelf life, handling, storage and sowing procedure vary between granular products, so check manufacturers' recommendations to maximise rhizobia survival. Clay-based granules have a reported shelf life of more than six months but this is very dependent on handling and storage conditions.

While moist soil conditions at sowing are recommended for peat-based granules, the clay-based granules provide some sowing flexibility. The rhizobia are protected in the clay granule and are less prone to desiccation than inoculated seed. Therefore, it is possible to sow into dry soil when granular inoculants are used. Follow the manufacturer's recommendations to optimise rhizobial survival and achieve the best results.

Although some forms of granular inoculant may be mixed with seed or fertiliser when sowing, field experience suggests that modifications to the seeder that allow for the granules to be separated from the seed and fertiliser will result in the most even distribution of the inoculant.

Preinoculated seed

Some companies and retailers offer precoated pasture legume seed. The seed coats contain the specific rhizobia and may also contain fungicides, insecticides and micro-nutrients.

This is a very convenient option and although precoating can extend the survival of rhizobia, **it is recommended that sowing occurs as soon as possible after the seed coating is applied**. Results from independent testing of inoculated seed samples collected from retail outlets showed that the number of rhizobia on preinoculated seed was extremely variable and that the viability of the rhizobia declined quickly after treatment. Many samples, irrespective of brand, did not have sufficient rhizobia present per seed for optimal nodulation.

If you are not confident of the handling and the conditions under which the precoated seed was stored, consider purchasing uncoated, bare seed and applying fresh inoculant using the slurry method.

There are Australian standards for rhizobium numbers on pasture legume seed at the time of sale, which govern the recommendations on shelf life of preinoculated seed. Note that the survival of rhizobia varies between species and the recommended shelf life is as follows:

- lucerne and annual medics – up to 6 months;
- subterranean clover – up to 6 weeks; and
- white clover, red clover and miscellaneous species – up to 2 weeks.

When using precoated seed it is important to check with your retailer the treatments used and when the coating was applied; ensure that every seed lot complies with the industry code of practice and that the product has been stored in a cool place. For more information go to the Australian Seed Federation website: http://www.asf.asn.au/

If there is any doubt about the survival of rhizobia or the shelf life of preinoculated seed, contact the supplying company regarding the need to re-inoculate. The viability of rhizobia can be tested but this may cause sowing delays.

Note: *When buying precoated seed, always ask for the percentage by weight of seed coating. This is important as the coating process increases seed size, resulting in fewer seeds per kilogram of product. In well controlled conditions coated seed is 66% seed and 33% coat. Therefore, sowing rates of coated seed should be increased to ensure adequate plant populations.*

Molybdenum (Mo)

Molybdenum is an essential trace element required by legumes for nitrogen fixation. It may be added to seed during the inoculation process as an alternative to using Mo superphosphate fertiliser. Molybdenum can either be mixed with the inoculant solution or dry with the liming material.

The forms of Mo that are suitable for seed treatment are molybdenum trioxide (66% Mo) at a rate of 76 g/ha; or ammonium molybdate (54% Mo) at a rate of 92 g/ha. These rates supply Mo at a rate of 50 g/ha, which is the recommendation for deficient soils.

Caution: *The fertiliser form of Mo is sodium molybdate, which is toxic to rhizobia and must not be used as a seed treatment. Refer to Chapter 9 – Fertiliser at sowing for more detail.*

Pest treatment

Ant theft treatments

Ants can potentially "steal" large volumes of seed, particularly grass seeds. Loss of seed from ant theft is greatest when seed is broadcast and not covered. Seed treatment with permethrin is recommended for all grass and small legume seed that is to be surface sown. This treatment does not affect rhizobia.

Earth mite treatments

Various miticides are registered for treatment of pasture seed. These chemicals are highly toxic and are potentially hazardous to the operator. They are also highly toxic to rhizobia. If a miticide is to be used on legume seed, it must be applied 24 hours before inoculation. Once inoculated, the seed must be sown immediately, preferably into moist soil, to minimise rhizobia death.

Disease control

Fungicide treatments

Treatment with a fungicide is recommended where 'damping-off' diseases such as *Pythium* and *Phytophthora* are anticipated, particularly with autumn/winter sowings. Fungicides can be applied during the inoculation process to protect seedlings. Check label recommendations for manufacturers' instructions to reduce impact on rhizobia survival.

Legumes are most susceptible to these diseases. They are most likely to occur when seed is sown into paddocks with excessive plant residue that is only partly broken down.

References and further reading

Anon (2005) Inoculating and pelleting pasture legume seed. Agfact P2.2.27. NSW Department of Primary Industries

Clements B, Ayres L, Langford C, McGarva L, Simpson P, Hennessy G, Keys M, Upjohn B and Leech F (2003) The Grazier's Guide to Pasture. NSW Agriculture

Drew E, Herridge D, Ballard R, O'Hara G, Deaker R, Denton M, Yates R, Gemell G, Hartley E, Phillips L, Seymour N, Howieson J and Ballard N (2012) Inoculating Legumes: a practical guide. Grains Research and Development Corporation

13 Sowing – timing, soil moisture, seeding rate and depth

The sowing operation and timing are critical for successful pasture establishment. Date of sowing, soil moisture, seeding rate and sowing depth are all important considerations.

Sowing time

While temperate perennial pastures have been successfully established in autumn, winter and spring, the climatic conditions, growth and development of the pasture species, and weed and insect life cycles vary between seasons. Therefore, there is no single recipe; each sowing period has its own set of management considerations.

Autumn

Autumn has traditionally been a reliable period for the establishment of temperate pastures – seedling growth should be vigorous while soil temperatures are adequate and air temperatures mild, provided there is adequate soil moisture. Rainfall of 50–100 mm prior to sowing and a moist profile to a depth of 20 cm is ideal. This will stimulate germination of the majority of annual weed seeds, allow for effective control and so minimise weed competition for the emerging seedling.

The 'autumn break' can be unreliable in many areas and it may be necessary to delay sowing until late autumn or early winter when soil moisture is adequate and annual weeds have germinated. Pre-sowing weed control will ensure the seedlings are sown into a weed-free seed bed.

Winter

The germination and early growth of pastures is slow in winter and any factors that reduce plant vigour will further affect establishment. Planning and management of constraints such as nutrient deficiencies, soil acidity, and weed and pest populations are particularly important for winter-sown pastures.

Insecticide mixed with the pre-sowing knockdown herbicide application will address early weed competition and also provide insurance against earth mite damage.

"Frost lift" is an issue for winter-sown pastures in high altitude areas. The soil surface freezes and causes physical tearing of the plants when the frozen surface expands and separates from the soil below. This issue is more likely to occur when pasture is sown into cultivated, heavy clay soils. Sowing into these soil types should be avoided when the risk of severe frosts is high, e.g. mid-July on the Tablelands. Direct drilled pastures are rarely affected by frost lift.

Temperate pasture species can tolerate temperatures as low as −8 °C and pastures on the Southern Tablelands have successfully established despite exposure to long periods of consecutive, severe frosts. However, moisture-stressed seedlings are more vulnerable and may be damaged by frosts and temperatures of −3 °C to −4 °C.

Annual legumes such as sub clover must be sown by mid-July in order to set sufficient seed for regeneration the following autumn. Check the maturity ratings and 'days to flower' of your preferred sub clovers varieties. Ensure the proposed sowing date allows sufficient time for seed to mature before moisture stress and hot temperatures in late spring stop seed development.

Spring

Spring sowing can be very successful for perennial grasses and legumes such as lucerne, if it occurs by mid-September, and provided there is adequate soil moisture to support the young seedlings over summer.

Annual legumes (e.g. sub clover) should not be sown in spring. The plants will not have enough time to establish, flower and set seed before they are affected by moisture stress and high temperatures.

Results from broadcasting annual legume species into spring-established perennial grass or lucerne pastures the following autumn are variable. Therefore, if annual legumes are an essential component of the perennial-based pasture, it is recommended that the pasture is not sown until the following autumn.

Moisture

Never dry sow temperate perennial pastures as there is a very high chance of establishment failure. Speed of germination and seedling growth is determined by soil temperature but the correct time to sow is when there is adequate soil moisture.

'Adequate moisture' means sufficient moisture at the surface for immediate germination, and moisture down to 20 cm for seedling survival until there is follow-up rain. There is risk involved with dry sowing as sufficient rain may fall to germinate the seed, but lack of subsoil moisture means that seedling survival is dependent on substantial follow-up rain.

Note: *It has been demonstrated that adequate soil moisture in the soil profile is more important to a successful pasture establishment than sowing date.*

Seed rate and seed size

The sowing rate will be largely influenced by sowing method (direct drilled, cultivated or broadcast), planned use of the pasture (irrigated, dryland, for weed or erosion control) and soil fertility. Establishment can vary from as low as 10% for broadcast seed and as high as 80% in well prepared cultivated or direct drilled situations. Seed counts per kilogram of seed and recommended sowing rates for key pasture species are shown in Table 13.1.

Shotgun mixes

'Shotgun mixes' that include small quantities of a number of perennial grass species are often sown to deal with paddock variability. However, such mixes jeopardise the long-term persistence of the pasture.

A pasture that includes just one, or at the most, two well adapted grass species is much easier to establish and manage. Species composition of most pastures will change over time and only a couple of perennial species will persist. It is important to promote and minimise competition against the productive, persistent species. Do not include species that will compete but are unlikely to persist.

The impact of competition on uncompetitive but well adapted species is demonstrated by the results of a survey of established, commercial pastures by NSW Department of Primary Industries at Wagga Wagga. The survey assessed the persistence of phalaris when sown either as the only grass in a clover/phalaris mix or when the mix also included perennial ryegrass. Table 13.2 shows that the percentage area of the pasture occupied by phalaris plants (% basal cover per square metre) in 2 and 3 year-old pastures ranged from 32–72% where phalaris was the only grass species sown, but dropped to 0–21% when ryegrass was included in the pasture mix. Phalaris establishment was clearly affected by the more vigorous ryegrass seedlings, but the results also show that the ryegrass did not persist. By years 2 and 3 the surveyed phalaris/ryegrass pastures had a basal cover of perennial grass of less than 10%, which was predominantly phalaris.

Table 13.1 The number of seeds per kilogram varies greatly between species and has a strong influence on the sowing rate and plant establishment.

Pasture species	Bare seeds (seeds/kg) *Approximate*	Seed rate range (kg/ha)	Plant establishment range (plants/m^2) *Assuming 25% establishment of sown seed*
Cocksfoot	1,300,000	1–2	32–64
Phalaris	650,000	2–4	32–64
Tall fescue	420,000	8–10	60–100
Ryegrass (perennial)	530,000	6–8	80–160
Arrowleaf clover	704, 000	1–4	13–52
Balansa clover	1,400 000	0.5–1	18–36
Bladder clover	526, 000	3–5	30–50
Biserrula	1,000,000	0.5–2	20–80
Lotus	2,062,000	1–2	52–104
Lucerne	1,456,000	4–6	20–30
Persian clover	1,456,000	1–2	36–72
Serradella	196,000	4–6	20–30
Sub clover	120,000	2–6	12–18
White clover	1,600,000	0.5–1	20–40

Source: The Graziers' Guide to Pastures, I&I NSW

Table 13.2 Persistence of phalaris was reduced when sown in mixes with perennial ryegrass.

Paddock ID	Basal area (%)		Ryegrass sown?
	Perennial ryegrass	Phalaris	
1	0	65	No
2	0	43	No
3	0	72	No
4	0	51	No
5	0	32	No
6	2	15	Yes
7	0	7	Yes
8	0	6	Yes
9	0	2	Yes
10	0	9	Yes
11	0	1	Yes
12	1	0	Yes
13	0	0	Yes
14	3	21	Yes
15	1	11	Yes

Variable paddocks may require grass species with very different management requirements, for example, one to cope with waterlogging and another for long-term persistence on drier ridges. When sowing paddocks with such distinct zones, two separate grass-legume mixes may be needed, e.g. one for the areas prone to waterlogging and another for the ridges. Consider sub-dividing such paddocks, for ease of management and to control grazing.

Sowing depth

Deep burial of pasture seed is a major reason for poor establishment. Pasture seeds are small and the seedlings will not emerge if sown too deeply. To optimize germination and emergence, aim to sow into moist soil, ensure good seed-to-soil contact and a coverage of no more than 1–2 cm of loose soil.

Attention to the set-up of the seed drill is essential to manage seed placement. For more information see *Appendix 4 – Calibrating a seeder.*

Note: *The optimum sowing depth for some very small seeded species is less than 1 cm, e.g. balansa clover (Trifolium michelanium) and biserrula (Biserrula pelecinus).*

References and further reading

Clements B, Ayres L, Langford C, McGarva L, Simpson P, Hennessy G, Keys M, Upjohn B and Leech F (2003) The Grazier's Guide to Pasture. NSW Agriculture

Virgona J and Hildebrand S (2006) A survey of pasture establishment practices in southern NSW. In: "Ground breaking stuff" – Proceedings of the 13th Australian Agronomy Conference. Perth, Western Australia

14 Sowing techniques and machinery

The three methods most commonly used to sow pastures are: direct drilling, conventional sowing and broadcasting.

Pastures are often also sown with an annual crop (cover crop) but this approach can affect pasture establishment and should take into account factors such as pasture species and crop sowing rate.

Sowing techniques

As a general rule, sowing techniques that create good seed-to-soil contact and some seed coverage will maximise emergence. To illustrate this, research by NSW Department of Primary Industries at Wagga Wagga compared the effect of sowing technique on the emergence of sub clover seedlings. Under ideal sowing conditions:

- only 16% of the germinable seed emerged when it was broadcast onto uncultivated ground;
- 57% of seed emerged when the seed was dropped onto cultivated ground and covered by harrowing;
- 68% emerged when the seed was direct drilled; and
- 72% emerged when seed was sown using a band seeder and rubber tyred roller system.

Seed placement and soil coverage are particularly important for lucerne and perennial grasses as their seeds are small and seedlings are generally not vigorous.

Direct drilling

Direct drilling involves sowing into an undisturbed seed bed using either disc or narrow point tyne seeders. Direct drilling of perennial pastures can be as reliable and effective as sowing into cultivated ground and is often less costly.

Benefits of direct drilling

Major advantages of direct drilling are savings of time and soil moisture. Other advantages include:

- Paddocks can be grazed until the time of sowing, whereas fallowed paddocks produce no feed for many months.
- Direct drilling allows pastures to be established successfully in areas that could not be sown conventionally due to rocks, stones or erosion risk.
- Direct drilling retains topsoil and organic matter at the surface of shallow soils; it is not mixed with the less fertile subsoil.
- Reduced seed bed preparation improves timeliness of sowing and increases the chance of successful establishment.
- Minimal soil disturbance means very little moisture is lost when sowing.
- Erosion risk is greatly reduced by maintaining ground cover and minimising disturbance of the surface soil.
- Paddocks prepared for direct drilling are likely to be trafficable and ready to sow soon after 'breaking' rain. In wet seasons, direct drill sowing is often possible while cultivated paddocks remain too wet.
- Pre- and post-sowing weed and/or insect control operations are easily completed in direct drilled paddocks. There is less risk of damage from wheel tracks or bogged machinery compared with conventionally cultivated paddocks.
- Direct drilling into a firm seed bed ensures precise seed placement.
- Direct drilling produces plants which are well anchored and able to tolerate early grazing.

Residue management

When using direct drill systems attention must be given to the amount of plant residue in a paddock at sowing. Aim for no more than 800 kg DM/ha of residue, as excessive amounts can cause blockages, slow the sowing operation, affect seedling emergence and provide a harbour for pests and fungal diseases.

Direct drilling can be an efficient method of establishing pastures.

Photo: D Chalker

Direct drilling machinery

Direct drill machines can be adjusted to place small pasture seeds accurately at a chosen depth, and leave a shallow cover of loose soil over the seed.

When checking sowing depth, a small amount of fertiliser (about 5%) should be seen on the surface.

Photo: L Ayres

Under good conditions most machines can successfully sow pasture, particularly if attention is paid to seed placement during set-up and there is no 'seed bounce' due to excessive sowing speed. There are two classes of sowing machinery: machines with (i) ground or contour following capability, or (ii) rigid frame machines (see Table 14.1).

Machines with ground following capability

Triple discs, traditional single disc seeders (and their conversions), drills with trailing tynes and single disc precision seeders all have ground following capability. These machines are preferred for sowing small pasture seeds as they can provide more uniform and precise sowing depth than the rigid frame seeders. The ground following capability ensures accurate seed placement as such machines are able to automatically adjust to localised variability of the paddock.

The single disc seeder may produce a poor tilth and unsatisfactory seed coverage when sowing into a moist seedbed. Smearing can also be an issue on wet, heavier clay soils when the furrow is either left open or the sod falls back into the furrow, burying the seed. It is recommended that single disc seeders are converted to fit inverted "T" points, which can be done relatively cheaply.

Single disc precision planters have individually mounted, ground following sowing units comprising a single, vertical disc opener with a depth control device, a seed and fertiliser delivery tube, an angled slot closing wheel and a press wheel. These machines are two to three times heavier than conventional seeders, which can be a problem in wet conditions.

Rigid frame machines

Most combines, whether coil tyne, spring tyne or spring release (including chisel seeders) are rigid frame machines. All tynes have a fixed position on the frame and there is no mechanism to enable the individual tynes to follow the contour of the ground. Therefore, it is necessary to compromise when selecting a sowing depth for variable paddocks. For example, if the machine is set at 25 mm, the seed may be sown into furrows that vary in depth from 0–50 mm.

There is a risk that the walls of deep furrows will collapse and bury seed. This can be an issue if there is heavy rainfall soon after sowing.

Do not harrow or roll direct drilled pasture. The inverted "T" direct drill points are designed to create a narrow, shallow furrow, with most of the disturbed soil thrown onto the undisturbed soil between the rows. Sowing depth should be set so that loose soil just covers most of the seed and fertiliser in the furrow. There is a risk of burying seed if harrows are used as they simply rake the loose soil from between the furrows back over the seed.

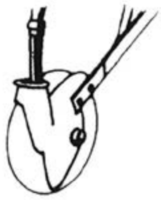
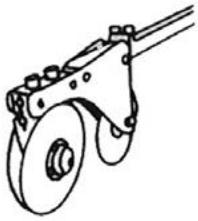
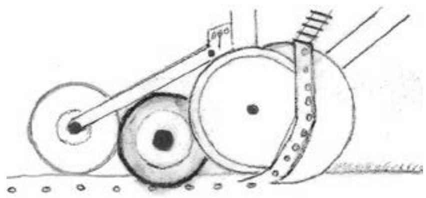
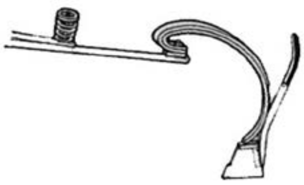
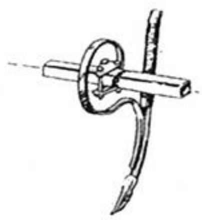
Rollers and press wheels are, in general, not recommended when sowing pasture. The exception is precision seeders with integrated press wheels; these have been designed to minimise soil movement. Light rollers may have a role in situations when the surface soil is drying, but in most situations are unnecessary. They should not be used if the surface soil is prone to crusting or in lighter soils where they may cause soil from the side walls of the furrows to collapse and bury the seed.

Direct drilled pasture paddocks are trafficable and less prone to erosion than conventionally cultivated seed beds.

Photo: B Clements

At sowing

Table 14.1 Seeding machinery options suitable for direct drilling pasture.

Ground or contour following machines		
	Disc Seeders (old style) Connor Shea Super Seeder Massey 500 Disc Seeder Shearer Disc Seeder Rock Hopper Drill	Not recommended for direct drilling Most machines suited to conversion with inverted "T" points Trash and sticks are a major problem for converted machines
	Triple Disc Drills Duncan 730/734 Multi-seeder	Good ground following and depth control Suitable in stony or tussocky ground Slot walls can become glazed in moist or heavy soils High maintenance costs due to the many bearings
	Single Disc No-Till Drills John Deere Simeato Baldan	Very precise depth control and seed placement but expensive Heavy machines; not suitable for sowing into wet dispersive soils
	Trailed Tyne Drills Baldan SA 3000 Caldow, Grassliner Begg TD 150	Good ground following and depth control Suitable in rocky or tussocky ground Grassliner & Begg seeders only available second hand
Rigid frame machines		
	Coil Tyne Seeders Connor Shea Coil Tyne Duncan Eco Seeder Agrowdrill Davimac Maxiseeder	Generally fitted with Baker boots Some have poor trash clearance High break-out strength of many tynes produce minimal tilth in light or moist soils
	Spring Release Rigid Tyne John Shearer Tyne Drill CSN Tyne Drill	"Inverted T" or bolt-on-points are options Rugged stump-jump action is very severe on points in rocky ground Slacken the break-out adjustment to the minimum to create adequate tilth
	Spring Tyne Drills Duncan 750 Till Drill Spring Tyne Combines	Ideal for sowing into basalt soils with lots of small, loose rock Flexible tynes can create excessive disturbance in friable soils

Coulters and residue managers

There are few cases where optional extras such as disc coulters and residue managers are likely to improve pasture establishment. The extra cost, plus maintenance requirements of these additional components may outweigh the benefits. Forward planning to avoid issues such as excessive residue is the recommended strategy. Experience has shown that the set-up of coulters is critical, for example if not properly lined up with the sowing furrow, two cuts are made in the undisturbed sod, making control of seed placement very difficult.

Sowing points for direct drill pasture establishment

Accurate placement of seed and contact with moist soil is vital to ensure the maximum number of sown seeds germinate and establish. The choice of sowing point is an important element, especially when direct drilling.

Direct drill points must be narrow with the leading edge no more than 6–10 mm wide. This ensures the sod is cut to create a narrow, protected furrow. Even 25 mm wide lucerne renovation points are unsuitable, as the leading edge is blunt. The sod breaks either side of the point and is turned out to leave an open, exposed furrow. Strips of 2.5–4.0 cm thick sod are flung aside and some land back in the furrow, burying the seed and preventing its emergence.

Baker boot

The Baker boot was the first direct drill point developed specifically for sowing pastures. The design was a revolutionary edge-on blade that incorporated wings at the bottom of the boot to create tilth and to throw most of the soil out of the furrow. This point is best described as an "inverted T" that produces a flat-bottomed furrow with a narrow surface opening. It creates a firm bed for the seed and protects the seedling from moisture stress if dry conditions follow sowing.

The Baker boot can be fitted to conventional tynes using an adaptor. High wear rate is a problem with such narrow points. Although the boots can be protected to some extent by hard-facing or tungsten bars, the unprotected parts of the point or blade wear rapidly in coarse soils and in time the protected parts are undermined and break off.

Caldow 'T' boot

The Caldow 'T' boot is a development of the Baker boot, designed to have less surface exposed to wear. It produces a 'V' shape at the bottom of the furrow and throws more soil out of the furrow than the Baker boot. The 'V' bottom is achieved by pitching the point forward so the leading tungsten tip is 6–8 mm lower than the rear of the wings. The wings then produce a mini seedbed at the bottom of the furrow with tilth scraped from the side walls.

To overcome wear problems in very abrasive soils, Caldow boots are made from high tensile steel with a tungsten bar on the leading edge and hard-facing along the wings (triple tungsten). It is recommended that wear is monitored and hard facing re-done as required.

Cast points

Baker boot and Caldow 'T' boot designs are available in hard wearing Ni-Hard alloy or high tensile steel. Although expensive per point they are a cost-effective option in most soils. Cast points are very resistant to abrasion and the low wear rate extends their life, saving time and maintenance costs. Cast points are not suitable in rocky soils.

A selection of commonly used cast points is shown below.

The design of cast points affects the patterns of soil flow and tilth. Left to right: Super seeder, lucerne point, Cast Caldow (mini T) and cast boot.

Super seeder points

Super seeder points are made of Ni-Hard cast alloy and have a sharp leading edge and an inverted 'T' shape that is wider than the Baker boot or Caldow designs. These points can be bolted directly onto most tynes, so there is no need for an expensive adaptor. On the negative side, their greater width means they throw more soil than the Baker or Caldow points. This can be a problem in some soils, particularly when sowing at fast speeds, as the rear row of tynes throw soil and cover adjacent rows sown by the front row of tynes. This problem can be partly overcome if Super seeder points on the rear row of tynes are replaced by narrow points (e.g. cast lucerne points).

Triple disc openers

Triple disc soil openers have a relatively low wear rate and provide accurate sowing depth. The leading coulter disc makes a vertical cut in the soil and the double discs form a 'V'-shaped furrow. The coulter disc should be set 5–10 cm deeper than the sowing discs.

At sowing

In wet soils with high clay content the discs may cause smearing and compact the soil at the bottom of the furrow, or leave the furrow open with the seed exposed. Fluted coulters can overcome some of these problems, but they tend to increase soil disturbance and leave a wider furrow.

Steel 'pick' points

Steel 'pick' points (or lucerne points) are inexpensive but they must be hard faced as wear and maintenance is excessive in most soils. These points perform best when used on light spring tyne drills where vibration assists in producing a good tilth. This set-up is suitable for sowing into stony, basalt soils.

Chisel points

Chisel points are wide (25–50 mm) and often fracture the sod along both sides of the point forming an open furrow, which can leave the seed exposed. When using these points, trailing chains behind each tyne is essential to cover the seed with soil.

Conventional sowing

Historically the conventional preparation of pasture seedbeds may have involved up to eight passes of cultivators such as chisel ploughs, scarifiers, off-set discs and harrows. Most seedbeds are now prepared with minimal soil disturbance, with the aims of preserving soil structure, conserving soil moisture and reducing the risk of erosion during the fallow period.

Cultivation is not recommended for shallow soils or steep slopes. If sloping paddocks are to be cultivated, reduce the risk of erosion by following the contour of the slope.

When preparing a cultivated seedbed the aim is to produce a weed-free, firm, fine seedbed with clods of less than 1 cm. Burying pasture seed under large clods or into 'fluffy' soil is a major cause of sowing failure in conventional seedbeds and is one reason seed is often simply dropped on the surface and 'covered' by light harrows or a roller. However, seed sown into a dry surface tilth, or worse still, exposed on the soil surface, is at risk from seed harvesting ants and desiccation after sprouting. Band seeders are strongly recommended when sowing into cultivated seedbeds.

When using a conventional sowing method, a fallow period of at least 10 weeks is required to achieve a fine seedbed and good weed control. This may require several cultivations and include use of herbicides to control hard-to-kill perennial weeds such as couch (*Cynodon dactylon*). Each cultivation should be more shallow than the previous one. Initial workings, preferably with tyned implements, will break up hardpans, increase water infiltration, but must cause minimal inversion of the subsoil. Secondary tillage work may be done with discs, tynes or heavy harrows. The aim of this secondary tillage is to even up the seedbed and to control germinating weeds. Ideally cultivate soil when it is moist to avoid damaging soil structure – avoid working dry soil and do not cultivate when the soil is wet. Wet soil is most susceptible to structural damage. Cultivating wet soil is an ineffective weed control option as weeds may be simply transplanted, not killed.

Rolling just before sowing may be useful and improve accuracy of seed placement. It will break up large clods and firm a 'fluffy' seedbed. However, do not use rollers after sowing on soils that are prone to surface crusting.

Benefits of conventional sowing

There are a number of situations where pasture establishment may be improved by sowing into a cultivated seedbed:

- in heavy clay or compacted soils;
- where the soil surface is very uneven as a result of pugging;
- where there are heavy infestations of tussocky grass; and
- if lime is to be applied. Incorporation of the lime by cultivation will achieve a much faster and more effective pH response, to the depth of cultivation, than if it was left on the soil surface.

Band seeders and conventional cultivation

A band seeder attached to the combine's small seed box or a stand-alone seedbox/band seeder/roller assembly is the recommended implement to use when sowing pasture into cultivated soil. A levelling bar should be used in front of the band seeder if the combine tynes are leaving ridges when working the soil.

The band seeder includes lengths of pipe or angle iron (arms) that support the drop tubes and create a shallow furrow for the seed. Each arm is hinged individually, which allows it to follow the contour of the ground so the seed is placed at an even depth across the width of the machine. The seed is covered by a thin layer of soil, which is dragged across the furrow by lengths of chain attached to the end of each arm. A rubber tyred roller pulled behind the band seeder may be used to firm the soil, improve seed-soil contact and aid germination.

Delay sowing until after autumn rains and control annual weeds, using a knockdown herbicide, just prior to sowing.
Photo: G Johnson

Broadcasting

In general, broadcasting, including aerial sowing, is a last resort option for establishing perennial pastures. When pasture seed is dropped onto the soil surface, weed control, excessive plant residue, ant theft and slug damage are all factors that can reduce pasture establishment. Broadcasting should only occur when soil moisture is 'adequate' and follow-up rain is expected. Seeding rates should be increased to account for seed theft and reduced seedling survival.

Broadcasting is a relatively cheap operation and can be a solution when a paddock is too wet for other methods of establishment. It is a method used to supplement existing pastures. For example, in moist coastal areas ryegrass and clover seed is often broadcast after the existing pasture, dominated by summer-growing perennials, is mulched or slashed to a height of about 1–2 cm. The method, also referred to as 'mulch planting', is not suitable for establishing species with less vigorous seedlings such as phalaris, cocksfoot, fescue and lucerne.

Aerial sowing is occasionally used to establish pastures in non-arable country but it is the least reliable method of establishing pasture. The economics of this operation and potential productivity gains should be properly costed.

Cover cropping

Cover cropping (also known as undersowing or companion cropping) is a common practice used to establish pasture. It involves sowing an annual grain crop with the pasture species, with the intention of harvesting the crop for grain. One of the main reasons for including a cover crop is to achieve income from the harvested grain to off-set the cost of pasture establishment. However, a cover crop will compete with pasture seedlings for moisture, nutrients and light; it reduces the size (and root system) of the perennial pasture seedling, as well as seed production from the annual legume component. The cover crop compromises pasture establishment and long-term productivity of the perennial pasture. Cover cropping is not recommended when sowing perennial grass species.

Recent results from the Future Farm Industries EverCrop experiments in the South West Slopes of NSW show that establishment of perennial pasture is affected by the choice of pasture species, cover crop sowing rate and seasonal conditions. The ability of the pasture species to recover from the crop competition and establish successfully is very dependent on climatic conditions during spring and summer of the establishment year. Therefore, the use of a cover crop increases the risk of poor pasture establishment, particularly in seasons of low rainfall.

The decision to sow with a cover crop or as a 'straight-sown' pasture (i.e. no cover crop) is likely to vary from paddock to paddock and often from season to season. It will also depend on factors such as the relative value of the grain versus livestock products, feed requirements of the livestock enterprise, feed availability and options to meet these. The EverCrop program included economic analyses that considered the financial value of the cover crop and its long-term impact on livestock productivity. The results highlighted that grain price and crop yield, stocking rate and livestock gross margin, and length of the pasture phase should all be considered in the decision to use a cover crop. The *Cover crop decision support* tool (DST) provides farmers with a simple tool to test the financial consequences of their approach to establishing pastures. To access the DST, please go to: https://www.csu.edu.au/research/grahamcentre/resources#horizontalTab2

The DST allows farmers to use their own information and experiences to check the trade-off between income from grain and the long-term impact on livestock productivity. The results indicate that cover cropping is not advisable when the pasture phase is intended to extend for more than four years, as income from harvested grain is unlikely to cover the cost of lost livestock production resulting from a long-term pasture phase disadvantaged by a cover crop.

Guidelines aimed at minimising the impact of cover crops on pasture establishment include:

- **Do not sow perennial grass species or chicory under cover crops**. The establishment of phalaris, chicory and sub clover is affected more by the use of a cover crop than it is for lucerne, even at low cover crop sowing rates.
- Sow the cover crop in alternate rows 30–35 cm apart and reduce crop sowing rates to one quarter of the normal rate. Do not reduce pasture sowing rates. Trial results show that lower crop sowing rates had little impact on grain yield but had a potentially large benefit on pasture establishment, particularly in dry years.
- Sow early in the sowing window when warm temperatures benefit the less vigorous pasture seedlings.
- Choose less vigorous, low tillering cereal cultivars that have an erect growth habit.
- Canola has been used successfully for lucerne establishment. Other cover crop options to consider are tap-rooted species such as late maturing forage brassicas or turnips.
- Delay nitrogen applications to limit early vigour and growth of the cover crop.
- Additional fertiliser is necessary to provide for the nutritional needs for both the crop and pasture. Apply extra phosphorus (5 kg/ha) and sulfur (5 kg/ha) to meet these needs
- Do not graze grain crops. Grazing must only be used to salvage the pasture if it is severely overgrown by the crop prior to harvest. It should be quick and concentrated, and delayed until the plants are well anchored. Salvage grazing should not occur if the soil is wet.

Cover cropping impacts on clover seed production and seed size

Even in favourable seasons, cover cropping reduces seed set of annual legumes and the size of the seed produced. NSW Department of Primary Industries research found that sub clover sown with a cover crop only produced 20–30 kg seed /ha (target is 100–150 kg/ha to ensure regeneration) and the seed produced was half the size of seed produced without a cover crop. Seed number and seed size of the annual legume component is crucial for regeneration in year 2 and long-term productivity of the pasture.

Nurse crops

Nurse crops include fast establishing annual species such as oats, which are added to a perennial pasture mix to provide protection (shelter) to the pasture seedlings. Nurse crops can be lightly grazed to provide feed in autumn and promote tillering of the establishing perennials. As is the case with cover crops, nurse crops compete with pasture seedlings and sowing rates must be reduced so that their overall effect may be positive. In many cases, it is better to sow a perennial pasture without an nurse crop, forego any autumn grazing, and instead focus on giving the pasture its best chance of establishment.

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15 Post sowing weed, disease and pest control

It is essential that new pastures are monitored to minimise the impact of weeds, disease and pests. Weed and pest infestations are the main reasons that emerging seedlings fail to establish.

Weed control in seedling and established pastures

Weeds cause more pasture establishment failures than any other factor. Regular, thorough paddock inspections are critical to ensure any weed problems are identified and addressed early.

Weed control in seedling grass-legume pastures

There is no herbicide available that will control grass weeds in a seedling grass pasture. Grass weeds must be controlled before sowing the pasture.

Broadleaf weed seedlings can be controlled using selective herbicides with minimal impact on pasture species if the principles below are followed:

- Use only herbicides registered for the target weed in the current situation;
- Use the registered rate;
- Control is most effective while the weeds are young and actively growing;
- Ensure legume seedlings are at least at the third trifoliate leaf stage, but before the eighth trifoliate leaf for some herbicides – check label recommendations;
- Ensure the temperature is appropriate for the herbicide used. For some herbicides there is increased risk of damage to legumes if used when temperatures are greater than 18 °C, e.g. bromoxynil and flumetsulam; and
- Herbicide applications late in the season will significantly reduce seed production of annual legumes.

Weed control in established grass–legume pastures

While there is a range of selective herbicides registered for broadleaf weed control in pastures, the options for grass control in grass-legume pastures are limited.

Spray topping of annual weeds such as capeweed, annual ryegrass, barley grass and vulpia with glyphosate or paraquat in Year 2 will prevent set seed and slow the build-up of these invasive weeds (see *Chapter 7 – Weed control prior to sowing*).

Always read the herbicide label and follow all directions and precautions to minimise any damage to the young pasture. Check and follow label recommendations for stock withholding periods.

Disease control post sowing

Identification of diseases is essential to determine appropriate treatments or strategies. Chemical control of disease of pastures is often expensive and is usually only used in specialist pastures, e.g. seed crops. The only option for many pasture situations is to minimise disease risk by selecting resistant or tolerant varieties, if available.

The impact of disease on can be reduced by techniques including the following:

- Maintain plant vigour and avoid stress by ensuring adequate moisture and nutrients;
- Avoid conditions that favour disease development. For example, tall, rank growth will increase humidity within the canopy and favour fungal diseases such as rust in ryegrass and phalaris.
- Grazing or harvesting slightly early can open up a canopy and remove diseased material. However, do not risk the spread of disease by moving stock from infected to disease-free areas.
- Practise good hygiene with farm equipment when travelling from diseased areas.

Pest control post sowing

Monitor your new pasture for signs of pest attack. Identify and treat early, if required.

Pest monitoring

Pest infestation can occur at any time, but plants are particularly susceptible during emergence and the seedling stages. Pastures should be checked for pests and signs of damage frequently, throughout the growing season. Commencing 2 to 3 days after sowing, newly sown pasture should be checked at least weekly in the first 3 to 4 weeks.

For more information on the major pests of establishing pastures see *Chapter 8 – Pests of pastures*.

Beneficial insects in pastures

Beneficial insects occur naturally in pastures. These natural enemy species are mobile and move freely across the landscape. They can be very effective in reducing pest populations.

Pesticides can be used to rapidly, reliably and, in most cases, to economically control a wide range of pests. However, they can have a negative impact on beneficial insect populations, and may result in the development of pesticide resistance and outbreaks of secondary pests. However, even when beneficial populations are present and resistant cultivars have been used, there are situations where pesticides provide the best option to suppress pest populations.

It is important to reduce reliance on pesticides and minimise adverse effects on populations of beneficial insects by adopting an integrated pest management approach (IPM – outlined in *Chapter 8*).

Spiders

Spiders are opportunistic predators that target many species of insect, including heliothis, cicadellids and aphids. Although they are commonly found in pastures, the populations are slow to build up and so have limited capacity to respond to pest outbreaks. Spiders are sensitive to most commonly used pesticides.

The orb-weaver spider.

Photo: NSW DPI

Predatory beetles

Beetles dominate the ground layer of pastures. The most important families are ground beetles (*Carabidae*), rove beetles (*Staphylinidae*) and ladybirds (*Coccinellidae*). The majority of species in these three families are predators of pasture pests. Ground beetles are very susceptible to pesticides and other environmental pollutants.

Ladybirds (Coccinellids)

The adult and larval stages of ladybirds are voracious predators. Many species are recognised for their ability to regulate aphid populations in lucerne and have been shown to keep spotted alfalfa aphid and pea aphid populations well below economic thresholds. Some ladybird species are also predators of thrips, pest moths and butterflies.

Ladybird species appear to be more tolerant of pesticides than other predatory insects.

The adult and larval forms of ladybird (*Coccinellids*).

Photo: L Turton

Damsel Bug (Nabis kinbergii)

Damsel bugs are slender insects with grasping front legs. Both the nymphs and adult forms are predators. They feed on insects such as aphids, leafhoppers and small caterpillars, but favour the eggs and larvae of moth and butterfly pests.

Adult damsel bug.

Photo: L Turton

Brown lacewing (Micromus spp.)

Brown lacewing larvae are important predators of aphids.

Brown lacewing attacking an aphid.

Photo: L Turton

Care when using pesticides

The negative impacts of pesticides can be moderated by their judicious use including:

- use of selective 'soft' pesticides when available;
- attention to timing, method and rate of application.

Pest control thresholds

Before undertaking a pesticide spray program consider whether control of the pest is necessary and if removal will have an economic benefit.

Thresholds fluctuate depending upon a number of factors. Consider the following when making the decision to use pesticides:

- environmental conditions and the 'condition' of the pasture;
- the extent and severity of the pest infestation and how quickly the population is increasing;
- prevalence of natural control agents such as parasitic wasps, predatory shield bugs, ladybirds and diseases;
- type and location of pest damage and whether it affects pasture yield indirectly or directly;
- stage in the life cycle of the pest and the potential for further damage;
- growth stage and capacity of the pasture to compensate for damage; and
- the amount of damage which has already occurred and the potential for further damage if a pesticide is not used.

16 Grazing management

Grazing management refers to the process of managing the frequency (i.e. how often) and the intensity (i.e. stocking density) with which grazing is applied to the pasture. Sound grazing management of establishing pastures is essential for their long-term productivity and persistence.

Grazing pastures in the first year

Perennial pastures are most vulnerable during the establishment phase and during drought. Inappropriate grazing at these times can adversely affect persistence.

- Do not graze perennial grass pastures that are less than 12 months old if they are moisture stressed.
- Do not graze new pastures when conditions are very wet to avoid damage from trampling and pugging.
- Newly sown pastures can be grazed when they are at least 10 cm tall, provided there is adequate soil moisture to depth. Before introducing stock, test by gently tugging representative plants, to ensure the plants are well anchored and won't be pulled out by grazing stock.
- Newly sown pastures should always be allowed to set seed in the first year. This not only provides seed for regeneration, but also encourages development of the root system.
- Never make hay or silage from pasture in the first year.

As a general rule new pastures should not be grazed in the year of establishment. However, a short period of grazing in spring can be beneficial and enhance tillering, provided that conditions are favourable. Graze the pasture to a height of no less than 5 cm using sheep or young cattle (e.g. weaners), while the plants are actively growing and leafy. Achieve even grazing across the pasture by using large numbers of stock for short periods (2 to 3 days, or less). Avoid overgrazing as this puts plants under considerable stress and they may not recover.

If newly sown pasture is grazed, stock must be removed before seed heads form. Stock should not be re-introduced until the following autumn, before 'the break', when the pasture can be grazed down to a height of 5 cm. They can then be grazed intermittently throughout autumn and winter. (See *Appendix 5 – Grazing systems*)

Grazing established pastures

Grazing management should be reviewed routinely and considered in combination with other management tools such as weed control and fertiliser application. Perennial pasture species vary in their response to grazing. Therefore, knowledge of how the different pasture species respond to grazing and soil fertility, as well as specific nutrient requirements, is essential to optimise persistence and production.

Nutrition

The ability of perennial plants to recover from stresses such as drought and grazing pressure will be compromised if other constraints are not addressed. Nutrient deficiencies and low fertility are among the main factors that limit recovery (see *Chapter 4 – Soil testing*, *Chapter 9 – Fertiliser at sowing* and *Chapter 17 – Fertiliser requirements*).

Grazing pressure

Determining the carrying capacity of an area and the most appropriate grazing strategy are among the most important management decisions. Paddock variability means that grazing regimes and stock classes need to be carefully matched to land class and capability (production potential) in order to avoid issues of overgrazing, and to optimise pasture utilisation.

Both understocking and overstocking can affect the persistence of desirable species. This is accentuated in set stocking systems where a pasture can be understocked but overgrazed. The ability of animals to selectively graze the more palatable species is greatest at low stocking rates. Stock will leave the less desirable species and weeds ungrazed. Over time the less palatable species dominate and the overgrazed, more nutritious species become less competitive for light, moisture and nutrients and are likely to die.

Rest periods

Continual defoliation weakens all plants and therefore, an adequate rest period should be included in all grazing programs. It is very important for the productivity and long-term persistence of perennial pastures. During the rest period perennial plants accumulate leaf area, rebuild photosynthetic capacity and replenish root energy reserves.

Botanical composition

Grazing management should aim to maintain a balance of grass and legume species and keep weeds under control. Ideal botanical composition of a perennial grass-based pasture in spring is:

- 60–70% perennial or sown grass
- 20–40% legume
- less than 20% annual grass
- less than 10% broadleaf weed
- near 100% ground cover.

Grazing management strategies that will assist in maintaining a balanced pasture include:

- Rotational grazing, which is essential for the persistence of lucerne, is also beneficial for other perennial pasture species.
- While set stocking (continual defoliation) in spring may have no adverse effects, continual defoliation in late summer/autumn, when perennial plants are often under moisture stress may lead to their death. However, during periods of moisture stress a light grazing of summer active pasture species, such as lucerne and chicory, will reduce leaf area and may assist their survival.
- Paddocks should be de-stocked during extended dry periods or droughts. It is important to maintain ground cover for soil protection and to protect perennial grasses from desiccation.
- Resting or very light grazing of a pasture at critical periods of a desirable species' growth cycle will allow these to set seed for recruitment. For example, rest or light grazing of ryegrass or cocksfoot in late spring and again in autumn will encourage seed set and enable new seedlings to establish.
- Paddocks with variable topography and a combination of aspects are susceptible to overgrazing. They should not be continuously stocked as this can result in selective grazing and degradation on areas of the paddock. For example, during winter stock are likely to concentrate on warmer, north-facing slopes. The pasture in these areas is likely to be overgrazed, while pastures on the cooler, southern aspects will become rank and unpalatable. Fencing to aspect will assist in overcoming this problem.
- High stocking densities in spring can prevent grass dominance, reduce seed set of annual grass weeds and encourage legume seed production.
- Grazing for short periods at high stocking densities will force stock to eat plants they may otherwise avoid. This strategy can prevent weed build up and remove low quality pasture residue over summer or early autumn.
- The 'spraygraze' technique is effective in controlling many broadleaf weeds without damaging sown species (see *Chapter 7 – Weed control prior to sowing*).

Note: *Consider enrolling in a PROGRAZE® course for more information on using grazing management to ensure productivity, persistence and optimal pasture utilisation.*

Grazing lucerne stands in the first year

Avoid grazing lucerne in the first year of establishment, until it has reached full flower. However, earlier grazing or mowing may be necessary under exceptional circumstances, e.g. if weed competition has been severe or if plants become moisture stressed.

A winter or early spring grazing may also be necessary for lucerne that has been sown with a vigorous, dense cereal cover crop. This will allow light to reach the lucerne seedlings and promote development. In order to minimise competition, it is recommended that the cover crop sowing rate be cut to one quarter of the normal rate. For more information on the use of cover crops, see *Chapter 14 – Sowing techniques and machinery*.

A short period of grazing may be necessary following crop harvest, to help disperse crop stubble. This should be followed with a rest period until the lucerne reaches full flowering. Subsequent grazing management is outlined below.

Grazing established lucerne

In order to maintain a vigorous, persistent lucerne stand it is essential that grazing is alternated with a rest period. The rest period is the key to lucerne management. The plants draw on essential root energy reserves in the early regrowth period, and are at their lowest 2 to 3 weeks after grazing. During the rest period the plants regain leaf area, the root reserves are replenished and peak at full flower.

Periods of grazing should be in the range of l to 3 weeks, followed by, as far as is practicable, rest periods of 5 to 6 weeks. For example, if lucerne is grazed when the stand is at 10% flower, it takes about 35 days in the warmer months to replenish root reserves to the level prior to grazing. The rest period should be extended in winter. Note that high temperatures and moisture stress shorten the period to reach flowering and reduce the plants' ability to accumulate root reserves.

As a general rule, remove stock when lucerne is 5 cm high in order to preserve basal buds and retain some leaf. This allows rapid regrowth and recovery. Grazing lucerne during winter will remove the growing point at the top of the plant and reduce spring and summer production.

Continuous stocking can cause a rapid decline in plant numbers. The heavier the stocking rate, the more rapid is plant death, as constant removal of new shoots quickly depletes root reserves, especially when growing conditions are unfavourable.

Moisture stressed lucerne plants will drop leaves, in which case it is preferable to graze the stand before leaf is lost, rather than waste feed.

The following management practices may improve productivity and persistence of lucerne stands:

- Do not graze until newly sown lucerne is well established (full flowering).
- Allow lucerne to flower and replenish root reserves whenever possible, and ideally before stress periods. For example, a period of recovery during spring, when there is ample alternative paddock feed available, ensures root reserves can be fully replenished at the start of the summer/autumn period. This will improve the plants ability to recover from heat stress and prolonged dry periods, typical of this period.
- Rotational grazing with strict management of the rest and grazing intervals is essential to optimise production and persistence.
- Persistence will generally be better where cattle are grazed in preference to sheep and where stocking density is low to moderate.

Note: *Grazing management should also consider the requirements for livestock health, especially in relation to bloat, redgut, fertility etc. See Chapter 18 – Livestock health, for more details.*

Maintain a competitive pasture

Grazing management and adequate nutrition will help maintain a competitive pasture. This is the key to weed control.

A competitive pasture will limit the growth and seed set of any emerging weeds. Maintaining ground cover reduces the opportunity for invasive weeds, such as capeweed (*Arctotheca calendula*) or white heliotrope (*Heliotropium europaeum*), to occupy bare ground.

Overgrazed pastures are not competitive. They allow weed populations to build-up and dominate over time. Maintaining ground cover and rotationally grazing (rather than set stocking) may save on costly herbicides or pasture re-establishment in the long term.

Ensuring that pastures have adequate nutrition not only allows the pastures to better compete with weeds but also increases the production and feed quality of the pasture.

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17 Fertiliser requirements

A well planned fertiliser program is one of the best on-farm investments, when it is combined with sound pasture and livestock management. The long-term persistence and vigour of a sown pasture is dependent on adequate nutrition. Healthy, well fertilised plants tend to have deeper root systems and are better able to cope with environmental stresses and grazing pressure than nutrient deficient plants.

Fertiliser requirement is closely related to the intensity of production. As stocking rate and production (and therefore, product removal) increases, the demand for nutrients will also increase.

How much fertiliser to apply

The amount of fertiliser applied will depend on whether the objective is to maintain the current fertility levels and so hold the paddock at a constant soil test level, **or** increase soil fertility over time.

'Maintenance fertiliser' applications hold soil fertility at a specific level by ensuring nutrient inputs match nutrients exported in animal products, accumulated in stock camps, lost in run-off, or bound in organic materials or the soil inorganic cycles.

Regular soil testing is essential to monitor nutrient trends over time and to check that fertility levels are not falling and impacting on the production. Soil sampling should be carried out at the same time of the year, avoiding very wet, cold periods. Ensure an interval of at least six months between fertiliser application and soil testing (see *Chapter 4 – Soil testing*).

Maintenance fertiliser rule of thumb:
For each DSE/ha allow
1 kg P/ha plus 1 kg S/ha each year

The guidelines developed for the 'Five Easy Steps' information package provide a framework to refine fertiliser programs, and focus on improving the efficiency of applied fertiliser by matching fertiliser rates to soil type, growing season and stocking rate (Simpson et al 2009). Soil testing and 'critical' soil fertility levels are used as to determine whether the fertiliser applied is likely to produce a pasture response. For example, the critical P value that will achieve 95% of potential pasture production, for the Bray P test is 25 mg/kg, the Olsen P test is 15 mg/kg soil, while the value for the Colwell P test varies depending on soil type and phosphorus buffering index (see the 'Five Easy Steps' information package for more detail). While the focus of the program is on P requirements for legume-based pastures, the process can be applied to management of other limiting nutrients.

When soil tests indicate nutrient levels are below the critical values, there is potential to significantly increase pasture and animal production by applying additional fertiliser, above the amount required for maintenance. These additional, 'capital applications' will increase soil fertility up to a point where it reaches a critical level, above which there will be no further pasture response. Once the target critical level is reached, it is then possible to revert to maintenance fertiliser applications and maintain production at the new, higher level.

Research by Watson et al (2000) has shown that in low fertility situations, pasture production can decline by 30% if fertiliser is not applied for 1 year, by 50% when it is not applied for 2 years and by 70% if it is not applied for 3 consecutive years. Much of this production loss is due to reduced legume growth, which declines quickly when P and/or S levels fall below critical levels. Decreased nitrogen inputs from the legumes in turn reduce the growth of the non-legume component, and there is a gradual decline in pasture quality. Weed populations increase as pastures become less vigorous and some perennial species may be lost, resulting in pasture instability and further loss of production potential.

Follow-up with maintenance fertiliser applications is needed for development and persistence of new pasture.

Photo: L. Turton

Prioritising paddocks for fertiliser

The best value for your fertiliser dollar will be achieved with a program that uses soil test information to prioritise fertiliser applications at the paddock level, as outlined in the 'Five Easy Steps' program. A 'blanket' fertiliser program across the whole farm is inefficient and carries the risk of over-fertilising some areas and under-fertilising others. The following are guidelines to help prioritise pasture paddocks for fertiliser application:

1. **Recently established pastures**
   Recently established pastures should be a top priority. They are costly to establish and are reliant on fertiliser inputs for development and persistence.
2. **Special purpose pastures**
   Product removal is greatest from specialist pastures used for fattening, weaning, lambing, hay/silage making or where large numbers of stock are run (e.g. close to shearing shed or yards). These areas will therefore need relatively high fertiliser inputs to maintain their soil fertility.
3. **Older sown perennial pastures**
   There is opportunity to improve the production and persistence of established pastures in paddocks which have low soil fertility, provided there is a reasonable density of desirable pasture species.
4. **Other pastures**
   Areas with low to moderate soil fertility have potential for increased production as soil test values are increased to critical levels, provided they contain legumes.

The lowest priority areas for fertiliser application include:

- paddocks with a long fertiliser history and high levels of P, S and K;
- pastures dominated by undesirable and weedy species such as Paterson's curse, thistle and vulpia; and
- native pastures containing no legume.

When to apply fertiliser

Timing of fertiliser application is important to improve nutrient use efficiency and to minimise environmental risks. Aim to:

- minimise fixation of applied P. Avoid topdressing in winter – cold, wet acidic soils absorb large amounts of applied P, thereby reducing availability to plants.
- minimise the risk of nutrient run-off into waterways. Avoid spreading fertiliser onto areas with poor ground cover, especially in summer where high intensity storms can generate large volumes of run-off.
- maximise pasture growth at critical times. The ideal is to ensure nutrients are readily available, therefore time applications to coincide with new pasture growth. This may be from late spring to early autumn and will vary with fertiliser type, location and pasture type.

Fertilisers and the environment

Algal blooms in dams and waterways have been linked to excessive use of P and N fertiliser and erosion of nutrient-rich soil. An environmental stewardship approach and a fertiliser program that matches inputs to production and environmental targets will minimise the impact of agriculture on water quality.

Algal bloom in dams and waterways can be avoided by prevention of nutrient run-off.

Photo: NSW DPI

Fertiliser DOs

- conduct a soil test to determine the nutrient status before investing in fertiliser
- follow the guidelines of 'Five Easy Steps'
- start with the most responsive paddocks based on soil test results, soil type, pasture type, production targets and landscape features
- utilise existing feed, while maintaining ground cover targets
- adjust stocking rates to utilise extra feed produced in fertilised pastures
- avoid applying fertilisers in cold, wet conditions or when heavy rain is expected within the next three days
- maintain a buffer of 10–30 m with waterways (depending on slope and riparian vegetation)

- apply fertilisers when pastures are actively growing
- keep paddock records (fertiliser rate and type applied, date and paddock stocking rate).

Fertiliser DON'Ts

Fertiliser should not be applied to:

- bare soil
- drainage lines, waterways and riparian zones
- non-responsive native species e.g. kangaroo grass
- stock camps.

Fertiliser types

Manufactured fertilisers

Phosphorus fertilisers are manufactured using phosphate rock which is found in deposits throughout the world. Single superphosphate is manufactured by adding sulfuric acid to finely ground rock phosphate, which is then granulated.

Compound fertilisers (those containing different proportions of N, P, K and S) are manufactured by mixing phosphoric acid, sulfuric acid, ammonia, muriate of potash and/or sulfate of potash in proportions appropriate to each product.

Trace elements such as molybdenum, boron, copper and zinc can also be added to meet particular needs.

Organic fertilisers

There are many commercially available organic and organic-based fertilisers. All are derived from plant or animal materials, either solely (organic) or substantially (organic-based). The collective term for products made from food residues, organic matter, municipal wastes and biosolids is 'recycled organics'. Other organic products include animal manures, fish preparations, and blood and bone. Several of these are composted in order to increase their stability.

Some organic-based products, which are primarily organic, have had their nutrient content increased by the addition of inorganic fertilisers. Most of the nutrients in these products are in an organic form, which must be broken down to the inorganic form before they are available to plants. Therefore, nutrients in organic fertilisers are available more slowly, over a longer period, than those in most manufactured fertilisers. This may be a disadvantage when plants have an immediate need for nutrients, but it is an advantage in situations where there is risk of nutrient leaching.

Green waste is often processed into compost.

Photo: L Turton

Once organic nutrients are converted to inorganic forms in the soil there is no longer any distinction between sources of supply. Therefore, in the long-term the excessive or inappropriate application of organic fertilisers can be as harmful to the environment as the unsound use of manufactured fertilisers.

Organic fertilisers generally have a variable and low content of the major nutrients N, P and K. Unless boosted with manufactured fertiliser, they need to be used in large quantities. Organic fertilisers are bulky and generally not pelletised and this makes them costly to transport and spread. Because of the generally limited supply and frequently higher cost per unit of the major nutrients, it may be prohibitively expensive to fully replace manufactured fertilisers with organic fertilisers.

Refer to *Comparing fertiliser cost example* in *Chapter 9* to compare the cost of fertilisers, based on the cost per kilogram of the nutrient(s) required by your pasture.

Biosolid products

Biosolids are the nutrient-rich organic materials produced by the municipal waste water treatment process, and were previously referred to as sewage sludge. Biosolid products include dewatered biosolids.

Dewatered biosolids offer a nutrient-rich alternative to conventional inorganic fertilisers. They are high in organic matter (40–60%), contain nitrogen (2.9–5.1%), P (1.0–4.2%) and other smaller amounts of Ca, K, Mg, S and Zn. The nutrients are slowly 'released' and available to plants.

Biosolids can contain microbiological and heavy metal contaminants. However, regular testing of all biosolids is conducted and any product that exceeds the allowable limits under the Environmental Guidelines is not available for use in agriculture.

Note: *An environmental impact assessment is mandatory for all sites, before any land application of biosolids.*

An environmental impact assessment must be carried out before spreading biosolids.

Photo: L. Turton

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18 Livestock health

An increase in the incidence of certain livestock health disorders may be associated with introduced pastures and pasture improvement. Livestock and production losses from some disorders may occur and management may need to be modified to minimise risk. Consult your veterinarian for further advice.

Livestock disorders associated with introduced pasture species

Some of the more common animal disorders associated with improved pastures are presented below. The references listed on the next page provide information and guidelines to manage or avoid production losses from these disorders.

Bloat

Most legume species including clovers, lucerne and medics have the potential to cause bloat when ruminants graze young, lush legume-dominant pastures. Bloat is a major problem in cattle but it can also occur in sheep. Animals with mild bloat can be treated orally with anti-bloat preparations, while moderately and severely affected animals will show signs of distress and will require urgent veterinary attention. There are a number of preventative measures available and these should be discussed with your veterinarian or livestock advisor.

Cow showing symptoms of bloat.

Photo: C Begg

Oestrogen in clovers

'Clover disease' causes infertility in sheep. Pasture containing clover plants with moderate to high levels of the natural oestrogenic plant substance, formononetin, can inhibit conception. Long-term exposure can result in permanent changes to reproductive organs. Some older varieties of sub clover (e.g. Yarloop and Dwalganup) and red clover (Grasslands Hamua and Grasslands Turoa) are particularly high in oestrogen. Most new varieties are selected for low formononetin content.

Grass tetany

Grass tetany is a complex disorder affecting cattle, in which many factors contribute to low blood magnesium levels (hypomagnesaemia). Grass tetany particularly affects animals in late pregnancy or early lactation. It can be a seasonal risk for stock, especially breeding cattle grazing young, actively growing, grass-dominant pastures or cereals in late winter and early spring.

Nitrate poisoning

Under certain environmental conditions certain plant species accumulate high levels of nitrates. This usually occurs when actively growing plants are stressed due to frost or a lack of moisture. Prolonged cloudy weather can be another contributing factor. Nitrate concentrations are usually higher in young plants and rapidly decrease as plants grow and mature. Although grazing animals usually adapt to changes in nitrate concentration, high concentrations can cause nitrate poisoning and death.

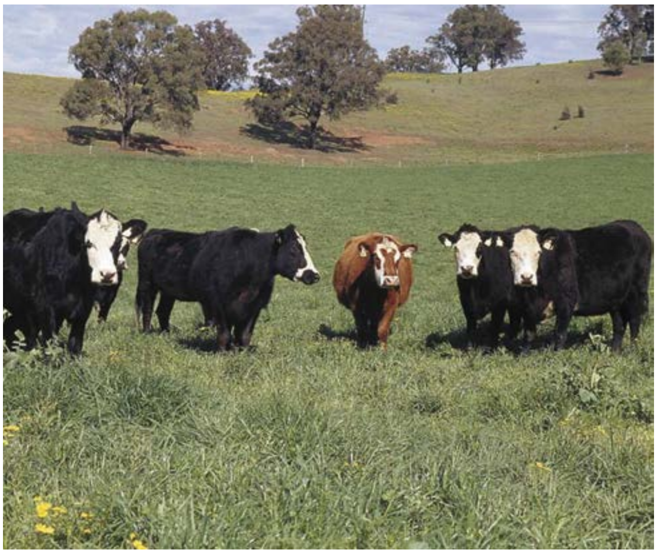
Phalaris poisoning

Sheep tend to be more susceptible to phalaris poisoning than cattle. While some phalaris varieties have been selected to reduce the risk, all varieties have the potential to cause poisoning, both the 'sudden death' and 'staggers' form. In areas with a history of the problem, selecting low risk varieties may reduce the risk of poisoning. Staggers can be avoided by administering cobalt bullets. 'Sudden death' is more likely to occur when animals graze young, moisture stressed phalaris.

Photosensitisation

Photosensitisation is an ailment in which the skin becomes abnormally sensitive to bright sunlight after stock have eaten certain plants. Severe skin damage may result. Some weed species such as St John's wort (*Hypericum perforatum*) cause primary photosensitisation. Others, such as witchgrass (*Panicum capillare*), sweet grass (*Panicum laevifolium*), caltrop (*Tribulus terrestris*) and possibly heliotrope (*Heliotropium europeaum*). Paterson's curse (*Echium plantagineum*) and lantana (*Lantana camara*) can also cause liver damage and possibly secondary photosensitisation.

Photosensitisation has also been observed in sheep grazing the introduced legume biserrula (*Biserrula pelecinus*). The photosensitisation has commonly occurred in late winter and early spring with sheep grazing pasture containing a high proportion of biserrula that is actively growing and close to flowering. Lambs and freshly shorn sheep are reported to be more susceptible to photosensitisation.



Careful planning and preventative management will minimise production losses caused by animal health disorders on improved pastures.

Photo : G Johnson

Pulpy kidney

Pulpy kidney (enterotoxaemia) is a constant risk for stock grazing high quality, lush pastures and the risk increases when animals have a sudden change in diet. Pulpy kidney can be readily prevented by making sure stock are up to date with their 5-in-1 clostridial vaccination during the danger period, when pastures are young and actively growing.

Ryegrass staggers

Ryegrass staggers is associated with endophyte fungi living in the leaf, stem and seed of perennial ryegrass. The endophytes produces neurotoxins, which affect sheep, cattle, deer and horses. Other symptoms that may develop before staggers appears are ill-thrift in young stock, heat stress, scouring and reduced fertility. Outbreaks are more common in summer and autumn when animals are grazing a low herbage mass close to the ground. Affected animals will recovery after being removed from toxic pastures, but severely affected animals will need particular attention. Hay and silage from affected pastures can also cause staggers.

Endophytes occur naturally in perennial varieties of ryegrass and tall fescue. They can benefit the infected plants by improving seedling vigour, tillering, seed production and resistance to drought and some insect pests.

Red gut

Red gut, or haemorrhagic enteritis, can be a major cause of mortality in young sheep, particularly merinos, when grazing lush, legume-dominant pastures. It is sometimes confused with pulpy kidney, as both disorders are associated with sudden dietary changes or unrestricted access to lush, green feed. Red gut is most commonly seen when the pasture is in the vegetative stage, growing rapidly, is highly digestible and has low fibre content. Sowing pasture mixes that include grass species will reduce the risk of red gut.

Selenium deficiency

Selenium deficiency is associated with acidic basalt/granite and sandy soils, in high rainfall areas and clover-dominant pastures. Livestock symptoms include ill-thrift in young stock, white muscle disease and infertility. Management options include selenium supplementation of animals or topdressing with selenium-enriched fertiliser.

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Appendix 1 Assessing species composition and ground cover

The two methods recommended for measuring the species composition and/or ground cover percentage of your pasture are the step point method and the pointed stick method.

1. The step point method for species composition

This method involves making observations and recording plant species at points at specified intervals along a straight path. Make a mark on the toe of each of your boots. Next, take 200 equally spaced steps through the pasture, along a fixed bearing or towards a landmark to ensure a straight line. At each point, look at what the mark on your boot is touching and record desirable perennial plants, legumes, annual grasses, weeds, litter, bare ground or other. The process is repeated 50–100 times throughout the paddock. For large paddocks, this should be done in several locations to ensure that you get a representative assessment.

2. The pointed stick method for species composition

The method is undertaken using a 1 cm thick dowel about 30 cm long with pointed ends – or a nail can be driven into each end of the stick. It is randomly thrown across the paddock and the plants that are nearest the ends of the stick are recorded. The process is repeated 50–100 times throughout the paddock. Fifty observations of a double-ended stick will give you 100 observations (hits) and the composition can be easily recorded as a percentage. The total hits for each pasture component, divided by the total number of hits, indicate the percentage of each species in the pasture. Note that this method is not suitable in pastures of varying height as the stick will bounce off tall plants and you will not get a representative assessment.

The pointed stick method provides an assessment of pasture composition at randomly selected sites across a pasture.

Photo: B Stein

The pointed stick method is not an accurate method for tall pasture. The stick will bounce off tall plants.

Photo: B Stein

The recording sheet on the next page may be used to determine pasture composition and ground cover. In this example, 100 observations were made across the paddock. The number of times each plant species is encountered is recorded by making a mark next to the appropriate category and the percentage of each category can then be calculated based on the total number of observations.

You may want to categorise species or look at them individually. For example, you may wish to group all undesirable species as 'weeds', group all perennial grasses (introduced and native species) together, and group annual grasses together.

Species											Total
Perennial introduced grass: e.g. cocksfoot, phalaris	卌	卌	卌	卌	卌	卌	卌	IIII			39%
Perennial native species: e.g. danthonia, kangaroo grass, red grass	卌										5%
Legume: clover or medic	卌	卌	卌	卌	II						22%
Annual grasses: e.g. barley grass, vulpia	卌	卌	IIII								14%
Broadleaf weeds	卌	卌	卌	I							16%
Litter											0
Bare ground	IIII										4%

Appendices

Appendix 2 Benchmark levels typical of soil test results from the NSW Tablelands

Levels relate to 0–10 cm soil sampling depth

Chemical property (test method, units)	Low	Medium	High	Comments
pH_{Ca} (calcium chloride method)	less than 4.8	4.8 to 6	greater than 6	Actual critical value depends on plant tolerance and location.
Aluminium** Expressed as % of exchangeable cations	less than 5	5 to 15	greater than 15	Actual critical value depends on plant tolerance, age of plant and location of Al in the soil profile. **High values are undesirable.**
Phosphorus (Colwell method, mg/kg =ppm) These values only apply to low PBI soils(<140)	less than 20	20 to 30	greater than 30	Critical values are higher for high PBI soils and lower for low PBI soils.
Sulfur (KCl 40)	less than 6	6 to 8	greater than 8	Organic matter recycling and leaching in high rainfall areas influence values.
Cation exchange capacity (me/100 g)	less than 3	3 to 6	greater than 6	A measure of general fertility.
Sodium** Expressed as % of exchangeable cations	less than 2	2 to 5	greater than 5	**High values are undesirable.**
Organic carbon (Walkley Black, %)	less than 1.5	1.5 to 3	greater than 3	Multiply by 1.7 to convert to organic matter level
Potassium* (Colwell K, mg/kg)	Critical value depends on soil texture. Values are the values to achieve 95% of predicted maximum pasture yield			Responses unlikely unless P is high. Use of test strips is recommended
	139 Sandy loam	143 Sandy clay loam	161 Clay loam	
Electrical conductivity (1:5)	Critical value depends on soil texture			

* *Gourley C, Melland AR, Waller RA, Awty IM, Smith AP, Peverill KI and Hannah MC (2007) Making Better Fertiliser Decisions for Grazed Pastures in Australia. Victorian Government Department of Primary Industries*

** *High values are undesirable*

Based on: Clements B, McCormick L and Keys M (2010) LANDSCAN™: Landscape and Soil Test Interpretation for Sustainable Pasture and Land Management – Workshop Manual. 4th ed. Industry and Investment NSW

Appendix 3 Calibrating a boom spray

Calibration procedure

Boom sprays should be calibrated regularly to check that application rates and flow distribution are accurate. Regular calibration ensures cost-effective application of pesticides and that the desired amount of chemical is hitting the target. The following templates will enable you to calculate how much chemical and water to use.

Part A: General information		Part B: Recording	
Equipment to be calibrated		Minimum water application rate (i.e. label recommendation)	L/ha
Spray tank capacity	L ❺	What chemical rate is to be used?	L/ha ❹
Area to be sprayed	ha ❼	Select an appropriate ground speed	gear rpm km/h ❸
Chemical used		Record spray operation pressure	kPa or bar
		Record nozzle type and size	mL/min
		Rated output	
		Record minimum boom height above target	cm

Part C: Measuring								
Record the output for every nozzle for 1 minute (L/min)								
1	2	3	4	5	6	7	8	Total spray output (add all nozzles) ❶
9	10	11	12	13	14	15	16	
17	18	19	20	21	22	23	24	
Replace nozzles that vary from +/– 10% (from stated output)								
Record actual effective spray width (metres)				m ❷				

Part D: Calculating			
Actual **ground speed***	distance covered (m) × 3.6 / time taken (seconds)	( ) × 3.6 / ( )	= ________ km/h ❸

* Determine actual ground speed by measuring a set distance, say 100 metres, under similar conditions to the area to be sprayed and timing how long it takes using the pre-determined speed (gear and engine revs)

❶ **Total spray output** (L/min) ❷ **Effective spray width** (m) ❸ Actual **ground speed** (km/h)

Water application rate	❶( ) × 600 / ❷( ) × ❸( )	( ) / ( )	= ________ L/ha ❻
Chemical rate	= ________ L/ha ❹	**Spray tank capacity**	= ________ L/ha ❺
How much chemical to mix in each tank?		❹( ) × ❺( ) / ❻( )	= ________ L
How many tank loads are needed for the job?		❼ ha × ❻ L/ha	= L of spray mix ❽
		❽ L ÷ ❺ L	= ________ tanks

Source: SMARTtrain Calibration and Records Supplement 2010

Appendix 4 Calibrating a seeder

Setting up and calibrating the seed drill before the sowing season is time well spent. It is the only way to achieve accurate seed placement.

Eight steps to setting up and calibrating a seeder

1. Seeder levelling

Adjust the machine on a level surface to ensure all tynes are sowing at the same depth. If Caldow boots are fitted, ensure the "heel" of the boot is 6–8 mm higher than the front tip.

2. Coulter alignment

If coulters are fitted to the machine alignment must be checked regularly. Pull the machine through the soil to check alignment. If alignment is out, raise the machine, slightly loosen the nuts on the coulter assembly and re-position the coulter using a straight edge and a heavy hammer. Re-tighten and re-check with the machine in the ground.

3. Calibration

Always calibrate both the seed and fertiliser box(es) in the workshop area using a jack and rotating the drive wheel.

A hessian bag can be tied to each tyne to collect product during seeder calibration.

(i) Determine the number of wheel revolutions required to travel 100 m using the following formula:

revolutions = 16 ÷ wheel radius (m)

You will need to measure the radius of the wheel which is the distance from the centre of the wheel to the outside edge of the tyre.

(ii) Turn the drive wheel a few turns to ensure the seed or fertiliser is flowing down all tubes.

(iii) Place a tarp under the seeder (or buckets or bags under the hoses), then rotate the wheel the number of revolutions required to travel 100 m. Some of the newer pasture seeders are fitted with special features to divert seed into trays for easy and accurate calibration.

(iv) Check to see all tubes have delivered similar amounts then collect and weigh the total amount of material.

(v) Compare the result with the amount required which is easily calculated using this simple formula:

Amount (kg) =
[sowing rate (kg/ha) x machine width (m)]
÷ 100

(vi) The calibration should then be checked in the paddock to be sown. This is done by placing bags over the seed and fertiliser tubes while the machine is dummy sowing.

The next four adjustments (4–7) must be made in the paddock after operating the machine at the speed you propose to use when sowing.

4. Tyne tension

Correct tension allows the tyne to vibrate and create tilth, while maintaining the correct point angle. Lift the machine and mark the soil at the front of the point. With a spring balance scale attached at the position of the bolt hole pull the tyne back so the point is 2.5 cm behind the mark and read the tension. Tyne tension should be in the range of 260–400 N (30–40 kg). Too much tension results in excessive point wear.

5. Furrow depth

Furrow depth is not as critical as the amount of soil covering the seed. Check seed depth after travelling at least 200 m. Seed should not be placed deeper than 2 cm and less for very small seed (see *Chapter 13*).

6. Soil coverage

The amount of soil covering the seed is critical regardless of the depth of the furrow.

Aim for 0.5–1.0 cm of loose soil over the seed. Ideally a small amount of fertiliser (about 5%) should be seen on the surface.

Too much soil cover. If you cannot see some seed and fertiliser on the furrow surface then it is likely that the seed is buried too deep.

Too little soil cover. If there is a high percentage of seed and fertiliser visible in the furrow this is an indicator of insufficient soil cover. A single loop of heavy chain attached at either side of the seeder or half metre long chains attached behind each sowing tyne can be used to improve coverage in the furrow. Seed that is not covered and exposed to the sun is more vulnerable to drying out and removal by ants and birds.

Caution: *Never use harrows or a roller when direct drilling pastures as these implements place excess soil in the furrow. Triple disc seeders are the exception.*

7. Soil types and moisture

Soil type and moisture level often vary within a paddock and change as sowing proceeds. If possible, sow different soil types in separate blocks and check the soil cover over the seed with changes in soil type. Also check soil cover as the surface soil dries out during the day – changes in moisture level affect soil flow.

8. Point maintenance

Seed placement and the shape of the furrow formed can be affected by worn points. Attention to point wear is essential, particularly when direct drilling because the points are narrow and need to effectively carve a channel through undisturbed soil.

Appendix 5 Grazing systems

Principles of grazing management

Pasture composition is dynamic, fluctuating within and between years according to a range of factors including seasonal conditions, grazing and soil fertility. Effective grazing management is important in preventing weed incursions and maintaining a persistent and significant perennial component. An effective grazing system will:

- prevent selective grazing of species, i.e. patch grazing of paddocks, which is common in understocked paddocks;
- increase overall pasture utilisation;
- optimise pasture growth and maximise the quality of pasture feed on offer;
- match stock feed requirements (i.e. animal nutrition) to seasonal growth;
- ensure the persistence of desired species by allowing rest periods for recovery, seeding and recruitment of new plants;
- maintain a productive perennial component to help prevent soil salinity, acidity and invasion by undesirable or weedy species; and
- maintain ground cover and minimise erosion (wind and water).

The following strategies highlight the role of grazing management in manipulating pasture composition:

- Heavy grazing (i.e. high stocking density) in late winter and early spring can prevent grass dominance, reduce seed set of annual grass weeds and encourage clover seed production.
- Lenient grazing in spring and summer can promote seeding of perennial grasses and reduce clover seeding.

Grazing systems

There is a wide range of grazing management systems, including continuous grazing, set stocking, rotational grazing, cell or time-controlled grazing, and tactical or strategic grazing. The main grazing systems are described in Table A5.1.

Continuous stocking

At low stocking rates, this is an unmanaged system that allows animals to graze with a high degree of selectivity. The pastures are rarely rested and continuous selection of preferred species may lead to their elimination. Patch grazing and poor utilisation are common under continuous stocking. Depending on stocking rates, this system may result in acceptable animal performance but there is likely to be a composition shift over time, with the pasture becoming dominated by less palatable and weedy species. Maintaining ground cover may be an issue, depending on grazing pressure.

Set stocking

Often used to describe continuous stocking, but more appropriately set stocking is a term that refers to a specific grazing period when stock are not moved; for example, paddocks are often set stocked with ewes over the lambing period.

Set stocking of pastures for extended periods, e.g. up to three months, will not necessarily be detrimental to the pasture. It will depend on the type of pasture, seasonal conditions and stages of growth when the plants are grazed. In general the larger the paddock and the lower the stocking density the more selective animals can be. This places pressure on desirable species and could result in shifts in pasture composition over time.

Rotational grazing

Rotational grazing refers to a period of grazing followed by a period of rest. The rest period or rotation length should be determined by pasture growth rate and can vary from days to weeks, or months. There can be a large variation in the number of paddocks in a rotational grazing system and therefore a wide variation in periods of grazing and rest. The system may rotate across 3 to 4 paddocks per mob/flock, or more than 30 in intensive rotational systems such as cell or time-controlled grazing. There are productivity gains to be made by moving from a set stocked system to a rotational system due to increased pasture utilisation.

Cell or time-controlled grazing

Cell or time-controlled grazing systems have a short but intense grazing period followed by a long recovery period. Stocking densities are often higher than 100 DSE/ha. The speed of rotation is determined by pasture growth rates. Stocking densities can also be matched to seasonal conditions and pasture growth rates.

Table A5.1 Summary of grazing systems and features of each.

Grazing option	Examples	Paddocks per herd	Other features	Stock density relative to continuous grazing
Continuous	Continuous grazing Set stocking	1	Stocking rate varies but no movement of animals in relation to either plant or animal requirements	–
Rotational resting	Deferred rotation grazing Merrill system	Generally 2 or less	Calendar based movements	Moderate
Low intensity rotational grazing	High intensity low frequency grazing	3–7	Calendar based movements	Moderate – high
High intensity rotational grazing (high utilisation grazing)	Non-selective grazing Crash grazing Short duration grazing	>7	Each paddock severely grazed before moving; calendar based movements	High
High intensity rotational grazing (high performance grazing)	Controlled selective grazing	>7	Each paddock lightly grazed before moving; calendar based movements	High
Time-controlled grazing (production focus)	Block grazing Strip grazing Rational grazing High density, short duration grazing	20–40	Moves based on pasture growth rate and physiological requirement for rest; requires high stock density.	Very high
Time-controlled grazing (holistic focus)	Savory grazing method (Savory, 1988) Cell grazing Controlled grazing Management intensive grazing Ultra-high density grazing Planned grazing	20–40	Moves as above; focus on ecosystem sustainability and optimising profits	Very high
Tactical grazing	n/a	Variable	Movements determined by defined objectives and management strategies for individual paddocks and livestock	Variable

Based on: Waters C, Hacker R, Howling G and Hulme T (2008) Integrating biodiversity and agricultural production in Northern and Western New South Wales. Report to Western, Namoi, Border-Gwydir Catchment Management Authority

Tactical or strategic grazing

Tactical or strategic grazing is a flexible management system with a specific outcome, such as a change in pasture composition or an animal production target. Tactics are likely to vary from year to year, depending on the desired outcome and the opportunities. Some examples of tactical grazing methods include:

- resting pastures to recover from periods of stress, e.g. drought
- removing stock for extended periods to allow perennial grasses (new or thin, established pasture) to seed and regenerate
- using different types of stock: sheep, cattle and goats have different grazing habits and dietary preferences. Sheep tend to graze closer to the ground and can be highly selective, while cattle are less selective. Goats have a highly variable diet and tend to browse;
- using different classes of stock. Wethers or dry cows can graze on less palatable species or lower quality

feed with little penalty compared with growing or lactating stock; and
- crash grazing undesirable species such as vulpia species, during winter while they are most palatable, to reduce seed production.

Further reading

Savory A (1988) Holistic Resource Management: A new Framework for Desicion Making (2nd ed.). Washington, D.C.: Island Press

Waters C, Hacker R, Howling G and Hulme T (2008) Integrating biodiversity and agricultural production in Northern and Western New South Wales. Report to Western, Namoi, Border-Gwydir Catchment Management Authority

Temperate perennial pasture establishment guide

Steps to ensure success

Department of Primary Industries